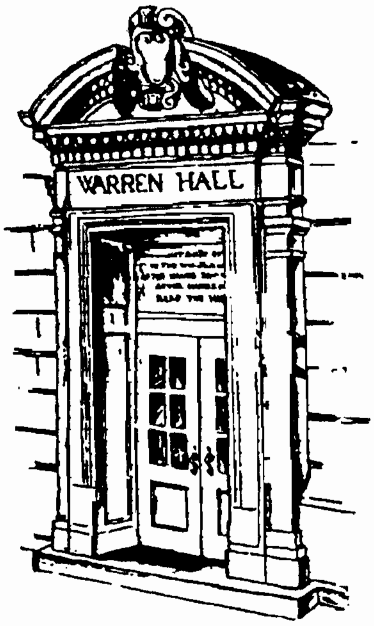

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Assessing the Accuracy of Benefits Transfers: Evidence from a Multi-Site Contingent Valuation Study of Groundwater Quality

by

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Abstract: Using a multi-site contingent valuation study of groundwater quality, this paper compares the accuracy of alternative methods of transferring values from study sites to policy sites. Transferring benefit functions is more accurate than transfers of average contingent values. Relative accuracy is highly dependent on how study sites are grouped.

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Assessing the Accuracy of Benefits Transfers: Evidence from a Multi-Site Contingent Valuation Study of Groundwater Quality

Large monetary and time expenditures associated with primary valuation research have renewed academic and policy interest in benefits transfer of non-market values [Water Resources Research; Western Regional Research Project W-133; US EPA]. While expert opinion, unit-day use values, and more formalized econometric techniques have long been used to transfer estimated resource values from original 'study' sites to unstudied 'policy' sites, there has been little systematic assessment of the accuracy of benefits transfers. Such a formal assessment is an essential first step for establishing when transfers should be conducted in lieu of original research, identifying strengths and weaknesses of the technique, and subsequently improving upon transfer use.

Using a multi-site contingent valuation (CV) study of willingness to pay (WTP) for improvements in groundwater quality, this paper examines the relative accuracy of alternative benefits transfer methods. In contrast with previous studies of groundwater quality that have transferred values across studies with different questionnaire formats, commodity definitions, population groups and policy issues [e.g., Crutchfield; Bergstrom and Boyle, 1993b] the data for this analysis was collected concurrently using the same CV questionnaire. As such, this study more closely approximates the ideal conditions for assessing the accuracy and validity of benefits transfers [Boyle and Bergstrom; McConnell].

Conceptual Framework and Hypotheses

Groundwater quality has emerged as an important policy issue, as evidenced by several recent CV studies of groundwater protection programs [Edwards; Schultz and Lindsay; Caudill; Sun, Bergstrom, and Dorfman; Powell; McClelland *et al.*; Poe]. The conceptual model underlying this body of research centers on the measurement of option prices for a risk change, and can be quite complex. For the purposes of this paper a simple characterization of WTP for groundwater quality improvements for the ith individual at the jth site is specified as;

$$WTP_{ij} = \omega_j(Q_{ij}^0, Q_{ij}^1; P_{ij}^W, P_{ij}^X, I_{ij}, D_{ij}) \tag{1}$$

where: ω_j is a functional specification of an average valuation function for the jth site; Q^0 and Q^1 are pre and post improvement quality levels; P^W denotes a vector of water prices including alternate sources; P^X is a price vector for all other goods; I is income; and D represents a vector of socioeconomic characteristics. Adopting the simplifying assumption that prices (and substitutes) are constant across sites,[1] the 'naive' transfer of average values from a study site (s) to an unstudied policy site (p) can be denoted:

$$\overline{WTP_s}(s) = \frac{1}{n_s}\sum_{i=1}^{n_s} \omega_s(Q_{is}^0, Q_{is}^1; I_{is}, D_{is}) \approx \frac{1}{n_p}\sum_{i=1}^{n_p} \omega_p(Q_{ip}^0, Q_{ip}^1; I_{ip}, D_{ip}) = \overline{WTP_p}(P) \tag{2}$$

For site specific water quality issues, it is unlikely that equality of average WTP values will hold due to differences in socioeconomic characteristics and differential changes in quality. To account for such inter-site differences, Desvousges *et al.*, Loomis, and others propose that a preferred method for benefits transfers is to predict policy site values by combining study site benefit functions with policy site population characteristics. For linear functions, this 'benefit function' transfer can be characterized using the following notation:

$$W\hat{T}P_s(\bar{p}) = \omega_s(Q_p^0, Q_p^1; \bar{I}_p, \bar{D}_p) \approx \overline{WTP_p}(p) \tag{3}$$

The relationships and assumptions underlying the approximate equalities depicted in equations (2) and (3) provide testable hypotheses if values are available at both the study and policy sites. The relationship characterized in equation (2) corresponds to the following null hypothesis, $H_1^0: \overline{WTP_s}(s) = \overline{WTP_p}(p)$, while the theoretical basis for the benefit function transfer in equation (3) can only be supported by the failure to reject the equality of coefficients (β_j^k) across study and policy site benefit functions, or $H_2^0: \beta_s^k = \beta_p^k \ \forall k$. While statistical testing of such hypotheses provides useful insights, it is perhaps more important from a policy perspective to systematically assess the relative accuracies (or inaccuracies) associated with the approximations in equations (2) and (3). Statistical citeria associated with hypothesis tests may not correspond to acceptable notions of accuracy in a policy context. Specifically, the relative accuracy of benefit function and naive transfers can be assessed by comparing the magnitudes of $\frac{|W\hat{T}P_s(\bar{p}) - W\bar{T}P_p(p)|}{W\bar{T}P_p(p)}$ and $\frac{|W\bar{T}P_s(s) - W\bar{T}P_p(p)|}{W\bar{T}P_p(p)}$.

Past groundwater CV studies have reported annual average WTP values ranging from $56 to $1,154 ($1992), suggesting that H_1^0 will be rejected in most cases given the current body of research. In a meta analysis of these studies Boyle, Poe, and Bergstrom found evidence of systematic variation in WTP values across study site characteristics, but concluded that the transfer of benefit functions using existing studies would be premature.[2] To date, the relative accuracy of naive and benefit function transfer methods has not been addressed using study and policy site data for drinking water quality.[3]

Data

Data for this analysis is taken from a CV study of groundwater quality reported in detail in Powell and Allee and Powell, Allee, and McClintock. Although the original study was not intended for benefits transfer research, the multi-site study design offers a unique opportunity for assessing the above stated hypotheses and the relative accuracy of transfers. Questionnaires were mailed concurrently to 12 towns in Massachusetts, New York, and Pennsylvania selected on the basis of population size (<20,000), reliance on groundwater for water supply, and history of groundwater contamination. After adjusting for bad addresses the survey response rate was 51%. A total of 617 households on public water supplies were used in this analysis.

The CV scenario used to elicit WTP values was developed over two questions. First respondents were asked to indicate their current perceived water safety level on a range from unsafe to very safe. Next respondents were presented a hypothetical scenario which queried them for their WTP to increase their water safety level to a "Very Safe" level using a payment card format. Both the safety and CV questions are provided in Figure 1.

Table 1 shows that WTP, socio-economic characteristics, and perceptions used in the analysis varied across towns, providing a desirable data set for evaluating the relative accuracies of transfer methodologies. An OLS regression was estimated for the entire set of observations. As depicted in Table 2, the sign of the coefficients corresponds to prior expectations. WTP generally increases with subjective perceptions of past contamination, number of contamination sources, likelihood of future contamination, and perceptions that water sources were not safe. Respondents with higher incomes and education have higher WTP values on average, as do respondents who have a greater aversion to voluntary risks and a greater trust in ability to protect public water supplies. Although the model has a low R^2 value of 14%, this value falls within the range of other groundwater CV studies of public water users that might be used for benefits transfers [e.g., McClelland *et al.*, 6.8%; Jordan and Elnagheeb, 11 to 14%].

Benefits Transfers Across Individual And All Town Study Sites

Given the diversity in WTP and socio-economic characteristics across towns, there are several possible subgroups of similar towns that might be considered for the assessment of benefits transfers. This section evaluates the hypotheses and relative accuracy for two extreme cases: transfers of mean WTP values using individual towns as study and policy sites; and transfers using study site mean WTP values computed for all but one town which subsequently serves as the policy site (respectively referred to as the n-1 and nth values). The former approach corresponds with crude scoping studies that attempt to develop "ball park" estimates of potential benefits at policy sites [Bergstrom and Boyle, 1993a] and was employed by Crutchfield in an analysis of benefits transfers of groundwater protection values to unstudied sites. The latter, n-1 to nth transfer approach, approximates the protocol of forming values to transfer from several study sites.

Examination of hypothesis $H_1°$ for individual town transfers rejects equality of mean WTP values in 28 (or 42.4%) of the 66 possible pairwise comparisons at $\alpha=10\%$, using a standard difference of means test. Comparisons of n-1 mean WTP values to nth town mean WTP values result in rejections of equality in 4 (or 25%) of the 12 possible tests. This decline in rejection proportion may be attributed to the greater study site variation of hypothetical sample sites, consisting of n-1 towns, and the smaller number of comparisons (n=12).

Hypothesis $H_2°$ was examined using a Chow test for model coefficient equality to compare study and policy site benefit functions. Across individual towns the hypothesis of benefit function equality, $H_2°$, was rejected in 36% of the 66 comparisons. Rejection of $H_2°$ occurred in 25% of the 12 tests using the n-1 approach. These results suggest that variations in average WTP values may not simply be attributed to differences in population distributions or differences in survey design. Instead, it appears that valuation functions are not homogeneous across all sites. Simultaneously, the majority of cases do support $H_2°$ and the theoretical rationale for function-based transfers.

The relative accuracy of naive and benefit function transfers for study sites based on individual and n-1 town groupings are depicted in the first two columns of Table 3. Transfers of individual town WTP values for naive and benefit function transfers have average accuracies of 42.12% and 44.12% respectively. When study sites are pooled across 11 towns for transfer to the 12th town, there is an improvement in the accuracy of both the naive and benefit function approaches. This improvement in accuracy is most dramatic for the benefit function approach, for which the average error fell to 18.2%. Similar trends are noted for the maximum possible error, which fell considerably for both naive and benefit function transfers as demonstrated in the range of errors in Table 3.

Thus it appears that the construction of study sites used to conduct transfers has a distinct impact on the accuracy of value estimates. Aggregating several towns to form study sites improves the accuracy of benefit function transfers, and to a lesser extent naive transfers. Importantly, from a safety-first perspective, maximum errors dropped substantially from the individual and n-1 study site town groupings.

Transfers Within Alternate Study Site Town Groups

In practice benefits transfers do not typically use all available study sites. Applying prior information and judgement, researchers frequently group particular study sites into like categories for assimilation into the analysis, while omitting other sites [e.g., Desvousges *et al.*; Loomis; Boyle and Bergstrom]. This section examines the effect of alternative town groupings on the accuracy of benefits transfers, using the n-1 data splitting technique for comparisons.

Various criteria were used to identify groupings of like towns. Categorization by state and contamination history follow from the primary study design. An alternate grouping, dividing towns equally among three income categories, reflects the conjecture that different income groups will have different environmental preferences. These criteria for identifying town groupings are based on *a priori* conjectures of similarity. A fourth grouping of towns was established upon benefit function similarity, as indicated by Chow test analyses, in correspondence with the theoretical rationale for inter-site benefit function transfers. Towns in this set include Chalfont, Perkasie, Horsham, E. Greenville, Olean, and Salamanca.

The predictive accuracy for these four groupings is summarized in the last four columns of

Table 3. Grouping by states and by income lead to relatively similar results in terms of accuracy. Naive errors improved to 21-22%, and average benefit function transfer error fell to about 19%. Two factors appear to contribute to this reduction in error. First, there is an aggregation effect associated with merging multiple towns into a single study site, and second there are benefits from organizing towns into like groups. To isolate these effects, 100 random combinations of 4 towns, taken without replacement from all 12, were used to compute overall average naive and benefit function prediction errors of 34.33% and 21.46% respectively, using a split sample method. Comparing the within state and income results with these average random grouping errors suggests that aggregation effects have a large impact on benefit function accuracies, while the like town effect is more dominant for naive transfers. The relatively small like grouping effect for benefit function transfers is consistent with the result that, even when sites were grouped by income or state, H_2^0 was rejected in 25% of comparisons. In contrast, the like grouping effect is particularly large for naive transfers because the high correlation of WTP values with state (ρ=0.57) and income (ρ=0.73).

When towns were grouped by contamination and Chow test results, the accuracy of benefit function and naive approaches diverged. Relative to the prior subgroupings, naive transfer accuracy worsened with average predictive errors of 35.50% and 27.41% respectively. Benefit function accuracy improved with average errors of 15.51% and 14.66% for contamination and chow groups respectively. This divergence is further reflected in the frequency that naive transfer errors were lower than that of benefit function transfers. The proportion of individual to individual town transfers where naive function transfers have less error than benefit function transfers is 52.73%, while the proportion of naive transfer superiority falls to 8% and 14% for contamination and Chow groupings. These results are consistent with fewer rejections of H_2^0, and the fact that these groups have a wide range of WTP and socioeconomic characteristics. For the Chow grouping, the low average error, range of error and complete superiority of individual predictive results relative to the naive model are strong support for arguments in favor of benefit function transfers.

Discussion

The previous analysis has indicated that the accuracy of naive transfers improves when subgroups are organized on the basis of factors highly correlated with WTP, such as state and income classes. Overall, benefit function transfers are relatively more accurate than naive transfers for all groupings, with additional improvements in accuracy for groupings satisfying H_2^o. Clearly study site town aggregation plays an important role in the relative accuracy of transfers, a point that benefit transfer practitioners need to recognize in future research.

An important policy question is the relative accuracy of benefit transfer derived values compared with primary CV study estimates. At best, predictive error averaged about 15% for benefit function transfer, and 21% for naive transfers in this study. For comparative purposes the absolute proportion of the 90% confidence interval to mean ratio (i.e., $\frac{1}{n_s}\sum_{s=1}^{n_s}\frac{1.645 * S.E.(\bar{X}_s)}{\bar{X}_s}$) for individual towns provides an average error ratio of about 4.2% for primary study values. The best transfer estimates fall outside this range on average, with widely divergent individual prediction errors. It remains an open policy question whether the relative inaccuracies of transfers are reasonable trade-offs with the cost savings of transfers.

Future benefits transfer research should apply techniques analogous to those used here to determine if these results can be replicated for different commodities and for transfers across studies. Such efforts will improve understanding of transfer accuracy and suggest methods to improve transfer reliability.

Figure 1. Safety and Contingent Valuation Questions

14. There are many ways to protect private wells, and communities vary greatly in the extent to which they protect water supplies. We would like to get your opinion on how well you feel your household drinking water supply is protected from contamination.

Study the chart below and circle one letter (A, B, C, or D) that corresponds to how safe you feel about your household drinking water supply.

HOW SAFE I FEEL	PROTECTION LEVEL	DESCRIPTION
VERY SAFE	A	I feel absolutely secure. I have no worries about the safety of my household water supply at present. I am certain the level of protection is excellent and I cannot foresee any contamination occurring in the near future.
SAFE	B	I feel secure. I am confident my household water supply is safe at present. I am sure the level of protection is good and I am reasonably sure the water will not be contaminated in the near future.
SOMEWHAT SAFE	C	I feel apprehensive. I am unsure about the safety of my household water supply. I think the level of protection is adequate at present, but I am uneasy about the future. There is a possibility it could become contaminated in the near future.
UNSAFE	D	I feel troubled. I am anxious about the safety of my household water supply. I have doubts about the level of protection and I think it is very likely the water will become contaminated in the near future.

15. One way to prevent pollution of the supply is to establish an areawide special water protection district. This district would develop and implement pollution prevention policies specifically designed to suit the needs of your community situation. Those in the district who would benefit from the increased protection would make an annual payment which would be added to their water utility bill.

We are interested in discovering what you would be willing to pay, in higher water utility bills, per year to increase the level of protection for your community water supply. Take into account your household income and the fact that the money would have to come from some part of your budget.

Using the payment card below, please indicate how much you are willing to pay, per year, to go from your present protection level, which you indicated on the chart in Question 14, to the highest level (For example, if you feel "SOMEWHAT SAFE" now, what would you pay to move to "VERY SAFE")? Circle one dollar range as your annual payment.

$0	$51-75	$201-225
$0-10	$76-100	$226-250
$11-20	$101-125	$251-275
$21-30	$126-150	$276-300
$31-40	$151-175	$301-325
$41-50	$176-200	$326-350

If you would be willing to pay more than $350, what is the maximum amount per year that you would pay $_____

Table 1. Descriptive Statistics by Town

	WTP ($)	Obs.	Prev. Cont. (TCE)	Prcept. Hist. Cont.	Likeli. Future Cont.	Water Safety	Interest	Avg. Risk	Number Sources	Avg. Trust	%College Educated	Income ($1,000)
Massachusetts												
Westford	71.54	47	0	1.30	2.38	2.62	2.98	4.06	3.45	1.86	46.4	45.9
Groveland	108.49	48	1	2.40	2.58	2.46	3.33	4.05	3.31	1.96	40.4	37.8
Rowly	79.45	50	1	1.90	2.84	2.50	3.14	4.04	3.12	1.76	49.1	41.3
Salisbury	74.07	51	0	1.31	2.98	3.52	2.84	4.03	3.37	1.72	22.4	32.8
Pennsylvania												
Chalfont	61.71	57	0	1.19	2.39	2.68	2.82	4.06	3.35	1.87	34.2	43.2
Perkassie	48.69	61	1	1.49	2.66	2.57	2.89	3.97	3.28	1.94	35.1	29.7
Horsham	67.45	46	1	1.24	2.63	2.54	2.63	4.00	3.17	1.91	48.2	45.5
E. Grnville	65.00	38	0	1.18	2.61	2.60	2.87	4.11	3.02	1.91	16.7	27.2
New York												
Olean	41.19	70	1	1.31	2.59	2.63	2.77	3.87	3.46	1.90	19.3	28.7
Salamanca	31.96	68	0	1.97	1.97	3.04	2.91	3.75	2.99	1.99	18.9	21.5
Bath	42.44	42	0	1.26	1.95	2.98	2.69	3.96	2.81	2.09	34.8	27.4
Macedon	74.87	39	1	1.56	2.74	2.54	2.77	3.92	3.79	2.08	25.6	30.4

Table 2. OLS Coefficients (S.E.)

WTP =	-73.81 -3.48 Maybe Cont	+23.48 Yes Cont	-9.41 Maybe Like	+17.51 Very Like	+9.51 Some Int
	(75.30) (9.61)	(8.10)	(7.56)	(10.95)	(7.30)
	+20.66 Very Int	+21.07 Maybe Safe	+29.91 Unsafe	+9.91 Any Risk	+2.56 Source
	(8.53)	(11.68)	(12.82)	(5.87)	(1.73)
	+15.67 Trust	-17.51 No College	-15.71 Some Coll.	+0.78 Income	
	(6.91)	(8.42)	(7.74)	(0.17)	
	N = 617 R^2 = 0.14				

Table 3. Relative Accuracy (%) Using Policy Site as Base

	Ind. to Ind. (n=132)	All n-1 (n=12)	State n-1 (n=4)	Income n-1 (n=4)	Contam. n-1 (n=6)	Chow n-1 (n=7)
Naive Error (NE) [Range]	42 .12 [1.07, 239.42]	31.41 [0.18, 104.96]	21.84 [3.29, 57.02]	21.53 [0.76, 66.30]	35.49 [3.06, 100.13]	27.41 [1.91, 30.29]
Func. Error (FE) [Range]	44.12 [0.36, 297.61]	18.33 [0.75, 55.61]	19.06 [0.15, 38.68]	19.80 [0.89, 47.99]	15.51 [2.11, 50.35]	14.66 [4.08, 25.51]
% NE < FE	52.73	25.00	33.33	33.33	8.33	14.28
% Reject H_2^0	36.36	25	25	25	0.17	0

Notes for Tables 1 and 2

WTP: Willingness To Pay for additional groundwater protection, ($/Household/Year).

Previous Contamination: Binary variable indicating towns that had experienced past ground water contamination by Trichloroethylene(TCE).

Perception of Historical Contamination: Categorical response variable for perception of previous pollution of household drinking water: 1= No Cont., 2= **Maybe Cont.**, 3 = **Yes Cont**. No Cont was excluded from the binary transformation of these responses in the regression.

Likelihood of Future Contamination: Scale response to likelihood of future contamination ranging from very unlikely to very likely. Grouped into categorical responses: 1=Unlikely, 2=**Unsure/Maybe Likely**, 3= **Very Likely**. Unlikely was excluded from the binary transformation of these responses in the regression.

Interest: Scale response to how interested respondent is in drinking water quality in the community: 2=No or Mild Interest, 3=**Some Interest**, 4=**Very Interested**. No or Mild Interest was excluded from the binary transformation of these responses in the regression.

Safety: Categorical response to current safety question: 2=Unsafe (and Somewhat Safe), 3=**Safe**, 4=**Very Safe**. Very Safe was excluded from the binary transformation of these responses in the regression.

Any risk: Voluntary risk perception variable, mean of 3 questions: answers ranging from 1=extremely safe to 5=extremely unsafe.

Source: Number of perceived potential contamination sources, out of six possible.

Trust: Composite variable of respondents' trust in government and scientific organizations, an average of 9 questions: answers ranging from 1=Do not trust to 3=Great trust.

College: Response to education attainment question.

Income: Household income ($/year) based on the midpoint of the reported income interval.

Endnotes

1. This assumption is made, in part, because of lack of such information for each of the study sites.

2. This conclusion is supported by the application of a proposed value function methodology to groundwater quality studies, which found that predicted values for policy sites deviated from actual values and can be attributed to inconsistent definitions of groundwater contaminants, explanatory variables and policy issues in the individual studies [Bergstrom and Boyle, 1993a, 1993b].

3. In an evaluation of travel cost of sport fishing, Loomis found that the benefit function generally performs better than naive transfers when H_2^0 is not rejected.

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