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Is a costly river restoration project beneficial to the public? Empirical evidence from the Republic of Korea

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ABSTRACT

Public water supply service is to provide certain guaranteed level of quantity and quality in any given circumstances. In this regard, public water supply service treated as public goods that either central or state authority governs for good intentions. Growing concerns about water scarcity in national level due to its vulnerability on climate change lead public to suppress economic burden. In fact, Korean government has had a similar concern bringing to construct 16 weirs in the four major rivers. This construction was launched under the name of green growth mega project in 2008 and consumed almost 17 billion dollars up to today for improving water quality and quantity. In this research, six different models were applied to calculate willingness to pay (WTP) for the future water scarcity. If we allow that the mega project lasts for 30 years without any maintenance, the maximum WTP becomes approximately 320 million dollars in 3% discount rate. In addition, if we assume that the Korean economic growth rate becomes much lower than anticipated, the maximum WTP will be about 416 million dollars. None of these numbers is higher than the total construction cost of this mega project under the given conditions.

Keywords: Mega project; Water quality and quantity; Contingent valuation method; Probit; Logic

1. Introduction

Since the late of twentieth century, a general consensus has recently existed among policymakers and decision makers at all levels of governments and international organizations that we need to transition towards a new development paradigm, the green growth, as a new pathway for global sustainability. In 2008, the President of the Republic of Korea announced the vision of “Low-Carbon Green Growth” that the

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most people accepted it as a growth pathway altering from "develop first and cleanup later" to environmental friendly development [1]. The Low-Carbon Green Growth not only envisioned a new development pathway toward low carbon society, but also introduced a sound natural resource management to either mitigate or adapt mainly to the future water management.

Implementing the green growth development strategy, the Korean government spent approximately 17.3 billion dollar to restore major rivers to prevent from the future water scarcity and flood. The main purposes of this mega project, "Four major rivers restoration project," are followed: (1) preventing flood; (2) capturing sufficient water resources; (3) improving water quality; and (4) improving regional economy. Beside the first purpose, the expected outcome from the four major rivers restoration project was supposed to leads us to overcome water scarcity by increasing water volume to 1.3 Billion Cubic Meters (BCM) [2].

Yet many positive performances from the four rivers restoration project, the actual assessment of its efficiency to public has still left in question since the water supply is a public good. A public good is characterized as both non-excludable and non-rivalrous in that while the consumption behavior of users often tends to be rather irrational. In the same manner, the water supply system is defined as public goods in an economic manner and seems to have similar irrational consumption patterns in many countries. Of many reasons to excessive use in public water, the combination from the low service charge, political components, and the myopic consumption behavior generally triggers overuses and are often interlinked in the process of water supply price system. In many countries, the gap between the competitive market price of water and the real rate of water consumption is compensated under an incentive regime. This mechanism leads public water consumers to give rise to a misperception that the value of public water is a cheap resource and aggravate over use. This excessive consumption may exacerbate the future water scarcity especially when a country or a region is classified as the water-stress region.

In spite of non-market system of public goods, it is conventionally required to invest a massive amount of financial input for water resources and to keep a stable water supply with low charges by governments. Then the government determines the water price based on complicated economic and financial equations as a public good provider.

Considering the mechanism of public water supply and Korea strategy, a number of fundamental research questions have been brought up immediately. To secure 1.3 BCM of fresh water, Korean government spent about 17.3 billion dollar. Will that be worth? Should we consider the price gap as an incentive to public? Or is it an economically efficient way to spend money for water supply?

There are a wide range of studies that have examined the impact of public water service improvement using various valuation methods, including the contingent valuation and hedonic price method attributable to water scarcity issues. One of the oldest, but recognized studies was done by Whittington et al. [3] that analyzed the impact of water service improvement in southern Haiti where people suffered from water shortages and concluded that the contingent valuation surveys were a feasible method for estimating the WTP among a very poor, even illiterate population. North and Griffin [4], however, investigated water source as a housing characteristic using a hedonic price method in one region of the Philippines and concluded that public water policy for improving the quality of water would be inappropriate. On the contrary to this, Jordan and Elnagheeb [5] conducted the contingent valuation method (CVM) in Georgia, US and found out that the improvements in drinking water quality statewide would be benefit to consumers. These mixed results may come from the lack of survey codification.

Recent studies showed better consistent results that the WTP for water quality improvement was high enough to guarantee economic and social viabilities [6–10], but we have not yet seen any literature, investigating the impacts of water quality and quantity improvement by mega project such as the "four major rivers restoration project" in the Republic of Korea.

In this paper, we investigated the WTP for the improved public water supply service in water-stressed regions in the Republic of Korea. Our analysis is based on double-bounded dichotomous choice (DBDC) survey data, similar to those done by many economists [11,12]. The rest of the paper was organized as follows. Section 2 provides an overview of the theoretical approach to estimate the WTP for the improvement of the public water service. Section 3 describes the survey design that we conducted for water-stressed regions in the Republic of Korea and the public water supply service related data including the "four major rivers restoration project." Section 4 presents empirical results from the case study. And the last section, we conclude the paper with a summary of the main findings and a brief look at policy dimensions.

2. Model specification

For the last few decades, the CVM has remarkably evolved as a quintessential tool for estimating the conceptual demand curve of non-marketed goods [13]. Inferring stakeholders' WTP for a hypothetical commodity, the CVM attempts to generate points of the Total Value Curve (TVC). It assumed that the individuals utility can be defined over a non-market good (Q_0) and Hicksian composite (Y), the TVC is the locus of all points for which $U(Q_0,Y) = U(Q_1,Y - \text{WTP})$, where Q_1 denotes a change in the level of non-market good and WTP is the individual WTP for availing the proposed change [14].

Among the many ways to induce the WTP, we followed the DBDC, which has been highly recommended by [15,16]. Unlike the singe-bounded dichotomous choice, two sequences of bids are offered to the respondents in the DBDC questionnaire format. First, whether a respondent would be willing to accept or reject an initial bid; subsequently, a second bid is asked depending on the answer to the first bid from the respondent. In other words, a respondent is asked whether an initial bid B^1 is acceptable or not. If a respondent accepts an initial bid, the double of the first bid B^2. will be offered as a second bid ($B^1 < B^2$). If an initial bid B^1 is rejected, half of the first bid B^3 will be offered ($B^1 > B^3$). Therefore, in this DBDC questionnaire format, there are four possible responses: "yes-yes"; "yes-no"; "no-yes"; "no-no". The likelihoods of these responses are π^{yy}, π^{yn}, π^{ny}, π^{nn}, respectively [16].

Under the assumption of a utility maximizing respondent, for these likelihoods are as follows. In the first case, we have $B_i^1 < B_i^2$, and

$$\begin{aligned}\pi^{yy}(B_i^1, B_i^2) &= \Pr\{B_i^1 \leq \text{WTP and } B_i^2 \leq \text{WTP}\} \\ &= \Pr\{B_i^1 \leq \text{WTP} | B_i^2 \leq \text{WTP}\} \Pr\{B_i^2 \leq \text{WTP}\} \\ &= \Pr\{B_i^2 \leq \text{WTP}\} = 1 - G(B_i^2; \theta)\end{aligned} \tag{1}$$

where i is the number of respondent; $G(\bullet;\theta)$ is some statistical distribution functions with the parameter vector θ. Hanemann [17] pointed out that this statistical model can be interpreted as a utility maximization response, where $G(\bullet;\theta)$ is the cumulative density function (CDF) of the individual's true maximum WTP. If we assume that $G(B)$ is the logistic CDF, it can be expressed as the logit model and if the lognormal or normal CDF were used in place of $G(B)$, this would be interpreted as the probit model.

In the second case when a "no" is followed by a "yes", we have $B_i^1 < B_i^2$ and

$$\pi^{yn}(B_i^1, B_i^2) = \Pr\{B_i^1 \leq \text{WTP} \leq B_i^2\} = G(B_i^2; \theta) - G(B_i^1; \theta) \tag{2}$$

When a "yes" is followed by a "no", the likelihood of this outcome can be expressed as follow.

$$\pi^{ny}(B_i^1, B_i^3) = \Pr\{B_i^3 \leq \text{WTP} \leq B_i^1\} = G(B_i^1; \theta) - G(B_i^3; \theta) \tag{3}$$

Finally, if answers from the respondent are both "no", then the likelihood can be rewritten as follow. It is noted that with $B_i^3 < B_i^1$, $\Pr\{B_i^3 \leq \text{WTP} | B_i^1 \leq \text{WTP}\} \equiv 1$, then,

$$\pi^{nn}(B_i^1, B_i^3) = \Pr\{B_i^1 > \text{WTP and } B_i^3 > \text{WTP}\} = G(B_i^3; \theta) \tag{4}$$

It is noted that the second bid allows us to place both an upper and a lower bound on the respondent's unobserved true WTP in Eqs. (3) and (4) while Eqs. (1) and (5) give us similar results to the single bound. When there are N number of respondents (i.e. $i = 1, \ldots, N$), the log-likelihood function takes the form as,

$$\ln L(\theta) = \sum_{i=1}^{N} \left\{ \begin{array}{l} d_i^{yy} \ln \pi^{yy}(B_i^1, B_i^2) + d_i^{yn} \ln \pi^{yn}(B_i^1, B_i^2) + d_i^{ny} \ln \pi^{ny}(B_i^1, B_i^3) \\ + d_i^{nn} \ln \pi^{nn}(B_i^1, B_i^3) \end{array} \right\} \tag{5}$$

where d_i^{yy}, d_i^{yn}, d_i^{ny}, and d_i^{nn} are indicator variables.

Assuming the logistic CDF of $G(B)$, when the WTP is bigger or equal to 0, the truncated mean of WTP (WTP^+) can be expressed as followed by Hanemann [18].

$$\text{WTP}^+ = \frac{1}{b} \ln\{1 + e^a\} \tag{6}$$

where a is the estimated constant and b is the estimated coefficient on the bid variables.

In addition, the mean WTP (WTP^*) are given by the following equation.

$$\text{WTP}^* = \frac{a}{b} \tag{7}$$

It is necessary for us to analyze covariates to see how the socioeconomic variables impact to the response. Thus, Eqs. (7) and (8) can be modified when we consider covariates.

$$\text{WTP}^+ = \frac{1}{b} \ln\left\{1 + e^{(a + x_i'\beta)}\right\} \tag{8}$$

$$\text{WTP}^* = \frac{a + x_i'\beta}{b} \tag{9}$$

where x_i is the covariate vector for the respondents socioeconomic characteristics, β is the parameter to estimate. Since the WTP is derived from the ML estimates of a and b, which are random variables. Moreover, their distribution solely depends on ML estimates; those are asymptotically normal with variance–covariance matrices. Followed by Park et al. [19], we applied Krinsky and Robb [20] simulation technique to obtain confidence intervals for the point estimates of WTP.

3. Application

3.1. Four major rivers restoration project

In Korea Peninsula, the annual average precipitation is 40% greater than the world average, but two-third of the annual rainfall occurs during the rainy season (from June to September) and almost no rain during the dry season. In this sense, Korea is categorized as a water-stressed region and annual repeated floods and droughts are commonplace [21]. To mitigate these natural disasters, the Korean government launched the four major rivers restoration project where the four major rivers are the *Han*, *Nakdong*, *Geum*, and *Yeongsan* rivers in 2008 (Fig. 1). The project was designed to build 16 weirs, to dredge 570 million m^3 of sands, and to gravel to deepen almost 700 km of riverbed; surely it was one of the costliest engineering projects in the Korean history ever [21]. The total estimated budget for this mega project was approximately 17.3 billion dollars [2]. It is believed that the project will secure the future water scarcity as well as the improvement of water quality.

3.2. Survey design and data

Prior to the main survey, 30 sample surveys were conducted in *Jeolla-Do*, *Gangwon-Do*, and *Gyeonggi-Do* where these providences are the best representatives of those affected by a direct influence from the four major rivers restoration project. Considering demographic characteristics, 1253 samples were collected by the face-to-face interview from residences of the selected providences. Professional interviewers explained about the current situation of the water scarcity problem in Korea followed by the current policy of tap water focused on quality and quantity aspects. To increase reliability of the research, six different initial bids were provided (i.e., 500 Korean Won, 800 Korean Won, 1,100 Korean Won, 1,400 Korean Won, 1,700 Korean Won, and 2,000 Korean Won). Main survey was executed for 3 weeks in July, 2011 by the professional data collecting companies.

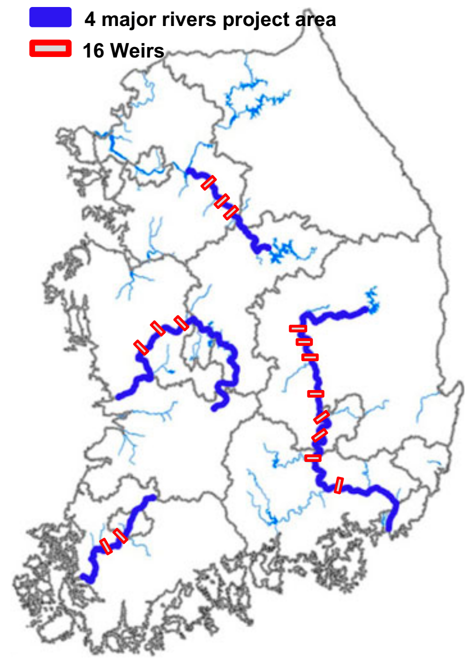

Fig. 1. Four major rivers restoration project.

The main questionnaire was consisted of three parts: (1) the demographic information; (2) the satisfactory level on the tap water quality in any given providence; and (3) the WTP for the water quality improvement and the prevention from the water scarcity via four major rivers restoration project. Prior to take a survey on the WTP of water service improvement, we explained the status quo of water quality in Korea and inefficient water allocation problems that include necessity of the four major rivers restoration project. The DBDC style questions were asked with six different initial biding amounts. For the comparison purpose, the first initial bid and response can be used to calculate a single-bounded dichotomous choice. Table 1 summarized the basic statistics of survey results about different bids amount on study regions.

The age, the monthly average water rate paid by each household, the education level, the number of household, and the average monthly household income were considered as covariates. The average, mean, and standard deviation value of each covariate were followed as in Table 2.

In addition to foregoings, respondents were asked how the quality and quantity of water were important for their daily usage. Respondents expressed a strong belief that the water quality was very important but the satisfaction of its usage was not as high as its importance. The detail description of these two covariates follows (Table 3).

Table 1
Summary statistics of regions and bids

	Bids (Korean Won)						
Regions	500	800	1,100	1,400	1,700	2000	Total
Jeolla-Do	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	63 (15.3%)	413
Gangwon-Do	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	420
Gyeonggi-Do	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	70 (16.9%)	420
Total	210	210	210	210	210	203	1,253

Table 2
Summary statistics of covariates

	Age	Average rate	Education	Household	Income
Sample	1,253	1,253	1,253	1,253	1,253
Average	44.45	15,727.71	2.18	3.52	391.63
Mean	44	15,000	2.00	4.00	400.00
SD	9.196	8,849.64	0.799	0.960	126.414

Note: SD stands for the standard deviation.

Table 3
Description and summary statistics of water quality importance and satisfaction

	Description	Average	SD
Importance	Degree of importance of water quality (1) very important ~ (4) not important	1.44	0.497
Satisfaction	Degree of water usage satisfaction (1) very satisfied ~ (4) not satisfied	2.19	0.567

4. Results

Table 4 gives the estimation results for selected models of a single-bounded dichotomous choice without covariates. Both the logit and probit models reject the null hypothesis with 1% significance level. In addition, an initial bid had a negative sign with 0.0004 and 0.0003 from the logit and probit models, respectively. This result indicates that the higher the bid, the lower the responses of "yes."

In this research, to analyze the impacts of respondents or household characteristic on the WTP of water quality and quantity improvement by the four major rivers restoration project, the covariate model is estimated. The result of this analysis is given in Table 5.

Table 4
Estimates without covariates in the SBDC

	Model	
Variables	Logit (std. err.)	Probit (std. err.)
Constant	0.5398 (0.1504)**	0.3370 (0.0938)**
Initial bid	−0.0004 (0.0001)**	−0.0003 (0.0007)**
# of observation	1,253	
Log-likelihood	−859.77	−859.79
Chi^2 (p-value)	17.12 (0.000)**	17.08 (0.000)**

**stands for 1% significant and std. err. stands for the standard error.

Table 5
Estimates with covariate in the SBDC

	Model	
Variables	Logit (std. err.)	Probit (std. err.)
Constant	2.2228 (0.6109)**	1.4080 (0.3791)**
Initial bid	−0.0004 (0.0001)**	−0.0003 (0.0000)**
Age	−0.0082 (0.0074)	−0.0050 (0.0045)
Average water rate	−0.0000 (0.0000)	−0.0000 (0.0000)
Importance	−0.2767 (0.1228)*	−0.1771 (0.0761)*
Satisfaction	−0.5407 (0.1115)**	−0.3447 (0.0695)**
Education	0.0632 (0.0842)	0.0394 (0.0521)
# of household	0.1478 (0.0700)*	0.0943 (0.0436)*
Income	−0.0008 (0.0005)	−0.0000 (0.0003)
# of observation	1,253	
Log-likelihood	−842.72	−842.40
Chi^2 (p-value)	51.22 (0.0000)**	51.87 (0.0000)**

**stands for 1% significant.
*stands for 5% significant while std. err. stands for the standard error.

Table 6
Estimation of DBDC

	Model (probit)	
Variables	Without covariate (std. err.)	With covariate (std. err.)
Constant	0.1173 (0.0802)	1.0826 (0.3716)*
Initial bid	−0.0001 (0.0000)	−0.0000 (0.0000)
Age		−0.0015 (0.0046)
Average water rate		−0.0000 (0.0000)
Importance		−0.2305 (0.0753)**
Satisfaction		−0.3583 (0.0687)**
Education		0.0445 (0.5175)
# of household		0.0842 (0.0429)*
Income		−0.0005 (0.0003)
# of observation	1,253	
Log-likelihood	−1394.03	−1336.15
Chi^2 (p-value)	6.22 (0.0446)*	108.65 (0.0000)**

**stands for 1% significant.
*stands for 5% significant while std. err. stands for the standard error.

Table 7
Estimated WTP and Krinsky and Robb 95% confidence interval

Model		WTP	LB	UB	CI/Mean
SBDC	Logit w/o covariate	1172.01	862.45	1430.92	0.49
	Probit w/o covariate	1173.12	862.60	1431.59	0.49
	Logit w/ covariate	1179.24	881.71	1437.91	0.47
	Probit w/o covariate	1183.03	890.92	1437.73	0.46
DBDC	Probit w/o covariate	1049.01	−1139.10	2362.67	3.34
	Probit w/ covariate	817.91	−5692.33	8250.34	17.05

Note: Unit: Korean Won (2011).

Like SBDC without covariate, the average water rate paid by each household does not have the significant relationship with the WTP. However, as expected, the higher the education level, the higher the response of "yes" to the initial bid. Since the way of asking the importance and satisfaction of water quality and quantity was reverse, these estimates indicate that the more the importance and satisfaction higher the response of "yes" as them expected.

Since the logit model does not give a significant level with the DBDC, only the probit model is reported in this research. Table 6 gives estimation results of the DBDC with and without covariates under the probit model. Even though an initial bid gave us a negative sign, it was not significant at 5% level.

Table 7 gives estimated WTP based on these six difference types of models, the mean WTP on the water quality and quantity improvement was estimated. The 95% confidence interval was calculated by the Krinsky and Robb [20] method with 5,000 repeats.

It is noted that SBDC model gave us more efficient WTP measures than the DBDC model [22]. Therefore, we can get the total significant WTP measures by multiplying 12,218,750, which is the total household numbers in the Republic of Korea in 2011.[2] Total WTP for improving the water quality and quantity can be approximately calculated from 10.5 Korean Won to 17.6 Korean Won that are equivalent to 9.6–15.9 million dollar.[3] Assuming that water quality and quantity improvement project last for 30 years, the overall WTP with considering 3% discount rate would be about from 192 million dollar to 320 million dollar. Table 8 presents the sensitivity analysis discount rate.

[2]Population in 2011 was 48,875,000 (http://kostat.go.kr/portal/korea/index.action).
[3]Exchange rate was approximately 1 dollar = 1,100 Korean Won.

Table 8
Sensitivity analysis with discount rate change

Discount rate	Willingness to pay	
	Minimum	Maximum
1%	249.54	416.04
3% (baseline)	192.35	320.71
5%	152.60	254.42
8%	113.30	188.90

Note: Unit: million dollars (2011).

It is evitable that when the speed of Korean economic growth slows down, the total WTP for improving the water quality and quantity becomes higher than the baseline. Even though 1% discount rate can be translated as an economic disaster to Korean economy, total WTP will come higher, 250–416 million dollars. However, this would be to an exaggerated scenario based on the status quo. If Korean economy growth faster than its projection, total WTP will come about 189 million dollars maximum.

5. Conclusions

Korean government decided to build a sequence of weirs in rivers to provide better water supply service to public in terms of the green growth strategy. Improving the water quality and quantity to mitigate the future water scarcity through major public constructions, "four major rivers restoration project," has been started almost 4 years ago. The total construction cost of this project was estimated at approximately 17 billion dollars. Many public infrastructure construction projects often exceed the social benefit over the project costs so that the social welfare is always positive.

In this sense, this research tried to estimate the WTP for improving the water quality and quantity in terms of a green growth project. Although benefits of the mega project were estimated with a holistic approach, few studies have tackled to calculate the public monetary perception on the project through survey. In this research, six different models were applied to calculate the WTP. The most efficient one was the single-bounded dichotomous choice probit model without any covariates. If we allow that the mega project lasts for 30 years without any maintenance, the maximum WTP rises approximately 320 million dollars in 3% discount rate. In addition, if we assume that the Korean economic growth rate becomes much lower than anticipated, the maximum WTP will be about 416 million dollars. None of these numbers is higher than the total construction cost of this mega public construction.

The results of this study can be translated into several perspectives: (1) respondents of this research have low perception of the importance and satisfaction on the water supply service in Korea, but respondents who have higher perception of its importance and satisfaction higher the additional pays for water quality improvement; (2) the average monthly water bill has no impacts on the WTP, this implies that the water resources are treated as somewhat public goods; (3) respondents with higher education level and income are willing to pay more than the rest of the public, meaning that there are certain level of incentives for the wealthy people to have better water supply services. Policy makers should aware of these results and apply when there is a need for water resource policy reform. Although this research has some limitations such as the survey does not cover all the providences in Korea and non-use value of the mega project is not considered, policy makers cannot escape from overuse of public budget for the premature decisions due to the lack of proper economic assessment analysis of the mega project.

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