The Cost-Benefit Analysis of the Improvement of Water Quality of the Paldang Reservoir in Korea.

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Introduction

The Paldang reservoir supplies drinking water to the 5.8 million households in the Seoul metropolitan area in Korea. The water quality of the Paldang reservoir, however, has been graded the third class water based on the Chemical Oxygen Demand (COD) criterion, meaning that it is no longer suitable for drinking water. This is due to liquid waste from manufacturing industry and wastewater from livestock farming in the region. In order to improve water quality of the Paldang reservoir, it is necessary to require wastewater treatment for factories discharging effluent and also stricter regulations for the agricultural sector in using pesticides and discharging animal waste into the Paldang reservoir. Therefore, the environmental regulations to protect the water quality of Paldang reservoir would impose potentially significant economic costs to the industry and livestock farming in the region.

This study estimated monetary value of water quality improvement from 3rd class to 1st class in the Paldang reservoir using the contingent valuation method (CVM) to measure individuals' willingness to pay (WTP) of questionnaire respondents for improving the water quality of the Paldang reservoir and analyzed what factors influence their WTPs. This study also measured compliance costs of proposed regulations to the polluting sources. The estimated individual WTP was used to calculate the total WTP of the community affected, and then it was compared with the compliance costs of proposed regulations to the polluting sources. Various regulatory options by local and central government to improve the water quality of the Paldang reservoir and their costs to prevent a degradation of Paldang reservoir were analyzed. Finally, the cost and benefit associated with each option was compared and most cost-effective regulatory option to improve the Paldang reservoir based on the cost-benefit analysis was identified. Finally, distribution of costs and benefits of water quality improvement of the Paldang reservoir was also studied. This study focused on economic benefits and costs of improving the water quality of the Paldang reservoir to the households in the Seoul metropolitan area in Korea. Information on benefits and costs will help policymakers in finding socially desirable level of water quality improvement of the Paldang reservoir.

Literature Review

Many studies have used the contingent valuation method (CVM) to measure households' willingness-to-pay (WTP) for water quality improvements (Edwards; Shultz and Lindsay; Jordan and Elnagheeb; Poe; Kim and Cho). The dichotomous choice methods in which respondents answer either yes or no to one randomly assigned dollar amount chosen by the interviewer have been widely used to elicit WTP for water quality improvement (Edwards; Shultz and Lindsay; Poe). The dichotomous choice methods are likely to elicit more valid responses than an open-ended question format that asks respondents to report their WTP for a specified change in water quality. However, this approach is that the dichotomous response data may provide less information than an open-ended question format for the respondents' WTP and a large sample also may be required to obtain a statistically significant WTP estimate by this approach.

The payment card or checklist method asks respondents to circle the highest WTP from an ordered set of values. The respondents' WTP are assumed to lie between the circled value and the next higher value. Only a few studies have used CVM with a checklist format in estimating WTP for water quality improvement (Jordan and

Elnagheeb; Kim and Cho). Jordan and Elnagheeb reported WTP for improved ground water quality and residents' perceptions of potential groundwater contamination in Georgia using a mail survey. The advantage of this method is that it is easy to answer and can reduce the number of non-responses to WTP questions. The disadvantage of this method is that respondents' WTPs are influenced by the suggested WTP ranges and WTPs can be concentrated at a certain amount in the range (reference?). Comparing the parameter and WTP estimates from the dichotomous choice and payment-card models using Monte Carlo experiments, Jordan and Elnagheeb found that the parameter estimates by the payment-card model were more often consistent and efficient than those by the dichotomous choice model. Kim and Cho also used the payment-card model to determine how much consumers would be willing to pay to reduce copper in their drinking water and what factors influence their willingness-to-pay (WTP). The annual mean WTP per household was estimated using survey data from nine counties in southwestern Minnesota where copper contamination is high. A payment-card model was used to estimate consumer's WTP to improve their drinking water quality in this study.

The Model

Suppose that we obtain the consumer's WTP and auxiliary information about socioeconomic and demographic characteristics from a survey. The structure of the model to be considered is:

$$WTP_i = \mathbf{X_i}'\boldsymbol{\beta} + e_i \tag{1}$$

Where $\mathbf{X_i}$ is a vector of theoretically important explanatory variables and β is a vector of coefficients. The e_i is assumed to be an independent, identically normally distributed random variable with zero mean, and variance σ^2 where i = 1, 2, …, n denotes individuals in the sample. The conditional distribution of the WTP is given by $WTP_i \mid \mathbf{X_i} \sim N(\mathbf{X_i}'\beta, \sigma^2)$, i = 1, 2, …, n. The tobit model is of the form: $WTP_i^{Tobit} = \mathbf{X_i}'\beta + \varepsilon_i$, where WTP_i^{Tobit} is an unobserved continuous dependent variable and ε_i is an independently distributed error term assumed to be normal with zero mean and constant variance σ^2, i = 1, 2, …, n. The observed WTP variable takes the form:

$$(2) \qquad WTP_i = \begin{cases} \mathbf{X_i}'\beta + \varepsilon_i & \text{if } WTP_i^{Tobit} > 0 \\ 0 & \text{if } WTP_i^{Tobit} \le 0 \end{cases}$$

The log likelihood for the censored regression model is given by:

$$(5) \quad ln\, L(\boldsymbol{\beta}, \sigma) = \sum_{WTPi = 0} ln\,[1 - \Phi(\frac{\mathbf{X}_i'\boldsymbol{\beta}}{\sigma})] + \sum_{WTPi > 0} [\ln(\frac{1}{\sqrt{2\pi\sigma^2}}) - (\frac{1}{2\sigma^2})(WTP_i - \mathbf{X}_i'\boldsymbol{\beta})^2]$$

The maximum likelihood estimator of $\beta_{\mathbf{Tobit}}$ is obtained as a solution to the first-order condition for maximization, $[\partial \ln L(\beta)/\partial\beta] = \mathbf{0}$. Once the optimal values of $\beta_{\mathbf{Tobit}}$ and σ are estimated, the expected value of WTP_i when censored at zero can be obtained from:

$$(6) \qquad E[WTP_i] = \mathbf{X_i}'\beta^{e}_{\mathbf{Tobit}}\Phi(\mathbf{X_i}'\beta^{e}_{\mathbf{Tobit}}/\sigma^e) + \sigma^e\phi(\mathbf{X_i}'\beta^{e}_{\mathbf{Tobit}}/\sigma^e)$$

where β^e_{Tobit} and σ^e are the estimated values of β_{Tobit} and σ, respectively, Φ is the normal cumulative distribution function, and ϕ is the normal distribution function.

SURVEY DESIGN

The household survey was designed to collect information on socio-economic characteristics of the respondents, their WTP for improving the quality of the drinking water, their awareness and perception of the water quality of the Paldang reservoir, types of water source and use, and monthly water bill. Two pilot surveys were conducted to test the survey instrument as a final step in the construction of the survey questionnaire. The pretest helped the researcher detect problems and correct them before actually doing the survey. Open-ended questionnaire was used in the first pilot survey to analyze respondents' distribution of WTP. The ranges from the payment -card were developed based on the distribution of WTP from the first pilot survey. The second pilot survey was conducted with the payment-card method to simulate actual sampling conditions. The main survey was conducted in the form of personal interview from the March 7, 2001 to March 25, 2001 for 565 individuals who are at least 20 years old and also live in the Seoul metropolitan area where the drinking water is supplied by the Paldang reservoir. Efforts were made to word the questionnaire for respondents from all educational levels to be able to comprehend the language, concepts, and questions used in the survey.

The personal interview provided specific information about the quality in Paldang reservoir and respondents were asked to circle, from a set of predetermined values, the most she would be willing to pay. The respondents were also asked to provide their perception about the water quality in the Paldang reservoir, type of their drinking water, monthly water bill, and other socio-economic characteristics of the respondents.

ESTIMATION OF WTP

A tobit with sample selection model was used to estimate the WTP for improving water quality of the Paldang Reservoir in Korea. Table 5 displays monthly WTP indicated by the survey respondents. Since 18% of the respondents indicated zero values for WTP, a tobit model is an appropriate to estimate the WTP.

Table 1: Monthly WTP for Improving Water Quality of the Paldang Reservoir in Korea (1200 Won = $1)

WTP (in Won)	Number of Respondents	Percentage
0	103	18.2
1000	48	8.5
2000	42	7.4
3000	46	8.1
4000	13	2.3
5000	75	13.3
6000	14	2.5
7000	10	1.8
8000	41	7.3
9000	12	2.1
10,000	96	17.0
15,000	22	3.9
20,000	12	2.1
25,000	6	1.1
No response	25	4.4
Total	565	100

Table 2 explains the variables used in the tobit model and their statistics such as the mean and standard error. The results of the WTP function are presented in Table 3.

Table 2: Variable Description and their Statistics in the Model

Variable	Description	Mean	Standard Error
USE	1 if the respondent drinks bottled water or purified water; 0 if the respondent drinks tap water	0.62	0.49
WQUL	1 if the respondent is satisfied with the quality of tap water; 0 otherwise.	0.41	0.49
PERC	1 if the respondents is satisfied with the water quality of Paldang Reservoir; 0 otherwise.	0.25	0.44
WTP	Individual household's monthly WTP for improving water quality in Paldang Reservoir. (in Won)	5,497	4,910
SEX	1 if female; 0 otherwise.	0.57	0.50
AGE	Age	38.66	11.12
AGE2	Square of the AGE variable	1,618.19	875.77
YEAR	Number of years that the respondents have resided at the current addresss	20.67	13.36
INCOME	Monthly household income 1 if INCOME is less than 1,000,000 Won; 2 if INCOME is between 1,010,000 and 1,500,000; 3 if INCOME is between 1,510,000 and 2,000,000; 4 if INCOME is between 2,010,000 and 2,500,000; 5 if INCOME is between 2,510,000 and 3,000,000; 6 if INCOME is between 3,010,000 and 3,500,000; 7 if INCOME is between 3,510,000 and 4,000,000; 8 if INCOME is over 4,000,000.	4.16	2.10
WBILL	Monthly water bill 1 if WBILL is less than 5,000 Won; 2 if WBILL is between 5,001 and 6,000; 3 if WBILL is between 6,001 and 7,000; 4 if WBILL is between 7,001 and 8,000; 5 if WBILL is between 8,001 and 9,000; 6 if WBILL is between 9,001 and 10,000; 7 if WBILL is between 10,001 and 11,000; 8 if WBILL is over 11,000.	4.82	2.35
FAMINO	Household size	3.77	1.15

Table 3: Results of the Tobit with Sample Selection Model

Variable	Coefficient	T-value
Constant	2795.94	0.625
SEX	-1467.92	-2.233**
AGE	-85.41	-0.353
AGE2	1.04	0.338
YEAR	-42.24	-1.617*
INCOME	393.40	2.725***
WBILL	392.45	2.746***
FAMNO	-309.04	-1.034
	N	505
	Log likelihood	-3062.41
	σ	6896.57***
	ρ	0.870***

***, **, * respresent 1%, 5%, and 10% confidence level, respectively.

SEX has a negative and significant effect on WTP for improving water quality of Paldang Reservoir. If the respondent is male, he is on average willing to pay more to improve the water quality . YEAR also has a negative and significant effect on WTP. If the respondent has resided longer at the address, the less he/she is willing to pay to improve water quality of Paldang Reservoir. Both INCOME and WBILL has positive and significant effects on WTP. If the respondent has more income and pays higher water bill, then he/she is willing to pay more to improve the water quality of Paldang Reservoir. AGE and FAMNO shows that the respondent is willing to pay more if he/she is younger and has a smaller size of household, which seems to be contracdictory to the findings in other studies. However, these variables don't have significant effects on WTP for improving water quality in Paldang Reservoir.

The average WTP based on predicted value from the estimated WTP function in this study was 1,860 won. This average WTP was multiplied by the total number of households (5,792,619) in the Seoul metropolitan area where the drinking water is supplied by the Paldang reservoir to calculate annual aggregate WTP to improve water quality of the Paldang reservoir. The annual aggregate WTP was estimated at 1,292 billion Won, which is a little bit over $ 1 billion.

COST-BENEFIT ANALYSIS

The government of Korea developed the plan to improve the water quality of the Paldang reservoir from the 3rd class to the 1st class water by the end of the year 2005 and has been investing 12 billion Won in 1999; 1,877 billion Won in 2000; 2,475 billion Won in 2001; 2,348 billion Won in 2002; 2,679 billion Won in 2003; 2,966 billion Won in 2004; and 2,966 billion Won in 2005. The plan includes building up more wastewater treatment facilities and updating the existing facilities to further control liquid waste from manufacturing industry and wastewater from livestock farming in the region.

Assuming the life span of the new investment is 20 years, we calculated net benefits (as of 2005 basis) associated with 4%, 5%, 6%, 7%, and 8% discount rate, respectively. Table 4 displays net benefits for improving the water quality of the Paldang reservoir from the 3rd class to the 1st class water for discount rates ranging from 4% to 8%.

Table 4: The net benefits for improving the water quality of the Paldang reservoir (in million Won)

Discount Rate	Cost	Benefit	Net Benefit
0.04	1,678,538	2,060,397	381,859
0.05	1,717,384	1,965,029	247,645
0.06	1,757,198	1,880,539	123,340
0.07	1,798,001	1,805,634	107,633
0.08	1,839,813	1,739,199	100,613

Table 4 shows the aggregate WTP for improving water quality of Paldang reservoir was estimated higher than the cost for all ranges of discount rates considered in this study.

The WTP estimate in this study is an increase in the respondent' s current monthly water bill. Different financing options for water improvement could alter the respondent's WTP elicited in this study. Therefore, this study is limited in fully comparing the benefits and costs of improving the water quality of the Paldang reservoir from the 3rd class to the 1st class water. This limitation indicates the need for continued research in this area.

CONCLUSION

This study used the contingent valuation method to determine how much households would be willing to pay to improve the water quality of Paldang reservoir in Korea. The average WTP based on predicted value from the estimated WTP function in this study was 1,860 won. The annual aggregate WTP was estimated at 1,292 billion Won, which is a little bit over $ 1 billion. The net benefits of improving the water quality was ranged from 1,006 billion Won to 3,816 billion Won depending on discount rates assumed in this study. The estimated WTP was estimated to be sufficient to pay the full cost of providing improved water quality to the Seoul metropolitan areas. This study focused mainly on the economic costs and benefits to households of water quality improvement in Paldang reservoir in Korea. Information on benefits and costs will help policymakers find the socially optimal level of abatement of water contamination in Korea.

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