The Recreational Value of Coral Reefs: Classical and a Bayesian Meta-analytic Approaches

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1. INTRODUCTION

Considered as the rainforest of the oceans, coral reefs are among the most biologically productive ecosystems on earth (Raynolds Ed., 2006)

- Status of coral reefs in the world (Wilkinson, 2008):
  - 19% of effective loss
  - 15% are seriously threatened with loss within the next 10–20 years
  - 20% are under threat of loss in 20–40 years
- Decision makers are increasingly using socioeconomic assessments to support conservation schemes
- Applications to coral reef valuation are hindered by the sparseness of primary studies in the literature.
- Meta-analysis is particularly challenging in this case

1. INTRODUCTION

The overall goal is to provide insight into the capacity of various meta-analysis methods to capture systematic variation in WTP associated with coral reef recreation, and to support benefit function transfer.

Compare the performance of Bayesian methods and the classical regression technique for meta-analysis (MA) in an international context with substantial inter-study site heterogeneity.

Provide meta-analytic value surfaces that are unconfounded by the methodological heterogeneity present in the only prior coral reef MA in the literature (Brader et al. 2007) – thereby providing an MA with greater correspondence to guidelines in the literature

2. Coral Reefs, Meta-analysis and Benefit Transfer

Meta-analytic BT is the procedure of transferring an existing value estimate to an application different from the original one, based on meta-data (Boyle and Bergstrom, 1992).

the meta-analytic BT approach to resources valuation typically uses a large set of studies to estimate a benefit function, which is determined by a set of variables explaining welfare estimates.

Brander et al. (2007) is the only reference in the literature on meta-analytic BT for the recreational value of reefs. They report large average transfer errors based on convergent validity testing.

This paper provides a more rigorous protocol of studies selection, and the application of alternative statistical approaches, not yet applied to reef valuation.

2.1. Coral Reefs, Meta-analysis and Benefit Transfer

Primary valuation of reefs

Few non-market valuation studies (Carr & Mendelsohn, 2003; Brander et al., 2007).

Focus on recreational value and conservation benefits. Travel cost (TC) and contingent valuation (CV) methods are widely used(Asafu-Adjaye and Tapsuwan, 2008; Laurence, 2003; Andersson, 2007; Bhat, 2002).

Classical meta-regression

It is the traditional approach in the literature (Brander et al., 2007; Shrestha and Loomis, 2001; Rosenberger and Loomis, 2000 ; Johnston et al.,2006).

Bayesian meta-analysis

Provide an alternative approach when sample sizes are small (Leon et al., 2002; Atkinson et al., 1992; Moeltner et al., 2007).

This research provides an empirical exploration based on a comprehensive methodological approach

2.2. Classical Meta-analytic BT

- A large set of studies is used to estimate a benefit function to predict welfare measures at sites others than the study site.
- Generates a sampling distribution for the *true unknown* population mean of WTP

Advantages when compared to other BT approaches (Rosenberger and Loomis, 2000c; Shrestha and Loomis, 2001; Shrestha and Loomis, 2003, Rosenberger and Stanley, 2006):

- More rigorous estimation of central tendency measures
- BT function can be adapted
- It can provide better approximations for the policy site value
- Multi-activity, multi-site analysis

Sources of limitations (Bergstrom and Taylor, 2006; Brouwer, 2000, Leon et al., 2002, Desvousges et al., 1998):

- Commodity consistency
- Consistency of the welfare measure
- Site similarity
- Quality of original studies
- Publication bias
- Small sample size

2.3. Bayesian Meta-analytic BT

- A set of studies is used to estimate a benefit function to predict welfare measures at sites others than the study site by implementing Bayesian techniques
- Generates the entire predictive distribution of WTP. It doesn't assume the existence of a *true unknown* WTP

Advantages (Larouse, 1996; Moeltner et al., 2007, Leon-Gonzalez and Scarpa, 2007, and Leon, 2002):

- More robust statistical results in situations of small samples
  - It doesn't rely on the large sample theory
  - Specifies prior distributions for data with incomplete regressors
- More rigorous interpretation of BT results in context of methodological differences in the meta-sample

Classical and Bayesian approaches are compared on a specific empirical setting

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Improved value surfaces to support policy-making?

3. Modeling Framework

3.1 Classical model with a semi-log functional form and random coefficients:

$$Ln(y_{js}) = x'_{f,js}a_{f,x} + x'_{r,js}a_{rs}\ m'_{s}a_{f,m} + \varepsilon_{js} \quad (1)$$

Where:

y_{js} : Estimate of the true sub-population mean WTP for site *j*, study *s*

X_{js} : Mean vector of population characteristics for site *j*, study *s*

a_s : Estimated parameter vector for study *s*

ε_{js} : Stochastic error term for site *j*, study *s*

m: vector of methodological characteristics for study *s*

Subscripts f and r: indicate fixed and random effects

$a \sim MVN(\alpha, \Sigma)$, and $\varepsilon_{js} \sim N(0, \sigma^2)$

$Ln(y_{js})$ is normally distributed with the following statistical properties:

$$E[y_s \mid x_{rs}, w_s] = x_{rs}\,\alpha + w_s a_f$$

$$E[ys\ yt'] \begin{cases} x_{rs}\,\Sigma x'_{rs} + \sigma^2 I_{ns} & \text{if } s = t \\ 0 & \text{if } s \neq t \end{cases}$$

3. Modeling Framework

3.2. Bayesian Hierarchical Model:

- Likelihood function:

$$p(y| x_r, w, a_r, a_f, \sigma^2) = \Pi_{s=1}^{S} [1/(2\pi\ \sigma^2)^{n/2}] \exp[(-1/ 2\sigma^2)(y_s - x'_{rs}\ a_{rs} - w_s\ a_f)' (y_s - x'_{rs}\ a_{rs} - w_s\ a_f)]$$

Where x_r and w are the matrices of covariates with random and fixed effects respectively

- Prior distribution for the sample parameter a:

$$p(a| \alpha, \Sigma) = mvn(\alpha, \Sigma)$$

- Hyper-prior distribution of the population mean α:

$$p(\alpha) = mvn(\mu, V)$$

3. Modeling Framework

3.2. Bayesian Hierarchical Model (Cont):

- Marginal posterior distribution for WTP:

$$p(\tilde{y} \mid x_p, Z_p) = \int_{\beta} \left(\sum_{t=1}^{T} p(\tilde{y} \mid \beta, x_p, Z_p, m_t)\pi_t\right) p(\beta \mid y, x_r, Z)\, d\beta \qquad (2)$$

$\tilde{y}$: forecasted WTP

x_p : mean vector of population characteristics for the policy-site

Z_p :vector of site quality attributes for the policy-site

m: vector of methodological attributes

β: contains all the Bayesian parameters

t: indicate the combination of methodological attributes for the policy site

π_t: is the probability of the methodological combination.

4. Empirical application

- **Data Sources:**
  - Published journal articles
  - Theses and dissertations
  - Technical reports
  - US Institutional databases: Coastal and Ocean Resource Economic Program and The National Ocean Economics Program

- **Data features:**
  - Studies: 26 different studies were selected from a larger preliminary collection
  - Observations: 75
  - Type of data: a panel dataset

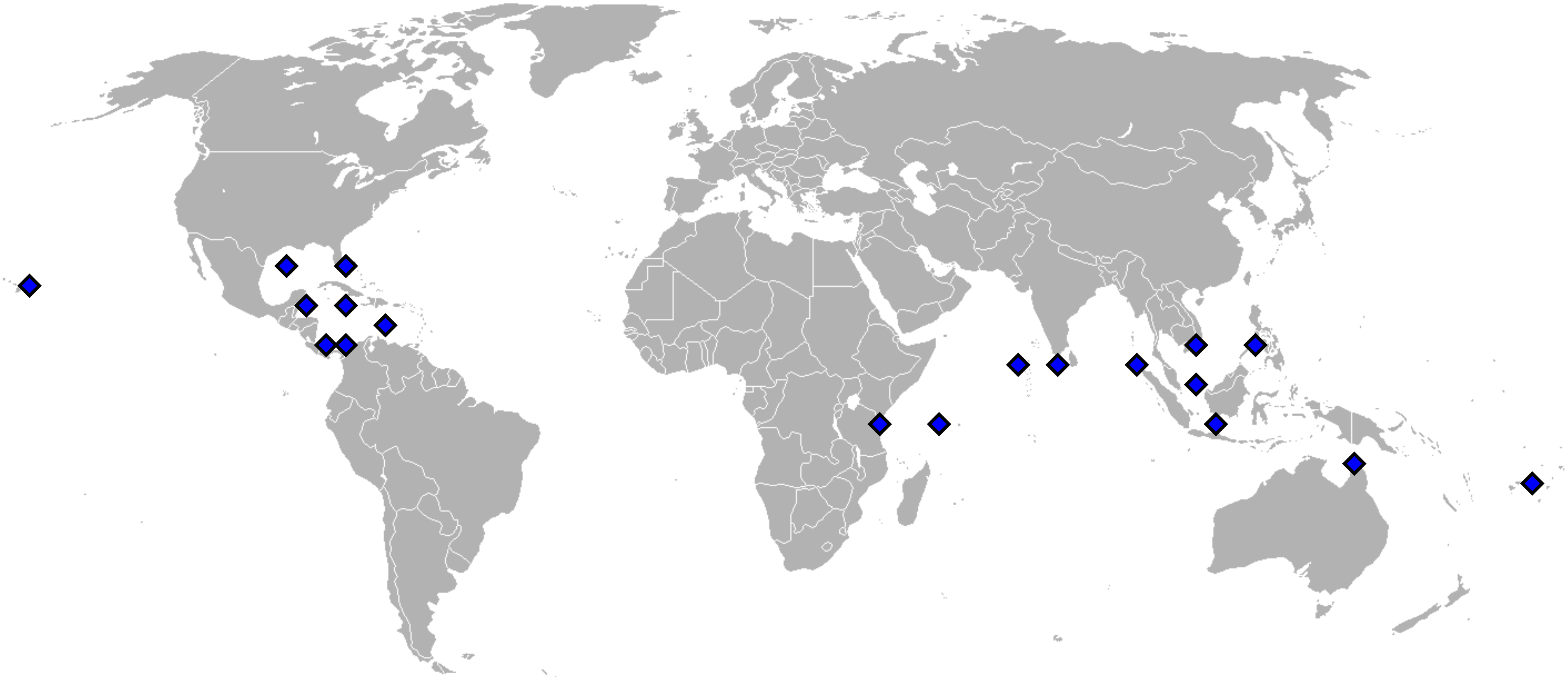
- **Variables:**
  - Dependent variable: recreational benefits, measured as the WTP in US dollars per person/day, for a common base year (2000) and adjusting for international parity conditions.
  - Independent variables:
    - Site characteristic: protected area, recreational activities, etc.;
    - Population characteristics: origin;
    - Study design variables: elicitation method, payment vehicle, etc.

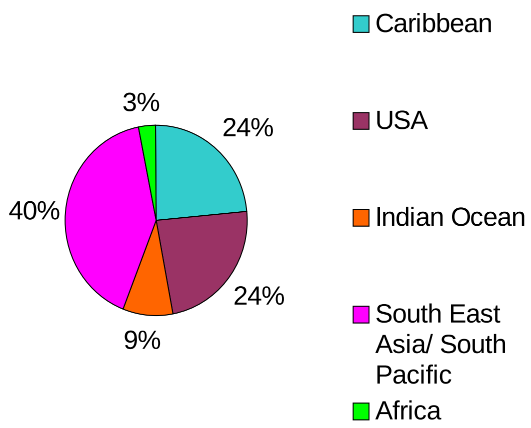
4.1. Data

Authors and year of publication	Study Area	Observations per study
Parsons and Thur, 2008	Bonaire, Netherlands Antilles	2
Diaz Jose Andres, 2001	Corales del Rosario, Colombia	1
Newball, 2001	San Andres Isla, Colombia	1
White et al., 1997	Sri Lanka	3
Wright, 1995	Negril, Jamaica	8
Hundloe, T. 1990	Great Barrier Reef	2
BAPPENAS, 1996	Bunaken, Indonesia	3
Ditton and Stoll, 2008	Texas offshore waters	2
Cesar et al., 2005	Hawaii	4
Westmacott et al., 2000	Maldives	2
White, 2008	USA	1
Laurence, 2003	Seychelles	1
Nam and Son, 2001	Hon Mun Islands, Vietnam	4
Dixon et al., 1993	Bonaire, Netherlands Antilles	1
Anderson, 2007	Zanzibar and Mafia, Tanzania	6
Rivera-Planter and Munoz-Piña, 2005	Mexico	4
Seenprachwong, 2003	Phi Phi islands, Thailand	4
Ngazy, 2001	Zanzibar, Tanzania	1
Asafu and Tapsuwan, 2008	Ko similan, Thailand	2
Arin and Kramer, 2002	Philippines	3
Yeo, 1998	Pulau Payar, Malaysia	2
Ahmed et al., 2007	Bolinao, Philippines	2
Rosales, 2003	Philippines	3
Mohd, 2001	Samoa	2
Mohamed, 2007	Maldives	4
Johns et al., 2001	Florida Keys, USA	16

4. Empirical application

4.1. Data





Coral reefs valuation studies from most tropical regions in the world

4. Empirical application

4.1. Data

Variable	Description	Mean	Std. Dev.
WTP	Willingness to pay person/day in PPP US$ (2000)	15.32	19.17
Dich. Choice	Dummy variable for elicitation method: takes the value of one when it is dichotomous choice, zero otherwise	0.16	0.37
Open-ended	Dummy variable for elicitation method: takes the value of one when it is open-ended, zero otherwise	0.37	0.49
Payment card	Dummy variable for elicitation method: takes the value of one when it is payment card, zero otherwise	0.45	0.50
Fee	Dummy variable for payment vehicle: takes the value of one when it is an entrance fee, zero otherwise	0.27	0.45
Trip cost	Dummy variable for payment vehicle: takes the value of one when an additional trip cost is used, zero otherwise	0.39	0.49
Donation	Dummy variable for payment vehicle: takes the value of one when it is a donation, zero otherwise	0.15	0.36
Onsite	Dummy variable for the sampling method: takes the value of one when it is onsite sampling, zero otherwise	0.56	0.50

4. Empirical application

4.1. Data(Cont)

Variable	Description	Mean	Std. Dev.
Visitors	Scalar variable on the total number of visitors site/year	1.71E+06	3.45E+06
Caribbean	Dummy variable for region: takes the value of one when it is Caribbean, zero otherwise (Indo-pacific and others)	0.48	0.50
MPA	Dummy variable for existence of a protection category: takes the value of one when it is a marine protected area, zero otherwise	0.85	0.36
Snorkeling-Diving	Dummy variable for recreational activities: takes the value of one when the study is focused on snorkeling and diving, zero otherwise (fishing, viewing and others)	0.28	0.45
Reef quality	Percentage of live coral cover reported during the year corresponding to the study or within a one year difference	0.31	0.25
Local	Dummy variable for the recreationist's origin: takes the value of one when the recreationist is local, zero otherwise	0.25	0.44
Reef type	Dummy variable for type of reefs: takes the value of one when it a natural reef, zero if artificial	0.88	0.33

4. Empirical application

4.2. Estimation Results

	RE-ML		OLS		Bayes		
	Coefficient	s.e.(robust)	Coefficient	s.e.(robust)	Post. Mean	Post. Std	NSE
Constant	2.080	(0.836)**	2.203	(0.596)***	2.279	2.160	0.100
Dich. Choice	-0.616	(0.674)	-0.632	(0.374)*	-0.432	3.630	0.246
Open ended	-0.380	(0.688)	-0.372	(0.222)*	0.592	5.160	0.371
Payment card	1.057	(0.676)	-1.155	(0.229)***	-0.914	4.410	0.312
Fee	-0.342	(0.301)	-0.354	(0.345)	-0.399	1.470	0.052
Trip cost	0.766	(0.317)**	0.751	(0.308)**	1.149	3.670	0.235
Donation	-0.437	(0.401)	-0.523	(0.466)	0.200	1.690	0.060
Onsite	-0.373	(0.273)	-0.487	(0.206)**	0.149	1.760	0.076
Visitors	-5.00E-05	(3.14E-05)	-4.51E-05	(2.54E-05)	7.22E-05	0.160	6.8E-04
Caribbean	0.377	(0.287)	0.280	(0.297)	0.073	3.830	0.242
MPA	1.291	(0.393)***	1.364	(0.636)**	-0.230	2.930	0.161
Snorkeling-Diving	-0.084	(0.231)	-0.047	(0.240)	-0.272	1.180	0.032
Reef quality	0.420	(0.148)***	0.407	(0.165)**	0.264	0.870	0.021
Local	-0.379	(0.171)	-0.363	(0.268)	0.114	0.850	0.025
Reef type	0.544	(0.247)**	0.521	(0.278)*	0.698	1.810	0.089
N=	75						
Log likelihood=	-70.246						
Adj, R^2			0.48				
BIC	205.253		207.362		147.448		

*Significant at 10%
**Significant at 5%
***Significant at 1%
s.e. = Standard error; Post. Mean = Mean of the posterior distribution of the parameter; Post. Std = posterior standard deviation
NSE= Numerical standard error
BIC= Bayesian information criterion

5. Conclusions

Both classical and Bayesian MA allowed us to provide value surface insight – although differences between results of the two methods occur and doubts on the asymptotic convergence of the classical model remain.

Major differences between the two models occur in terms of sign and magnitude of point estimates for the model coefficient. However, more conclusive remarks on these findings could be made upon the refinement of our prior distribution setting.

A better model fit in the case of the Bayesian model suggests that further research can be addressed to obtain posterior distributions for the model parameters by incorporating more informative priors as our preliminary results are only based on diffuse priors.

Results also, point to substantial challenges in the use of such results for benefit transfer.