Estimation of a Surface Water Quality Valuation Index for the Appalachian Region

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Abstract

A surface water quality valuation index is developed and used to compare counties across the Appalachian Region. This index was based on a meta-analysis of non-market water quality valuation studies along with an application of benefit transfer. The results reveal that Pennsylvania, Georgia, and New York had the highest percentages of counties with high index values within the Appalachian Region. As this research was part of an inter-disciplinary team assembled by the Appalachian Regional Commission, results of this index can be compared to other indices computed for water resources in the region.

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Introduction

The Appalachian Region extends for over 250 thousand square miles from the southern New York to northeast Mississippi and Alabama. This region includes 420 counties within 13 states and is home to almost 25 million people. Forty-two percent of the region's population is rural and 40 percent of total counties fall under distressed and at-risk categories of economic status (ARC 2011). Among the all regions of the U.S., Appalachia has a strategic significance in water resources as it is part of 14 major basins, serving as headwaters for many rivers and their tributaries. Many cities and rural communities in the region are dependent upon a wide variety of water uses, such as agricultural, industrial, household, and environmental values (biodiversity, aesthetic, recreation). The improvements of surface water quality and access to better quality water resources for rural and urban communities can generate both market and non-market benefits within and around the region.

Many rivers, streams, and lakes in the Appalachian Region are impaired from the different uses and sources. About 30 percent of assessed surface water in the region is impaired (EPA 2008). This impairment is being accelerated by urban population growth and land use changes. Problems associated with this surface water quality impairment include low quality agricultural, industrial and household water supplies, disrupted growth and reproduction of aquatic plants and animals, decline in valued recreational fish species, and restricted stream use for recreation (Collins *et al.* 2005). However, these problems are not uniform across all areas of the region. In some areas, better surface water quality may exist and people can gain more benefits from the use of water resources than other areas. Some studies indicate that good quality water resources are an important source of individual and social well-being and have been linked to population and economic growth (Deller *et al.* 2008, Johnson and Beale 2002).

Improving water resource management requires recognizing how the overall water sector is linked to the economic growth and development (FAO 1996). A better understanding of this linkage at the county or sub-regional levels will allow policy-makers to design and implement better policy for water resource management and improvement of surface water quality. In order to analyze the linkages between water resource and economic growth, an inter-disciplinary team was assembled by the Appalachian Regional Commission to develop water asset indices across the Appalachian Region based on water quantity, quality, and use along with valuation of water assets.

This research develops an index for surface water quality valuation in the Appalachian Region. The objectives of this study are to: (1) compute a surface water quality value index that can be used to compare counties across the Appalachian Region in terms of the monetary value of their current surface water quality resources; and (2) determine the primary contributing factors on surface water quality value index in the Appalachian Region. This research outcome provides important information by constructing surface water quality value index to compare counties across the Appalachian region in terms of the economic value of their surface water quality resources. The outcomes of this study will be useful to develop an aggregate water asset index that can be linked to economic indicators in the Appalachian Region.

Two steps were used to create a surface water quality value index: (1) a meta-analysis of contingent valuation (CV) studies to determine factors explaining household willingness-to-pay (WTP) for current surface water quality conditions; and (2) benefit transfer to project county level average household WTP values in order to rank counties based on Appalachian Regional Commission (ARC) county status designation. In the first step, data were gathered from existing CV research on water quality and regression models were developed to explain WTP with variables related to the CV methods, water resources, and sample population characteristics. In the second step, a benefit transfer method utilized these estimated coefficients along with projected values for the explanatory variables to compute county mean WTP per household for existing surface water quality.

All counties in the Appalachian Region were divided into the five ARC county status designation categories based on the ranked average annual mean WTP. Correlation coefficients and t-tests for mean differences were used to examine which variable had the most important impacts on surface water quality value index. Finally, preliminary analyses were conducted comparing the surface water quality valuation index to results from other indices computed for water resources in the Appalachian Region.

Meta-Analysis for Benefit Transfer

The availability of large number of valuation studies based on primary data makes it possible to apply the outcomes from the existing study sites to new policy sites. This application is considered as an alternative to avoid undertaking costly and time consuming primary studies for policy implications. Meta-analysis method summarizes the results of primary studies by estimating statistical relationship between reported resource values and explanatory variables (Bergstrom and Taylor 2006). An estimated meta-regression model (MRM) can be used to predict values from the study sites to policy sites (Johnston et al. 2005; Rosenberger and Loomis 2000). This benefit transfer application of meta-analysis based on MRMs is very useful and promising techniques for resource valuation and policy implications (Johnston and Thomassin 2010).

The meta-analysis methods and models developed by different researchers have been applied for benefit transfer in the field of natural resource valuation, for example, wetlands (Brander et al. 2007), aquatic resources (Johnston et al. 2005), and outdoor recreation (Rosenberger and Loomis 2000). The validity and applicability of this method have also widely discussed in the resource economics literature in order to minimize the errors in the benefit transfer (e.g. Boyle et al. 2010; Johnston et al. 2005, Kristofersson and Navrud 2005). Such literature provides valuable information to estimate and adjust values (e.g. willingness-to-pay) in improving benefit transfer from meta-analysis method. It is generally considered that function transfer from the meta-regression model does a better job in benefit transfer than direct value transfer. This approach can includes wide variations across the valuation studies and provide more information regarding the differences between the study and policy sites (Navrud and Ready 2007). Additionally, explanatory variables can be adjusted in order to represent the new policy site (Bateman and Jones 2003).

Theoretical model of meta-analysis and benefit transfer for this paper was adopted from Bergstrom and Taylor (2006). Their “weak structural utility theoretic” (WSUT) model explicitly specifies the relationship between explanatory variables and an underlying utility function. The theoretical model represents a household or individual utility function including environmental attributes, for example, change in water quality. Bergstrom and Taylor (2006) note that by using WSUT model a researcher can estimate a WTP function empirically while maintaining the flexibility to introduce additional explanatory variables in the model, such as core economic and methodological variables.

A general meta-regression model represents WTP as a function of many independent variables. Model assumes that WTP is influenced by the change in the level of environmental services, demographic and socioeconomic variables, location and time of study, methodological variables, and type of resource. These independent variables in the model describe corresponding policy site's resource and population attributes that explain the variation in WTP across the primary studies (Nelson and Kennedy 2009). The estimated meta-regression equation represents a WTP function in which values are assigned for selected independent variables that reflects attributes of policy site (Johnston and Thomassin 2010). A transferable WTP projection for policy site can be obtained from this WTP function.

Data and Methods

The approach utilized to place monetary values on the quality of surface water was to estimate econometric models using a meta-analysis of contingent valuation (CV) studies and then apply a benefit transfer method using these models. Data from existing CV studies were utilized in the econometric models for the meta-analysis. Johnston *et al.* (2005) provided a template for how to conduct this meta-analysis in terms of what explanatory variables to include in the models and what functional forms to use for the econometric models to explain WTP for a surface water quality change. A WSUT type model was employed using three different functional forms (semi-log, translog, and weighted semi-log based on the number of WTP observations obtained from the study) for estimation in order to assess the robustness in statistical results. The dependent variable in the semi-log model was the natural log of estimated household WTP for water quality improvements and all right-hand-side variables were linear. Johnston et al. (2005) mention that this functional form of the model has ability to capture curvature in the valuation function and allows independent variables to influence WTP in a multiplicative rather than additive. Trans-log model had similar variables in both sides except water quality change variable. This variable was included in the model by taking natural log of water quality change. In the semi-log weighted model, all observations were weighted in such a way that each study is given identical weight in the analysis.

Using the estimated coefficients from the three models along with projected values for the explanatory variables, a benefit transfer method was applied to estimate county mean WTP per household for existing surface water quality. These mean WTP values represent our estimate of what would have been found if a CV study had been conducted with a county level accuracy throughout the entire Appalachian Region to value surface water quality.

Data for the meta-analysis came from a total of 49 contingent valuation studies of surface water quality (Table 1). Johnston et al. (2005) provided 81 observations from 34 studies conducted between 1981 and 2001. Additionally, we collected a data set of 27 observations from 15 studies conducted between 2000 and 2009. Total WTP observations are greater than the number of study because many studies reported more than one WTP estimates based on the change in the water quality conditions, type of uses, and methods of estimation. The studies included 29 journal articles, 13 research reports or academic papers, four Ph.D. dissertations, one book, and two Master's theses. Only CV studies conducted in the U.S. were used. Forty WTP observations from nineteen CV studies represent Appalachian Region. Non-published research studies were included if they were conducted within the Appalachian Region. The complete metadata comprised of 108 observations.

For the data utilized, the main coding categories included WTP reported, CV and survey methodology utilized, type of water body, water quality improvement valued, aquatic improvements included in the valuation, and sample population characteristics. All of the reported WTP values and household income data were adjusted to 2009 dollars using the U.S. Consumer Price Index. All lump sum payments and monthly payments were converted to an annual WTP estimate.

CV methodology details include survey mode (e.g., mail, phone, and in-person interview), survey response rate, and sample frame (e.g. users, nonusers or general population). In most of the studies, the elicitation techniques for contingent valuation models were open ended, discrete choice, iterative bidding, payment card, modified payment card, and multiple methods. All studies in the metadata use either parametric or nonparametric method to estimate the WTP.

Details of the water body included its geographic location, number and water body type (e.g. river/stream, lake, freshwater, salt pond, and estuary), baseline water quality condition, extent of water quality change described in the CV question, species affected by water quality change (e.g. game fish, shellfish, all recreational fish, multiple categories, etc.), and recreational uses changes by water quality change (e.g. drinking, swimming, game fishing, boating, multiple uses, etc.).

Our updated metadata followed Johnston et al. (2005) by converting water quality measures to a standard description for water quality - the Resources For the Future (RFF) ladder (Mitchell and Carson 1989). However, as described in Johnston et al. (2005) many studies often defined baseline and subsequent quality in terms of suitability for comparison with RFF ladder. Thus, we converted descriptive information provided to respondents in the CV survey to approximate the baseline level of water quality and the magnitude of the change. A new variable, *wq_ladder*, was created to distinguish those studies that were not originally based on the RFF water quality ladder from those that were based on this ladder. Table 2 presents description of all variables including descriptive statistics included in the meta-analysis.

The three econometric model specifications: semi-log, trans-log, and semi-log with weighted parameters, were estimated from the meta-data set. All three models estimated included most of the variables utilized by Johnston et al. (2005). Some of variables with insignificant coefficients found by Johnston et al. or deemed to be irrelevant to the Appalachian Region water resources from the original models (*salt_pond, num_river_ponds, southeast, plains, WQ_fish, WQ_shell, WQ_many, WQ_non, baseline*) were excluded in our estimation.

Our meta-analysis included two additional variables, *wq_dummy* and *wq_change*, that were not included in their original models. Variable *wq_dummy* was a binary variable indicating if desired water quality change (post water quality level minus baseline water quality) was negative, i.e. a contingent valuation study based on protection of current water quality for a particular water body. Variable *wq_change* is absolute value of change in mean water quality specified on the RFF water quality ladder. The variable *baseline* utilized by Johnston et al. was excluded from all models because in semi-long and semi-log weighted parameter models variable *wq_change* is included and in trans-log model variable *lnwq_change* is included. Both *wq_change* and *lnwq_change* are generated based on the difference between baseline level of water quality and post change water quality level.

Model Results

Meta-Analysis Estimations

Meta-regression results show that the majority of independent variables in all three models were statistically significant at $p < 0.10$ (Table 3). F statistics in all models indicated good statistical fit ($p = 0.000$). The explanatory powers (R^2 values) of semi-log and trans-log models were similar to the results of Johnston et al. (2005). The R^2 value for weighted semi-log model was slightly below that of Johnston et al. (2005). About three-fourths of the variables (18 out of 25) had statistically significant impacts on WTP. This compares with approximately 77% of variables in Johnston et al. (2005) models which were statistically significant. The inclusion of additional studies to the meta-data only slightly changed the coefficient values and magnitude of standard errors in the model outcomes. However, coefficient values, magnitude of standard errors, and number of statistically significant variables and their signs do not vary in a large extent across the models.

Statistically significant, positive impacts on WTP occurred with the variables *wq_change*, *protest_bids*, *single_river*, *single_lake*, *multiple_rivers*, *regional_fresh*, and *fishplus*. Coefficients for the year index, voluntary donation, lump sum payment method, non-parametric methods, exclusion of outlier bids, a high survey response rate, pacific and/or mountain region studies, valuation in multiple regions, and non-fish use changes had statistically significant, negative impacts on WTP. Five statistically significant independent variables (*discrete_choice, lump_sum, multiple_river, single_river, and multiple_region*) had opposite signs compared to the results presented by Johnston et al. (2005). Variables *single_river* and *multiple_rivers* have positive effects on the WTP. The signs for discrete choice method and river are consistent with the Rosenberger and Loomis (2001) meta-analysis model results estimated for benefit transfer of outdoor recreation use values. There is no such theoretical intuition to explain the negative significant effect of *multiple_reg* variable beyond respondent concerns on water quality issues and awareness may be local rather than regional.

Our two additional variables, *wq_dummy* and *wq_change*, that were not included in their original models had statistically significant effects on WTP with expected signs. The coefficient of *wq_change* was positive and statistically significant ($p < 0.05$) indicating that higher WTP can be expected with larger water quality improvements. Two variables, *income* and *nonusers*, were used to characterize population attributes. Both variables had expected signs; however, income was not significant in any of three models. The *nonusers* variable had a statistically significant negative impact only in the semi-log model. These results were consistent with the econometric results found by Johnston et al. (2005) and Johnston and Thomassin (2010).

Application of Benefit Transfer

The benefit transfer method involved using coefficients from the estimated econometric models presented in Table 3 along with projected values for their respective variables to estimate mean WTP per household for surface water quality in each Appalachian Region county. Benefit transfer involves adopting meta-analysis functions to the characteristics and conditions of the policy site and predicting the WTP values that would result if a CV study based on this adaptation of the function was conducted. For the policy site in question (the Appalachian Region), our analysis assumed the variable values as listed in Table 4.

Three variables were varied across Appalachian counties in this benefit transfer method: water quality change (*wq_change* or *lnwq_change*), mean household income for the county (*income*), and changes in fish population (*fishplus*). The variable *wq_change* was the most complicated to compute. It required determination of a baseline water quality, an assessment of water quality conditions by county, and conversion into RRF ladder units. To compute baseline water quality, statewide water use assessment and designated use data were collected from Integrated Water Quality Monitoring and Assessment Reports for each state (see Appendix A).

Then, county level data for the percentage of assessed streams and rivers that have not been designated as impaired were averaged for Appalachian Region counties within each state. This within state Appalachian Region percentage was subtracted from the impairment score computed for each county as the percentage of catchments in each county that are not impaired. This difference was multiplied by the RFF ladder value for state level designated water use (5=aquatic life or fishing, 6=no designated use, 7=contact recreation).

In benefits transfer computations, the variable *wq_change* was allowed to be negative when the county percentage of not impaired catchments was less than the state baseline percentage. Since the log of negative values does not exist, *lnwq_change* values were computed by taking the natural log of *wq_change* plus 1.0. For those values that were still less than zero, the ln(0.001) was used. A total of 17 counties had the ln(0.0001) for for *lnwq_change*.

The other two variables that varied by county (*income* and *fishplus*) were not as complicated to compute. For *income*, mean household income data from 2008 for Appalachian Region were collected from the U.S. Census Bureau (2010). To estimate fish population differences between counties, trout stocking data were collected from the each state's Department of Natural Resources website (see Appendix B for a listing of these reports). Those counties with trout stocking rates greater than the statewide county median were coded a one for *fishplus* and those counties with less than the median stocking level were coded a zero.

The fixed, non-zero variables from Table 4 include: 2008 as the data year (*year_index*), a mail survey method was used (*mail*), protest bids were excluded (*protest_bid*), the survey was implemented over nonusers (*nonusers*), valuation of water quality was conducted for multiple rivers (*multiple_river*), the water quality valuation measure takes place in a fresh waterbody (*regional_fresh*), and changes in aquatic uses other than fishing were assumed to be described in the survey (*nonfish_uses*).

Finally, variables excluded from WTP computations with a zero value included that the survey was assumed not to: use discrete choice or non-parametric methods, a voluntary donation or lump sum payment mechanism, use a RFF ladder or be for protection, use a median WTP computation, exclude outlier bids, have response rate greater than 75%, be for a single river or lake, be for in the pacific or mountain regions, and be for multiple regions (Table 4). Thus, our analysis assumed a mail survey CV study conducted in 2008 to include non-users and focusing on multiple fresh water rivers. A response rate under 75% was assumed and a mean WTP was computed with protest bids excluded.

Across 428 counties and cities[1] of the Appalachian Region, average projected annual mean WTP for surface water quality was about $8.0 per household and varied little among the three econometric models (Table 5). Translog had the widest variation of mean WTPs across counties of any model (from $2.22 to $11.24).

The average of county mean household WTP across all three models ($8) was much lower than the mean WTP from the CV studies included in the meta-analysis. The mean WTP for the studies outside the ARC region was $116 and, within ARC region, the mean WTP was $83. These large differentials are not surprising given that the variable, *wq_change,* utilized for benefit transfer was computed based on current levels of water impairment within ARC counties in each state and state level designated water uses. Thus, the $8 indicates an average county wide household WTP for the current level of water quality and not a WTP for substantial water quality improvements as were measured in studies included in the meta-data.

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[1] Eight independent cities in Virginia were included in the analysis.

Surface Water Quality Value Index

Projected mean WTP for each county was averaged over the three econometric models and then converted into a percentage based on the maximum county average mean WTP in order to rank counties (i.e. county's percentage of maximum mean WTP = county average annual mean WTP per household/ maximum mean WTP * 100). Cannon County, Tennessee had the highest average annual mean WTP per household ($10.39). Tennessee and Virginia dominated the top ten counties with three counties in Tennessee and two counties in Virginia. At the low end of the ranking, counties from Tennessee and West Virginia were the most prevalent in the bottom ten with five and three counties, respectively. Scott County, Virginia had the lowest average mean WTP per household ($4.81).

Ranked average annual mean WTP counties were divided into the five ARC county status designation categories: (1) attainment (top 10%); (2) competitive (best 10+ to 25%); (3) transitional (middle 50%); (4) at-risk (worst 10+ to 25%); and (5) distressed (worst 10%). A breakdown of counties in each category per state is presented in Table 6.

Other than the small county number state of Maryland, the states of Pennsylvania, Georgia, and New York had the highest percentages of counties in the attainment category. In the at-risk and distressed categories, the states of Mississippi and South Carolina had 50% of counties falling into these categories. Over one-fifth of West Virginia and Tennessee counties were in the distressed category. Figure 1 depicts that majority of distressed counties are located around the central Appalachian Region, Kentucky, West Virginia, Virginia, and Tennessee.

Correlation coefficients and t-tests for mean differences were used to examine which variable had the most important impacts on county WTP rankings. The correlation coefficient between *wq_change* and county average annual mean WTP was high (0.623), particularly when compared to the low correlation coefficient between *income* and county average annual mean WTP (0.028). The lack of significance for the correlation between WTP and income was not surprising given that the income variable was not statistically significant in any of three meta-regression models.

Also, the 125 Appalachian counties where fish stocking was above the state median level had a statistically larger county average annual mean WTP ($9.88) than those Appalachian counties below the median (WTP = $8.02). Thus, water quality as measured by a percentage of catchments which are not impaired and the level of fish stocking in the county were the primary contributing factors ranking order for average annual county mean WTP for the 428 Appalachian counties.

Conclusions

This paper presents a meta-analysis and benefit transfer conducted to estimate a surface water quality valuation index that can be compared across counties of the Appalachian Region. We generally followed the systematic protocol for model selection, data collection and analysis, and benefit transfer developed by Bergstrom and Taylor (2006). Our estimated models represent a weak structural utility theoretic approach between explanatory variables and an underlying utility function. The WTP functions estimated from the meta-regression formed the basis for benefit transfer. Our results demonstrate how a benefit transfer method can be applied for surface water quality valuation at a regional level.

The surface water quality value index presented in this paper takes into account the variation in water quality and income across the counties in the sub-region. It also takes into account the possible public responses to recreational fish stocking that affect the values of surface water resources. These features of surface water quality value index allow the direct comparison and ranking of counties in terms of the economic value of their surface water quality resources.

Our results reveal where water resources have potentially greater values within the Appalachian Region and perhaps could be useful to the policy makers for setting priorities and implementing effective clean water programs. This paper also presents a systematic and comprehensive method to create county specific surface water quality value index that could be very useful to relate other water related indices (such as water quality index, water quantity index, and recreational access index) and economic indicators in the region.

Preliminary results have been developed by comparing our surface water quality valuation index to other indices developed by the inter-disciplinary team assembled by the Appalachian Regional Commission. One comparison shows that six counties within Appalachian were in the top 10% ranking for both water quality valuation and recreation access. However, there was one county (Cannon, TN) which is the top 10% of water quality valuation but in the bottom 10% of recreation access – showing a potential for economic development related to improved access.

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Table 1: Surface water quality contingent valuation studies included in the meta-analysis data set

Study	**No. of Observations Utilized**	**State**	**Water-body type**	**Methodology**	**WTP (2009$)**
Aiken (1985)	1	CO	All freshwater	CVM- multiple methods	198.97
Anderson and Edwards (1986)	1	RI	Salt pond/ marshes	CVM-open ended	186.13
Azevedo et al. (2001)	5	IA	Lake	CVM-discrete choice	12.12-66.20
Benson (2006)	6	VA/WV	River/stream	Multiple method	4.38-33.42
Bockstael et al. (1989)	2	MD	Estuary	CVM-discrete choice	77.94-248.16
Brox et al. (2003)	2	Canada	River/stream	Payment card	9.16-16.57
Cameron and Huppert (1989)	1	CA	River/stream	CVM-discrete choice	51.02
Carson et al. (1994)	2	CA	Estuary	CVM-discrete choice	4.24-7.99
Clonts and Malone (1990)	3	AL	River/stream	CVM-iterative bidding	80.66-131.31
Collins et al. (2004)	2	WV	River/stream	Multiple method	176.2-219.70
Collins et al. (2007)	1	WV	River/stream	Modified payment card	2.43
Croke et al. (1987)	9	IL	River/stream	CVM-iterative bidding	63.75-96.49
Cronin (1982)	4	DC	River/stream	CVM-open ended	73.26-251.98
De Zoysa (1995)	2	OH	Lake and river	CVM-discrete choice	4.25-7.23
Desvousges et al. (1983)	2	PA	River/stream	CVM-discrete choice	41.33-73.27
Egan et al. (2009)	1	IA	Multiple lakes	CVM-discrete choice	179.69
Eisen-Hecht and Kramer (2002)	1	NC/SC	River/stream	Payment card	96.56
Farber and Griner (2000)	3	PA	River/stream	CVM-discrete choice	24.67-58.89
Farber and Griner (2000)	3	PA	River/stream	CVM-discrete choice	30.76-44.25
Hansen et al. 2008)	2	PA	River/stream	CVM-open ended	2.43-3.56
Hayes et al. (1992)	2	RI	Estuary	CVM-discrete choice	402.40-146.32
Herriges and Shogren (1996)	2	IA	Lake	CVM-discrete choice	29.93-100.59
Homles et al. (2004)	2	TN	River/stream	CVM-iterative bidding	46.61-61.29
Huang et al. (1997)	2	NC	Estuary	CVM-discrete choice; revealed and stated preference	115.79
Kaoru (1993)	1	MA	Salt pond/marshes	CVM-open ended	225.17
Lant and Roberts (1990)	3	IA/IL	River/stream	CVM-discrete choice	57.21-77.86

Table 1: *Continued*

Study	**No. of Observations Utilized**	**State**	**Water-body type**	**Methodology**	**WTP (2009$)**
Loomis (1996)	1	WA	River/stream	CVM-discrete choice	95.86
Loomis et al. (2000)	1	CO	River/stream	CVM-discrete choice	315
Lyke (1993)	2	WI	Lake	CVM-discrete choice	61.55-100.68
Magat et al. (2000)	2	CO/NC	All freshwater	CVM-iterative bidding	135.61-302.01
Matthews et al. (1999)	2	MN	River/stream	CVM-discrete choice	18.68-26.08
Mitchell and Carson (1981)	1	National	All freshwater	CVM-discrete choice	28.05
Olsen et al. (1991)	3	Pacific NW	River/stream	CVM-open ended	45.57-127.44
Roberts and Leitch (1997)	1	MN/SD	Lake	CVM-discrete choice	8.60
Rowe et al. (1985)	1	CO	River/stream	CVM-open ended	138.63
Sanders et al. (1990)	4	CO	River/stream	CVM-open ended	83.44-216.34
Schulze et al. (1995)	2	MT	River/stream	CVM-discrete choice	17.86-25.06
Strong and Flores (2008)	1	CO	River/stream	CVM-open ended	42.34
Stumborg et al. (2001)	2	WI	Lake	CVM-discrete choice	32.30-49.29
Sutherland and Walsh (1985)	1	MT	River and lake	CVM-open ended	150.41
Viscusi et al. (2008)	1	National	Multiple waterbody	CVM-iterative bidding	31.7
Welle (1986)	6	MN	All freshwater	Multiple methods	112.88-245.57
Wey (1990)	2	RI	Salt pond/marshes	Multiple methods	65.87-237.49
Whitehead (2000)	2	NC	River/stream	CVM-iterative bidding	164.71-431.56
Whitehead (2006)	1	NC	River/stream	CVM-discrete choice	100.32
Whitehead and Groothuis (1992)	3	NC	River/stream	CVM-open ended	39.11-54.76
Whitehead et al. (1995)	2	NC	Estuary	CVM-iterative bidding	80.64-115.97
Whitehead et al. (2000)	1	NC	River/stream	CVM-discrete choice	42.50
Whittington et al. (1994)	1	TX	Estuary	CVM-discrete choice	94.44
Total studies = 49	108				

Table 2: Meta-analysis variables and descriptive statistics

Variable	Description	Units and measurement	Mean (SD)
ln_WTP	Natural log of household willingness-to-pay on an annual basis for specified resource improvements. WTP for all studies was converted to 2009 dollars US CPI	Natural log of WTP (Range: 0.386 to 2.64)	1.79 (0.51)
year_index	Year in which the study was conducted, converted to an index by subtracting 1970	Year Index (Range:3 to 39)	22.64 (8.92)
voluntary	Binary variable indicating that WTP was estimated using a payment vehicle described as voluntary	Binary (Range: 0 or 1)	0.09 (0.29)
discrete_ch	Binary variable indicating that WTP was estimated using a discrete choice survey instrument	Binary (Range: 0 or 1)	0.12 (0.33)
Interview	Binary variable indicating that the survey was conducted through in-person interviews	Binary (Range: 0 or 1)	0.14 (0.35)
mail	Binary variable indicating that the survey was conducted through the mail	Binary (Range: 0 or 1)	0.57 (0.49)
lump_sum	Binary variable indicating single lump sum payment	Binary (Range: 0 or 1)	0.30 (0.46)
nonparam	Binary variable indicating that WTP was estimated using nonparametric methods	Binary (Range: 0 or 1)	0.35 (0.47)
wq_dummy	Binary variable indicating that desired water quality change is negative (e.g. respondent wants to protect current level of water quality)	Binary (Range: 0 or 1)	0.23 (0.42)

Table 2: *Continued*

Variable	**Description**	**Units and measurement**	**Mean (SD)**
wq_change	Absolute value of change in mean water quality, specified on the RFF water quality ladder (post water quality – baseline water quality)	Water quality ladder units (Range: 0.05 to 8.25)	2.46 (1.42)
lnwq_change	The natural log of wq_change	Range: -1.30 to 0.91	0.29 (0.33)
wq_ladder	Binary variable indicating that the original survey reported resource changes using a standard RFF water quality ladder	Binary (Range: 0 or 1)	0.25 (0.43)
protest_bids	Binary variable indicating that protest bids were excluded when estimating WTP	Binary (Range: 0 or 1)	0.42 (0.49)
outlier_bids	Binary variable indicating that outlier bids were excluded when estimating WTP.	Binary (Range: 0 or 1)	0.17 (0.38)
median_WTP	Binary variable indicating that the study reported median, not mean, WTP	Binary (Range: 0 or 1)	0.06 (0.24)
hi_response	Binary variable indicating that the survey response rate exceeds 74% (i.e., 75% or above).	Binary (Range: 0 or 1)	0.25 (0.43)
income	Mean household income of survey respondents, either as reported by the original survey or calculated based on US	Dollars in 1000 (Range: 28.0 to 163.1)	56.58 (16.09)
nonusers	Binary variable indicating that the survey is implemented over a population of nonusers	Binary (Range: 0 or 1)	0.13 (0.34)
single_river	Binary variable indicating that resource change explicitly takes place over a single river	Binary (Range: 0 or 1)	0.34 (0.47)

Table 2: *Continued*

Variable	**Description**	**Units and measurement**	**Mean (SD)**
single_lake	Binary variable indicating that resource change explicitly takes place over a single lake.	Binary (Range: 0 or 1)	0.09 (0.29)
multiple_river	Binary variable indicating that resource change explicitly takes place over multiple rivers	Binary (Range: 0 or 1)	0.20 (0.40)
regional_fresh	Binary variable indicating that resource change explicitly takes place in a fresh water body	Binary (Range: 0 or 1)	0.09 (0.29)
pacif_mountain	Binary variable indicating that survey was conducted in the USDA Pacific/Mountain region	Binary (Range: 0 or 1)	0.16 (0.37)
multi_reg	Binary variable indicating that survey included respondents from more than one of the regions	Binary (Range: 0 or 1)	0.09 (0.29)
nonfish_uses	Binary variable identifying studies in which changes in uses other than fishing are specifically noted in the survey	Binary (Range: 0 or 1)	0.27 (0.44)
fishplus	Binary variable identifying studies in which a fish population or harvest change of 50% or greater is reported in the survey	Binary (Range: 0 or 1)	0.12 (0.32)

Table 3: Estimated econometric models

Variable	Model I: Semi-log parameter estimate (std. error)	Model II: Trans-log parameter estimate (std. error)	Model III: Semi-log (weighted) parameter estimate (std. error)
intercept	2.63098***	2.66546***	2.65158***
	(0.222)	(0.225)	(0.225)
year_index	-0.03030***	-0.03020***	-0.03147***
	(0.007)	(0.007)	(0.007)
discrete_ch	0.04134	0.03221	0.01356
	(0.111)	(0.134)	(0.163)
voluntary	-0.74567***	-0.76525***	-0.80799***
	(0.136)	(0.112)	(0.116)
interview	0.15969	0.16276	0.17685
	(0.163)	(0.163)	(0.166)
mail	-0.14124	-0.13020	-0.11447
	(0.103)	(0.101)	(0.105)
lump_sum	-0.58980***	-0.58112***	-0.53857***
	(0.101)	(0.102)	(0.098)
nonparam	-0.31170***	-0.29741***	-0.36586***
	(0.087)	(0.088)	(0.088)
wq_dummy	-0.18704*	-0.19391*	-0.08444
	(0.113)	(0.113)	(0.119)
wq_change	0.04710**	-	0.07864***
	(0.025)		(0.030)
lnwq_change	-	0.18202*	-
		(0.105)	
wq_ladder	0.15738	0.16411	0.19137
	(0.122)	(0.122)	(0.119)
protest_bids	0.22490***	0.20831**	0.25510***
	(0.083)	(0.084)	(0.106)
outlier_bids	-0.54752***	-0.55254***	-0.58965***
	(0.110)	(0.109)	(0.121)

Table 3: Continued

Variable	Model I: Semi-log parameter estimate (std. error)	Model II: Trans-log parameter estimate (std. error)	Model III: Semi-log (weighted) parameter estimate (std. error)
median_WTP	0.11498	0.11608	0.05640
	(0.135)	(0.136)	(0.117)
hi_response	-0.35092***	-0.34036***	-0.36497***
	(0.094)	(0.095)	(0.091)
income	0.00255	0.00278	0.00232
	(0.002)	(0.002)	(0.001)
nonusers	-0.15422*	-0.14137	-0.17263
	(0.094)	(0.094)	(0.111)
single_river	0.19652*	0.21589**	0.16985*
	(0.108)	(0.105)	(0.138)
single_lake	0.41582***	0.39675***	0.28139
	(0.147)	(0.148)	(0.157)
multiple_river	0.32078**	0.36985***	0.26967**
	(0.136)	(0.128)	(0.141)
regional_fresh	0.36824**	0.36400**	0.40577**
	(0.173)	(0.174)	(0.167)
pacif_mountain	-0.16844*	-0.18061*	-0.17050***
	(0.104)	(0.103)	(0.111)
mult_reg	-0.54221***	-0.52831***	-0.58095***
	(0.145)	(0.146)	(0.170)
nonfish_uses	-0.17888**	-0.20310**	-0.25991**
	(0.080)	(0.079)	(0.108)
fishplus	0.23268**	0.20771*	0.30135***
	(0.112)	(0.114)	(0.093)
	$R^2 = 0.773$	$R^2 = 0.772$	$R^2 = 0.748$
	F = 11.79	F = 11.72	F = 12.93
	p = 0.000	p = 0.000	p = 0.000
	N = 108	N = 108	N = 108

***, **, and ** indicate significant at 1%, 5%, and 10% respectively.

Table 4: Variables utilized to project WTP for surface water quality in Appalachian counties

Variables that Vary across Counties	Variables Fixed at a Non-Zero Value (value utilized)	Variables Equal to Zero
wq_change or *lnwq_change*	*year_index* (38)	*discrete_ch*
Income	*Mail* (1)	*voluntary*
Fishplus	*protest_bids* (1)	*interview*
	Nonusers (1)	*lump_sum*
	multiple_river (1)	*nonparam*
	regional_fresh (1)	*wq_dummy*
	nonfish_uses (1)	*Wq_ladder*
		Outlier_bids
		median_WTP
		hi_response
		single_river
		single_lake
		pacif_mountain
		mult_reg

Table 5: Projected mean annual WTP per household for surface water quality over 428 counties in the Appalachian region

	Model I: Semi-log	Model II: Trans-log	Model III: Semi-log (weighted)	Model Average
Average	$8.08	$8.34	$7.58	$8.00
Minimum	$6.59	$2.22	$5.58	$4.81
Maximum	$10.18	$11.24	$10.00	$10.39

Table 6: Percentages of counties in ARC categories based on mean county level WTP rankings for surface water quality

State (number of counties)	Attainment	Competitive	Transitional	At-Risk	Distressed
	Percentage				
Alabama (37)	13.5	18.9	51.4	16.2	0.0
Georgia (37)	16.2	5.4	56.8	13.5	8.1
Kentucky (54)	0.0	22.2	42.6	22.2	13.0
Maryland (3)	66.7	0.0	33.3	0.0	0.0
Mississippi (24)	8.3	16.7	25.0	45.8	4.2
New York (14)	14.3	14.3	57.1	14.3	0.0
North Carolina (29)	6.9	37.9	48.3	6.9	0.0
Ohio (32)	3.1	6.3	65.6	25.0	0.0
Pennsylvania (52)	17.3	21.2	48.1	3.8	9.6
South Carolina (6)	0.0	0.0	50.0	33.3	16.7
Tennessee (52)	13.5	7.7	50.0	7.7	21.2
Virginia (33)	9.1	0.0	60.0	18.2	12.1
West Virginia (55)	7.3	14.5	49.1	9.1	20.0

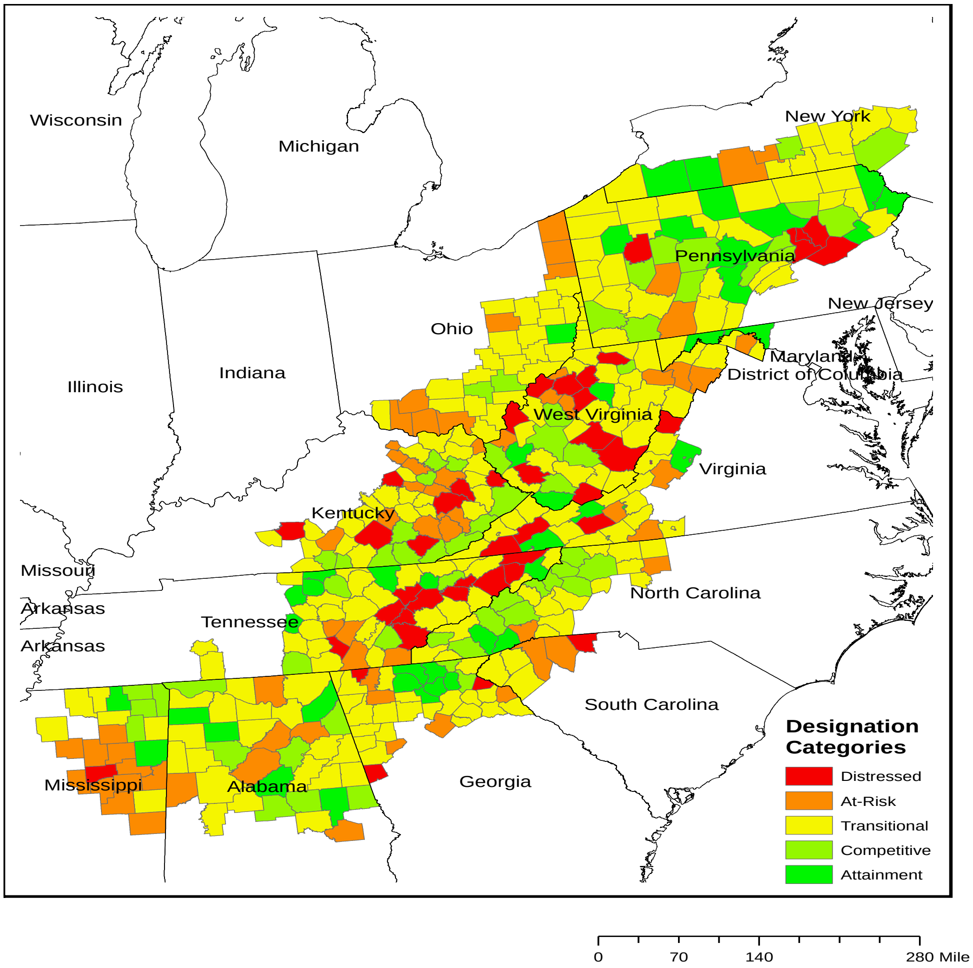

Figure 1: Distribution of counties by designation categories in the Appalachian Region