Analysis of Benefit Transfer for Water Management in Bukhan River Using Meta-Regression Analysis

Shin, Hio-Jung (1); Jeon, Chul-Hyun (2); Lee, Saem (3); Koellner, Thomas (3); Nguyen, Trung Thanh (4); Tenhunen, John (4)

(1) Department of Agricultural and Resource Economics, Kangwon National University, 200-701 Chuncheon, Republic of Korea, hiojung@kangwon.ac.kr
(2) Korea Forest Research Institute, 130-712 Seoul, Republic of Korea, chjeon@forest.go.kr
(3) Professorship of Ecological Services (PES), University of Bayreuth, 95440 Bayreuth, saem.lee@uni-bayreuth.de, thomas.koellner@uni-bayreuth.de
(4) Department of Plant Ecology, University of Bayreuth, 95440 Bayreuth, Germany, thanh.nguyen@uni-bayreuth.de, john.tenhunen@uni-bayreuth.de

Abstract: The purpose of this study was to estimate the magnitude of economic benefits that are justified in transfer to up-stream communities and rural populations for use of Bukhan River water by downstream populations. Alternatives for regional cost-benefit sharing are estimated by meta-regression analysis with models with and without the inclusion of socio-economic variables. Based on these models, an equitable benefit transfer of 14,362 to 31,327 KRW per household per month is obtained in the case of a “revealed preference model” formulation, while 411 - 1,689 KRW per household per month is suggested with a “stated preference model.” The benefit transfer estimated when socio-economic variables are included, are more than four times as much as without them in the stated preference model. With the revealed preference model, the benefits with socio-economic variables are more than twice as much as without them. An important reason why large differences in estimated values for benefit transfer have been reported appears to be the model method used. When applying the study results to the Bukhan River case, 14,362 to 31,327 KRW per household per month as calculated with the revealed preference model are reasonable. Then total benefits paid for water resource use of Bukhan River are calculated to be around 74.6 to 162.8 billion KRW per month with Seoul providing the largest contribution and Incheon the second largest. Benefits to Incheon of 4.1 billion to 8.9 billion KRW, to Gyunggi of 17.0 billion to 37.0 billion KRW, and to Gangwon of 18.6 billion to 40.7 billion KRW per month should be paid by Seoul metropolitan city through such incentives as tradable development rights. Costs for water quality and quantity management should be shared based on the derived benefits indicated. In the case of success with 100 percent benefit transfer, the costs should be paid by the local and/or provincial governments. In the case of success in less than 100 percent benefit transfer, the costs should be determined by agreements between local and/or provincial governments apart from the issues on benefits distribution. The results of our study provide economic indicators useful in the planning of environmental policy and to consider stakeholders' rights within the framework of regional costs and benefits.

Key words: *cost-benefit sharing, revealed preferences, stated preferences, benefit transfers*

1. Introduction

According to international organizations including the UN, benefits and costs from water resource use should be equally and/or equitably distributed among river basin stakeholders. As a background, such principles recognize that downstream communities and their people (DCP) or midstream communities and their people (MCP) are, in general, economically well-developed while upstream communities and their people (UCP) may not be. In other words, UCP are often related to rural populations while MCP and DCP are urban or metropolitan. If economic activities to protect water quality and to maintain adequate water yield for MCP and DCP are restricted only to UCP, then UCP lose their opportunities for economic development. In this situation, some measures could be made to achieve Pareto improvement or to maintain a Pareto optimality. According to principle, DCP and/or MCP should distribute some benefits to MCP and/or UCP, should pay in part for costs of maintenance and management of the river system, and should contribute to equity and equality. One should strive for a Pareto efficient outcome.

However, such efforts have not been carried out in Korea, especially along the Bukhan River, which has led to many controversies and disputes among stakeholders. Previous studies within the watershed have been implemented by independent interest groups rather than with participation of all stakeholders. Thus, one stakeholder does not accept the other's results, leading to information exchange with neither objectivity nor rationality. What is needed are efforts that result in a rational distribution of the benefits from water resource conservation, and rational water use among stakeholders, considering equity, equality, and economic efficiency.

Consequently, the purpose of this study is to provide a clear rationale with respect to the benefits and costs related to water resource management, applying scientific methods with which all stakeholders should be satisfied. Meta-regression analysis provides a technique that can contribute to solutions with objective validity. It can bring together all relevant study results and information that has been gathered on UCP, MCP and DCP. Consideration of possible benefit transfers, via a meta-regression analysis applied to the Bukhan River case, would provide an economic indicator useful in assigning redistribution of costs and benefits, and could result in more efficient use and conservation of water resources as well as overall improved social welfare.

2. Methods

2.1. Concepts of Benefit Transfer and Meta-Regression Analysis

Benefit transfer refers to the application of economic information about existing benefits in goods and services at one location to another similar location, when it is impossible to collect new raw data due to limits in budget and time (Desvousges, *et al*., 1998; Rosenberger and Loomis, 2001). Since benefit transfer studies were first introduced in 1992, case studies in various fields, such as water quality management policy (Luken, *et al*., 1992), water quality related health risk assessment (Kask and Shogren, 1994), waste disposal (Brisson and Pearce, 1995), and forest management (Bateman, *et al*., 1995), have been published (see also Brouwer, 2000; Ruijgrok, 2001). The number of benefit transfer case studies using meta-regression analysis have also been increasing (Rosenberger and Loomis, 2001; Shrestha and Loomis, 2001; Muthke and Holm-Mueller, 2004).

Meta-regression analysis (MRA) attempts to estimate the effect size of quantifiable factors on benefits via regression analysis. In MRA, the dependent variable is expressed as a valued benefit as defined at actual study sites or in related literature. The independent variables are characteristics of population, goods and/or services or factors related to specific sites. Dummy variables or those which occur only as values of 0 and 1, presence or absence, are often included. The MRA is able to extract the apparent influences on the desired benefit that occur due to particular factors, the estimation methods applied, the study design, and data characteristics, even to statistically identify differences in individual study results due to gaps in summarized statistics.

2.2 Model Selection

Data for the MRA has a similar structure to panel data. If observations extracted by individual studies are not the same, it is similar to unbalanced panel data. Therefore, the data may also be considered in the context of a fixed effect model (FEM) or random effect model (REM), which are the common methods used in panel data analysis.

Assuming variation shared by observations in the same study to reflect their structural differences, the FEM includes dummy variables for all individuals. Therefore, expected values of the error term and variance are written as below:

$$y = \alpha + \beta' \mathbf{x} + \varepsilon \qquad (1)$$
$$E[\varepsilon_{ij}]=0,\ Var[\varepsilon_{ij}]=\sigma^2_{\varepsilon}$$

where i denotes individual studies, j observations are derived from the specific study and α_i is a mean constant term for the individual study. Accordingly, FEM, as the classical linear regression model, includes dummy variables for each individual study which may have a limit in actual applications because the degrees of freedom may be significantly decreased in comparison to the case with a number of studies.

On the other hand, if individual studies are regarded to be randomly sampled from a mother distribution of observations in REM and with the assumption that it truly exists (Desvousges et al., 1998). That is, it can be assumed that variation between observations in the same study could be a stochastic variable in the REM. The error term is the sum of an error related to individual observations, ε_{ij}, and an error related to specific studies which they are taken from, u_i.

$$y = \alpha + \beta' \mathbf{x}_{ij} + \varepsilon_{ij} + u_i$$

$$E[ui] = 0,\ Var[ui\ ]=\sigma^2 u, \qquad (2)$$
$$Var[\ \varepsilon\ ij{+}ui]=\sigma^2\varepsilon\ + \sigma^2 u\ ,\ Cov[\varepsilon\ ij,ui]=0$$

Compared with FEM, REM would not cause problems such as loss in the degrees of freedom, since one more parameter would be estimated. Thus, from the theoretical point of view, it appears that REM would be more appropriate for empirical analyses than FEM, depending upon the presence of heteroscedasticity and its characteristics. Accordingly, hypothesis testing is needed to identify the presence of variation between observations in the same study in model (2). The null hypothesis is $H_0 : \sigma^2 u = 0$. If the alternative hypothesis is not rejected, then REM is not statistically better than a linear regression model with the assumption of homoscedasticity between observations.

3. Estimation Results for Benefit Transfer

In this study, we first chose the independent variables to be used in MRA, and subsequently we tested via a Lagrange multiplier whether or not specific variation existed in particular studies. The final models for MRA were selected after the existence of heteroscedasticity was identified with a Breusch-Pagan test.

3.1 Variables

To select the independent variables, 31 relevant studies were identified in a search of Korean literature. The data base in these previous studies included 30 to 50 variables. Observed data included special features of river basins, valuation methods, and natural environmental factors related to the Bukhan River.

When selecting independent variables in model, we must keep in mind significant differences between a regression model applied for meta-analysis and a meta-regression model (MRM) for benefit transfer. The purpose of the former is to generally analyze impacts by selected estimation methods as well as characteristics of studies through summarized statistics. In order to conduct meta-analysis, hypotheses should be set up, and then independent variables included in the model should be tested. In the case of MRM for estimating benefit transfer, however, it is more appropriate to include the most suitable independent variables into the model rather than be concerned about correlation between summarized statistics and independent variables. This is because MRMs are used as a tool to predict best benefit transfers, and is less oriented to the meta-analysis itself.

Table 1 shows description of variables that were used in the model for meta-regression analysis. 12 variables are used for the analysis. 9 out of them are dummy (taking values of 0 or 1) while the rest are socio-economic variables.

Table 1. Description of variables chosen from 31 published studies for the meta-regression model analysis

Variables	Description
C	constant
CLOSED	closed WTP question (0: no use, 1: use)
CA	conjoint analysis question (0: no use, 1: use)
CVM	CVM question (0: no use, 1: use)
EDU	education (year)
GENDER	sex (0: female, 1: male)
INCOME	income (won)
MARKET	market value approach (0: no use, 1: use)
OPEN	open WTP question (0: no use, 1: use)
RIMO	special features of natural environment (river and mountains) (0: no use, 1: use)
TREND	years of study (origin of study year = 1)
AGE	ages (year)
AREA	special features of river basin (0: no use, 1: use)

3.2 Results for Estimated Equitable Benefit Transfer

In this study, two models of meta-regression analysis were used. The first model includes socio-economic variables and generally applied variables. The second one is without socio-economic variables. Dependent variables of both models are ln WTP(willingness to pay for clean water). The estimation results show that $\bar{R}$-squared values of models with and without socio-economic variables are 0.84 and 0.79. The models are plausible and have relatively high statistical significance. Estimated values have low statistical significance, however, with less confidence in the case of the model with socio-economic variables than in that without. Possibly this occurs because the number of studies is small.

Table 2. Estimation results for regressions relating factors to willingness to pay (WTP)

Variable	model w/ socio-economic variables		model w/o socio-economic variables	
	Coefficient	t-Statistic	Coefficient	t-Statistic
C	8.623991	2.849811	11.01537	18.19442
CLOSED	-0.314288	-0.54586	-0.528	-1.14303
CA	-1.450279	-0.79957	-2.54924	-3.66983
CVM	-0.843629	-0.49053	-1.78502	-2.91552
EDU	0.119033	0.596353	-	-
GENDER	2.681226	0.940136	-	-
INCOME	-1.99E-07	-0.90761	-	-
MARKET	0.559607	0.354235	-0.54204	-1.06609
OPEN	0.42263	1.618929	0.484809	2.065571
RIMOUNT	-0.482844	-1.2502	-0.16806	-0.50021
TREND	-0.032878	-0.8429	-0.02577	-0.93891
AGE	-0.021199	-0.49253	-	-
AREA	-0.13076	-0.62998	-0.10277	-0.56578
	R^2 : 0.84 (*Adj* R^2 : 0.72) *D.W.* : 1.94 *P(F-stat)* : 0.000227 *N* : 31		R^2 : 0.79 (*Adj* R^2 : 0.71) *D.W.* : 2.17 *P(F-stat)* : 0.000022 *N* : 31	

Based on the regression modeling results, Table 3 indicates derived benefits with adjusted coefficients by using the "2008 Socio-Economic Index". Benefits are determined to be 14,362 - 31,327 KRW per household per month in the case of revealed preference model (RPM) and 411 - 1,689 KRW per household per month in the case of stated preference model (SPM). The benefits from the model with socio-economic variables in the RPM are more than 8.5 - 76.3 times higher than the model without them in the SPM. It means that if the natural environment (river) is in actual use, e.g., economic gains such as water related recreation activities in rivers, views of clean water to attract tourists, reliability in the supply of drinking water occurred, then the level of water quality would play a very significant role in water-related decision making.

Also, socio-economic variables turn out to have an influence on water related benefits. Benefits estimated from the model with socio-economic variables are more than four times that in the model without them in the SPM, while those from the latter are more than twice that in the former in the RPM. Such results might be due to SPM's methodological framework. Since respondents would state their WTPs based on given information in the SPM regardless of use of natural resources, reliability of their WTPS could be highly related to their socio-economic backgrounds. Also, they generally prefer non-use of the natural environment to its use.

In the case of RPM, the positive relationship between WTP and cleanliness and favorability of natural resources should be recognized since the respondents' WTPs are closely related to their actual use of natural resources. Accordingly, since their WTPs are not from the hypothetical market but from the real market, their socio-economic backgrounds would not influence the estimation by SPMs. Also, the reason why the range in estimated values appears to be large might depend on which method is being used. Therefore, when applying the study results to the Bukhan river case, 14,362 - 31,327 KRW per household per month in the case of RPM could be more reasonable.

Table 3. Benefit derivation results

variables	model w/ socio-economic variables			model w/o socio-economic variables		
	coefficients	coefficient adjustment of policy site		coefficients	coefficient adjustment of policy site	
		revealed	stated		revealed	stated
C	8.623991	1	1	11.01537	1	1
CLOSED	-0.314288	0	1	-0.528001	0	0
CA	-1.450279	0	0	-2.549243	0	1
CVM	-0.843629	0	1	-1.785023	0	1
EDU	0.119033	11.25	11.25	-	-	-
GENDER	2.681226	0.5023	0.5023	-	-	-
INCOME	-1.99E-07	2.58E+06	2.58E+06	-	-	-
MARKET	0.559607	1	0	-0.54204	1	1
OPEN	0.42263	1	0	0.484809	1	1
RIMOUNT	-0.482844	1	1	-0.168057	1	1
TREND	-0.032878	13	13	-0.025774	13	13
AGE	-0.021199	55	55	-	-	-
AREA	-0.13076	1	1	-0.10277	1	1
calculated coefficient		9.57	7.43	c.c.	10.35	6.02
estimated value		14,362 KRW per mo. per hh.	1,689.47 KRW per mo. per hh.	e.v	31,327 KRW per mo. per hh.	410.75 KRW per mo. per hh.

3.3 Benefit Derivation

Total benefits from water use along the Bukhan River are estimated to be about 76.6 billion to 167.0 billion KRW per month. The highest benefits account for 76.23% of the total and are assigned to Seoul. Next, 19.03% of benefits must be assigned to Incheon which has the second highest number of households.

Table 4. Regional benefits from use of Bukhan River (including Gangwon)

Region	Benefits per hh. (won per month)	no. of Households	Total Benefits (mil. won per month)	percent
Seoul	14,362~31,327	4,064,117	58,368.8~127,317.0	76.23
Gyunggi[1)]	14,362~31,327	118,087	1,696.0~3,699.3	2.21
Incheon	14,362~31,327	1,014,755	14,573.9~31,789.2	19.03
Gangwon[2)]	14,362~31,327	134,423	1,930.6~4,211.1	2.52
Total	14,362~31,327	5,331,382	76,569.3~167,016.0	100.00

1): Gyunggi means Gapyeong, Yangpueong, and Hanam.
2): Gangwon means Chuncheon, Hwacheon, Inje, and Yanggu.

Since Soyang Dam was established in 1973, however, Gangwon has had little benefit from the Bukhan River, considering opportunity costs of development forgone under regulations. Thus, zero benefit from water uses is applied to Gangwon in this study (Gangwon, 2007).

Based on the above, total benefits from water resource use of Bukhan river are calculated to be around 74.6 bil. - 162.8 bil. KRW per month with Seoul the first and Incheon the second. Benefits of Incheon 4.1 bil. - 8.9 bil. KRW, Gyunggi 17.0 bil. - 37.0 bil., KRW and Gangwon 18.6 bil. - 40.7 bil. KRW per month should be paid by Seoul metropolitan city through such policy tool as tradable development right.

Table 5. Regional benefits from use of Bukhan River (excluding Gangwon)

Region	Benefits per hh. (won per month)	no. of households	Total Benefits (mil. won per month)	percent
Seoul	14,362～31,327	4,064,117	58,368.8～127,317.0	78.20
Gyunggi	14,362～31,327	118,087	1,696.0～3,699.3	2.27
Incheon	14,362～31,327	1,014,755	14,573.9～31,789.2	19.53
Total	14,362¢～31,327	5,196,959	74,638.7～162,805.0	100.00

3.4 Redistribution of Benefits

According to WCD (World Commission on Dams, 2000) based on Agenda 21, benefits from water resource use should be equally distributed among all stakeholders. Also, all stakeholders with various disadvantages including water resource related regulation should not only to be included in benefit distribution, but also DCP with the largest benefits from water use should pay for water resource management costs. Following WCD, each community's benefit from water resource use of Bukhan River would be, respectively, about 18.6 billion to 40.7 billion KRW by equal distribution of total benefits. It means that three other communities outside of Seoul have been losing their benefits (opportunity costs). Seoul with more benefits should return its extra benefits to the other communities, 4.1 to 8.9 billion KRW to Incheon, 17.0 billion to 37.0 billion KRW to Gyunggi, and 18.6 billion to 40.7 billion to Gangwon monthly.

Table 6. Benefit allocation along Bukhan River

(unit : million won per month)

Region	Total Benefit	Adjusted Benefit	Amount of Benefit Transfer
Seoul	58,368.8~127,317.0	18,659.7～40,701.3	(-)39,709.1~86,615.7
Gyunggi	1696. 0~3,699.3	18,659.7~40,701.3	(+)16,963.7~37,002.0
Incheon	14,573.9~31,789.2	18,659.7~40,701.3	(+)4,085.8~8,912.1
Gangwon	0	18,659.7~40,701.3	(+)18,659.7~40,701.3
Sum	74,638.7~162,805.0	74,638.7~162,805.0	0

4. Summary and Conclusion

Based on previous independent studies by many stakeholders along the Bukhan River, costs and benefits related to use of water resources were estimated with MRA. While variation occurs in estimates of the total benefits from the Bukhan River, our study suggests a justifiable framework for redistribution of benefits. The main study results are as follows:

Variables were selected to be included into the models after differences were analyzed between characteristics of study sites and policy for testing validity of benefit transfer. The models for benefit estimation had $\bar{R}$-squared values with and without socio-economic variables of 0.84 and 0.79, which means that both models have relatively high statistical significance.

Water use benefits of Bukhan River according to the revealed preference models are found to be 14,362 - 31,327 KRW per month per household. Extending to all stakeholders along the Bukhan river, total benefits of water use per month are calculated to be 74.6 bil. - 162.8 bil. KRW; 58.4 bil. - 127.3 bil. KRW in Seoul, 14.6 bil. - 31.8 bil. KRW in Incheon, and 1.7 bil. - 3.7 bil. KRW in Gyunggi, respectively. Based on the equity principle of benefits, however, extra benefits in Seoul beyond adjusted benefits of 18.7 bil. - 40.7 bil. KRW should be reallocated to other stakeholders. Their additional monthly benefits they should receive from Seoul would be 4.1 bil. - 8.9 bil. KRW in Incheon, 17.0 bil. - 37.0 bil. KRW in Gyunggi, and 18.7 bil. - 40.7 KRW bil. in Gangwon.

In the case of 100% achievement of benefit transfer, management costs for water quality and quantity of Bukhan River should be paid by the polluter's pay principle. Otherwise, its costs should be determined according to agreements between stakeholders based on the fairly shared principle of cost, and independently of amounts of transferred benefits.

The estimates for transferred benefits are not the exact amounts of money stakeholders should pay and be paid, but the size of benefits is a value for negotiation. Thus, our estimates should be used as scientific and economic indicators related to equitable benefit distribution and cost sharing between stakeholders along the river. An economic incentive such as tradable (transferable) development rights could be applied to obtain the economic justice of Pareto improvement. Such policy suggestions are based on results from independent studies by many stakeholders, which means that they probably are rational and have objective validity. The study results, therefore, might contribute to abatement of serious disputes which have occurred in all river basins in Korea as well as to achieving sustainable development.

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