Economic Evaluation of Water Resource Management in South Korea Based on Benefit–Cost Analysis

Hyun No Kim

Abstract
The economic evaluation of the government policy is useful to identify the effectiveness of its financial management and the achievement of its goal. Based on valuation studies of water quality improvement from the Environmental Valuation Information System database provided by Korea Environment Institute, this study employed a meta-regression to measure the benefits of water quality improvement in three major river basins in South Korea. The empirical model is specified to capture the differentiated impact of water quality improvement by each river basin and the regression results showed that the increase in water quality grade has an impact on willingness-to-pay values. The total benefits provided by Han, Nakdong, and Geum River are estimated to be about US$490 million, about US$173 million, and about US$50 million per year, respectively. The estimated benefits were then compared with the costs, namely river management funds (RMFs) which are financial resources to support a variety of projects for water quality improvement. Based on benefit–cost comparison, this study explores the economic evaluation of water resource management in South Korea. This study also provides policy options including the equity of imposing water use charges, operational efficiency of RMFs, and stakeholder engagement for inclusive water governance that are helpful to maintain the sustainability of water resource in the long run.

Keywords
economic evaluation, water resource management, meta-regression method, river management funds, sustainability of water resources

Introduction
Water management can improve the quality of aquatic ecosystem services. The implementation of the water management can, for instance, result in stabilization of water quality. This implies, in turn, the water management can have a significant influence on water environment and can lead to changing the amount and quality of the services that the aquatic ecosystem provides (Phaneuf et al., 2008). Therefore, water management can provide tangible/ intangible benefits as a consequence of the increased water quality to the society (H. N. Kim et al., 2016a). On the contrary, the implementation of water management can be costly and the associated costs are covered by national taxes collected by water users.

The economic evaluation of the government policy has recently received attention because it is helpful to identify whether the government is efficiently managing their finances or not, which can be in turn useful to determine the accomplishment of its goal (H. N. Kim et al., 2016b). A wide range of approaches can be applied, but the benefit–cost analysis has been widely adopted for the policy evaluation measured in economic aspects (Champ et al., 2017). The benefit–cost comparison for the water management has been also emphasized by the EU Water Framework Directive. Accordingly, it is worthwhile to conduct the ex-post evaluation of the government policy to determine its effectiveness, which can provide a valuable guideline to maintain the sustainability of water resources by improving the planning and performance of water management in the long run.

The major rivers in Korea, namely the Han River, the Geum River, the Nakdong River, and the Yeongsan-Seomjin River, have provided the stakeholders with various favorable services such as drinking water, recreational activities, and aesthetic amenities. This has led the National Assembly to enact the Han River Act in February 1999 in an attempt to ensure more systematic efforts for water resource management. This law proposed collecting water use charges as an additional way of raising the necessary financial resources to
enhance water quality in the river. The other three major river systems soon followed the suit and adopted water use charges of their own. The water use charges collected became the seed money for the river management funds (RMFs) in August 1999 for the Han River and in 2002 for the other three major rivers.

Since the enactment of Han River Act, midstream and downstream water users have paid water use charges to provide financial resources to stabilize the water conditions in the upstream areas of the river basins based on the User Pays Principle (UPP; which is a well-known price approach that requires consumers to pay the full cost of the goods and services that they consume for the efficient allocation of scarce resources. The RMFs were formed based on the UPP to offset the losses in opportunity costs associated with regulation against various economic activities in upstream regions). However, there have been ongoing debates with regard to efficient management of RMFs between stakeholders. Nevertheless, few researches have been made to solve these ongoing issues.

Consequently, this study aims to conduct the analysis that explores plausible evaluation of the economic efficiency of water resource management based on benefit–cost ratio. To assess the economic benefits provided by the major rivers, this study utilizes a meta-regression approach which uses the relevant information from the previous researches (Shin et al., 2016). This study specified a meta-regression model which allows for estimating different economic benefits from each river because of possible heterogeneity between rivers based on a unique water condition and compared them to its own RMFs. A few case studies which assess economic values of non-market goods using a meta-regression analysis (MRA) have been found (Examples among many others include Columbo & Hanley, 2008; Ge et al., 2013; Griffiths & Wheeler, 2005; Hanley et al., 2006; Iovanna & Griffiths, 2006; Johnston et al., 2005; McComb et al., 2006; Muthke & Holm-Mueller, 2004; Rosenberger & Loomis, 2001; Shin et al., 2016; Shrestha & Loomis, 2001; Van Houtven et al., 2007). However, this study may be the first attempt to explore economic evaluation of water resource management in Korea based on benefit–cost analysis.

**Water Management in Korea**

The Han River basin encompasses 28 mid-sized regions, seven metropolitan cities and provinces including 112 cities, counties, and boroughs; the Geum River basin, 22 mid-sized regions, eight metropolitan cities and provinces including 47 cities, counties, and boroughs; the Nakdong River basin, 33 mid-sized regions, nine metropolitan cities and provinces including 87 cities, counties, and boroughs; the Yeongsan–Seomjin River basin, 31 mid-sized regions, five metropolitan cities and provinces including 42 cities, counties, and boroughs. Figure 1 presents geographical regions that
correspond to each river basin in Korea (more information regarding each river basin can be found at Water Resources Management Information System; http://www.wamis.go.kr:8081/ENG/).

The overarching objective of the RMFs is thus to raise and manage the financial resources necessary to ensure appropriate management of water resources and pollutants through effective water management projects and resident support projects for upstream communities by funding these projects with money collected from midstream and downstream users. The RMFs are mostly made up of water use charges collected from midstream and downstream communities. The water use charges have been rising steadily due to an increase in project funds supported by RMFs, increase in water consumption, and an increase in the population number of people who pays water use charges year in and year out. In 2016, the water use charge rates were KRW 170/m³ for the Han, Nakdong, and Geum Rivers, and KRW 160/m³ for the Yeongsan–Seomjing River.

The water use charges are levied from midstream and downstream communities. Based on water use charges and returns on their investment, the RMFs raised a total of KRW 10,143.6 trillion in fund by 2015. The Han River basin contributed 57.1%; the Nakdong River basin, 24.1%; the Geum river basin, 10.5%; and the Yeongsan–Seomjin River basin, 8.3%. The RMFs support a variety of projects for improving upstream water quality. There are mainly five types of such projects, that is, resident support projects, environmental treatment infrastructure projects, water quality improvement projects, land purchase and riparian zone projects, and the total pollutant management projects. Together, the RMFs expended KRW 10,051.9 trillion on such projects as of 2015. 47.7% of total expenses went to environmental treatment infrastructure projects; 18.7% to resident support projects; 18.3% to riparian zone projects; 8.3% to water quality improvement projects; 5.4% to total pollutant management projects; and 1.6% to administrative expenses.

**Review of Related Literature**

There is a relatively large literature using meta-regression models to estimate the benefits of non-market goods and services, but this section presents a few relevant empirical studies that are associated with measuring the benefits (willingness-to-pay values [WTPs]) for the use of water resources and/or water quality improvement.

Ge et al. (2013) conducted a meta-regression method to value the benefits of water quality improvement. Before setting up the empirical models, they used linkage between Secchi depth and water quality index to make consistent water quality measurement. Finally, using 332 valuations from 38 individual studies, this paper predicted the average WTP by the households living in a given area for a specific range of water quality improvement. For example, the predicted WTP was estimated to be about US$137.5 for 10-point increase in water quality in case of Iowa Spirit Lake.

Shin et al. (2016) examined the extent of economic benefits that can be used in transfer from downstream to upstream areas to compensate foregone economic benefits by government regulations. Focused on Han River in South Korea, they performed an MRA using 55 observations from 30 distinct researches. The WTPs the household would like to pay for the use of water resources along the Han River were estimated to be US$77 per year. The total net benefits which were derived by assuming reduction in households’ income in mid- and downstream regions were estimated to be US$449 million per year. Based on the equity principle of benefit distribution, they suggested that extra net benefits should be transferred to the other areas that received fewer net benefits.

Applying benefit transfer method, Cha et al. (2018) examined the economic value of Juam Lake in South Korea. They obtained 149 WTP estimates from the 72 studies associated with the valuation of water resources. They included in the independent variables site type, water resource value, and methodological and socioeconomic variables. They found that because of large capacity for water quality improvement and eco-environmental attributes, the water resources of Juam Lake have a high economic value, which was estimated to be US$229 per household per year. They indicated the limitation of the benefit transfer approach and suggested the systematic construction of relevant databases by conducting various new studies to improve the reliability of meta-regression results.

S. G. Kim et al. (2019) conducted meta-regression on the estimated value of water resources, which was obtained based on the stated preference method. They considered the characteristics of water sources, research method, and respondents’ characteristics as the factors that determined the amount of WTPs for water resource development. In terms of water resource characteristics, the more the size of water resources limited, the smaller the amount to be paid, with the exception of rivers. They also found that when the purpose of water resource development was to improve water quality, the estimated amount of WTPs was not significantly affected. With respect to research method, the mail survey method and annual based payment have a lower WTP value. In the case of respondents’ characteristics, while the respondents who have the relatively high geographic proximity or who are presented with specific information on the current state of water resources exhibited higher WTPs, the respondents who are given specific payment methods or who are provided with relative measure of change in water resources expressed lower WTPs.

Although this study is similar with the above studies in terms of applying MRA to estimate the benefits of qualitative
improvement in water resources, this study extends to the benefit–cost analysis to determine the effectiveness of water management policy. In addition, this study specified a meta-regression model which allows for different impact of water quality improvement by each river on the estimation of benefits.

**Method**

**Data**

This study utilized a data set obtained from the Environmental Valuation Information System (EVIS) provided by Korea Environment Institute (KEI). The EVIS establishes the database associated with environmental valuation studies conducted in South Korea and to form the relevant studies related to the valuation of water quality improvement in South Korea. As explained previously, the four major rivers in Korea have provided stakeholders with various tangible/intangible benefits (i.e., drinking water, recreational activities, and aesthetic amenities). Therefore, this study estimates total use values by including all eligible studies associated with economic values for direct and/or indirect use of water resources in South Korea. Fifty-one relevant studies were found, but 21 studies were excluded from the analysis because of inaccurate and/or missing information necessary for the analysis (e.g., we do not include the studies which do not provide information on baseline water quality and change in water quality, which is crucial variables that have an impact on WTPs; Kling & Phaneuf, 2018). A final 30 studies which provided 72 WTP estimates in total were used for the analysis. (Note that as no study relevant to Yeongsan-Seomjin River basin was found, this study focused only on three river basins.)

Table 1 shows the linkage between the grade and scientific indicators of water quality provided by Ministry of Environment, Korea. Using the water quality (WQ) grade in Table 1, most of the previous studies employed in this study designed the hypothetical scenarios associated with the water quality change. In Table A1, the quantitative characteristics for each individual study including study area, valuation techniques, the level of WQ improvement, baseline WQ grade, and economic values evaluated are also presented. Based on Table A1 in the appendix, a majority of studies measured the economic impact for 1 or 2 levels of WQ grade improvement starting with Grade 3.

Table 2 presents variable definitions, expected signs, and descriptive statistics of variables. The expected signs of each variable are based on the previous similar studies (Cha et al., 2018; Ge et al., 2013; Johnston et al., 2017; S. G. Kim et al., 2019; Shrestha & Loomis, 2001). For independent variables, this study included dummy variables for study type (stypedum), value type (drinking), study area (han, geum, nakdong), baseline WQ grade as a status quo effect (good, normal, bad, verybad), survey mode(ftf), valuation method (cvm), payment type (tax), model type (truncdum), as well as respondents’ income range (lowinc, medinc, highinc). Other socioeconomic variables such as gender, age, and education levels were available, but these variables were finally removed from the optimized model taking their statistical significance and theoretical point of view into consideration (Shrestha & Loomis, 2001). For a dependent variable, the WTP values were converted to constant 2015 Korean currency (KRW) using Consumer Price Index (CPI) provided by Statistics Korea to take into account inflationary effects.

To examine relative effects of baseline WQ on WTP values, dummy variables for each WQ grade (good, normal, bad, and verybad) were generated (Kling & Phaneuf, 2018). Trend variable was included to capture any systematic changes and indirect effect of time on WTP values that are not accounted. Dummy variables for each river basin (han, geum, and nakdong) were interacted with the variable for WQ improvement (improve). These interaction variables are expected to capture the economic impact of increase in WQ grade differentiated by each river basin.

### Table 1. The Linkage Between Water Quality Grade and Scientific Water Quality Measure.

| Water quality grade | Scientific water quality measure |
|---------------------|----------------------------------|
| Grade               | Definition                        | BOD | COD | DO   |
| Very good           | Suitable for domestic use after simple treatment | Below 1 | Below 1 | Above 7.5 |
| Good                | Suitable for recreation           | Below 3 | Below 1 | Above 5 |
| Normal              | Suitable for industrial use       | Below 6 | Below 6 | Above 5 |
| Bad                 | Suitable for agricultural use     | Below 8 | Below 8 | Above 2 |
| Very bad            | Possible for industrial use       | Below 10 | Below 10 | Above 2 |

*Source.* Water Quality and Aquatic Ecosystem Conservation Act, Ministry of Environment, South Korea.

*Note.* BOD = biochemical oxygen demand; COD = chemical oxygen demand; DO = dissolved oxygen.
Table 2. Description and Descriptive Statistics of Variables.

| Variable     | Expected sign | Description                                                                 | M (SD)     |
|--------------|---------------|------------------------------------------------------------------------------|------------|
| WTP          | n/a           | WTP per household per month (2015 KRW)                                       | 4,719.1 (3,392.9) |
| stypedum     | ±             | 1 if study was published in the peer-reviewed journal, 0 otherwise (DV)       | 0.778 (0.419)  |
| drinking     | −             | 1 if values measured is for drinking water, 0 otherwise (DV)                  | 0.292 (0.458)  |
| han          | n/a           | 1 if study area belonged to the Han River basin, 0 otherwise (DV)             | 0.583 (0.496)  |
| geum         | n/a           | 1 if study area belonged to the Geum River basin, 0 otherwise (DV)            | 0.139 (0.348)  |
| nakdong      | n/a           | 1 if study area belonged to the Nakdong River basin, 0 otherwise (DV)         | 0.278 (0.451)  |
| good         | ref.          | 1 if WQ grade is equal to 2 at the time of study, 0 otherwise (DV)            | 0.125 (0.333)  |
| normal       | +             | 1 if WQ grade is equal to 3 at the time of study, 0 otherwise (DV)            | 0.667 (0.475)  |
| bad          | +             | 1 if WQ grade is equal to 4 at the time of study, 0 otherwise (DV)            | 0.111 (0.316)  |
| verybad      | +             | 1 if WQ grade is equal to 5 at the time of study, 0 otherwise (DV)            | 0.097 (0.298)  |
| improve      | +             | WQ change calculated by hypothetical WQ minus baseline WQ                    | 1.5 (0.504)   |
| han × improve| +             | Interaction between han and improve                                          | 0.861 (0.827) |
| geum × improve| +            | Interaction between geum and improve                                         | 0.181 (0.484) |
| nakdong × improve| + | Interaction between nakdong and improve                                      | 0.458 (0.786) |
| ftf          | +             | 1 if survey mode was face-to-face (ftf), 0 otherwise (DV)                    | 0.903 (0.298) |
| cvm          | −             | 1 if CVM is applied, 0 otherwise (DV)                                        | 0.778 (0.419) |
| tax          | −             | 1 if payment vehicle is tax, 0 otherwise (DV)                                | 0.111 (0.316) |
| truncdum     | n/a           | 1 if truncated model is used, 0 otherwise (DV)                               | 0.028 (0.165) |
| lowinc       | ref.          | 1 for low income if household’s monthly income is ≤3,444,000 (2015 KRW), 0 otherwise (DV) | 0.306 (0.464) |
| midinc       | +             | 1 for middle income if household’s monthly income is >3,444,000 and ≤4,190,000 (2015 KRW), 0 otherwise (DV) | 0.292 (0.458) |
| highinc      | +             | 1 for high income if household’s monthly income is >4,190,000 (2015 KRW), 0 otherwise (DV) | 0.403 (0.494) |
| trend        | +             | The study year (1993 = 1, . . ., 2015 = 23)                                  | 14.22 (5.04) |

Note. KRW = Korean currency; DV = dummy variable; ref. = reference; n/a = not applicable; WQ = water quality.

Model Specification

A data set for the MRA has a panel structure because each study can provide different value estimates based on different scenarios. In other words, if a number of outcome values (e.g., WTPs) provided by each individual study are different, it follows unbalanced panel formats. In this case, a fixed effect model (FE) or a random effect model (RE) can be employed to control for the characteristics of the panel data format.

To specify appropriate empirical models, a Hausman test was carried out to choose better econometric models between FE and RE. The results indicate RE is preferred to FE, \( \chi^2 (5) = 5.75, \ p\text{-value} = .332 \). Next, a Breusch and Pagan Lagrangian multiplier (LM) test was employed to verify whether or not random effects should be accounted for to obtain unbiased parameter estimates. The results indicated absence of random effects between observations in the same study, \( \chi^2 (1) = 0.80, \ p\text{-value} = .186 \). This implies meta-regression models based on ordinary least square (OLS) would produce unbiased parameter estimates. A final econometric model is specified in Equation 1.

\[
\ln \text{WTP}_i = \alpha + \beta x_i + \Sigma \gamma_{j \times \text{improve}} j \times \text{improve}_i + \epsilon_i \quad (1)
\]

where \( \ln \text{WTP}_i \) represents the log of WTP from the study \( i \) measured in per month per household, \( x_i \) is a vector of independent variables such as study characteristics as well as socioeconomic variables of study \( i \). The variable, \( j \times \text{improve} \), represents interaction variables between \( j \) (\( j = \text{han}, \text{geum}, \text{and nakdong} \)) where \( j \) is a dummy variable for each river basin and \( \text{improve} \) which denotes the level of water quality improvement. \( \alpha \) and \( \beta \) are the vector of parameters to be estimated. \( \gamma_{j \times \text{improve}} \) are the parameters to be estimated capturing the impact of water quality improvement differentiated by each river on the dependent variable. \( \epsilon_i \) represents a normal error term.

Based on the parameter specified in Equation 1, the economic impact for a marginal change (i.e., marginal willingness to pay, MWTP) associated with increase in water quality can be derived as follows:

\[
\text{MWTP}_j = \gamma_{j \times \text{improve}} \times \text{WTP}_{j \times \text{mean, median}} \quad (2)
\]
Table 3. Estimation Results of Optimized Meta-Regression Model.

| Variable | Coefficient | Robust standard error | p > t |
|----------|-------------|------------------------|-------|
| constant | 9.1820***   | 0.7540                 | .000  |
| stypedum | -1.0339***  | 0.3093                 | .001  |
| drinking | -0.5175**   | 0.2255                 | .025  |
| han × improve | 0.8084*** | 0.2360                 | .001  |
| geum × improve | 0.6238**  | 0.2859                 | .033  |
| nakdong × improve | 0.9643*** | 0.3260                 | .005  |
| good     | reference   |                        |       |
| normal   | -0.0610     | 0.2769                 | .826  |
| bad      | 0.8988***   | 0.2777                 | .002  |
| verybad  | -0.5121     | 0.3688                 | .17   |
| ftf      | -0.4324     | 0.3077                 | .165  |
| cvm      | 0.4087      | 0.2827                 | .154  |
| tax      | -1.5709***  | 0.4634                 | .001  |
| truncdum | 0.1217      | 0.2067                 | .558  |
| lowinc   | reference   |                        |       |
| medinc   | 1.2876***   | 0.3374                 | .000  |
| highinc  | 0.9524***   | 0.3362                 | .006  |
| trend    | -0.1342***  | 0.0207                 | .000  |
| Mean VIF | 4.11        |                        |       |
| R²       | .78         |                        |       |
| Observation | 72             |                        |       |
| No. of study | 30             |                        |       |

Note. VIF = variance inflation factor.
**Significant at 5%. ***Significant at 1%.

where in Equation 2, \( y = \text{han}, \text{geum}, \) and \( \text{nakdong} \) and \( \text{WTP}^{\text{mean, median}} \) is the mean and median WTP values related to each river basin in the sample, respectively.

The validity tests of meta-regression model should be carried out to verify whether or not the predicted values obtained from the model are appropriate for benefit calculations. Presented in the appendix is the result of two statistical tests which are used to ensure the validity of a meta-regression model (see Table A2).

**Results**

Table 3 presents model estimation results. Because of the presence of heteroscedasticity, robust standard errors are used to obtain unbiased standard errors of OLS coefficients. The mean variance inflation factors (VIFs) which diagnose multicollinearity issues in an OLS regression were below 5 exhibiting very less collinearity of the estimated coefficients. The value of \( r^2 \) indicates that regression model explains a reasonable variation in WTP values.

As expected, most of the parameters statistically significant at 5% level are consistent with the similar meta-regression studies in terms of their signs. The negative sign for the dummy variable on \( \text{stypedum} \) implies the studies published in the peer-reviewed journals produce lower WTPs compared with other studies. This might be explained by the fact that the researches published in the academic journal place in general greater attention on research methodology than the estimated amount, which can lead to rather conservative WTPs. The variable \( \text{drinking} \) is also negative and significant, indicating the studies measuring the economic values for drinking water quality yield relatively lower estimates of WTP than other studies which estimated total economic values provided by water resources (Ge et al., 2013). Compared with other studies, the negative sign of \( \text{tax} \) variable implies the studies using tax as a payment vehicle have lower WTP values. This is probably due to the fact that respondents exhibited passive payment due to the resistance to pay more taxes. In terms of baseline WQ variables, \( \text{bad} \) variable is statistically significant with the positive sign only. (Note that the coefficient on \( \text{verybad} \) variable is not of the expected sign and statistically insignificant, which may be due to the small sample size associated with fifth WQ grade; see Table A1 in the appendices). The coefficient for this categorical dummy variable implies, holding other features constant, the studies starting with the fourth WQ grade produced higher WTP values compared with the studies associated with second WQ grade.

The coefficients on the variables, \( \text{medinc} \) and \( \text{highinc} \), indicate that in comparison to low-income households (\( \text{lowinc} \)) the higher income households are more willing to pay for water quality changes. The magnitude of the \( \text{medinc} \) coefficient, however, is bigger than that of \( \text{highinc} \) coefficient implying middle-income households have higher WTP values than high-income households, which is not of expected result. This result can be regarded as high-income households are less sensitive to the change in water quality conditions than middle-income households. For instance, as high-income households are relatively more affordable to find substitutes for the water-based recreational activities than middle-income households, their utility can be less susceptible by water quality change in this case (Shin et al., 2016).

Turning to the core variables, the coefficients on the \( \text{han} \times \text{improve}, \text{geum} \times \text{improve}, \) and \( \text{nakdong} \times \text{improve} \) represent the impact of increase in WQ grade in each river on WTP values. These variables are all positive and highly significant, indicating WTP values increase as WQ grade increases. Note that the magnitude of \( \text{nakdong} \times \text{improve} \) coefficient is relatively larger than that of \( \text{han} \times \text{improve} \) and \( \text{geum} \times \text{improve} \). This is probably due to historical water pollution incidents in Nakdong River where phenol was leaked into the river twice by Doosan Electronics in 1991 (Jung, 1995).
Discussion: Benefit–Cost Analysis

Table 4 shows the calculated mean and median MWTPs associated with increase in WQ grade in each river basin using Equation 2. The mean and median MWTPs are calculated to be different for each river because of different sample values and different magnitude of coefficients associated with water quality improvement. In other words, even though each river is the primary water resource that generates many beneficial services to its own stakeholders, the benefits provided by each river could be different depending on the water quality conditions in each river. For example, the mean and median WTPs are calculated to be about KRW 4,738 (about US$4.7) and KRW 4,433 (about US$4.4) per household per month in Han River case, respectively, which is highest among three rivers. For the Geum River case, the mean and median WTP are extrapolated to be smaller than Nakdong River case, which is probably due to relatively small coefficients on geum × improve variable despite higher sample values in the data set.

Given the median WTP in Table 4, the annual MWTP and total benefits for each river applying total number of households who paid water use charges in 2015 in each river basin were calculated. The results are presented in Table 5. The total benefits provided by Han, Nakdong, and Geum River are estimated to be about KRW 713 billion (about US$713 million) per year. These benefits were compared with the RMFs (costs) that each river basin invested in the projects to manage water quality conditions such as environmental treatment infrastructure projects, water quality improvement projects, land purchase and riparian zone projects, and the total pollutant management projects in 2015.

The comparison of benefits to costs shows that there are relatively large differences in terms of benefit–cost ratio between rivers (i.e., last column of Table 5). For Han River case, the benefit–cost ratio indicates that benefits are enough to offset the costs spent in water quality improvement projects. Therefore, it seems that the Han River has been making an efficient investment because they are more than recovering their investments. In terms of Nakdong and Geum River case, however, the benefits are not large enough to offset the costs used in water quality management. Thus, in this empirical case, one could evaluate two rivers may not be making a reasonable investment, which raises issues associated with the operational inefficiencies of RMFs.

Based on the comparison of benefits and costs, this study provides a few policy implications that can be useful to improve the efficiency of water resource management. First, as the stakeholders belonging to each river gained different benefits, it would be reasonable to differentiate the amounts of water use charges in each river. Currently, the same amounts of water use charges in the three river basins are imposed on the water users. However, it would be more

### Table 4. Mean and Median MWTP Associated With Increase in WQ Grade by Each River.

| River   | Mean valuesa | Median valuesa | Mean MWTPb  | Median MWTPb  |
|---------|--------------|----------------|-------------|---------------|
| Han     | 5,861.2      | 5,484.1        | 4,738.0     | 4,433.2       |
| Nakdong | 3,055.0      | 3,133.0        | 2,946.0     | 3,021.2       |
| Geum    | 3,250.5      | 3,046.4        | 2,027.7     | 1,900.4       |

*Note. MWTP = marginal willingness to pay; WQ = water quality.
aValues are in 2015 KRW/household/month.
bSample values in the data set.

### Table 5. Annual MWTP, Benefit Assessment, and Benefit–Cost Ratios in Each River.

| River   | Annual MWTPa | No. of household | Total benefit (A) (billion won/year) | Total cost (B) (billion won/year) | Benefit–cost ratio (A/B) |
|---------|--------------|-----------------|--------------------------------------|----------------------------------|--------------------------|
| Han     | 53,198.2     | 9,210,710       | 490.0                                | 433.4                            | 1.13                     |
| Nakdong | 36,254.6     | 4,773,567       | 173.1                                | 228.0                            | 0.76                     |
| Geum    | 22,805.1     | 2,193,688       | 50.0                                 | 113.0                            | 0.44                     |
| Grand Total | —        | —              | 713.1                                | 774.3                            | 0.92                     |

*Note. MWTP = marginal willingness to pay.
aAnnual MWTP, total benefit, and total cost are in 2015 KRW.
bAnnual MWTP is based on Median MWTP in Table 4 because the null hypothesis of normality test for the mean values in the data set is rejected.
rational to levy more (less) costs on the water users who received more (less) benefits from the use of water resources (Shin et al., 2016).

Second, the RMFs should be operated more efficiently. As the implementation of the RMFs, the majority of the funds have been invested in resident support projects and wastewater treatment infrastructure projects. However, over-investment in these projects has raised ongoing debates between stakeholders and the National Assembly Research Service pointed out the operational inefficiency of RMFs in 2012. Recently, the main sources of water pollution in the rivers are attributed from the non-point sources, particularly from the agriculture and livestock farming in the upstream of the river basin. Therefore, the RMFs should be invested in the water quality projects that can better leverage funds to reduce non-point source pollutions in the upstream of the river basin, which can result in improving overall water quality. For instance, if the priority of RMFs investment is given to the purchase of agricultural lands in the upstream areas, overall water quality objectives can be achieved at lower costs (Choi et al., 2016).

Third, as water conditions in each river basin are unique, the operation of the RMFs should be tailored for each river. Each river basin has a different pollution source, which implies investment decisions of RMFs should be based on the natural properties of the river as well as the nature of the pollution affecting it in each river. Finally, a collaborative governance approach would be meritorious for the effective water management. A collective management approach with stakeholder engagement in setting regulations at the local level can create buy-in, increase trust in government processes, and ultimately find effective solutions to achieve desired water quality outcomes. Stakeholder engagement through inclusive basin water governance is increasingly recognized as critical to secure support for reforms, raise awareness about water risks and costs, increase users’ willingness to pay, and to handle conflicts (Organisation for Economic Cooperation and Development, 2015).

Summary and Conclusion

The economic evaluation of the water management policy is important to determine the achievement of its goals and performance of financial management. Applying the logic of benefit transfer approaches, this study aims to evaluate the economic efficiency of water resource management in South Korea based on benefit–cost comparison and to provide a valuable guideline that can help maintain the sustainability of water resources.

With the total of 72 observations from 30 studies obtained from the EVIS provided by KEI, a meta-regression model which allows for estimating different benefits provided by each river was estimated. This article specified a meta-regression model which allows for differential impact of water quality improvement on value estimates by each river taking the possible heterogeneity between rivers into account. Based on the optimized meta-regression model, two statistical tests were performed to ensure the validity of a meta-regression result. The estimation results revealed that the factors such as methodology-related variables, respondents’ characteristics, baseline water quality, and improvement water quality have an impact on WTPs. Especially, WTP values increase as water quality grade increases and its impact is distinguished by each river.

Using the coefficients associated with water quality improvement, the marginal benefits (MWTPs) for increase in water quality grade by the each river basin were computed. The estimated median MWTPs are calculated to be about US$4.7, US$2.9, and US$2.0 per household per month in Han River, Nakdong River, and Geum River, respectively. Applying total number of households in each river basin, the total benefits were estimated to be about US$490 million, about US$173 million, and about US$50 million per year in Han River, Nakdong River, and Geum River, respectively. The estimated total benefits were then compared with the total costs invested in managing water quality in each river to assess how well water management is maintained in economic aspects. The benefit–cost ratio indicates that while the Han River has been making an efficient investment (BC ratio >1), benefit–cost ratio for Nakdong and Geum River is less than 1, which implies two rivers may not be making a reasonable investment. Based on the benefit–cost analysis, this study recommended a few policy options including the equity of imposing water use charges, operational efficiency of RMFs, and stakeholder engagement for inclusive water governance that can be useful to maintain the sustainability of water resource management in the long run.

The limitation of this study is as follows. The sample size used in the analysis is relatively skewed toward the Han River case. Even though several tests to control for the unobserved impact of panel data structure were performed, there might exist some issues that can arise from the imbalanced sample size. Given small number of valuation studies related to the water quality improvement and the tendency toward Han River case, the new valuation studies need to be extended to Nakdong and Geum River case to balance the sample distribution. To conclude, as more databases are available, this study needs to be updated to improve the reliability of MRA. Moreover, a further research which can address ongoing debates between stakeholders regarding the suitability of amount of water use charges should be carried out.
Appendices

Table A1. List of Original Studies Used in Meta-Regression Analysis.

| Id | Study area | Year | Valuation technique | WQ improvement\(^a\) | Baseline WQ grade | Value measured | No. of WTP estimates |
|----|------------|------|---------------------|----------------------|------------------|----------------|---------------------|
| 1  | Han River  | 1996 | CVM                 | 1                    | G3               | Total value    | 1                   |
| 2  | Han River  | 1993 | CVM                 | 1                    | G3               | Drinking       | 4                   |
| 3  | Geum River | 2000 | CVM                 | 1 or 2               | G4               | Total value    | 4                   |
| 4  | Han River  | 2000 | CVM                 | 2                    | G3               | Total value    | 1                   |
| 5  | Han River  | 2000 | CVM                 | 2                    | G3               | Total value    | 3                   |
| 6  | Han River  | 2000 | CVM                 | 2                    | G3               | Total value    | 1                   |
| 7  | Han River  | 2001 | CVM                 | 2                    | G3               | Drinking       | 1                   |
| 8  | Nakdong River | 2001 | CVM                 | 1                    | G3               | Total value    | 1                   |
| 9  | Han River  | 2001 | CVM                 | 2                    | G3               | Recreation     | 1                   |
| 10 | Han River  | 2001 | CVM                 | 1                    | G3               | Total value    | 1                   |
| 11 | Han River  | 2003 | CVM                 | 1                    | G2               | Recreation     | 1                   |
| 12 | Han River  | 2003 | CVM                 | 2                    | G3               | Drinking       | 4                   |
| 13 | Han River  | 2003 | CVM                 | 2                    | G3               | Recreation     | 2                   |
| 14 | Nakdong River | 2004 | CVM                 | 2                    | G3               | Drinking       | 1                   |
| 15 | Nakdong River | 2004 | CVM                 | 2                    | G3               | Total value    | 1                   |
| 16 | Han River  | 2004 | CE                  | 1                    | G3 or G2         | Total value    | 2                   |
| 17 | Nakdong River | 2006 | CVM                 | 2                    | G3               | Total value    | 2                   |
| 18 | Han River  | 2006 | CVM                 | 2                    | G3               | Drinking       | 2                   |
| 19 | Nakdong River | 2006 | CVM                 | 2                    | G3               | Total value    | 2                   |
| 20 | Han River  | 2007 | CVM                 | 1                    | G3               | Total value    | 6                   |
| 21 | Han River  | 2007 | CE                  | 1 or 2              | G3 or G4 or G5 or G2 | Total value | 9 |
| 22 | Han River  | 2007 | CVM                 | 2                    | G3               | Total value    | 1                   |
| 23 | Nakdong River | 2008 | CVM                 | 1                    | G3               | Total value    | 4                   |
| 24 | Geum River | 2008 | CVM                 | 2                    | G5               | Total value    | 1                   |
| 25 | Nakdong River | 2009 | CVM                 | 2                    | G3               | Drinking       | 8                   |
| 26 | Nakdong River | 2010 | CVM                 | 1                    | G2               | Drinking       | 1                   |
| 27 | Geum River | 2012 | CVM                 | 1                    | G2               | Recreation     | 2                   |
| 28 | Han River  | 2014 | CE                  | 1                    | G2               | Recreation     | 2                   |
| 29 | Geum River | 2015 | CE                  | 1                    | G2               | Recreation     | 2                   |
| 30 | Geum River | 2015 | CE                  | 1                    | G2               | Recreation     | 1                   |

Note. WQ = water quality; WTP = willingness to pay; CVM = contingent valuation method; CE = choice experiment.

\(^a\)Level of WQ improvement calculated by hypothetical WQ grade minus baseline WQ grade.

Table A2. Validity Test Results of Meta-Regression Model.

| Category                  | Predicted WTP | Original WTP |
|---------------------------|---------------|--------------|
| Mean                      | 8.16          | 8.10         |
| % difference of mean WTP\(^a\) | 0.731         |              |
| Paired t-test (N)         | −0.838 (71)   |              |
| Pearson’s correlation coefficient | 0.804*        |              |

Note. WTP = willingness to pay.

\(^a\)Calculated as \(\frac{\text{predicted WTP} - \text{original WTP}}{\text{predicted WTP}} \times 100\).

\(^*\)Significant at 1% level.

Validity Test Results

To evaluate the credibility of the meta-regression model, the predicted WTP values were compared with the original values. The mean values of the predicted WTP and original WTP are provided in the first row in Table A2. As shown, two values are quite similar and the mean percentage difference between two values is only 0.731 (second row in Table A1), which indicates a relatively small prediction error. Furthermore, the meta-predicted values and original values are not statistically different according to the insignificant
t-statistics of the paired t-test in the third row. Similarly, the significant Pearson’s correlation coefficient indicated the positive correlations between two values. Therefore, these two statistical tests support credibility of the meta-regression model for benefit assessments.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was part of and was funded by the research project “An Integrated Approach to Environmental Valuation via Impact Pathway Analysis” (GP2018-11) of the Korea Environment Institute (KEI).

ORCID ID
Hyun No Kim https://orcid.org/0000-0001-8386-1399

References
Cha, J., Yoo, Y.-H., & Lee, H. (2018). A study on value estimation of water resource using benefit transfer method: Focusing on meta-regression analysis. Journal of Environmental Policy and Administration, 26(4), 105–122.
Champ, P. A., Boyle, K. J., & Brown, T. C. (2017). A primer on nonmarket valuation (2nd ed.). Springer.
Choi, I., Kim, H. N., Shin, H., Tenhunen, J., & Nguyen, T. T. (2016). Willingness to pay for a highland agricultural restriction policy to improve water quality in South Korea: Correcting anomalous preference in contingent valuation method. Water, 8, 547.
Columbo, S., & Hanley, N. (2008). How can I reduce the errors from benefits transfer? An investigation using the choice experiment method. Land Economics, 84, 128–147.
Ge, J., Kling, C. L., & Herriges, J. A. (2013, March). How much is clean water worth? Valuing water quality improvement using a meta analysis (Working Paper No. 13016). Iowa State University.
Griffiths, C., & Wheeler, W. (2005). Benefit–cost analysis of regulations affecting surface water quality in the United States. In R. Brouwer & D. Pearce (Eds.), Cost–benefit analysis and water resources management (pp. 223–250). Edward Elgar.
Hanley, N., Colombo, S., Tinch, D., Black, A., & Aftab, A. (2006). Estimating the benefits of water quality improvements under the water framework directive: Are benefits transferable? European Review of Agricultural Economics, 33, 391–413.
Iovanna, R., & Griffiths, C. (2006). Clean water, ecological benefits, and benefits transfer: A work in progress at the U.S. EPA. Ecological Economics, 60, 473–482.
Johnston, R. J., Besedin, E. Y., Iovanna, R., Miller, C. J., Wardwell, R. F., & Ranson, M. H. (2005). Systematic variation in willingness to pay for aquatic resource improvements and implications for benefit transfer: A meta analysis. Canadian Journal of Agricultural Economics, 53, 221–248.
Johnston, R. J., Besedin, E. Y., & Stapler, R. (2017). Enhanced geospatial validity for meta-analysis and environmental benefit transfer: An application to water quality improvements. Environmental and Resource Economics, 68, 343–375.
Jung, J. (1995). A study on the policy response process to the social crisis: The accident of phenol pollution of Nakdong River. Korean Public Administration Review, 29(1), 23–46.
Kim, H. N., Boxall, P. C., & Adamowicz, W. L. (2016a). Analysis of the impact of water quality changes on residential property prices. Water Resources and Economics, 16, 1–14.
Kim, H. N., Boxall, P. C., & Adamowicz, W. L. (2016b). The demonstration and capture of the value of an ecosystem service: A quasi-experimental hedonic property analysis. American Journal of Agricultural Economics, 98, 819–837.
Kim, S. G., Jeong, J., & Nam, H. (2019). Impact of water resources information on non-market valuation. Journal of Environmental Policy and Administration, 27(4), 23–40.
Kling, C. L., & Phaneuf, D. J. (2018). How are scope and adding up relevant for benefits transfer? Environmental and Resource Economics, 69, 483–502.
McComb, G., Lantz, V., Nash, K., & Rittmaster, R. (2006). International valuation databases: Overview, methods and operational issues. Ecological Economics, 60, 461–472.
Korea Environmental Policy Bulletin. (2016). Korea Environmental Policy Bulletin, South Korea: Ministry of Environment.
Muthke, T., & Holm-Mueller, K. (2004). National and international benefit transfer testing with a rigorous test procedure. Environmental and Resource Economics, 29, 323–336.
Organisation for Economic Cooperation and Development. (2015). Stakeholder engagement for inclusive water governance: OECD studies on water. OECD Publishing. http://dx.doi.org/10.1787/9789264231122-en
Phaneuf, D. J., Smith, V. K., Palmquist, R. B., & Pope, J. C. (2008). Integrating property value and local recreation models to value ecosystem services in urban watersheds. Land Economics, 84(3), 361–381.
Rosenberger, R. S., & Loomis, J. B. (2001). Benefit transfer of outdoor recreation use values: A technical document supporting the forest service strategic plan (2000 revision) (No. RMRS-GTR-72). U.S. Department of Agriculture, Forest Service.
Shin, H., Kim, H. N., Jeon, C., Jo, M., Nguyen, T. T., & Tenhunen, J. (2016). Benefit transfer for water management along the Han River in South Korea using meta-regression analysis. Water, 8, 492.
Shrestha, R., & Loomis, J. (2001). Testing a meta-analysis model for benefit transfer in international outdoor recreation. Ecological Economics, 39, 67–83.
Van Houtven, G., Powers, J., & Pattanayak, S. K. (2007). Valuing water quality improvements in the United States using meta-analysis: Is the glass half-full or half-empty for national policy analysis? Resource and Energy Economics, 29(3), 206–228.