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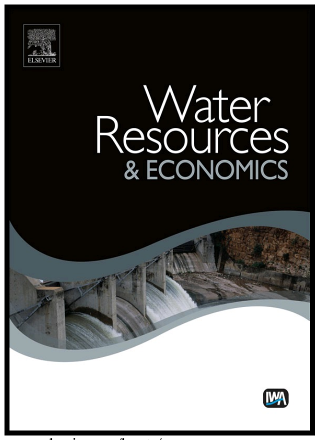

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PII: S2212-4284(17)30020-8
DOI: http://dx.doi.org/10.1016/j.wre.2017.02.005
Reference: WRE89

To appear in: *Water Resources and Economics*

Cite this article as: Roy Brouwer and Oleg Sheremet, The economic value o river restoration, *Water Resources and Economics* http://dx.doi.org/10.1016/j.wre.2017.02.005

The economic value of river restoration☆

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1. Introduction

Water policies are often still evaluated primarily on the basis of their budgetary financial costs since these costs are typically relatively easily calculated. The calculation of all costs and benefits, including (second-order) indirect effects on sectors and (non-priced) environmental effects, often referred to as the broader social costs and benefits (e.g. Brouwer and van Ek, 2004), is a more difficult task. Social cost-benefit analysis (CBA) is a widely applied method for evaluating public water policies, since government interventions are often related to the provision of public goods, having an impact on society as a whole. Such impacts should consequently be valued and evaluated from a societal perspective, not the perspective of the investor only, such as a central or local government. Restored or 'natural' river corridors

☆ **Introduction to the special issue and a meta-analysis of the nonmarket valuation literature to inform river restoration policy and decision-making** typically have the potential to provide a wide range of ecosystem services (Vermaat et al., 2016). It is the wider social value attached to these ecosystem services besides their ecological value that is often missing in information supply supporting river restoration policy and decision-making.

CBA is carried out in order to evaluate and compare the various advantages and disadvantages of river restoration projects in a structured and systematic way. The benefits from a restoration project are compared with the associated costs within a common analytical framework with clearly defined spatial and temporal boundaries. To allow comparison of these costs and benefits related to a wide range of impacts, measured in widely differing units, money is used as the common denominator. The results of this analysis can be interpreted as a B-C ratio, that is, total benefits divided by total costs, where a ratio larger than one indicates that the policy measure is beneficial from a social point of view and hence yields a welfare improvement. A CBA compares the costs and benefits of different restoration options in monetary terms. Strictly speaking, only those costs and benefits are included in a CBA that can be quantified in monetary terms. This is where usually most problems start for river restoration project appraisal since many effects, in particular ecological benefits, are often not priced in monetary terms. For many goods and services provided by restored or natural water resources, there is no market where they are traded, and therefore no market price is available, which reflects their economic value. Hence, it will hardly ever be possible to monetize all impacts all the time. Those impacts that cannot be monetized are therefore often left out of the analysis.

While a textbook CBA requires that all impacts be monetized, in practice different approaches exist on how non-monetized impacts are included in CBA. Non-monetized impacts, if considered relevant, can for instance be included in a qualitative discussion accompanying the CBA results. Pearce (1998) argues that in early CBA's conducted in the UK, such impacts would have been either ignored entirely, left for a subsequent environmental impact analysis, or monetized only partly. Applying an approach of monetizing impacts where possible, and including them in another form where monetization is not possible marks a deviation from the textbook ideal, but does not discredit the method as such. Moreover, there are nowadays several economic valuation methods, which allow placing a monetary value on non-marketed goods and services. Including these non-market values in a CBA means that a wide range of environmental goods and services provided by river restoration are explicitly recognized in the CBA.

This special issue focuses on the estimation of the economic benefits of river restoration, applying different stated and revealed preference methods, in urban and rural areas across Europe (Adeva Bustos et al., 2017; Lehtoranta et al., 2017), the US (Lewis and Landry, 2017) and Australia (Polyakov et al., 2017). The special issue also includes a qualitative review of existing valuation studies and their use and usefulness in US and European restoration policy and decision making (Bergstrom and Loomis, 2017), and a quantitative meta-analysis of the existing literature in this paper. The selected studies examine the trade-offs between the production of Atlantic Salmon smolt and hydropower in a regulated river in southern Norway (Adeva Bustos et al., 2017), the impact of hydropower dam removal in the Kennebec watershed in Maine, USA (Lewis and Landry, 2017) to restore sea-run fisheries on surrounding property values, the restoration of urban drains into fully functioning wetland ecosystems or living streams on property values in Perth, Australia (Polyakov et al., 2017), and restoration of sediment-stressed forest streams in the river Iijoki catchment in northeastern Finland (Lehtoranta et al., 2017).

In the remainder of this paper, the results of a quantitative meta-analysis of the existing literature are presented, summarizing the non-market values based on almost 40 stated preference studies for the ecosystem services associated with river restoration, such as flood regulation, erosion and sediment control, water quality regulation, recreational amenities, landscape aesthetics and biodiversity. The meta-analysis aims to test the reliability of the estimated meta-regression models for the purpose of benefits transfer, informing policy and decision-making about the economic (nonmarket) benefits of river restoration.

2. Existing river restoration valuation studies

Potential articles about the socio-economic benefits of river restoration were selected based on two criteria. First, the articles were required to address river restoration. The REFORM restoration measure typology in Ayres et al. (2014) was used as a guideline to determine whether the measures evaluated in a particular study could be considered as river restoration measures. Second, in order to be selected, the article had to focus on the economic valuation of the impacts of the river restoration measures analyzed in a study. The studies included in the database are listed in Table 1. One third of the studies (13) overlap with the studies included in the review by Bergstrom and Loomis in this special issue.

Scientific articles were searched via Google Scholar and the e-library of the VU University Amsterdam (http://elibrary.vu.nl/). In the search process we used key words such as *river*, *stream* and *watershed* to indicate the relevant type of waterbody. The words *restoration*, *rehabilitation* and *instream flow protection* were used to indicate the relevant type of improvement to be valued. *Contingent valuation*, *choice experiment*, *willingness to pay* and *willingness to accept*, and their abbreviations *WTP* and *WTA*, respectively, were used to search for relevant non-market valuation methods. The data provided in the collected papers were complemented with publicly available economic and socio-demographic data, climatic and geographic characteristics of the river study locations, and information derived from maps and related river images available on the web.

Table 1. Articles included in the database and number of value estimates per study

Nr.	Authors	Journal[a]	Study year	Country	Nobs[b]
1	Hanley et al. (2006)	ERAE	2005	Scotland	9
2	Bliem et al. (2012)	JEM	2007; 2008	Austria	9
3	Bliem and Getzner (2012)*	EEPS	2007; 2008	Austria	6
4	Grossmann (2012)	EE	2010	Germany	1
5	Grossmann and Dietrich (2012)	WRM	2008	Germany	1
6	Hanley et al. (2006)	JEM	2001	England, Scotland	9
7	Nardini and Pavan (2012)	JFRM	2004	Italy	1
8	Paulrut and Laitila (2013)*	AE	2008	Sweden	3
9	Jørgensen et al. (2012)	EE	2009	Denmark	4
10	Ramajo-Hernández and Saz-Salazar (2012)	ESP	2010	Spain	1
11	Stithou et al. (2012)	TESR	2010	Ireland	4
12	Soliño et al. (2013)	IJER	2007	England, Wales	6
13	Del Saz-Salazar et al. (2009)	STE	2006	Spain	5
14	Gómez et al. (2014)	JH	2013	Spain	1
15	Grazhdani (2013)	IJIRSET	2012	Albania	1
16	Honey-Rosés et al. (2013)*	EE	2012	Spain	2

17	Perni et al. (2011)	WEJ	2009	Spain	3
17	Meyerhoff and Dehnhardt (2007)	EuroE	2005	Germany	2
18	Acuña et al. (2013)	JAE	2008	Spain	1
20	Alam (2008)	IJWR	2001	Bangladesh	1
21	Alam (2013)	JDA	2001	Bangladesh	1
22	Han et al. (2008)	EIAR	2002	South Korea	1
23	Kenney et al. (2012)*	JAWR	2008	USA	4
24	Holmes et al. (2004)*	EE	2002	USA	4
25	Zhao et al. (2013)*	STE	2008	China	3
26	Loomis et al. (2000)*	EE	1998	USA	1
27	Weber and Stewart (2008)*	RE	2006	USA	8
28	Qiu et al. (2006)	JAWR	2002	USA	2
29	Meyer (2013)*	ERE	2008	USA	2
30	Ojeda et al. (2008)*	EE	2006	Mexico	2
31	Berrens et al. (1998)*	EE	1995	USA	1
32	Che et al. (2014)	EM	2012	China	6
33	Collins et al. (2005)*	WRR	2003	USA	6
34	González-Cabán and Loomis (1997)	EE	1995	USA	2
35	Lee (2012)	WI	2009	South Korea	3
36	Zhao et al. (2013)	ERE	2008	USA	6
37	Zhongmin et al. (2003)*	EE	2001	China	3
38	Schultz and Soliz (2007)	JAWR	2007	Bolivia	2
39	Tunstall et al. (1999)	JEPM	1995; 1997	England	2

[a] Abbreviations: *AE* Applied Economics; *EE* Ecological Economics; *EEPS* Environmental Economics and policy Studies; *EIAR* Environmental Impact Assessment Review; *EM* Environmental Management; *ERAE* European Review of Agricultural Economics; *ERE* Environmental and Resource Economics; *ESP* Environmental Science and Policy; *ESR* The Economic and Social Review; *EuroE* European Environment; *IJER* International Journal of Environmental Resources; *IJIRSET* International Journal of Innovative Research in Science, Engineering and Technology; *IJWR* International Journal of Water Resources; *JAE* Journal of Applied Ecology; *JAWR* Journal of the American Water Resources; *JDA* The Journal of Developing Areas; *JEM* Journal of Environmental Management; *JEPM* Journal of Environmental Planning and Management; *JFRM* Journal of Flood Risk Management; *JH* Journal of Hydrology; *RE* Restoration Ecology; *STE* Science of the Total Environment; *WEJ* Water and Environmental Journal; *WI* Water International; *WRM* Water Resource Management; *WRR* Water Resources Research;
[b] Number of observations in each article.

* Also included in the review paper by Bergstrom and Loomis in this special issue.

The database contains 39 different scientific articles that assess the non-market value of river restoration projects, as presented in Table 1, generating 129 observations. The number of observations per study varies between 1 and 9, with an average of 3.3 per study. The studies presented in these articles were conducted within a time span of 18 years, between 1995 and 2013, although only four studies were conducted before 2001 (Figure 1). Geographically, the majority of studies come from Europe (22), followed by the US (12) and Asia (5), see Figure 2.

Figure 1. Distribution of river restoration valuation studies across years

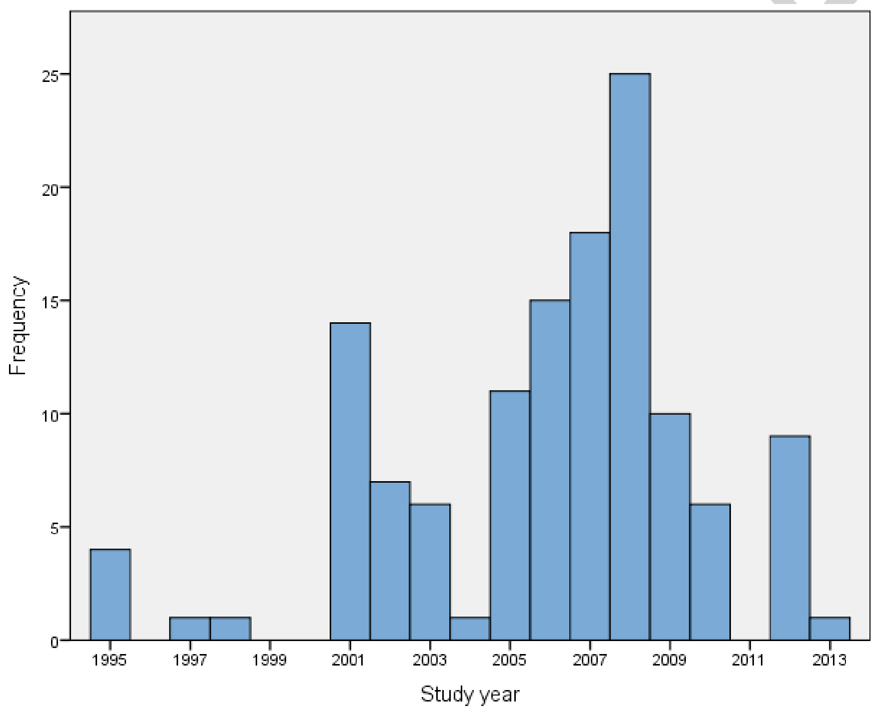


Figure 2. Maps with the locations of the river restoration valuation studies

Source: Devi Brands.

The monetary values are adjusted for inflation and expressed in 2015 US Dollars using the World Bank Purchasing Power Parities (PPP). In terms of valuation methods, contingent valuation (CV) is used as valuation technique in 21 of these articles, discrete choice experiments (CE) in 11 articles, and in the rest other non-market valuation techniques are used. For the meta-analysis, we limit our database to those papers focusing on CE and CV estimates only. This gives us 29 papers with 109 monetary observation.

3. River restoration values

The distribution of mean WTP estimates in the database is somewhat skewed, with the mean value across all studies being US$ 81.2 per household per year and the median US$ 56.3 per household per year (see Figure 3). Although the differences between WTP estimates averaged across world regions, e.g. US$ 74.0 for Europe, US$ 75.2 for Asia and US$ 100.1 for the US, are not statistically significantly different based on the non-parametric Mann-Whitney test, there is much more variation at individual country level, with mean WTP ranging from US$ 14.2 for Korea to US$ 135.0 for Scotland (Figure 4).

Figure 3. Histogram of mean WTP values for river restoration found in the stated preference literature (red line indicates median WTP and black line mean WTP)

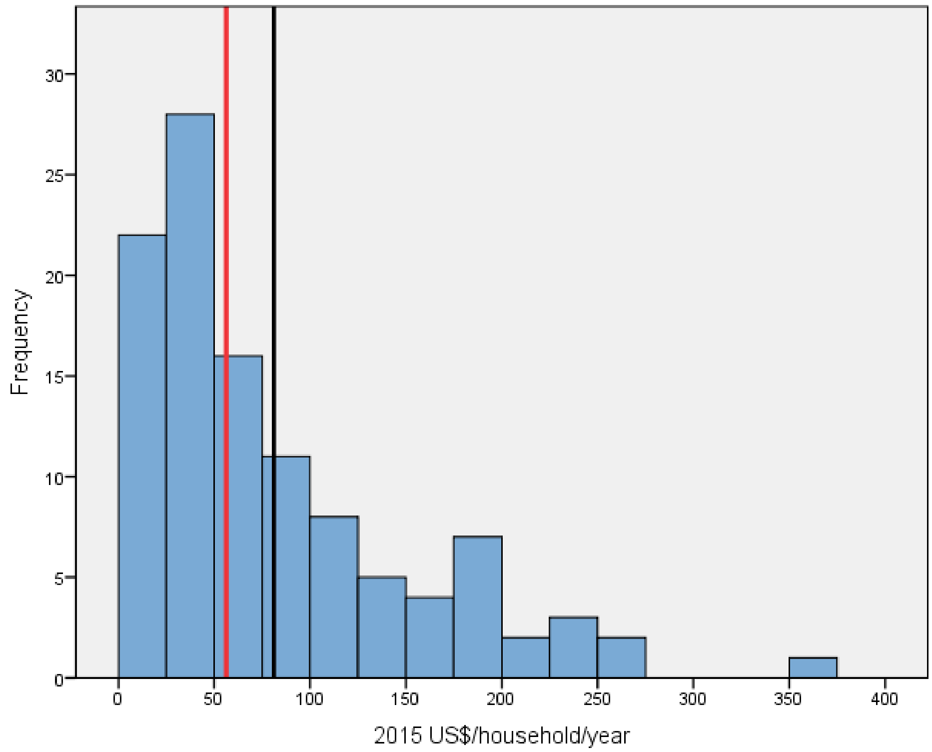
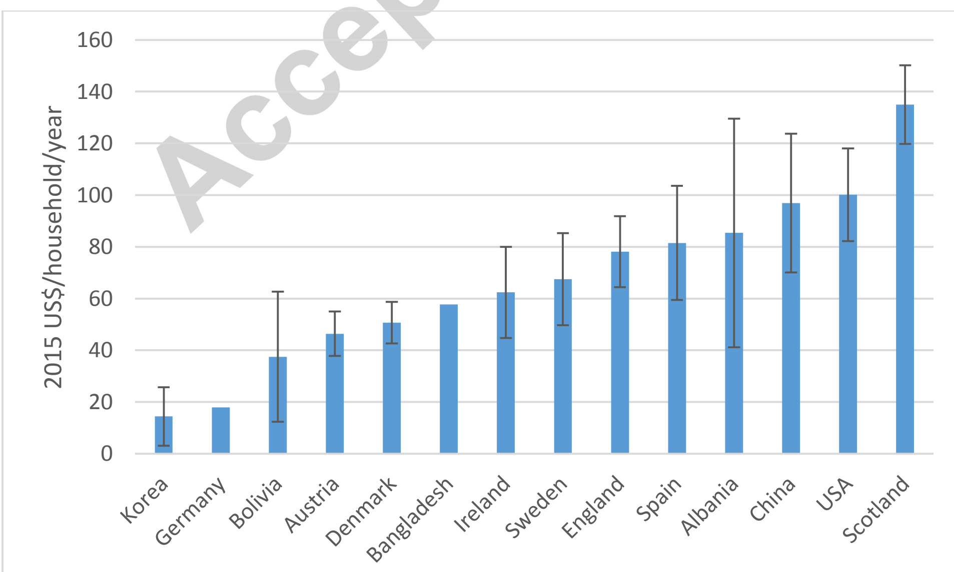


Figure 4. Ordered mean WTP for river restoration across countries



Similarly, also the mean WTP values across the different ecosystem services provided by river restoration (Table 2) are significantly different at the 1 percent significance level using the Kruskal-Wallis test (the test statistic equals 16.920, p=0.005). The ecosystem services presented in Table 2 follow a similar categorization of ecosystem services as Bergstrom and Loomis in this special issue, with the exception that erosion control is added as a distinct category and the broad group of recreational activities are grouped into one category. Remarkable is the very low value for flood regulation, even though this is based on 3 observations only. Early meta-analysis work related to wetlands ecosystem services (Brouwer et al., 1999) showed that this ecosystem service is valued highly, although the service was not significantly different from other wetland ecosystem services in subsequent meta-analyses (Woodward and Wui, 2001; Brander et al., 2006). The impacts of river restoration on water quality regulation and landscape amenities yield the highest average WTP values. The creation of wildlife habitat is valued most frequently in the existing stated preference literature related to river restoration. This may not come as a surprise given the fact that stated preference methods are especially useful in cases where substantial nonuse values are expected. Comparing the mean value that nonusers attach to river restoration (US$ 47.5) with the value held by users (US$ 72.9) shows that the latter value exceeds the former by more than 50 percent. Users of the sites where river restoration takes place, often anglers and public visiting river locations to walk and enjoy the scenery, hold both use and nonuse values. This is also evidenced by the fact that the mean value attached to recreation in Table 2 is lower than the value attached to wildlife habitat.

Table 2. Mean WTP for different ecosystem services provided by river restoration

Ecosystem service	**Mean WTP** (US$/household/year)	**St. error**	**Min-Max WTP**	**N**
Flood regulation	0.3	0.01	0.25-0.28	3
Erosion control	49.4	18.1	25.0-84.7	3
Water quality regulation	139.6	60.3	12.4-260.4	4
Water recreation	57.7	6.1	29.8-102.2	10
Landscape aesthetics	118.6	15.2	17.8-238.5	19
Wildlife habitat	76.9	8.7	0.6-366.4	68

Turning to the specific differences in methods applied to elicit the WTP values, a first important difference is found between values derived from CE (US$ 97.7) and CV studies (US$ 63.8), where the former generate significantly higher values than the latter (outcome of the Mann-Whitney test statistic is 2.177, p=0.03). Contrary to expectations, no significant difference can be found between average WTP values using different CV elicitation formats (open-ended, payments cards and dichotomous choice). A significant difference is, however, found when comparing mean WTP values across the three main survey methods. Web-based surveys produce significantly lower mean WTP values (US$ 44.1) than mail surveys (US$ 111.9), while in-person interviews (US$ 78.2) generate WTP values somewhere in between these two survey methods (the outcome of the Kruskal-Wallis test statistic is 12.511, p=0.002). Finally, the payment vehicle also has a significant influence on mean WTP (outcome of the Kruskal-Wallis test statistic is 5.586, p=0.061). A tax increase is the most frequently used payment mode (39% of the studies), followed by an increase in a household's water bill (26% of the studies) and an entrance fee (9% of the studies). A fee generates the highest value (US$ 104.7) and an increase in the water bill the lowest value (US$ 51.7). Increasing taxes, mainly municipality taxes, to a lesser extent general income taxation, produces an average value of US$ 95.1.

4. Meta-regression models

A mixed-effects multivariate regression panel model was estimated to test the influence of covariates simultaneously and address both within and between-study heterogeneity. For the multivariate meta-analysis we use 29 groups (studies) with 107 individual data entries (WTP estimates) in the database. In the process of model selection, several models were estimated that include the main characteristics of the river restoration project, the ecosystem services involved, and the socio-demographic characteristics of the respondents. Categorical variables are coded as dummies, and the continuous variables, such as estimated WTP, average household income, population density, and fraction of the river length studied in a particular river restoration project, are transformed into their natural log form to improve the model fit, and allow for easy interpretation of the coefficient estimates.

The estimation results for the statistically best-fit model, which includes the characteristics of the river and ecosystem services, site and population characteristics, as well as characteristics of the valuation methods, are presented in the first column of Table 3. The overall fit of the model is good, and the fixed effects explain 68 per cent of the observed variance. Compared to provisioning services such as drinking and irrigation water supply (the baseline category in the estimated models), WTP for the regulating service flood control is significantly lower and WTP for the regulating services water quality and erosion control significantly higher. Ceteris paribus, mean WTP for river recreation and landscape amenities is significantly higher compared to provisioning services.

Only in the reduced model a significant positive effect is detected for the fraction of the river that is being restored. Once control is included for the ecosystem services, this effect becomes insignificant. EU respondents have a significantly lower WTP than respondents elsewhere in the world. Also, WTP is significantly higher in more densely populated areas, as expected due to higher overall demand and/or scarcity conditions due to the pressure exerted by higher population density. Higher income results, as expected, in a significantly higher mean WTP in the full model. No significant differences are found between users and nonusers once other covariates are factored into the regression analysis.

With respect to the methodological study characteristics, discrete choice experiments generate significantly higher WTP values than CV studies in the full model, all else being constant. No significant differences exists between face-to-face (the baseline category) and web-based surveys. Mail surveys, however, generate significantly higher WTP values for river restoration than face-to-face interviews. When asked to pay on behalf of someone's entire household, this significantly reduces mean WTP compared to asking for someone's individual WTP (the baseline category). No significant effect of payment frequency can be detected. As for the univariate results, a significant effect is found for payment vehicle, where taxes reduce WTP significantly compared to other payment vehicles such as fees.

Table 3. Estimated meta-regression models

Variable	Full model	Reduced model (1)	Reduced model (2)
Intercept	-0.798 (2.139)	1.092 (2.018)	0.358 (2.937)
River and location characteristics			
Location (Europe=1)	-0.991** (0.418)		
Restored river fraction (0-1)	-0.173 (0.506)	1.178* (0.606)	0.771 (0.796)
Population density (people/km^2)	0.309*** (0.079)	0.016 (0.102)	0.178 (0.110)
Population characteristics			
River user (dummy)	0.245 (0.278)		
Average income (€/yr)	0.349* (0.199)	0.196 (0.196)	0.085 (0.278)
Ecosystem services			
Flood protection	-2.978*** (0.408)		-3.585*** (0.455)
Erosion protection	0.418* (0.238)		0.352 (0.261)
Water quality control	1.602*** (0.247)		1.238*** (0.268)
Recreational amenities	0.400** (0.188)		0.287 (0.201)
Landscape aesthetics	0.759*** (0.159)		0.716*** (0.168)
Wildlife habitat	0.255 (0.195)		0.127 (0.210)
Study characteristics			
Valuation method			
Choice experiment	0.589** (0.299)		
Administration mode			
Web-based survey	0.042 (0.509)		
Mail survey	1.059*** (0.400)		
Payment characteristics			
Household (instead of individual)	-1.699** (0.665)		

Payment frequency (1 = less than annual)	-0.349 (0.394)		
Payment vehicle			
Water bill	-0.358 (0.391)		
Tax	-1.411*** (0.451)		
Income tax	-3.465*** (0.904)		
Model summary statistics			
Log likelihood	-94.8	-168.5	-112.8
R^2 (fixed effect)	0.68	0.09	0.49
R^2 (overall)	0.89	0.38	0.95
AIC	233	349	249
Number of observations	107	107	107

Note: **p*<0.1; ***p*<0.05; ****p*<0.01

Reduced meta-regression models are estimated for benefit function transfer purposes. The results for these models are presented in the second and third columns of Table 3. Including only variables that can be measured based on available secondary data sources such as the fraction of the river that will be restored, population density and income, only the first variable is significant at the 10 percent level. This effect reflects sensitivity to scope: the higher the share of the river restored, the higher is mean WTP. Although positive, the estimated coefficients for income become insignificant, and also the significant effect of population density in the full model disappears.

Including the ecosystem services in the second reduced model, results in a much better fit compared to the first reduced model. In this case, the same ecosystem services are significant again except recreation and erosion protection, and only population density is marginally significant, as the fraction restored becomes insignificant, and income remains insignificant.

5. Reliability of the estimated models for the purpose of benefits transfer

In this final section, the transfer errors are reported for the full (best-fit) model and the two reduced models. These transfer errors are compared with the transfer errors for the fixed-effect-size (FES) model, i.e. when we take the average WTP to be the best predictor for observed WTP estimates, and there is no need to include any control for other explanatory variables. This allows us to conclude how good the models are in terms of predictive power to assist in future benefit transfer exercises and support river restoration policy and decision-making.

The transfer errors are calculated as out-of-sample (relative) prediction errors, where one observation is omitted from the sample, the model is re-estimated, and a new predicted WTP value is calculated. The resampling is done using the jackknife procedure for each meta-analysis model. Table 4 reports the average results (mean, median, and standard deviation of transfer errors) that are based on the jackknifed samples, i.e. across all possible one-entry data omissions. The most notable result is that the full regression model reduces the prediction error by an order of magnitude compared to the simple average WTP model, and substantially reduces error variance of the predicted WTP values. The second reduced model that includes the variables for the ecosystem services also performs well, compared to both average WTP and the first reduced model. Hence, including control for the fraction of the river that is restored, population density and income reduces the prediction error by almost a factor 3 compared to simply transferring mean WTP values. Adding in control for the ecosystem services further reduces the prediction error by almost a factor 4. The full model yields the lowest prediction error of, on average, 30 percent.

Table 4. Transfer errors for different transfer models

	Mean WTP	**Full model**	**Reduced model 1**	**Reduced model 2**
Mean error	10.85	0.31	4.02	1.07
Std. dev.	53.88	1.22	20.90	4.92
Median error	0.53	-0.09	-0.16	-0.16

We also test the statistical significance of the differences in sampling distributions of mean transfer errors for the different meta-regression models. Several two-sample tests, such as Wilcoxon and Kruskal-Wallis, deliver mostly comparable results. First, the difference between the average transfer errors for the simple fixed effects model and the full mixed effects model is highly significant (the p-value is less than 0.01), indicating that the latter significantly outperforms the former. Similarly, the differences in mean transfer errors for the fixed effects model and any of the reduced models are significant at the 1 percent level. However, the evidence for the differences between the full and reduced models is somewhat mixed, as different tests lead to conflicting conclusions about the significance of differences in mean transfer errors in this case.

In conclusion, the meta-regression model clearly outperforms the use of average unit values when using existing estimates from the literature for the approximation of the benefits in cost-benefit analysis of new river restoration projects.

Acknowledgements

This study was part of the European Framework 7 funded project ‘Restoring Rivers for Effective Catchment Management’ (REFORM), which aimed to develop guidance and tools to ensure river restoration measures are cost-effective and support future River Basin Management Plans (RMBPs) for the European Water Framework Directive (WFD). Thanks are due to the undergraduate student Devi Brands at Vrije Universiteit Amsterdam for his help putting the database together for the meta-analysis presented in this paper and making the map in this paper.

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