EVALUATING POSSIBILITIES FOR BENEFIT TRANSFER WITH HETEROGENEOUS RESOURCES AND RESEARCH METHODS:

BAYESIAN AND CLASSICAL META-ANALYSIS OF INTERNATIONAL CORAL REEF VALUES

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Evaluating Possibilities for Benefit Transfer with Heterogeneous Resources and Research Methods: Bayesian and Classical Meta-Analysis of International Coral Reef Values

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Abstract: This paper evaluates possibilities for meta-analysis and benefit transfer of willingness to pay for coral reef recreation, considering the heterogeneous, international nature of the reef valuation literature. We emphasize potential enhancements in metadata and model estimation that may improve value surface estimation and benefit transfer reliability. Results are compared to Brander et al. (2007), the only prior meta-analysis of reef values. By combining approaches to ensure metadata uniformity and supplementation of metadata with exogenous information, models are able to provide value surface insights unavailable elsewhere and improve benefit transfer potential. Results also highlight challenges in meta-analysis of heterogeneous reef values.

Introduction

Coral reefs exemplify a resource for which information on economic benefits is often sought for advocacy and policymaking, but for which high quality primary valuation research is rarely available. Welfare estimates are often desired by those seeking to understand the benefits of conservation programs and assess tradeoffs associated with alternative reef uses (Brander et al. 2007; Cesar 2000). Despite a recent emergence of a coral reef valuation literature, however, site specific estimates are often unavailable. Reasons include time and budget constraints as well as technical challenges of conducting research in areas where coral reefs are located (Brander et al. 2007). As a result, government agencies, nonprofit organizations and others have often sought to gain insight into the benefits of coral reefs using *benefit transfer*, defined as the use of results from extant primary research to predict welfare estimates for policy sites at which primary valuation estimates are unavailable. Within this context, the increasing need for reliable benefit transfer approaches is frequently noted (Spurgeon 2001; Brander et al. 2007).

The transfer of benefit estimates or functions for coral reefs faces numerous challenges. High-quality studies of coral reef values are sparse, distributed across heterogeneous international sites, and apply divergent methods. As a result, it is often difficult to identify sites of sufficient similarity for traditional site-to-site benefit function transfer; this is a common concern in benefit transfer more generally (Columbo and Hanley 2008; Johnston 2007; Stapler and Johnston 2009). In contexts such as this, some researchers have proposed meta-analysis as a means to estimate benefit meta-functions that synthesize information from multiple primary studies (Bergstrom and Taylor 2006; Rosenberger and Stanley 2006; Rosenberger and Johnston 2009).[1] Most examples involve the use of meta-regression, in which the dependent variable in a Bayesian or classical regression model is a summary statistic drawn from comparable primary studies (often a willingness to pay (WTP) estimate), and independent variables characterize policy, site and population attributes hypothesized to explain variation across observations (Nelson and Kennedy 2009). Estimated meta-functions are used to approximate WTP values for unstudied policy sites.

The same challenges that diminish possibilities for site-to-site coral reef benefit transfers, however, also affect the feasibility and validity of potential meta-analyses. When applied to resources such as coral reefs, meta-regression models (MRMs) can face interlinked difficulties related to a sparseness of primary research, lack of uniformity in effect sizes, heterogeneity of primary study methods, insufficient data reporting, and data from multiple countries; all of these have been noted as challenges in both benefit transfer and meta-analysis (Johnston and Rosenberger 2010). The one extant meta-analysis of coral reef values, Brander et al. (2007), reports non-trivial empirical challenges, many related to the heterogeneity and non-comparability of studies pooled in the metadata. Convergent validity tests of transfer reliability suggest that the result of this meta-analysis is “unlikely to be acceptable in most policy-making scenarios” (Brander et al. 2007, p. 215). Like findings have been reported in meta-analyses addressing similarly heterogeneous commodities such as wetlands (Woodward and Wui 2001).

[1] Partial reviews of the meta-analysis literature in benefit transfer and environmental/resource economics are provided by Johnston and Rosenberger (2010) and Nelson and Kennedy (2009), respectively.

Given calls for improved coral reef benefit transfer and limitations of existing approaches, this paper develops and evaluates possibilities for meta-analysis and transfer of coral reef benefit estimates. More specifically, we extend methods of Brander et al. (2007) through (1) more rigorous approaches for metadata sample selection and to ensure metadata uniformity and comparability, particularly with regard to research methods and theoretical properties of welfare estimates, (2) coordinated use of both Bayesian and classical meta-regression models to assess robustness and allay challenges related to small samples, and (3) supplementation of data from primary studies with information gathered from broader coral reef databases, following methods of Johnston and Duke (2010). MRMs and benefit transfer results are evaluated and compared to the prior findings of Brander et al. (2007), to assess whether these methodological enhancements improve empirical performance and possibilities for applied use.

Results are drawn from metadata including 85 observations from 29 unique studies conducted worldwide addressing the recreational value of coral reefs. Criteria used in selecting studies are designed to maintain commodity consistency for the dependent variable across observations (i.e., uniformity of the definition of the good that is valued), as well theoretical consistency of the welfare measure—two primary conditions for valid meta-analysis (Nelson and Kennedy 2009). Multiple classical and Bayesian MRMs are estimated, distinguished by elements including the subset of studies included in the metadata, the model specification, and (for Bayesian models) the use of diffuse versus informed priors. Empirical findings are assessed in terms of statistical fit, robustness and interpretation of value surfaces, and benefit transfer performance within a convergent validity framework. Results suggest the potential information which may be derived from meta-analyses of values for heterogeneous, international resources such as coral reefs, as well as the substantial analytical challenges.

Valuation Meta-Analysis with Heterogeneous International Resources

The seminal meta-analysis of Brander et al. (2007) addressing recreational coral reef values pools welfare estimates drawn from numerous methods, many of which generate theoretically non-comparable measures. These include contingent valuation, travel cost, net factor income, productivity and gross revenue methods. Here, in contrast, we emphasize recreational WTP per visitor/day of coral reef recreation estimated using two methods, travel cost and contingent valuation, with split samples allowing results from the two study types to be distinguished. This reflects increased emphasis in the meta-analysis literature on commodity and welfare consistency (Bergstrom and Taylor 2006; Nelson and Kennedy 2009; Smith et al. 2002).

Within meta-analysis of nonmarket values, *commodity consistency* requires that the commodity being valued is approximately the same across studies, and/or that any remaining differences are reflected in the specification of independent variables within MRMs (Bergstrom and Taylor 2006). Here, commodity consistency is promoted through the inclusion of studies whose results may be expressed in terms of WTP/person/day of reef recreation, excluding studies in which values can only be expressed in other metrics (e.g., value per acre of reef).

Welfare consistency, in contrast, requires that welfare measures pooled within metadata represent the same theoretical construct (Bergstrom and Taylor, 2006; Smith et al, 2002). For example, contingent valuation and travel cost studies typically provide Hicksian and Marshallian welfare measures, respectively, so that pooling values across these study types violates welfare consistency. Ideally, only observations that satisfy welfare consistency should be pooled. This, however, can reduce available sample sizes for meta-analysis. As a result, despite cautions against such approaches (Bergstrom and Taylor 2006; Nelson and Kennedy 2009), it is not uncommon for MRMs to pool theoretically inconsistent welfare measures and attempt to make associated adjustments on the right hand side of regression equations (Nelson and Kennedy 2009; Smith et al. 2002); this is the approach applied by Brander et al.'s (2007) seminal MRM. Here, in contrast, we compare models that impose varying degrees of welfare consistency, including strict consistency in which only estimates from stated preference methods are included.

Even given this emphasis on commodity and welfare consistency, meta-analysis of coral reef recreational values faces empirical challenges related to primary study heterogeneity and data reporting, as well as sample selection considerations that may diverge across sites (see related discussions by Brander et al. (2007), Lindhjem and Navrud (2008) and Rosenberger and Johnston (2009)). As noted by Brander et al. (2007), reef sites vary across a range of attributes, including physical attributes; economic, geographic and socio-cultural settings; biotic and bio-geochemical properties; and the site specific significance of various reef attributes and services. These variations affect both the underlying WTP for reef recreation, as well decisions regarding whether a particular site is chosen for a primary valuation study and the methods that are used to quantify values—the latter reflecting research selection bias of the type discussed by Rosenberger and Johnston (2009).

Challenges related to reef heterogeneity are exacerbated by the international pooling necessary to compile metadata with sufficient degrees of freedom for meta-regression analysis (Ready et al. 2004, Ready and Navrud 2006, Johnston and Thomassin 2010). Studies of reef recreational values are distributed across tropical sites in many areas of the world, including Southeast Asia (Rosales 2003; White et al. 1997; Nam and Son 2001; Seenprachawong 2003; Ahmed et al. 2007), the Caribbean (Parsons and Thur 2007; Díaz 2001; Wright 1995), the United States (Leeworthy and Bowker 1997; Bhat 2002; Ditton et al. 2008), Australia and the South Pacific (Hundloe 1990; Carr and Mendelsohn 2003), and East Africa and the Indian Ocean (Mathieu et al. 2003; Ngazy et al. 2001; Mohamed 2007; White et al. 1997). The relative sparseness of research within each area, however, provides insufficient studies in any single country or region to enable reliable meta-regression analysis. For this reason, both Brander et al. (2007) and the present analysis pool study data drawn from different regions and countries.

As noted by Johnston and Thomassin (2010), meta-analyses in the economics literature often give scant attention to the empirical challenges associated with such multinational data. In addition to the above noted heterogeneity and sample selection concerns, pooling of multinational valuation data may encounter complications related to such factors as (1) currency conversion, (2) user or population attributes and/or preferences, (3) wealth versus income, (4) cultural differences, (5) the extent of the market, and (6) value adjustments (Johnston and Thomassin 2010; Ready et al. 2004, Ready and Navrud 2006). As shown by Johnston and Thomassin (2010), resulting value surface divergences can lead to substantial benefit transfer errors, unless these differences can be explicitly modeled within MRMs. Their findings point to the risk of omitted variables and other biases in multinational MRMs that do not specify models to allow for at least some systematic variation in WTP across countries. For the case of coral reefs and similar resources, however, the sparseness of comparable primary studies limits the extent to which this can be accomplished.

These concerns reflect broader issues raised by Nelson and Kennedy (2009) when cautioning analysts to avoid abuse of meta-analysis in environmental and resource economics (cf. Smith and Pattanayak 2002; Johnston and Rosenberger 2010). Given the state of the literature, meta-analysis of coral reef recreational value faces unavoidable empirical challenges. Even so, appropriately specified MRMs of coral reef values might still have the potential to provide information unavailable through other methods, and support benefit transfers with lower generalization errors than would be otherwise possible. Such possibilities may be further enhanced through the ability of Bayesian statistical methods to accommodate parameter uncertainty and small samples; such possibilities are implied by the improved performance of the hierarchical Bayesian analysis of wetland values of Moeltner and Woodward (2009) contrasted to earlier findings of Woodward and Wui (2001). Considering the challenges facing meta-analysis of coral reef recreational values, however, MRM results should be treated with caution and applied for policy analysis only after comprehensive evaluation of empirical properties. This includes sensitivity analysis to assess the robustness of model results to varying model specifications, assumptions and estimation methods, as well as convergent validity testing to quantify the potential for generalization error.

Data and Conceptual Approach

Recognizing the challenges involved, this paper evaluates the potential for reliable, policy relevant meta-analysis of coral reef recreational values. Emphasis is given to the role of data heterogeneity (including commodity and welfare measure consistency) and estimation methods on model results and robustness, including a contrast of Bayesian versus classical regression results following Moeltner et al. (2007) and Moeltner and Woodward (2009), among others.

The metadata are drawn from existing contingent valuation and travel cost studies on the recreational value of coral reefs, conducted in reef sites worldwide. To ensure commodity consistency all included studies report or allow calculation of comparable estimates of WTP per visitor/day of coral reef recreation. Study sources include published journal articles, theses/dissertations and technical reports. Many of these sources were identified within a bibliographic database of coral reef valuation provided by the NOAA Coastal and Ocean Resource Economics Program; some of these are also included in the prior analysis of Brander et al. (2007). The resulting meta-data comprise a total of 85 observations from 29 unique studies conducted between 1986 and 2007, inclusive. The number of observations exceeds the number of studies because studies often provide more than one estimate of WTP, for example due to within-study variation in study methods or attributes of studied reefs.

Table 1 summarizes principal characteristics for included studies. Within the metadata, 14 observations reflect travel cost estimates and the remaining 71 represent contingent valuation estimates. WTP values for all studies were converted to comparable year 2000 dollars using the country-specific consumer price index (CPI). In cases where respondents were foreign visitors from multiple countries, the US CPI was used. All values were then converted to international dollars by using the Purchasing Power Parity rate for the year 2000 (United Nations 2009).

Independent variables included in the meta-analysis are derived from a list of attributes with potential influence on WTP, based on theory and prior findings in the empirical literature, including the prior meta-analysis of Brander et al. (2007). These variables are divided into two categories. These include: (1) site attributes such as habitat size, geographical location, recreational activities, status as a marine protected area, and reef quality (percentage of live coral cover), and (2) methodological characteristics such as elicitation method, payment vehicle, sample size, sampling method and publication type. Following standard practice outlined by Johnston et al. (2005) and others, care was taken to reconcile both dependent and independent variable definitions across observations. In most instances this reconciliation was straightforward. In others, however, it required assumptions to be made regarding the comparability of different measures across sites.[2] Population characteristics are omitted from the estimated models due to a lack of reporting in a substantial number of primary studies. Table 2 characterizes the full set of independent variables included in one or more estimated models, including the form (linear or natural log) in which they enter estimated models.

Two general model categories are estimated from the metadata summarized in Tables 1 and 2, distinguished by the empirical use of observations from travel cost studies. All models are estimated using both classical and Bayesian model variants. The first category pools all observations into a *combined* contingent valuation and travel cost MRM that relaxes the stronger welfare consistency conditions imposed in other estimated models, in return for a larger sample size (N=85). Here, travel cost observations are explicitly included in the metadata. The second category includes only observations from *contingent valuation* studies (N=71), representing a majority of the metadata. Within the latter analysis, however, we estimate a Bayesian model that uses the excluded observations to derive informed priors following Moeltner et al. (2007), in addition to a model with diffuse priors. More specifically, within the contingent valuation meta-analysis, travel cost studies are excluded from the primary metadata but are used to refine priors within the Bayesian model. To clarify the sensitivity and robustness of parameter estimates to these alternative treatments, identical variables are included in all models, with the exception of methodological variables that are invariant within a particular category.

Meta-Regression Models

The substantial majority of valuation meta-analyses in the literature apply classical statistical methods, in part due to their relative familiarity, ease of estimation, and the general skepticism of some researchers towards Bayesian statistics. The applicability of classical methods, however, can be constrained by the small sample sizes which often prevail in meta-analysis (Larose 1997). With large samples, the results of Bayesian inference are generally similar to those of classical maximum likelihood methods; for small samples Bayesian estimates should be more reliable (Leon-Gonzalez and Scarpa 2008; Koop et al. 2007; Moeltner et al. 2007; Leon et al. 2002; Larose 1997). Bayesian approaches are also well suited for addressing parameter and model uncertainty, even in small sample cases (Koop et al. 2007; Rossi et al. 2005). Finally, Bayesian hierarchical modeling supports the use of additional information not included in the metadata via the specification of prior distributions (Rossi and Allenby 2003); this is discussed in the context of valuation meta-analysis by Moeltner and Woodward (2009) and Moeltner et al. (2007). The

[2] For example, construction of the variable *reef_area*, representing the size of protected reef areas, required a number of assumptions to account for different types of actual and proposed protections across reef sites.

extent to which these properties contribute to divergent classical and Bayesian estimates in any given application, however, is an empirical question—here addressed through the comparison of Bayesian and classical estimates for the three categories of MRM described above.[3]

The Classical Multi-Level MRM

Here, the classical model is grounded in a standard multi-level MRM (Bateman and Jones 2003; Johnston et al. 2005), allowing for cross-sectional correlation among observations from the same study. If left unaddressed in the model, such correlation can lead to heteroskedastic errors and inefficient, inconsistent parameter estimates (Rosenberger and Loomis 2000). For each empirical study in the metadata, a central tendency measure (e.g., mean) of welfare for the representative individual is given by $\bar{y}_{js}$ is the measured effect size in the MRM:

$$\bar{y}_{js} = \bar{x}_{js}\beta + \varepsilon_{js} \,. \qquad [1]$$

Here, $\bar{y}_{js}$ is the welfare measure for observation *s* in study *j*, and $\bar{x}_{js}$ is a vector of variables measuring environmental conditions and change, research methods, temporal factors, and other factors expected to influence value surfaces across observations and/or sites. The vector β represents a conforming vector of parameters to be estimated.

To allow for potential effects of study-specific unobservable factors, we partition ε_{js} into two components,

$$\varepsilon_{js} = u_s + e_{js}, \qquad [2]$$

where u_s represents a systematic, normally distributed, study-level random effect with $E(u_s) = 0$ and $Var(u_s)$ = r is assumed to follow an inverse gamma distribution, where v_0 represent the sample degrees of freedom and

[3] Any comparison between Bayesian and classical estimates must, of course, recognize the fundamental distinctions in model outputs and interpretations between the two approaches. For example, while the interpretation of most classical models emphasizes coefficient point estimates, Bayesian interpretations tend to emphasize estimated coefficient distributions, from which various measures of central tendency (e.g., means) are reported.