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

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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 χ^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 (χ^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?

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