Ecological Economics 133 (2017) 74–85

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Threshold Effects in Meta-Analyses With Application to Benefit Transfer for Coral Reef Valuation☆

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ARTICLE INFO

Article history:
Received 20 February 2016
Received in revised form 7 November 2016
Accepted 16 November 2016
Available online xxxx

Keywords:
Meta-regression model
Convergent validity
Threshold
Contingent valuation

ABSTRACT

Policymakers and advocates often use benefit transfers to estimate the economic value of environmental amenities when primary valuation studies are infeasible. Benefit transfers based on meta-analyses, which synthesize site and methodological characteristics from valuation studies of similar underlying amenities, generally outperform traditional site-to-site transfers. We build on earlier meta-analyses of willingness-to-pay for tropical coral reef recreation by introducing a meta-regression model with threshold effects, with a goal of increasing transfer reliability. We estimate a threshold in coral reef quality and find that increases in live coral cover have a large impact on individuals' WTP for recreation at degraded coral reefs. Relaxing the assumption of users' constant valuation across the distribution of this characteristic improves the performance of coral reef benefit transfers in some instances: tests of convergent validity reveal that including the threshold effect reduces the mean transfer error and the interquartile range of transfer errors in 5 out of 8 tests.

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1. Introduction

A common problem facing government agencies, policy makers, and advocates is how to properly value an amenity that benefits the public, but is not traded in markets. Examples include improvements in air quality, decreases in violent crime rates, and reductions in health risks. In some instances, cost and/or time constraints prevent analysts from conducting a primary valuation study. When a site-specific study is infeasible, those who conduct valuation work turn to *benefit transfers*. A benefit transfer is defined as the use of results from extant primary research to predict welfare estimates for amenities when primary valuation estimates are infeasible (Johnston et al., 2015). In practice, analysts would transfer the value associated with an amenity from an already-studied site (the study site) to estimate the unknown value of the same amenity at the unstudied site (the policy site).

Frequently, there is no sufficiently comparable study site which analysts can use to estimate the value at the policy site (Parsons and Thur, 2008); this is one cause for concern in benefit transfer (Johnston and Rosenberger, 2010). In these situations, researchers can use meta-analysis for benefit transfer. As a tool for benefit transfer, meta-analysis integrates findings from multiple primary studies of a common amenity, and helps the analyst understand how values depend on site characteristics and valuation methodology. For example, researchers recently combined a meta-analysis of willingness-to-pay for coral reef recreation with a visitation model to estimate the value of foregone recreation that would occur under different ecological scenarios (Brander et al., 2015).[1] An attractive feature of meta-analysis is the ability to control for factual and methodological heterogeneity that might plague traditional benefit transfers (Nelson and Kennedy, 2009; Rolfe et al., 2015).

Many meta-analyses of environmental valuation make use of meta-regression (Smith and Huang, 1995; Shrestha and Loomis, 2001; Van Houtven et al., 2007; Braden et al., 2011), in which the dependent variable is an estimate of welfare, typically willingness-to-pay (WTP), drawn from primary studies that analyze similar

☆ We would like to thank two anonymous referees, Peter Edwards and Robert Johnston for useful comments and suggestions. We also gratefully acknowledge Robert Johnston for providing the metadata. The support of NOAA's Office of Science and Technology (EA-133F-14-BA-0013, Call No. 27 / 209574) is gratefully acknowledged. The views and opinions expressed or implied in this article are those of the authors and do not necessarily reflect the position of the National Marine Fisheries Service, NOAA.

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[1] Recent reviews on the use of meta-analyses in the benefit transfer and valuation literatures include Johnston and Rosenberger (2010), Boyle et al. (2015), and Johnston et al. (2015); more critical reviews are Smith and Pattanayak (2002) and Nelson and Kennedy (2009).

http://dx.doi.org/10.1016/j.ecolecon.2016.11.015
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underlying amenities. In a metadataset, a single study could provide multiple observations of WTP. The independent variables in a meta-regression model (MRM) characterize the site attributes and methodological approaches that could explain variation in WTP for the underlying amenity (Nelson and Kennedy, 2009). The researcher then combines the coefficient estimates from the MRM with the policy site characteristics to estimate welfare associated with the policy site.[2]

The standard approach in meta-analysis is to employ a linear MRM (Nelson and Kennedy, 2009), and a linear-in- parameters relationship between site characteristics and WTP. However, the recent work of Kaul et al. (2013) discusses the possibility of nonlinear effects in a MRM. One way to model non-linear impacts of site characteristics on WTP is to include the logged values of continuous right-hand side variables (Johnston et al., 2005; Brander et al., 2007; Londoño and Johnston, 2012).

We depart from earlier meta-analyses by modeling a discontinuous relationship between WTP and (some) site characteristics within a threshold model. In a threshold model, consumers' marginal WTP (MWTP) for improvements in a particular characteristic could vary depending on the level of that specific characteristic. For example, in a MRM analyzing estimates of WTP for improved air quality, populations may demonstrate large MWTP for improvements when concentrations of pollutants are above some level, and MWTP of zero when pollutants are below that level.

Of concern when using benefit transfer is the reliability of the transfer approach (Boyle et al., 2009; Londoño and Johnston, 2012). To quantify reliability, researchers compute benefit transfer errors: the difference between a benefit transfer's estimate of WTP and the actual WTP (Rosenberger and Stanley, 2006). The percentage transfer error between the transfer estimate (V_T) and known estimate (V_P), calculated as:

$$PTE = \frac{V_T - V_P}{V_P} \times 100 \tag{1}$$

is a common measure of transfer reliability; note that transfer errors are typically measured in terms of absolute value percentages.[3] Small transfer errors imply reliable benefit transfer, and benefit transfers generated from meta-analyses tend to be more reliable than those from alternative methods (Johnston and Rosenberger, 2010).

Unfortunately, in most policy applications, primary study estimates are unavailable, and so reliability is unknown (*i.e.*, benefit transfer is required only when high quality, site specific primary studies are unavailable). However, researchers can use test cases where primary study estimates are available to gain insights into the sort of errors that might be expected in actual transfers (Johnston and Rosenberger, 2010; Rosenberger and Stanley, 2006). In such cases, reliability is quantified using convergent validity tests that compare a transferred welfare estimate to an available primary study estimate for a particular site.

Among other things, reliability hinges on a properly specified MRM. To see why, suppose a researcher use a MRM to estimate the value of an unstudied policy site, V_P. To construct the estimate V_T, the researcher uses the set of coefficients for site characteristics and methodological approaches from the MRM, β_S, and the observed policy site variables X_P: $V_T(\beta_S, X_P)$. If the coefficient estimates from the MRM are biased, then the transfer estimate will also be biased, compromising reliability.

Our aim here is to determine if accounting for threshold effects in biophysical characteristics in a MRM of coral reef values can improve benefit transfer reliability. We find that threshold effects can improve the reliability of meta-analysis based benefit transfers, measured either by mean transfer error or the interquartile range from the full distribution of transfer errors. Moreover, even if there does not exist a threshold, the ability to test for a threshold allows one to consider the homogeneity of a sample of valuations across disparate coral reefs, which is one criteria that Boyle et al. (2009) listed for performing valid benefit transfers. We point out here that threshold estimation is not as simple as sample splitting; sample splitting implies that the value of the threshold is known to the analyst, which is typically not true in applied valuation.

This work builds on the suggestion of Kaul et al. (2013) to model nonlinearity in MRMs. Additionally, we follow the seminal work of Brander et al. (2007), Londoño and Johnston (2012) and Brander et al. (2015) and use meta-analysis to study coral reef valuation. We estimate a MRM with threshold effects on metadata comprised of primary studies that estimate the recreational value of coral reefs. To capture discontinuous effects of biophysical characteristics on WTP for reef recreation, we propose a threshold effect model that incorporates a discontinuity in the relationship between percentage of live coral cover and WTP for recreation. To our knowledge, this approach is new for both estimating a MRM, and for conducting a benefit transfer. We follow the work of Londoño and Johnston (2012), who used a more refined valuation dataset than that of Brander et al. (2007), and enhance it with additional valuation studies. We then perform convergent validity tests (leave-one-observation-out and leave-one-study-out cross validity tests) across both methods to gain insights into potential improvements in transfer reliability. We find that accounting for the threshold leads to smaller mean transfer error and error variance when considering the pooled data from our expanded sample. Another interesting result stemming from the use of threshold MRMs is that the interquartile range of transfer errors is reduced in the majority of our convergent validity tests. Further results are described in Section 5.

The remainder of the paper is structured as follows. Section 2 details common meta regression methodology, and describes our inclusion of a threshold in the MRM. Section 3 describes the growing interest in the economic value of coral reef ecosystems. Section 4 provides a brief description of the coral reef valuation dataset of Londoño and Johnston (2012), and of our additions to this dataset. Section 5 details our estimates of the MRMs and presents the convergent validity tests. Section 6 concludes.

2. Methodology

Our approach builds on the standard multi-level MRM, which is recommended for meta-analysis of this type of metadata (Nelson and Kennedy, 2009). Multi-level models allow for within-study correlation across the different observations of estimated of welfare (Bateman and Jones, 2003; Johnston et al., 2005). The benchmark multi-level MRM which estimates the impact of methodological ($\bar{x}_{js}$) and site ($\bar{z}_{js}$) characteristics on reported measures of welfare $\bar{y}_{js}$ for valuation estimate s from study j is:

$$\bar{y}_{js} = \bar{x}_{js}\beta + \bar{z}_{js}\delta + u_s + \varepsilon_{js}. \tag{2}$$

Here, u_s captures systemic study level effects and ε_{js} is a standard *iid* observation specific error with constant variance. Clustering by study is standard in the meta regression literature, though alternative clustering strategies may be deployed (clustering by author or region, for example). β and δ are vectors of parameters to be estimated to discern the impact that research methods and environmental

[2] When using meta-analysis for benefit transfer, the researcher must choose values for methodological variables when estimating welfare for the study site. The most common approach is to use the sample means for each methodological variable within the metadata (Moeltner et al., 2007).

[3] Here we employ the notation of Rosenberger (2015).

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