# Enhancing the Geospatial Validity of Meta-Analysis to Support Ecosystem Service Benefit Transfer

**Robert J. Johnston**
**Clark University, USA**

**Elena Besedin**
**Abt Associates, Inc.**

**Ryan Stapler**
**Abt Associates, Inc.**

*A Community on Ecosystem Services:  Linking Science, Practice and Decision-Making.  Washington, DC, December 8-12*

# Benefit Transfer and Meta-Regression Models

◆ Meta-analysis is increasingly used to implement benefit transfers that synthesize information on economic values from many primary studies.

◆ The dependent variable in a meta-regression model (MRM) is a comparable measure of economic value drawn from similar studies addressing the same service or resource at many different sites.

◆ Independent variables characterize site, resource, ecosystem service, population and methodological attributes hypothesized to explain variation in value.

◆ The goal is a statistical benefit function able to predict economic values for ecosystem changes at sites where no valuation studies have been conducted.

# Core Geospatial Factors in Meta-Analysis

◆ MRMs often give significant attention to the magnitude of resource quality (e.g., the size of water quality change).

◆ Less attention is given to spatial aspects relevant to WTP.

◆ geospatial scale (the geographical size of affected environmental resources or areas),

◆ market extent (the size of the market area over which WTP was estimated), and

◆ substitute availability (the availability of proximate, unaffected substitutes).

◆ Primary studies rarely report the information necessary to include these effects in metadata (e.g., the precise size of the studied water body or sampled market area).

# Geospatial Scale (Size of Affected Areas)

◆ MRMs commonly overlook value patterns associated with spatial scale or use imprecise categorical approaches.

◆ Examples include the use of dummy variables to distinguish size categories of affected resources or areas (e.g., "large" versus "small" wetlands; "national" versus "local" improvements).

◆ Only a few MRMs incorporate explicit measures of site area (e.g., Brander et al. 2007; Londoño and Johnston 2012; Ghermandi et al. 2010).

◆ No published MRMs incorporate explicit, quantitative measures of both a change in quality and the geospatial scale over which the quality change occurs.

# Market Area and Substitutes

- All else equal, larger sampled market areas (e.g., states versus communities) are associated with smaller mean per household WTP estimates (Johnston and Duke 2009).

  - Larger sampled areas imply greater average distances between people and affected ecosystem services, ceteris paribus.

- WTP is also expected to vary (inversely) with the quantity of unaffected substitute resources (Schaafsma et al. 2012).

- Variables quantifying these factors are almost universally omitted from valuation MRMs.

- At most, models include broad proxies for substitute availability (e.g., Ghermandi et al. 2010).

# The Present Analysis

◆ The present analysis develops a MRM for US water quality benefit transfer that incorporates quantitative measures of spatial factors expected influence WTP.

◆ Required extensive work to supplement data available from primary studies alone.

◆ The metadata combine primary study information with extensive geospatial data from geographic information system (GIS) data layers and other external sources.

◆ The result is the first meta-analytic benefit function able to adjust for simultaneous variations in geospatial scale, market extent and spatially differentiated substitutes.

# The Metadata

◆ Extend and update metadata of Johnston et al. (2005).

◆ Drawn from studies that estimate willingness to pay (WTP) for water quality changes in US water bodies that support non-consumptive ecosystem services.

◆ Include studies that estimate total (use & nonuse) values and use generally accepted stated preference methods.

◆ 140 observations from 51 stated preference studies conducted between 1981 and 2011.

◆ All monetary values are adjusted to 2007 US dollars.

◆ Supplementary geospatial data drawn from sources including National Hydrography Dataset, Hydrologic Unit Code Watershed Boundary Dataset, and National Land Cover Database.

# Core Geospatial and Water Quality Variables

◆ Geospatial variables chosen after testing of alternative specifications in preliminary models.

◆ Index of geospatial scale: *ln_ar_ratio* = natural log of the size of the sampled market area divided by the total area of counties that intersect with the affected water bodies.

◆ *sub_frac* = proportion of water bodies of the same hydrological type affected by the water quality change, within affected states.

  ◆ Measured using proportional shoreline (rivers & bays) or surface area (lakes).

◆ *lnquality_ch*: natural log of the change in mean water quality valued by the study, specified on the 100-point water quality index.

# The Meta-Regression Model

◆ Dependent variable: natural log of household WTP for water quality improvements measured on standard 100 point water quality index (McClelland 1974).

◆ 24 independent variables characterizing: (1) study methodology, (2) populations, (3) market areas and study sites, (4) water bodies and (5) water quality change.

◆ Multilevel regression model, robust variance estimation, non-weighted, translog functional form.

◆ Wald $\chi^2 = 683.44$, p<0.0001; $R^2$=0.65.

◆ 20 coefficients statistically significant at p<0.10 or better.

◆ Outperforms restricted model that omits core geospatial variables ($\chi^2 = 354.03$, df 2, p<0.0001).

# Results for Selected Variables

| Variable | Coefficient Estimates (Standard Errors) |
|---|---|
| *ln_ar_ratio* | -0.073 |
| | (0.025)*** |
| *sub_frac* | 0.668 |
| | (0.181)*** |
| *lnquality_ch* | 0.299 |
| | (0.106)*** |
| | |
| *nonusers* | -0.435 |
| | (0.119)*** |
| *lnincome* | 0.745 |
| | (0.374)** |

# Implications for Benefit Transfer

◆ Patterns match expectations suggested by theory, and enable benefit transfers that adjust values accordingly.

◆ How to the present MRM results compare to those from a parallel model that omits the core geospatial variables?

◆ To illustrate benefit transfer implications, we project per household WTP for illustrative water quality improvements, within policy sites that differ in geospatial scale, market extent and substitute availability.

◆ Ecosystem service values are forecast using both restricted (excluding geospatial variables) and unrestricted (including geospatial variables) MRMs.

◆ Results show the implications of common MRMs that exclude geospatial variables such as these.

# Illustrative Benefit Transfer Scenario

◆ WTP forecast for three otherwise identical scenarios: mean, minimum and maximum scales of two core geospatial variables (*ln_ar_ratio* and *sub_frac*). Larger values for *ln_ar_ratio* imply smaller scales.

◆ Water quality improvement equal to the mean over the metadata (*lnquality_ch*=2.907); equivalent to a change of 18.301 on 100-point WQI.

◆ Baseline of *lnbase*=3.589 (36.194 on the WQI).

◆ A single illustrative scenario is used to show implications for benefit transfer:

  ◆ Annual mean value (WTP) per household, assuming a general population sample in mid-Atlantic region, for an improvement to a single river.

# Illustrative Benefit Transfer Scenario

| Variable | Assigned Variable Values | | |
|---|---|---|---|
| | Scenario 1 (Mean of Sensitivity Analysis Variables) | Scenario 2 (Min. Scale of Sensitivity Analysis Variables) | Scenario 3 (Max. Scale of Sensitivity Analysis Variables) |
| *ln_ar_ratio* | -1.128 | 6.651 | -8.480 |
| *sub_frac* | 0.188 | 0.0003 | 1.000 |
| | | | |
| WTP Est.: **Unrestricted** Model | **$52.06** | **$26.03** | **$153.16** |
| WTP Est.: **Restricted** Model | **$52.01** | **$52.01** | **$52.01** |

# Conclusions

◆ It is possible to develop meta-analytic benefit transfers that better adjust for geospatial aspects of ecosystem services and affected populations.

◆ Robustness tests suggest that similar results hold across a wide range of specifications.

◆ The size of effects on ecosystem service value estimates are not trivial: effects of geospatial variables alone can lead to a six-fold difference in value estimates.

◆ The use of unit value or function transfers that ignore these factors risks large transfer errors.

◆ Because relevant geospatial information is often omitted from publications, additional work is required to develop the necessary metadata.

# Questions or Comments?

Robert J. Johnston
Director, George Perkins Marsh Institute
Professor, Department of Economics
Clark University
950 Main St.
Worcester, MA 01610
Phone: (508) 751-4619
Email: rjohnston@clarku.edu