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Methods

# Nonmarket valuation of water quality: Addressing spatially heterogeneous preferences using GIS and a random parameter logit model

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ABSTRACT

The spatial distribution of agri-environmental policy benefits has important implications for the efficient allocation of management effort. The practical convenience of relying on sample mean values of individual benefits for aggregation can come at the cost of biased aggregate estimates. The main objective of this paper is to test spatial hypotheses regarding respondents' local water quality and quantity, and their willingness-to-pay for improvements in water quality attributes. This paper combines choice experiment and spatially related water quality data via a Geographical Information System (GIS) to develop a method that evaluates the influence of respondents' local water quality on willingness-to-pay for river and stream conservation programmes in Canterbury, New Zealand. Results showed that those respondents who live in the vicinity of low quality waterways are willing to pay more for improvements relative to those who live near to high quality waterways. The study also found that disregarding the influence of respondents' local water quality data has a significant impact on the magnitude of welfare estimates and causes substantial underestimation of aggregated benefits.



## 1. Introduction

The choices made by researchers when aggregating individual benefits can significantly affect the estimates that are available to be used in cost benefit analysis (Morrison, 2000). Aggregation of environmental values commonly relies on sample mean values of individual benefits. However, individuals' locations in relation to impact sites (proximity) may influence valuation and hence, it is important to account for spatial differences in estimating aggregate benefits (Bateman, 2006). Analysis of how values differ spatially within the population being aggregated can mitigate bias by identifying values conditional on spatially related variables that are hypothesised to influence individual preferences.

This paper employed choice experiment (CE) methodology and spatially related water quality data in a Geographical Information System (GIS) to evaluate the influence of local water quality on respondents' willingness-to-pay (WTP) for river and stream conservation programmes in Canterbury, New Zealand. Identification and estimation of spatial patterns of nonmarket values have taken many forms in the literature. Hedonic studies are perhaps the most widespread approach to estimating spatial relationships of nonmarket values (Agee and Crocker, 2010; Kong et al., 2007; MacDonald et al., 2010). Travel cost valuation methodology explicitly incorporates geographical locations of respondents into the analysis (Taylor et al., 2010). A growing number of applications of these methods employ GIS tools to enhance accuracy of metrics and spatial modelling (Bateman et al., 2002). Comparison of separate models for individual regions is a traditional approach to investigating spatially differing values (Birol et al., 2006). However, this type of analysis does not systematically incorporate local spatially related variables into models and thus, fails to provide regionally specific benefit estimation.

Application of unadjusted existing nonmarket values to geographic maps has also been used to assess total values of conservation programmes (Egoh et al., 2008; Jenkins et al., 2010; Naidoo and Ricketts, 2006; Nengwang et al., 2009). This approach is a rudimentary form of benefit transfer and more sophisticated forms use valuation functions that vary across spatial as well as socio-demographic variables (Bateman, 2006; Plummer, 2009). Geostatistical interpolation methods have also been employed to assess the spatial distribution of nonmarket benefits (Campbell et al., 2009). Distance from a site being valued has received significant attention in the literature as a source of spatial preference heterogeneity. Highly significant distance decay in values has been found demonstrating that reliance on sample mean WTP can result in biased estimates (Bateman, 2006; Hanley et al., 2003). Concu (2007) was one of the first authors to have conducted a distance decay analysis using CE method. The author concluded that distance omission produces underestimation of aggregate benefits and losses.

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Other sources of spatial preference heterogeneity have been identified in a somewhat limited pool of studies outside of the revealed preference and distance decay literature. Brouwer et al. (2010) used CE method to examine spatial preference variability in the valuation of water quality improvements for the Guadalquivir River Basin in the south of Spain. The authors investigate whether respondents' value improvements in their own sub-basin more than three other sub-basins by specifying dummy variables for each of the four sub-basins. Parameters on interactions of these dummy variables with the environmental attributes were estimated. Results indicated that respondents' valued the change of water quality significantly more for their respective sub-basins, but only for the highest level of water quality considered. The authors found that not accounting for spatial preference heterogeneity results in an underestimation of around 30% of the estimated value for the highest water quality level in the whole river basin. In an alternative approach, Condon et al. (2007) examined the influence of respondents' geographical location on values for rural land conservation programmes in Florida. The study used a 20 kilometre (km) radius around respondents and four variables hypothesised to affect individual values which are constructed using a GIS. Results revealed that the share of agricultural land and distance to the coast are statistically significant influences on respondents' values. The authors found that compared to using sample mean values, aggregate values incorporating the respondents' geographic information were approximately 17% and 50% lower for the highest and lowest valued programmes respectively. Comparing this outcome with that of Brouwer et al. (2010) emphasises that the direction of aggregation bias from using sample mean values is not always obvious a priori.

This study considered respondents' local water quality conditions as a source of spatial preference heterogeneity in valuing stream and river conservation programmes in Canterbury. While providing specific policy advice to regional water managers, this study also has wider implications. Firstly, this paper contributes to the overall spatial preference heterogeneity literature, where evidence in New Zealand is limited. Secondly, this study provides an application supporting the use of methods that integrate spatial analysis into valuation exercises that enhances welfare estimates.

## 2. Background

Canterbury is the largest region in New Zealand, with an area of 45,346 $km^2$ and a population of approximately 500,000 (SNZ, 2007). Environment Canterbury is the regional council for Canterbury and is responsible for a wide variety of functions including environmental monitoring and investigations, regional policy and planning, water permits and discharge permits. The Canterbury region has a 160 year history of agricultural production and is currently experiencing a significant trend in water intensive dairy farming replacing traditional dry land pastoral and arable farming. Dairy stock unit numbers have increased rapidly and continue to do so. The environmental implications of these land use changes and intensification of production have been extensively researched with a growing body of scientific literature outlining the impending consequences if inadequate action is taken. Studies of trends in water quality and contrasting land cover indicate a positive relationship between dairy stock numbers and decreasing water quality (Larned et al., 2004). Increases in water borne pathogens such as *Campylobacte*r have been reported (Ross and Donnison, 2003) and there are risks of irreversible damages of land application of animal effluent as long term consequences are not well understood (Wang and Magesan, 2004). The rate of fertiliser and pesticide applications has increased dramatically over the past decade and are forecast to continue increasing (PCE, 2004) with evidence of increases in nitrogen and dissolved reactive phosphorous in waterways (Cameron and Di, 2004). There has been a significant increase in groundwater abstraction associated with land use intensification, contributing to a decline in groundwater levels and reduced flows in rivers and lowland streams. Environment Canterbury records show a 260% increase in the amount of irrigated land from 1985 to 2005, and some 70% of consumptive use of water in the region is for pastoral purposes. Increased irrigation allows more intensive use of land and leads to increased agricultural production.

In the application of agri-environmental water quality policy, some progress has been made in reducing point sources of pollution, however, non-point sources remain difficult to manage. Recent water quality planning has spurred development of policies such as the Dairying and Clean Streams Accord that targets farming practices on dairy farms, the Restorative Programme for Lowland Streams that aims to return water to dry streams and ensure minimum environmental flows, and the Living Streams project that encourages sustainable land use and riparian management practices.

## 3. Method

This study employed a CE to estimate the benefits of environmental policies aimed at reducing agricultural impacts on Canterbury waterways.[1] The respondent is presented with choice sets made up of several alternatives and each alternative is made up of combinations of environmental attributes reflecting policy outcomes. Combinations of attributes and their levels are varied systematically in the alternatives according to experimental design theory. The respondent is asked to choose the alternative from a choice set with the combination of attribute levels (policy outcomes) they prefer most. The resulting data are analysed using probabilistic models that relate the probability of an alternative being chosen to the levels of the attributes.

The development of the set of attributes to be valued consisted of two main procedures. First, a survey was conducted of relevant policy documents and expert based opinion of Environment Canterbury policy analysts. Second, focus groups and cognitive interviews (Dillman, 2007) were carried out with rural and urban Canterbury residents. Three environmental attributes were identified to be included in the CE and these are shown in Table 1. The cost attribute is defined as an annual household payment via council rates. The payment vehicle was framed as an ongoing annual cost as participants of resident focus groups and interviews indicated that they considered that funding would be required continuously for policy activities such as monitoring and enforcement.

The first water quality attribute is the risk of people getting sick from pathogens in animal wastes that end up in waterways. Exposure is by way of recreational contact, and risk is measured as the number of people out of one thousand that would become sick annually. This type of presentation of risk has been used elsewhere to value risk tradeoffs in water quality attributes (Adamowicz et al., 2007). The magnitude of changes in levels was guided by studies that examined current and potential water borne pathogen risks to human health in New Zealand (McBride et al., 2002).

The second water quality attribute allowed us to value the impact of excess nutrients on the ecological quality of rivers and streams. The descriptions of the ecological levels for water quality were in accord with Environment Canterbury measurement using the Quantitative Macro Invertebrate Index developed by them. Table 2 shows the descriptions used.

The third water quality attribute was used to value the impact of low-flow conditions. This attribute was measured as the number of months that a river is in low-flow. A waterway is experiencing low-flow conditions when the flow rate falls below a minimum level necessary to protect recreational and ecological quality. The description

[1] Louviere et al. (2000) provides a thorough presentation of choice experiments for the interested reader.