# Extending the Use of Meta-Analysis for Ecosystem Services Valuation

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# Ecosystem Service Benefit Transfer

- There is high demand for information on ecosystem service values, particularly those associated with policy or program impacts over large geospatial scales.
- The lack of time and resources required for primary valuation studies has led to an increasing use of *benefit transfer* (BT) to quantify these values.
- BT uses results from prior valuation research at one or more *study sites* to predict welfare estimates at other unstudied *policy sites* (Johnston and Rosenberger 2010).
- The ecosystem services literature commonly applies BT methods with low (or unknown) validity and reliability.
- Can we develop feasible BT for ecosystem services that enhances validity and reliability?

# Meta-Regression Models

- Meta-analysis is increasingly used to implement BTs 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 at sites where no valuation studies have been conducted.

# Needs for Validity and Reliability

- Although MRMs are increasing, most lack central features required for *valid* and *reliable* BT.
  - A degree of consistency in ecosystem services (commodities) and value types (welfare measures) required for validity.
  - Ability to account for effects of key factors such as income, downward sloping demand, and substitutes.
  - Ability to account for the systematic effect of spatial factors such as scale and distance.
  - A model of value per household or individual (rather than value per unit area) for well defined change.

# Needs for Validity and Reliability

- The goal of the present research is to enhance the capacity of valuation MRMs to model patterns suggested by theory, promoting more valid and reliable BT.
- Examples include effects of:
  - Scope sensitivity and downward sloping demand.
  - Characteristics of ecosystem services (e.g., uses).
  - Geospatial variables such as scale and distance.
  - Substitutes and complements.
  - Characteristics of beneficiary households.
  - Land use/cover within affected areas.

# The Metadata

- To develop the approach, we begin with and extend the metadata of Johnston et al. (2016, *Environmental and Resource Economics*).
- Guidelines of Stanley et al. (2013) followed for research identification and coding of new studies.
- Observations 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.
- 148 observations from 53 stated preference studies conducted between 1985 and 2016.
- All monetary values are adjusted to 2016 US dollars.

# The Meta-Regression Model—Details

- Dependent variable: natural log of (WTP/household/unit change), where units are measured on a standard 100-point water quality index (WQI) (Abassi 2012).
- 25 independent variables characterizing: (1) study methodology, (2) populations, (3) market areas and study sites, (4) water bodies and (5) water quality change.
- Unweighted OLS regression with cluster robust standard errors. Other estimation methods provide similar results.
- Structure of the model allows testing of scope sensitivity and downward sloping demand.

# Variables to Accommodate Core Effects

- To accommodate core effects, the metadata combine primary study information with geospatial data from GIS data layers and other external sources.
- Measures of valued change:
  - *Lnquality_ch*: natural log of the change in mean water quality valued by the study, specified on the 100-point water quality index.
  - *Q_avg*: Mid-point between baseline and improved water quality, on the 100-point WQI.
  - Variables characterizing affected uses.

# Characteristics of Beneficiaries, Substitutes and Complements

- *Nonusers*: binary (dummy) variable indicating that the survey was implemented over a population of nonusers.
- *Ln_income*: natural log of median income (in 2016$) for the sample area of each study based on U.S. Census.
- *Ln_pop*=The log of total population within affected area [intersecting counties], from 2010 US Census.
- Region of US where study took place.
- *Prop_chg* = proportion of water body area of the same hydrological type affected by the water quality change, within affected states.
- *Ln_ar_agr* = Natural log of the proportion of affected resource area [intersecting counties] in agricultural land use, based on National Land Cover Database.

# Distance and Scale

- Distance calculation reflects the average distance of the surveyed population from affected water bodies (Johnston et al. 2018).
- Variable in the model combines effects of distance and scale (size of the affected area).
- *ln_sz_ratio* = log of (area of counties touching affected water bodies [$km^2$] divided by average distance [km]).
  - Allows the effect of distance on *ln(WTP)* to vary inversely with the size of the affected area.
  - Expected sign (+).
- Model as a whole is statistically significant at $p<0.0001$, with $R^2=0.75$.

# The Meta-Regression Model—Results

| | **Spatial Variables and Water Quality Change** (std. errors in parentheses) | |
|---|---|---|
| **Scope and down-ward sloping demand** | *q_avg* (WQI midpoint) | -0.0105** |
| | | (0.0051) |
| | *lnquality_ch* (Δ WQI) | -0.5776*** |
| | | (0.1140) |
| **Size / Distance** | *ln_sz_ratio* (area / distance) | 0.1373*** |
| | | (0.0397) |
| **Substitutes & Complements** | *river_sz_ratio* | -0.000001001*** |
| | | (3.335e-07) |
| | *prop_chg* (proportional affect) | 1.1095*** |
| | | (0.3237) |
| | *ln_ar_agr* (fraction agriculture) | -0.3508*** |
| | | (0.07459) |
| **Population** | *ln_pop* (population) | -0.1729*** |
| | | (0.0517) |

# The Meta-Regression Model—Results

| Regions and Populations (std. errors in parentheses) | |
|---|---|
| *northeast* | 0.8065*** |
| | (0.2355) |
| *central* | 0.4947*** |
| | (0.1128) |
| *south* | 1.5661*** |
| | (0.1356) |
| *nonusers* | -0.3750*** |
| | (0.1206) |
| *lnincome* | 1.1255*** |
| | (0.3783) |

# The Meta-Regression Model—Results

| **Water Body Uses**<br>(std. errors in parentheses) | |
|---|---|
| *river* | -0.02346 |
| | (0.1397) |
| *swim_use* | -0.5423*** |
| | (0.1857) |
| *gamefish* | 0.3817** |
| | (0.1881) |
| *boat_use* | -0.3942** |
| | (0.1623) |

# The Meta-Regression Model—Results

**Methodological and Selection**

(std. errors in parentheses)

| | |
|---|---|
| *ce* | 0.4299 |
| | (0.2672) |
| *thesis* | 0.7177*** |
| | (0.2000) |
| *lnyear* | -0.5640*** |
| | (0.09168) |
| *volunt* | -1.4817*** |
| | (0.1757) |
| *outlier_bids* | -0.3694*** |
| | (0.1285) |
| *nonparam* | -0.4100*** |
| | (0.09350) |
| *non_reviewed* | -0.7027*** |
| | (0.1801) |
| *lump_sum* | 0.8772*** |
| | (0.1474) |

# Illustrative Benefit Transfer

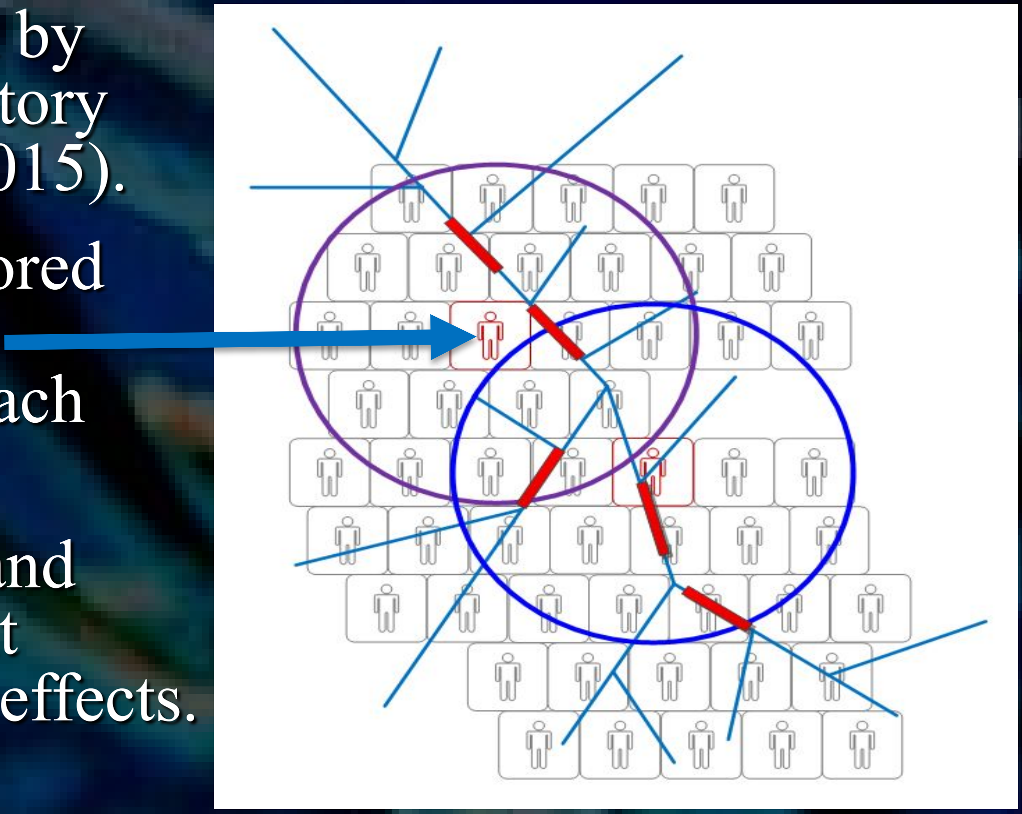
- Applications use these results to forecast WTP for site where no valuation study has been conducted.
- Assume we require an estimate of marginal WTP/household per unit of water quality change.
- Assume water quality midpoint and change at the mean for the metadata (gain of 17.86 WQI points; midpoint of 52.8882).
- Change occurs to rivers in the northeast US and affects 5% of rivers in Massachusetts.
- WTP desired for a general population (users & nonusers).
- Rivers are used for swimming but not fishing or boating.
- All other variables assumed at mean values for metadata.

# Illustrative Benefit Transfer

- Application of benefit function leads to predicted WTP = $4.50/household.
- These values change under different scenarios
  - If 10% of rivers are affected, WTP increases to $4.76.
  - If WTP of nonusers only is desired, WTP decreases to $3.09.
- Thus, MRM benefit transfers can adjust for different site, population and policy characteristics.

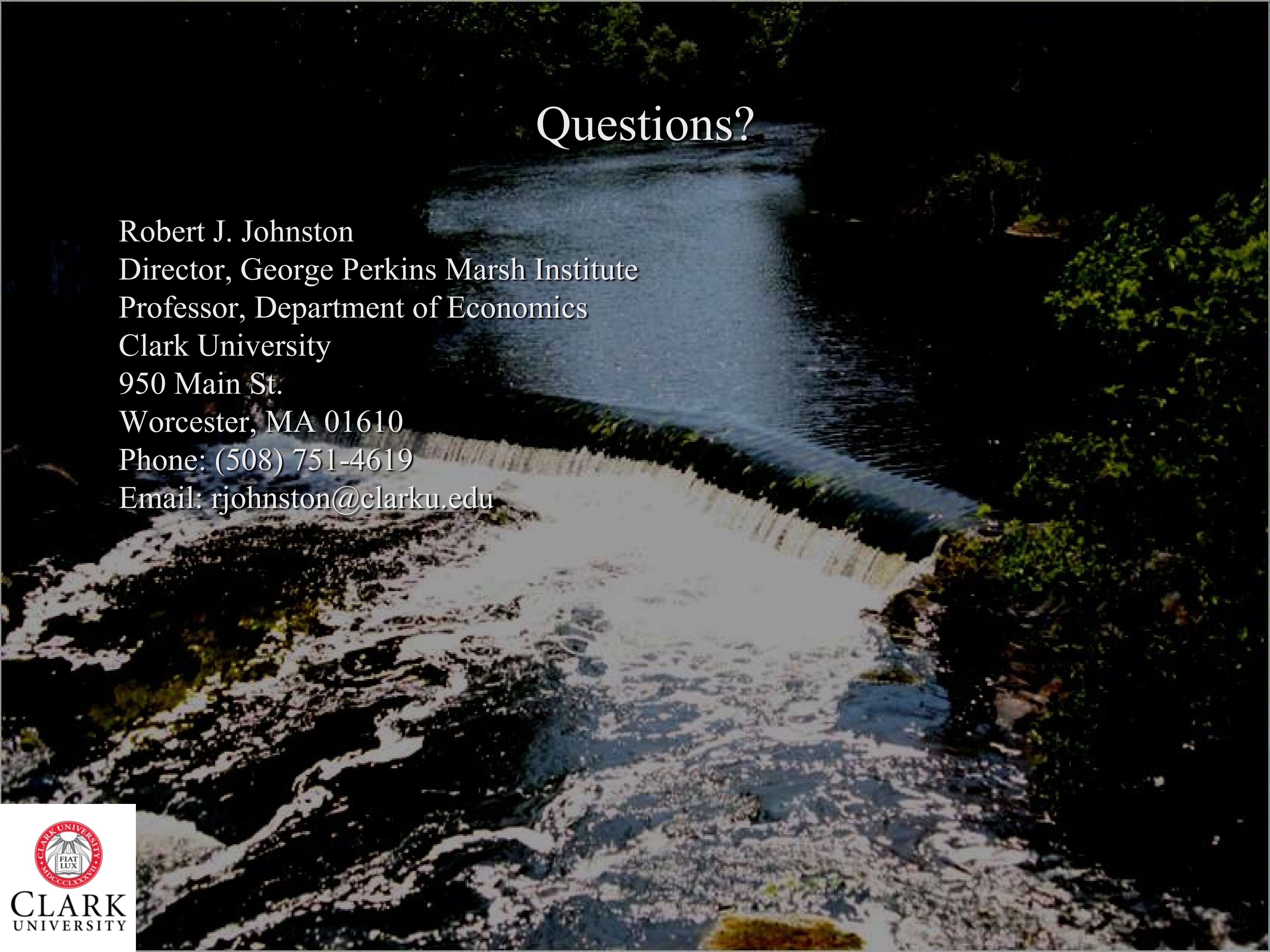
# Estimating Benefits for Large Scale Programs

- MRM results can be used to conduct spatial benefit estimation for nationwide water quality policy.
- This is the approach used by US EPA for recent regulatory analyses (e.g., US EPA 2015).
- Benefit estimates are tailored to water quality changes within a fixed radius of each census block.
- Effect of distance, areas and ΔWQI reflected in benefit calculation, among other effects.



# Final Comments

- Such approaches can be used for multiple and varied applications, without the need to re-estimate the MRM.
- Provides for feasible BT that also enhances validity and reliability.
- Statistical fit is necessary but not sufficient.
- Issues such as theoretical properties, value aggregation, and the interpretation of estimates are important.
- Functional forms can be adapted to impose particular theoretical properties, if desired.
- Ongoing research is developing MRMs that are even better suited to the needs of large-scale program evaluation.



# Questions?

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