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Abstract: To successfully predict the impacts of environmental change, modellers need to incorporate analyses of human behaviour into their predictions. The engagement of stakeholders, including participatory model development, is now widely advocated as an approach to account for stakeholder preferences. While participatory approaches are suitable to involve targeted stakeholder groups and technical experts, it is typically prohibitively expensive to engage a wide range of communities in the model development process. Many environmental modellers may be aware of social science research methods to participatory research. Socio-economic approaches to elicit stakeholder preferences are, however, less commonly used. This paper presents three stated preference techniques typically used by environmental economists to assess stakeholder preferences for environmental changes. These techniques use nonmarket valuation surveys to gain an understanding of the environmental issues, assets, and management options that are preferred by the wider community. The benefits and limitations of using nonmarket valuation techniques in environmental modelling are also discussed.

Keywords: Community opinion; Economic valuation; Preference elicitation; Social welfare; Stakeholder preferences.

1 INTRODUCTION

Environmental decisions typically involve trade-offs between social, environmental, and economic impacts, and is often confounded by divergent stakeholder preferences. Models that aim to support environmental decision making will need to incorporate this range in stakeholder opinions (particularly in cases where socio-economic systems are affected) and properly represent community views (e.g. Prell et al., 2007; Laniak et al., 2013).

The literature on participatory modelling demonstrates many excellent techniques to involve stakeholder groups in model development and deployment (van Asselt Marjolein and Rijkens-Klomp, 2002; Voinov and Bousquet, 2010). There is, however, a risk that participatory processes reach only a selection of stakeholders by focussing on technical experts or on specific interest groups (Hare et al., 2003). There are still limited guidelines on how to incorporate the range of preferences that exist in stakeholder communities (Arciniegas et al., 2013).

When modelling with stakeholders, it may be difficult to match the variables of interest to scientific modellers and the assets that are valuable to community members. Furthermore, technical experts may find it challenging to gauge what scenarios and trade-offs are most important to community members[1].

This paper explains how socio-economic survey techniques can be used to estimate the stakeholder preferences for environmental management. The survey techniques discussed can elicit a range of public opinions, which is important from a social welfare perspective. The next section will briefly introduce environmental economics and nonmarket valuation, followed by an examination of three widely used nonmarket valuation techniques, and how they involve stakeholders.

[1] In a project the author was involved in, expert scientists used macro-fauna population dynamics as a measure of water quality. This was of little interest to the community stakeholders, who did not link macro-fauna populations to water quality.

2 NONMARKET VALUATION

Environmental management, and thus models that aim to support decision making, inevitably involve value judgments (French and Geldermann, 2005). There are different philosophical bases for the measurement of values. For example, most ecologists and environmental scientists may consider ecosystem services to be important in their own right (intrinsic values). Neo-classical economics, on the other hand, defines environmental values as derived from impacts on human welfare (instrumental values; Straton, 2006). Environmental economics research focuses on human-environment interactions, and on the anthropocentric values derived from ecosystem goods and services.

Non-economists may think that economic values are primarily associated with resources that are traded in markets. Markets are practical vehicles to measure people's preferences for a resource—since they pay a market price to obtain the resource. They may, however, not capture all the relevant welfare impacts because environmental resources are often not traded in markets. In such cases, we need nonmarket valuation techniques to assess people's preferences for the environmental resource in question.

Environmental economists have a range of nonmarket valuation techniques at their disposal, including travel cost models, hedonic pricing and contingent valuation (Hanley and Barbier, 2009). Techniques are divided between 'revealed preference' and 'stated preference' techniques. Revealed preferences *infer* values from people's observed behaviour. For example, travel cost methods are often used to estimate recreational values that people derive from observing visitation to a region (see, e.g., Kragt et al., 2009). Hedonic pricing is another example of a revealed preference technique. Here, nonmarket values are inferred by estimating how non-marketed goods and services (for example, urban tree canopy - Pandit et al., 2013) influence property prices.

Stated preference techniques can be used to measure indirect use and/or non-use values (i.e. the values that people derive from an ecosystem good or service without actually using the resource). Stated preference techniques, such as contingent valuation or choice experiments, typically use household surveys to estimate values. These techniques have the advantage that they can estimate preferences associated with current, but also future (hypothetical) scenarios that are not yet experienced by respondents. In this paper, three stated preference approaches, and their potential usefulness to environmental modelling will be briefly discussed: best-worst scaling, choice experiments, and citizens' juries.

3 BEST-WORST SCALING

3.1 The BWS technique

Best-worst scaling (BWS) is an extension of the method of paired comparisons. Respondents are shown a predefined number of choice sets with multiple items, and are asked to choose the two items in each set that they prefer 'most' and 'least' (Finn and Louviere, 1992: Figure 1). BWS was designed to overcome common problems in survey research in which respondents are asked rating questions such as "How concerned are you about increasing sea levels?" Such questions lack the context of "relative to what?" BWS provides such context by asking respondents to make choices between a set of issues that may be relevant to respondents (such as sea level rise versus food safety, or traffic congestion).

Best-Worst Task

Identify the public issue that causes you the most concern and the public issue that causes you the least concern in each of the following sets of issues. Check only one issue for each of the Least and Most columns.

Least	Public Issues	Most
	Preserving the environment	
	Level of taxation	
	Quality medical care	
	The drug problem	

Figure 1. Example BWS question (Finn & Louviere, 1992)

BWS is based on the idea that people find it relatively easy to express their preferences in terms of "superior" and "inferior" items (Marley, 1968). The technique has its theoretical underpinning in the random utility framework (McFadden, 1986) where choice frequencies provide information about preferences. The frequency with which a person chooses an option is directly related to how strongly they like or dislike it: (i) a strongly preferred option will virtually always be chosen; (ii) a less preferred option will be chosen less often (as best); (iii) a strongly disliked option will rarely

be chosen as best, but often chosen as worst (Flynn and Marley, 2012). Via repeated rounds of best-worst choices in a survey, we can obtain a full ranking of preferences towards the items shown. Statistical models can be used to estimate the weighted utility that community members derive from different items in a choice set[2].

3.2 BWS and environmental management

Best-worst scaling methods are increasingly used in health care research (e.g. Lancsar et al., 2013), and in marketing (e.g. Louviere et al., 2013). There are remarkably few applications in environmental contexts.

Tutsch et al. (2010) use the BWS method as an expert consultation tool. For a study of the Gulf Islands National Park (Canada), the researchers mapped all the assets at risk of being affected by bushfire. The researchers then administered a BWS survey to determine forest fire managers' opinion about the relative importance of different assets. This ranking of assets was included in the risk mapping, enabling the researchers to estimate the overall consequences of a fire. The local fire managers found the task easy to complete, and Tutsch et al. (2010) concluded that BWS surveys are a suitable technique to elicit expert opinion. However, the authors acknowledged that to better understand the social welfare impacts of bushfires, they would need to consider opinions held by multiple resource users, stakeholders, and communities.

Cross et al. (2012) used BWS to elicit experts' opinions about the relative practicality and effectiveness of different measures that can reduce human exposure to *E. coli*. BWS proved a powerful tool for expert elicitation as it broke down the ranking exercise in simple, repeated, choice tasks. Another advantage of BWS is that statistical analysis of the resulting data can provide a weighted scoring of the items presented in a choice set, rather than just a ranking.

In a study on agricultural greenhouse gas (GHG) mitigation, Jones et al. (2013) administered a BWS survey to elicit experts' and farmers' opinions about the effectiveness and practicality of different mitigation measures. Considering farmers preferences for new mitigation measures is crucial when modelling the effectiveness of GHG mitigation policies. It is interesting to note that the GHG reduction potential of the various mitigation measures was based on expert opinion, rather than on biophysical modelling scenarios.

BWS is a convenient technique to eliciting stakeholder preferences for multiple items. The simple, pair-wise choices of the two extremes (most and least preferred) are often less cognitively demanding than ranking exercises where all items are ranked simultaneously.

4 CHOICE EXPERIMENTS

4.1 The CE method

A technique that is increasingly used to assess nonmarket environmental preferences is choice experiments (CEs - also referred to as choice modelling). In a CE survey, stakeholders are presented with series of choice questions, where each choice question describes different environmental management scenarios (Options A, B, C in Figure 2). The outcomes of each scenario are described by a set of different assets (or 'attributes'). These assets can serve as indicators of environmental conditions and take on different levels depending on the scenario presented. Survey respondents are asked to choose their preferred option from each choice set, thereby making implicit trade-offs between the levels of the different attributes. This allows the researcher to analyse the trade-offs that respondents make between attributes (Bennett and Blamey, 2001). A CE thus goes further than a BWS study, in which stakeholders rank individual scenarios without considering the impacts on multiple assets.

[2] For a mathematical background to BWS, the reader is referred to Marley and Louviere (2005).

Attributes	Option A (current situation)	Option B	Option C
Length of river with riparian vegetation	30%	75%	45%
Length of river with aquatic vegetation	5%	50%	35%
Length of river with good or very good appearance	55%	70%	70%
Additional levy on Council rates (per year)	$0	$60	$40
Please tick the box under the option you prefer	☐	☐	☐

Figure 2. Example choice experiment question (Source: Robinson et al. 2002)

CEs have their theoretical foundation in Lancaster's 'characteristics theory of value' (Lancaster, 1966) and in the random utility theory. The random utility model describes utility U_{ij} (the benefit) that individual i derives from choice option j as a latent variable that is observed indirectly through the choices people make. Utility consists of an observable 'systematic' utility component V_{ij} and a latent (unobservable) error term ε_{ij}:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad j = 1,2,\ldots,J \qquad (1)$$

The systematic component of utility is assumed to be an additive function of a vector of explanatory variables x_{ij}, which usually includes the attributes, and individual i's socioeconomic and behavioural characteristics. Option j will be chosen if and only if the utility derived from that choice is greater than the utility derived from any other option z (Equation 2):

$$\Pr(j \mid x_{ij}, \varepsilon_{ij}) = \Pr[(\beta'_i x_{ij} + \varepsilon_{ij}) > (\beta'_i x_{iz} + \varepsilon_{iz})] \qquad (2)$$

Different econometric models can be used to estimate parameter vector β_i. Widely used models include conditional logit, mixed logit, or latent class models (Hensher et al., 2005). CE survey respondents make choices between multiple attributes. These choices can be used to estimate the trade-offs between attributes, and thus their relative marginal utility. The marginal utility for each attribute (or 'marginal rates of substitution' MRS between attributes) is derived using the formula:

$$MRS_{12} = \beta_{attribute\ 1} / \beta_{attribute\ 2} \qquad (3)$$

If attribute 2 is a cost attribute with money as its unit of measurement, equation 3 will estimate the *marginal values* for the non-market attributes in terms of the marginal willingness to pay (WTP).

4.2 CE and stakeholder participation

CE surveys are now widely used in environmental economics. Since most environmental decisions have an impact on the community as a whole, it is important to consider public opinions. Environmental choice experiments are a tool to estimate preferences across a broad range of community stakeholders, thus providing information about the social welfare impacts of environmental changes. CEs surveys typically target large samples from respondents of different social background. For environmental modelling purposes, CEs can thus provide model input about social preferences more broadly than expert interviews or consultation with community focus groups alone.

Notwithstanding the benefit of integrating CEs and environmental participatory modelling, there exist only few examples of integrated environmental nonmarket valuation models (Bateman et al., 2006; Barton et al., 2008). Two examples are described below.

A multidisciplinary project examining the impacts of the European Water Framework Directive (the ChREAM project; Bateman et al., 2006) developed a suite of models to predict the hydrological, economic, and agronomic effects on river water quality, farm revenues and nonmarket values. Hydrological models and models of land use change provided input into ecological models of water quality. CEs were then used to estimate the nonmarket benefits that recreationalists and non-users of rivers derive from good river water quality. These values were integrated into a hydro-economic model to show the costs and benefits of implementing the EU Water Framework Directive.

Kragt (2013) provides another example where ecosystem services valuation is integrated with environmental modelling. In this study, the author estimated stakeholder preferences for multiple environmental assets using a CE study amongst the general population. These community preferences were subsequently included in a Bayesian Decision Network that predicted the ecosystem impacts, as well as the costs and benefits of catchment management actions. This, and other studies (see Landuyt et al., 2013), show that CE estimates can readily be integrated into Bayesian Network utility nodes.

5 DELIBERATIVE PROCESSES IN CITIZENS' JURIES

5.1 The CJ approach

Some researchers have argued that nonmarket valuation techniques measure 'consumer' preferences for environmental goods, rather than stakeholders' societal preferences as 'citizens' (Sagoff, 1988). The argument is that, in the case of environmental decisions, social preferences should reflect people's behaviour as 'citizens' rather than as individual consumers. Following this argument, deliberative, discursive preference elicitation methods that emphasise informed discussion may lead to a better representation of public interests (Spash, 2007).

Citizens' juries (CJs) can provide such a deliberative form of public participation. CJs are based on the model used in Western-style criminal court proceedings. The premise is that, given adequate information and opportunity to discuss an issue, a group of stakeholders can be trusted to make a decision on behalf of their community, even though others may be considered more technically competent (van Asselt et al., 2001). The jury is typically made up of between 12 and 24 randomly selected community members who hear evidence from a panel of expert scientists or other 'witnesses' about an issue over the course of 3-4 days. The role of the jury is to formulate policy recommendations through deliberative learning and interaction, while having no ultimate responsibility for the decisions made (van Asselt Marjolein and Rijkens-Klomp, 2002). The main techniques used in CJs are the question and answer sessions between the jurors and the witnesses, and the deliberation within the jury about the information obtained from the witnesses and the issue under consideration.

A potential advantage of a CJ process is that it yields citizen input from a stakeholder group that is both informed through discussions between the jury and experts (Robinson et al., 2002). Critics of CJs, on the other hand, argue that stakeholders are overly informed and no longer representative of the public.

5.2 CJs and stakeholder participation

Goodin and Niemeyer (2003) and Blamey et al. (2000) report on the findings of two citizens' juries (CJs) convened in Australia. The CJs were part of a deliberative process to inform public policy-making. Although their aim was to discuss policy recommendations for existing environmental management questions, the juries had no formal connection to any official policy process (Goodin and Niemeyer, 2003). The two juries considered management options for: (1) the Bloomfield Track; a controversial unimproved road running through the Daintree rainforest, in the Wet Tropics World Heritage area of northeast Queensland; (2) National Parks in New South Wales. The juries met for three or four days, during which the jurors heard technical experts and community representatives, and discussed among themselves.

The researchers found that jurors' preferences for different policy options shifted dramatically over the course of the jury, mostly due to the provision of more information compared to what jurors knew about the issue at the beginning of the jury process. A study by Shapansky et al. (2008) found, on the other hand, that participants in a deliberative choice experiment expressed no different opinions than CE respondents who had not gone through the deliberative approach. Robinson et al. (2002) and Alvarez-Farizo et al. (2007) also combined a CE and CJ approach, investigating water quality management in Queensland, Australia and consequences of implementing the European Water Framework Directive respectively. Similar to Shapansky et al. (2008), the two studies found no statistical differences between a CE survey administered prior to the deliberative CJ process and surveys administered afterwards. Only the variance in preferences decreased after the CJ, indicating that respondents' preferences became more similar following the information provision in the CJ (Robinson et al., 2002).

6 CONCLUSIONS AND RECOMMENDATIONS

French and Geldermann (2005) argue that environmental decisions should involve constant interactions and dialogue with the public and stakeholder groups. Indeed, if modellers wish to provide decision support for environmental management, the model will need to account for various stakeholders' opinions. Public consultations, that target regular community members, will be essential to integrate social welfare perspectives into a model.

Nonmarket valuation techniques have been used widely by economists to assess community preferences for environmental goods and services. These preferences are often expressed as the values associated with changes in environmental conditions. Nonmarket valuation techniques can also be used to rank multiple goods or evaluate preferences for proposed policy scenarios. Using nonmarket valuation techniques, environmental modellers can obtain information about stakeholder preferences for the systems that are being modelled.

In this paper, three nonmarket valuation methods were introduced. Each of these can be used to elicit preferences, but their application varies. Which nonmarket valuation technique to use will be contingent on the target group(s) of stakeholders, and the desirable level of consultation. Best worst scaling (BWS) is most often used to assess expert opinion or preferences of specific stakeholder groups. Previous studies have shown that BWS is easily understood, and useful in different contexts. For environmental modellers, BWS is a potentially useful to assess how stakeholder rank sets of items (be they policy actions, mitigation measures, impacts of environmental changes). Thus far, there exist no BWS studies that have integrated the estimated preferences into environmental models.

Choice experiments (CE) are mostly applied at a large (regional or national) scale to elicit public preferences for multiple characteristics of environmental management. CE techniques are particularly useful in cases where decisions affect social welfare, because CEs can estimate impacts of decisions on the community as a whole. Econometric techniques (not discussed here) can be used to estimate how preferences vary between groups in society. Drawbacks of CEs are their complicated questionnaires and the complex statistical analysis involved. While CEs have successfully been integrated into environmental models (Section 4.2), specialist expertise is needed to develop, administer, and analyse a CE survey.

An intensive, deliberative approach to stakeholder consultation is a citizens' jury (CJ). CJs may be well suited to complement other survey approaches (such as BWS or CEs). A citizens' jury approach will clearly provide more informed and deliberated community views than any survey method could achieve. A potential disadvantage of CJs is having a far smaller number of stakeholders represented (Blamey et al., 2000). Participants in a CJ may also be 'over-informed' and thus no longer provide a representative sample of public opinions. Whether this is of concern to environmental modellers depends on the targeted stakeholder groups, and on the level of community participation that is desirable for the modelling purpose.

The nonmarket valuation techniques discussed in this paper may not provide direct tools to engage stakeholders in the model design and development process. However, they offer several methods to elicit community opinions, which are important to incorporate in models about changes in public goods and services (such as environmental assets).

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