Valuing Agricultural Externalities in Canterbury Rivers and Streams: Three Essays

A thesis
submitted in partial fulfilment
of the requirements for the Degree of
Doctor of Philosophy in Economics

at
Lincoln University
by
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Lincoln University
2010

Abstract

This thesis adds to the literature on non-market valuation of agricultural externalities in rivers and streams. The thesis is a combination of three empirical articles; each article focuses on a particular practical element of valuation survey implementation.

Rural water quality and quantity concerns in New Zealand are intrinsically related to agriculture. Valuation of preferences for mitigating agricultural impacts on rivers and streams is generally lacking in policy debate. The first essay focuses on a choice experiment employed to estimate economic values of agricultural impacts on rivers and streams in the Canterbury region of New Zealand where increasing transformation of dry land pastoral and arable farming for water intensive practices have placed pressure on water resources. Three impacts are considered: health risks of pathogens from animal waste, ecological effects of excess nutrients, and low-flow impacts of irrigation. This study provides a valuation of outcomes for public agri-environmental policy implemented in Canterbury such as The Dairy and Clean Streams Accord, Living Streams, and The Restorative Programme for Lowland Streams. Significant differences are found between willingness-to-pay estimates derived from multinomial logit and random parameter logit models for some water quality attributes. Based on the results from the random parameter logit model, the average five year present value compensating surplus for improvements to rivers and streams in Canterbury provided by agri-environmental policy is $185,000,000.

The second essay presents a comparison of internet and mail survey modes for non-market valuation. The aim of the paper is to investigate the capability of internet surveying to provide robust welfare estimates of environmental goods. Results from a choice experiment conducted using traditional mail mode and the internet are compared based on three main testing procedures. Chi-square tests of respondent characteristics provide an indication of the impact of sample frame and self-selection bias. A test of parameter equality across mail and internet random parameter logit models is then conducted employing the Swait and Louviere (1993) approach. Finally, differences in the derived welfare estimates are assessed using the Poe (2005) Complete Combinatorial method. Some evidence of framing and additional self-selection bias in the internet sample is found. The null hypothesis of parameter equality across survey modes is rejected, however this difference in cognitive processes between samples does not translate into significantly different willingness-to-pay or compensating surplus estimates. Overall this case study supports the use of internet sampling to obtain viable welfare estimates of environmental policy.

The third essay explores possible sources of spatial heterogeneity in welfare estimates. The spatial distribution of agri-environmental policy benefits has important implications for 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 Geographical Information System to develop a method that evaluates the influence of local water quality on respondents' willingness-to-pay for river and stream conservation programs in Canterbury. The results show that those respondents whose local waterway is of low quality are willing to pay more for improvements relative to those whose local waterway is of high quality. The study also finds that disregarding the influence of respondents' local water quality data has a significant impact on the magnitude of welfare estimates and hence, causes substantial underestimation of aggregated benefits.

Keywords: Agricultural externalities, water quality, non-market environmental valuation, choice experiment, New Zealand, internet-based survey, survey mode effect, spatially heterogeneous preferences, Geographical Information System.

Acknowledgements

This thesis has benefited from the support, advice and encouragement of many individuals and organisations. In no particular order I want to express my sincere gratitude to; the Agricultural and Marketing Research and Development Trust for scholarship funding; Dr Lana Friesen, for critical discussions and proposal development at a crucial stage of the thesis; Professor Ross Cullen for his patient oversight of the project; Dr Ramesh Baskaran for his competent professionalism and technical assistance; Dr Yuki Takastuka for providing initial literature directions and discussion; Dr Kathryn Bicknell for joining the supervisory team midway through the project and stimulating discussion; Dr Steven Beville for his camaraderie and eagerness to discuss issues at any time; Brad Case for his valuable assistance in the Geographical Information System application; Dr Edward Hernshaw for countless discussions, often cathartic, always thought provoking; Dr Geoff Kerr for discussion on choice modelling method; North Canterbury Fish and Game for internet survey contribution; Greg Kerdemelidis for his expertise in setting up the internet based survey; Environment Canterbury staff for providing the spatial water quality data as well as internet surveying support; all those Canterbury residents who participated in the project; my parents Rose and Jim for their immeasurable support; my wife Amber and our son Raven, the love we share drives me forward. I would also like to thank Nick Hanley and Basil Sharp for their efforts in examining this thesis. This thesis in dedicated to all those who appreciate the need to protect our natural environment.

for Jos, the best of friends

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AIC	Akaike Information Criterion
ASC	Alternative Specific Constant
BIC	Bayesian Information Criterion
CE	Choice Experiment
CS	Compensating Surplus
CV	Contingent Valuation
DF	Degrees of Freedom
ECan	Environment Canterbury
EEF	Environmental Enhancement Fund
GIS	Geographical Information System
IID	Independent and Identically Distributed
IIA	Independence of Irrelevant Alternatives
LL	Log Likelihood
LR	Likelihood Ratio
Mg/l	milligram per litre
MfE	Ministry for the Environment
Mpn/ml	Most Probable Number per millilitre
MNL	Multinomial Logit Model
NZ	New Zealand
PCE	Parliamentary Commissioner for the Environment
RPL	Random Parameter Logit
RUT	Random Utility Theory
RMA	Resource Management Act
SQMCI	Semi Quantitative Macroinvertebrate Community Index
SNZ	Statistics New Zealand
SRG	Suitability for Recreation Grade
SFF	Sustainable Farming Fund
TLA	Territorial Local Authority
WTP	Willingness-to-pay

Chapter 1: Research Background, Framework and Objectives

1.1. Introduction

All public water resource managers must confront trade-offs when developing pragmatic strategies to meet required objectives. The allocation of funding to specific policy targets should be apportioned in a considered manner that reflects the political desire of those funding policy activities. In the pursuit of identifying how funding can be allocated to achieve these required objectives, the application of economics can make an important contribution. Economic analysis of water management policy can aid in forming efficient and effective strategies by explicitly identifying preferences for various policy outcomes, and how individuals trade-off these outcomes. In doing so, economic analysis has the potential to help direct scarce resources towards those areas deemed most important by those funding policy activities. In the context of public agri-environmental policy in Canterbury, funding is primarily sourced from ratepayers across the region. The Choice Modelling method is an economic analytic tool that provides measurement of individual preferences for water policy targets. With this in mind, the primary purpose of this thesis is to make available to water managers in Canterbury, information about how residents' value and trade-off water quality outcomes of public policy in the region.

In doing so, three empirical articles are developed; each article focuses on a particular practical element of valuation survey implementation 1) welfare estimates of agri-environmental policy changes 2) survey mode effects and 3) spatial heterogeneity of welfare estimates.

The first article ‘Valuation of Agricultural Impacts on Rivers and Streams using Choice Modelling: A New Zealand Case Study’ employs contemporary econometric methodology to develop a model of residents’ preferences over water quality outcomes for Canterbury rivers and streams. This model is then used to estimate values of welfare changes in monetary terms. The model developed identifies which water quality attributes are considered by residents to be the most important, and how these attributes are traded off for each other.

The second article ‘Comparing internet and mail survey modes in environmental valuation: Implications for welfare estimates’ explores the role of survey mode in environmental valuation. This article applies robust statistical testing procedures to help identify differences in data collected with two survey modes; a traditional mail-and-return self-administered mode, and an internet based mode. Tests of differences are performed on: respondents’ attitudes and responses to other qualitative questions, respondents’ demographics, model estimates, and welfare estimates.

The third article ‘Nonmarket Valuation of Water Quality: Addressing Spatially Heterogeneous Preferences Using GIS and a Random Parameter Logit Mode’ combines choice modelling data and spatially related water quality data in a Geographical Information System. This framework is employed to generate variables for inclusion in econometric modelling that facilitates the testing of spatial hypotheses relating individual’s willingness-to-pay and their local water quality and quantity. This framework is also used to examine the impact of the typical reliance on sample mean estimates for calculating aggregate compensating surplus measures when individual values are sensitive to local water quality.

The remainder of the thesis is organised as follows; the rest of this chapter first provides details on agriculture in Canterbury, its impact on waterways and agri-environmental policy, and then presents examples of non-market valuation of river and stream water quality. The chapter also provides the problem statement, objectives of the thesis and hypotheses to be tested. Chapter one concludes by discussing the justification for the study. The first, second and third articles are presented in chapters two, three and four respectively. Summary, limitations and future research directions are given in chapter five.

1.1.2. Agricultural Trends, Impacts on Waterways, and Agri-environmental Policy

Canterbury is New Zealand's largest region, with an area of 45,346 km^2. It has a population of approximately 550,000 (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. Canterbury is a region with a high dependency on both the quality and quantity of its water. Rivers and streams are fundamentally important to the regions residents. They are important for hydro electricity generation, agricultural production, drinking water and a large array of customary and recreational uses. Canterbury's rivers and streams support a diverse range of habitats and species. Some of these have national and international recognition. The Canterbury region is the largest water user in New Zealand with 58 percent of all water allocated for consumptive uses and 70 percent of the total irrigated land. Many water resources in Canterbury are at or are approaching their allocation limits.

At about eight percent of total employment (SNZ, 2010) and 4 percent of Gross Domestic Product (SNZ, 2010a), the agricultural sector is an important contributor to the New Zealand economy. For a small open economy such as New Zealand this sectors importance is underscored by food and fibre accounting for about 48 percent of the value of merchandise exports (SNZ, 2010b). Nationally agriculture dominates land and water use comprising around 47 percent of land use and 75 percent of water use (SNZ, 2010c).

The Canterbury region has a 160 year history of agricultural production and the industry has undergone substantial change over recent years. Until the 1990s, farming in Canterbury was primarily focused on sheep, but during the last 15 years there have been substantial changes in livestock numbers and land use. Sheep numbers have declined by 20 percent from 9.4 million in 1996 to 7.5 million in 2006. While sheep numbers have dropped dramatically, the Canterbury region still has the largest number of sheep in New Zealand. Beef cattle numbers rose 53 percent between 1990 and 1996 and slowed down to a steady 8 percent annual increase between 1996 and 2006. Deer numbers have increased by 67 percent and pigs by 33 percent over the last 10 years. Most significant has been the rapid expansion of the dairy industry in Canterbury and New Zealand. Between 1996 and 2006, Canterbury changed from being a relatively minor dairying region to a significant one with around 920,000 head of dairy cattle in 2009, a ten percent increase on the previous year which is double the national rate of increase (SNZ, 2010c).

Trends over the last couple of decades reveal intensification of production in the agricultural sector. The volume of agricultural production has increased on a declining area of farmland, while purchased farm inputs have grown more rapidly than has output (Smith and Montgomery, 2003; MacLeod and Moller, 2006). There have been significant increases in tonnes of phosphate and inorganic nitrogen fertilisers used (MacLeod and Moller, 2006; Barnett and Pauling, 2005). The application of urea to Canterbury farmland, for example, has increased by a factor of more than nine (852 percent) between 1992 and 2004 (ECan, 2008). The large alpine rivers tend to have low to moderate concentrations of nutrients. Only the upper reaches of most alpine rivers can be considered unenriched in both nitrogen and phosphorus. Hill-fed rivers and some intermontane basin streams also show relatively low nutrient concentrations in their upper reaches, but the cumulative impacts of land use are seen with higher nutrient concentrations in the lower hill-fed river sites. Volcanic, lowland and urban rivers are considerably more enriched than are alpine or hill-fed rivers. The average nutrient levels in both urban and pastoral waterways breach the Australia and New Zealand Environment Committee Council guidelines for ecosystem protection (MfE, 2007). The main mechanism of phosphorus contamination of streams is through surface run-off generated by rainfall and irrigation. Direct deposition from activities such as livestock intrusion, fertiliser and effluent applications and industrial and storm-water discharges is also important (ECan, 2008).

The discharging of animal effluents onto land impacts on health risks for recreationalists. In terms of microbial pollution (e.g. faecal coliforms and campylobacter) the suitability of rivers and lakes for contact recreation, such as swimming and boating, is primarily based on the risk of infection from microbial pathogens. At the end of 2006/07, almost half of the freshwater sites in Canterbury were graded as generally unsuitable for contact recreation (ECan, 2008). Most of these sites are on the lower reaches of rivers, where the cumulative impacts of land use activities result in a significant risk to water quality. The main pattern of trends detected in nutrient concentrations was of increasing dissolved nitrogen concentrations in hill and lowland steams, in contrast to decreasing concentrations in urban streams. Increases in dissolved phosphorus concentrations in lowland and urban streams were apparent but little change was noted in alpine or hill-fed streams (ECan, 2008).

Conversion of sheep and cropping farms to dairy farming has led to increased demand for water for irrigation in Canterbury. Unreliability of flows in foothill rivers has lead to an increasing number of wells for irrigation being sunk in the upper plains areas. As a result, connected lowland aquifers have suffered, reducing flows in lowland spring fed streams. The situation is made worse by increased surface water abstraction. Large-scale groundwater abstraction has meant that groundwater levels tend to decline more rapidly and show more seasonal variation from pre-1990 levels than could be attributed to climatic effects alone. This trend has contributed to river flows consistently below long-term trends (Martin and Aitchison-Earl, 2009).

Run-of-river takes are near the limit of what can be safely abstracted while maintaining environmental flows. Restrictions are already widely in use, with the greatest pressure on lowland streams. Pressure on aquifer systems has resulted nearly a third (10) of abstraction zones being classified as 'red zones' in Canterbury, where water has been fully allocated, and four 'yellow zones', where allocation exceeds 80 percent of the allocation limit. Not only is Canterbury the region with the greatest allocation of water in New Zealand, it is also the region with the highest dependency on irrigation during dry periods. The dairy industry has indicated that irrigated land area in Canterbury could double from its present 350,000 hectares (CPWT, 2006). The resulting tensions are a major driver for research in this area.

Historically, environmental management of land in New Zealand has focused on managing hill-country erosion, minimising flood risk, and improving the health of pasture soils. More recently, attention has turned to protecting riparian stream margins, excluding stock from waterways, minimising nutrient enrichment of waterways, including through nutrient budgeting and use of nitrification inhibitors, and protecting the land-based primary production sector from exotic pests and diseases (MfE, 2007).

Driven by the growing market demand for clean green products, New Zealand's primary industry associations are increasingly adopting environmental management systems (EMS) to demonstrate the commitment of their sectors to sustainable primary production. Examples of existing initiatives are Sustainable Winegrowing New Zealand (490 members in 2006), Forest Stewardship Council standards (covering 42 percent of New Zealand's commercial plantation forests), Market Focused (a dairy farmers' EMS initiative in 2001), and Official Organic. Ultimately, New Zealand land owners can benefit by managing, and being seen internationally to be managing their land in a sustainable way, taking account of the impact of their activities on waterways, erosion, soil health, and also climate change (MfE, 2007).

A range of policy instruments are used to achieve agri-environmental objectives. Almost ninety percent of government agri-environmental budgetary expenditure is provided for research and education, such as the Public Good Science and Technology Fund (Fraser, King and Knight, 2005). The Sustainable Farming Fund (SFF), established in 2000, has seen an increase in funding for projects up to 2009 at about ten million dollars annually. SFF projects seek to transfer information and technology from experts to primary producers in order to improve the financial and environmental performance of agriculture and forestry (Steele, 2005).

The national agri-environmental policy environment is characterised by decentralisation of decision making and devolution of responsibility to territorial authorities and regional councils. Authorities charge famers in order to recover the costs associated with programmes and applications, while resource management remains with the farmers (MAF, 2010). Three nationwide overarching laws address environmental concerns: the Resource Management Act (RMA, 1991); the Hazardous Substances and New Organisms Act (HSNO, 1996); and the Biosecurity Act 1993. The RMA integrates measures governing resource management. Its key themes are; sustaining the potential of natural and physical resources; safeguarding the quality of soil, water, air, and ecosystems; and avoiding, remedying or mitigating adverse effects on the environment. The HSNO aims to protect the environment by preventing and managing the adverse effects of hazardous substances including pesticides and new organisms not currently present in New Zealand. The Biosecurity Act is designed to systematically protect the nation's biological systems from the harmful effects of pests and diseases.

Farming is also affected by New Zealand's commitments under international environmental agreements including eliminating the use of methyl bromide under the Montreal Protocol; safeguarding biodiversity under the Convention on Biological Diversity; and reducing greenhouse gas emissions under the United Nations Framework Convention on Climate Change and its Kyoto Protocol.

Canterbury residents contribute significant funding for agri-environmental programmes aimed at mitigating the environmental impact of agricultural production. In the application of agri-environmental policy some progress has been made in reducing point sources of pollution such as from dairy sheds or animal processing plants, however it is the non-point sources of pollution that remain the most difficult to manage. Environment Canterbury launched the Living Streams project in 2003 aimed at encouraging sustainable land use and riparian management practices to improve the quality of Canterbury's streams. Each year the programme selects a number of areas of focus for its efforts. Stream care initiatives, education programmes in schools and the Environment Enhancement Fund (EEF) support this work and the protection of wetlands and bush habitat. A policy targeting dairying is The Dairying and Clean Streams Accord. This is a co-operative agreement between Fonterra Co-operative Group, Regional Councils, Ministry for the Environment and Ministry of Agriculture and Forestry. The accord focuses on reducing the impacts of dairying on waterways by including targets for excluding animals from waterways, requiring farmers to have effluent management systems and achieving 100 percent Resource Management Act (RMA) consent adherence (MfE, 2003). Regional councils monitor the environmental effects of the Accord and results to date are mixed. For example, for effluent discharge to land, Environment Canterbury monitoring shows that the percentage of farms with significant or major issues of noncompliance has remained consistent over the past five seasons. About 20 percent of farms were graded as significantly or majorly non-compliant each year over this period. Overall there continues to be a persistent level of non-compliance, but also a number of farms that are performing very well (Blakemore, Hidajat and Abbott, 2009). In 2006 Environment Canterbury announced its Restorative Programme for Lowland Streams Policy. The principal purpose of the restorative programme is to return water to dry streams and to ensure environmental flows occur that will preserve the intrinsic values of lowland aquatic ecosystems (ECan, 2008).

In 2003, the Ministry for the Environment and the Ministry of Agriculture and Forestry jointly launched the Sustainable Water Programme of Action (SWPoA) to identify priorities for government action to improve freshwater management in New Zealand. The SWPoA has a particular focus on addressing the pressures on water bodies from land-use change and intensification. Extensive consultation in 2005 revealed broad support for the development of policy in a number of areas of freshwater demand and quality management. By 2007, Cabinet had approved the development of a national policy statement on freshwater, as well as two national environmental standards, including one that will ensure methods used to allocate water are geared to safeguard aquatic ecosystems. Another focus of the SWPoA is to produce tools and best-practice guidance for regional councils on water quality and land-use management.

1.1.2. Non-market Valuation of River and Stream Water Quality and Quantity

Environmental impacts from agricultural production systems are costs that are not transmitted through markets for the goods produced - they are externalities. The case of agricultural pollution of streams and rivers in Canterbury represents technological externalities not borne by suppliers or consumers of related products and are not transmitted through prices but by some biological, physical, or chemical process. Externalities are not taken into consideration when farmers make profit maximising decisions. These negative externalities result in market failure and subsequent misallocation of resources as artificially low prices lead to inefficiently high quantity of output and too much pollution with no incentive to reduce either. This situation raises equity concerns as environmental costs are borne by society at large, through reduced value and quantity of consumption of water related goods and services and through the levying of rates on households to develop and enforce agri-environmental policy.

Thus environmental quality such as clean water is generally classified as a non-market commodity. There are few competitive markets trading bulk clean water and therefore market prices are unavailable to indicate its economic value. Non-market-based valuation methods must therefore be used to estimate the economic value of this environmental quality. In valuing changes in environmental quality, environmental economics draws on the tools and theory of the sub-discipline welfare economics. This a branch of economic theory concerned with the social desirability of alternative economic states (Rosen and Gayer, 2010). Welfare economics relies on the neo-classical concept of economic values based on individual utility maximisation. An essential element is the assumption that agents' stated willingness-to-pay amounts are related to their underlying preferences in a consistent manner.

There is a relatively extensive literature valuing changes in water quality employing both revealed preference; Hedonic Price and Travel Cost methods, and stated preference; Contingent Valuation and Choice Experiment methods. This section provides examples of relevant application to surface water resources including rivers and streams, and lakes. The intention is to provide context within this literature for the development of the current application. Although there is extensive literature employing these methods for other environmental goods it is not the intention to provide an exhaustive review here. A more extensive exposure to the literature may be obtained from several meta-analyses of water quality valuation studies published including Van Houtven, Powers and Pattanayak (2007), Johnston, et al. (2003), Johnston, Besedin and Wardwell (2005), and Woodward and Wui (2001). The purpose of presenting a review of literature here is to provide some indication of the context in which many practical decisions in the current application were made. These include crucial elements of the valuation procedure such as: attribute presentation format – pictures, graphics, or text; choice of attributes – seldom the same across studies; attribute levels – how many levels, what range in levels; definitions of attributes and levels – text, numerical, percentage or absolute change; choice set characteristics – number of choice sets, ordering issues, labelled vs. unlabelled, number of alternatives in choice sets, choice set opt-out options; econometric specifications – there are many different Discrete Choice models to choose from.

Early applications of hedonic models were not generally successful in establishing a statistical correlation between residential house prices and surface water quality. Malone and Barrows (1990) and Page and Rabinowitz (1993) focus on the relationship between actual contamination levels and the value of residential properties and found little or no effect of groundwater contamination on property values. As richer data sets and methodological improvements became available this situation improved with successful applications of hedonic price studies to various water values. Boyle et al. (1999) implemented a two-stage hedonic property value study to estimate lakefront property owners' demand for improved water clarity on Maine lakes. The clarity in Maine lakes problem arose from eutrophication, in this instance as a result of non-point pollution in the watershed (agriculture, forestry, residential sources). Leggett and Bockstael (2000) estimate the effect of water quality on property values along Chesapeake Bay. The authors take advantage of a unique geographical environment and a lively housing market along an estuary with large variations in water quality. The study concludes that waterfront homeowners have a positive willingness-to-pay for reductions in faecal coli-form bacteria concentrations. Boyle and Kiel (2001) provide a survey of house price hedonic studies of the impact of environmental externalities. Surveyed literature covers air quality, water quality and distance from toxic or potentially toxic sites. The authors find that in the air quality studies reviewed the coefficients of air pollutants are often statistically insignificant while the coefficients of water quality were significant in studies reviewed. Only a few studies have included measures of multiple environmental goods in their models.

Collection of adequate data and careful statistical analysis are primary challenges when applying the hedonic pricing method. The method is most successful when a data set reflecting enough variation in the characteristic of interest is obtainable. The market participants must be able to recognise differences in the environmental characteristic of interest. The value of water quality attributes, whose nature, future status, and impacts may be imperfectly perceived by market participants, may be difficult to isolate. Buyers and sellers must be able to recognise the actual physical differences in the level of characteristics to be valued. This may be difficult when water quality is highly variable. If the market for land is characterised by infrequent transactions or slow adjustments to new equilibria, then the derived implicit prices may not accurately measure producers' willingness-to-pay.

The travel cost method is another revealed preference technique that has been used to value water quality, in the context of recreation. Two studies are of particular interest in the context of this thesis as they value aspects of several Canterbury rivers. Kerr, Sharp and Leathers (2004) make available previously unpublicized value estimates of angling, water quality, option and preservation for the Rakaia and Waimakariri Rivers, Canterbury, New Zealand. Kerr and Greer (2004) apply an individual travel cost model of recreation behaviour to Rangitata River fishery, South Island, New Zealand. The authors highlight the nature of interactions between proximate fisheries with some being substitutes and others complements. The Travel Cost method suffers from a major limitation in not being capable of revealing non-use values. Non-use values may be significant for agri-environmental policy in Canterbury as many residents of the policy region may not visit river or stream sites.

Contingent valuation (CV) is the dominant methodology employed in terms of numbers of applications. Many characteristics of river water quality have been valued using this method. These include benefits of reducing non-point pollution of nutrient loadings (Lindsey et al., 1995; Poe and Bishop, 1999; Bateman et al., 2006), water salubrity (Le Goffe, 1995), maintained river flow, and low flow alleviation (Garrod and Willis, 1996; Willis and Garrod, 1999)), benefits of reducing risk of pesticidal active ingredients to groundwater and surface water (Mullen, 1997; Brethour, 2001), benefits of constructed wetlands to control agricultural waste-water runoff (MacDonald et al., 1998). These studies illustrate the wealth of stated preference non-market valuation studies that have been completed employing the stated preference method.

A particularly interesting application that provides some lead on the spatial heterogeneity manuscript presented in this thesis is that of Stenger and Willinger (1998). In their study these authors estimate preservation values for the Alsatian aquifer in Western Europe. The main objective of the paper is to compare WTP of households living in polluted areas with those having access to preserved water quality. Households living in polluted areas have higher WTP for a hypothetical programme of water quality preservation. Another determinant of the spatial heterogeneity of preference that has been incorporated in Stated Preference surveys is distance from the valuation site. Researchers have found evidence that respondents further away from the valuation site have lower WTP than those nearer the site (Concu, 2007). This result may reflect the increasing substation possibilities further from a site, or possibly that those closer to a site use it more than those further away.

Another stated preference methodology that is emerging as perhaps, the preferred method for valuing river water quality is Choice Modelling (CM) and in particular the Choice Experiment (CE). Choice experiments are one type of CM method; ranking and rating are other well known CM methods. Importantly this method differs from CV in its ability to value multiple tradeoffs amongst varying levels of attributes. The primary advantage of choice experiments are their ability to provide more detail relative to CV of respondents' utility functions. However the greater complexity of the survey instrument increases respondent burden. Several applications to valuing water quality attributes are directly relevant to the thesis and are reviewed here.

In an early application of Choice Experiments, Adamowicz et al. (1994) estimated recreationists' valuation of river water quality and availability in Alberta Province, Canada. Eight attributes were valued including terrain, fish size and water quality. All attributes were given either two or four levels with respondents presented with 16 choice sets. Choice sets were constructed for two river types, standing and running water. In each choice set respondents were asked to choose either a standing or running water site, or no site. The experimental design is an orthogonal main effects one. A Multinomial Logit model is specified. The study attempted to explain the choice of recreation site by combing a Travel Cost study parallel to the CE. The authors conclude that combining the TC and CE data resulted in improved statistical estimates compared to just one method on its own. This study is important as it provides one of the seminal applications to valuing water quality attributes and demonstrates the potential of the method to inform policy development. Blamey et al. (1999) provide an application to evaluate community values associated with different features of possible water supply options in the Australian Capital Territory. Attribute values include, 'improvements in river flows' – constructed as a three level qualitative attribute, and 'number of species with habitat loss' – constructed as a three level quantitative attribute. An orthogonal main effects experimental design is used and a Multinomial Logit model is specified.

Burton et al. (2000) valued management options for the Moore Catchment, Australia. This study relates to the current study as it aims to value impacts of farming activities. Attributes valued included, 'ecological impacts on off-farm wetlands', 'area of farmland planted with trees', and 'changes in farm income'. Heberling et al. (2000) valued benefits from reducing pollution from acid mine drainage in Pennsylvania. Attributes valued include 'water quality' and 'miles of river restored'. Water quality was measured according to what uses could be made of the stream, and took the levels 'drinkable' and 'fishable' and 'swimmable'. Morrison and Bennett (2004) report results from CE applications valuing improved river health in five New South Wales rivers, Australia. Attributes valued include range of 'recreational uses' – constructed as a three level list of activities, amount of 'healthy riverside vegetation' – constructed with four levels described as percentages of river length, the number of 'native fish' – a four level numerical definition, and ‘water birds and other fauna’ - a four level numerical definition. The data is modelled employing both Multinomial Logit and Nested Logit models.

Rolfe and Windle (2005) apply CE to value options for reserve water in the Fitzroy basin, Australia. Attributes valued include ‘healthy vegetation left in flood plains’, ‘unallocated water’ - these attributes levels were described as percentage changes, and ‘kilometres of waterways in good health’. An orthogonal main effects experimental design is used and Multinomial Logit models are fitted to the data.

In a more recent application of Choice Experiments, Hanley, Wright and Alvarez-Farizo (2006) value waterway improvements for two rivers, one in England the other in Scotland. The authors value three attributes, ‘ecology’, ‘aesthetics/appearance’, and ‘river banks’. Each attribute is qualitatively described with two levels – ‘fair’ and ‘good’. An orthogonal main effects experimental design is used and the data are modelled using Multinomial and Random Parameter Logit specifications. For the English river the authors find that people place insignificantly different values on these three aspects of river quality. The authors provide an interpretation that all three are seen as equally valid indicators of a healthy river. Another interpretation is that the amount of information provided to respondents was insufficient for them to distinguish between the three attributes. The authors suggest that it would have been easier to use CV to value the change from fair to good water quality. These findings provide insight into the importance of constructing attribute levels with sufficient range and variation to enable respondents to discern differences in policy outcomes when they choose an alternative in a choice set.

Hanley et al. (2006b) value water quality and quantity improvements in two Scottish catchments, Motray and the Brothock. Water quality in these catchments has deteriorated due to irrigation and eutrophication from agriculture. Attributes valued include the number of ‘local farm jobs’, number of ‘low-flow days’ and ‘ecological quality’. The ‘ecological quality’ attribute is described qualitatively, and has two levels – ‘slight improvement' and 'big improvement'. An orthogonal main effects experimental design is employed and Random Parameter logit models are fitted to the data. The Hanley et al. (2006, 2006b) studies are of particular relevance to this thesis as they constructed attribute definitions closely in line with policy outcome descriptions, an approach that is considered to be important to form robust estimates of Canterbury agri-environmental policy.

In an application of a Choice Experiment to valuing stream attributes in New Zealand, Kerr and Sharp (2008) identify community willingness to trade-off attributes for two different types of streams, a natural stream and a degraded stream. This method demonstrates preferences for off-site mitigation as an important element for urban water management. Attributes valued include 'water clarity' – described as either 'clear' or 'muddy', amount of 'native streamside vegetation' – described as 'little', 'moderate' or 'plentiful', number of 'fish species' – defined quantitatively, and amount of 'fish habitat' – defined quantitatively as kilometres of stream length. The authors used Latent Class models to identify classes of citizens who valued stream attributes differently. This study is important as it provides evidence of the successful application of Choice Experiments to valuing New Zealand streams.

This section indicates that non-market valuation has applied many approaches to valuing water attributes. The CE method is emerging as the preferred stated preference method and this is underscored by observing that the majority of CV applications were conducted prior to the year 2000. TC studies, although in the minority in terms of numbers of applications, remain a method utilised within the recreation valuation context. Hedonic Price studies are favoured by practitioners who prefer revealed preference valuation methods, but are constrained to be applied only where relatively developed housing market data is available. This may be contributing to the prevalence of this method in the United States while other countries such as New Zealand, where housing markets are arguably thinner and less extensive, have not seen its application to water quality valuation.

Limitations in the range of values obtainable by employing the TC method rule this option out for this thesis as nonuse values are envisaged as being significant. An adequate data set of the housing market rules this option out too. This is primarily because of the predominantly rural setting of the majority of rivers and streams in Canterbury and the lack of house sales data proximate to many rivers and streams. The advantages of the CE method over CV are discussed in chapter two, however, suffice to say here that CV is limited in its ability to value multiple attributes of agri-environmental policy. It is considered that valuation of multiple policy outcomes simultaneously will add considerable information to the water management debate that would not be possible by employing CV. It is to some extent on the basis of these observations that this thesis favours the CE method.

1.2. Problem Statement

Agricultural production is considered to be the major source of non-point pollution of rivers and streams in Canterbury (ECan, 2010). While the costs of environmental policies aimed at reducing agriculture's impact on Canterbury's waterways are relatively straight-forward to measure, the benefits of those policies are diffuse and much more difficult to quantify. The result is that valuation of public preferences for agri-environmental policy is often absent from policy advice. In this setting the prioritisation of policy efforts is often guided only by biophysical indicators and non-monetary measures of preferences.

This study explores two recent methodological developments evolving in non-market valuation of water quality. The first is the development of models incorporating variables spatially related to welfare measures of environmental quality. Stated preference models rarely incorporate spatial attributes or address spatial patterns in associated econometric models. This is an emergent area of research in choice experiment application. The development of methodology to incorporate spatially heterogeneous preferences into the choice modelling framework is emerging. What is required for this area to grow is the forming of an evidence base of differing method approaches viewed alongside subsequent results. This will throw light on strengths and weaknesses of each method and allow the direction of method development to be determined through open competition.

The second development is an exploration into the use of internet surveys for non-market valuation. Applied non-market valuation practitioners have been slow to adopt this opportunity in survey methodology. There are legitimate concerns about the prospect of sample frame bias resultant from lack of internet access coverage within policy target populations. A related difficulty is the influence of self-selection processes specific to the sample recruitment method used. There is a worry that these influences may impact subsequent welfare estimates and undermine the reliability of the internet mode when used for non-market valuation. There is a noticeable lack of comparative study between internet-based and other survey modes and so the contribution of the current research is significant.

1.3. Objectives and Hypotheses

This thesis is constructed in a three manuscript format with each manuscript focusing on a specific area indicated in the problem statement.

i) Manuscript 1: Valuation of Agricultural Impacts on Rivers and Streams using Choice Modelling: a New Zealand Case Study

The primary objective of this research is to provide estimates of the economic value of river and stream externalities from agricultural production in the Canterbury region. It is envisaged that this will aid agencies such as Environment Canterbury in assessing the relative magnitude and importance of environmental policy priorities. As noted above there is sufficient literature applying the choice experiment method to estimate water quality improvements to provide a lead for the current study. It is the intention of this study to employ the choice experiment method in the Canterbury context. This study endeavours to utilise contemporary developments in choice experiment methods where applicable in particular econometric specification. This manuscript will focus on testing the following hypothesis:

***H1. H_0*:** Canterbury residents hold significant preferences for increases in river and stream water quality. This hypothesis is tested using Wald tests for significance of parameters for different water quality attributes in an econometric model.

H1.1. H_0: Estimates from Multinomial Logit Models are significantly different to those of Random Parameter Logit models. This examination is warranted on the basis that MNL models are still being published in an environment in which the RPL is becoming the dominant specification. As such it is relevant to test whether these two models produce convergent welfare estimates.

ii) Manuscript 2: Comparing Internet and Mail Survey Modes in Environmental Valuation: Implications for Welfare Estimates

In considering the adoption of web-based surveys it is important to evaluate the quality of data from this relatively new method. The objective of this manuscript is to assess the suitability of web-based surveying to provide reliable data for environmental valuation. This objective is met through the statistical comparison of data obtained via a traditional self administered mail and return paper survey instrument with that obtained from a web based survey instrument. This manuscript focuses on testing the following hypotheses:

H3. H_0: There are no significant differences in data from a traditional mail and return survey mode and a web based mode survey.

H3.1. H_0: There are no significant differences in demographic characteristics of mail mode and internet mode samples. Chi-square tests will be employed to examine this hypothesis.

H3.2. H_0: There are no significant differences between utility weights of Logit models for mail mode data and internet mode data. This hypothesis will be tested using the method of Swait and Louviere (1993).

H3.3. H_0: There are no significant differences between willingness-to-pay estimates of mail mode and internet mode models. The method of Poe (2005) will be used to test this hypothesis.

iii) Manuscript 3: Nonmarket Valuation of Water Quality: Addressing Spatially Heterogeneous Preferences Using GIS and a Random Parameter Logit Model

The objective of this manuscript is to examine the relationship between the value of water quality improvements and spatially related variables hypothesised to influence those values. In particular it is intended to examine the relationship between respondent's local water quality and their willingness-to-pay for water quality improvements. Spatial relationships will be tested by combining biophysical and economic data in a Geographical Information System. This manuscript focuses on testing the following hypotheses:

H2. H_0: Canterbury residents' willingness-to-pay for water quality improvements are influenced by their local water quality conditions.

H2.1. H_0: WTP for reductions in the number of low-flow-months is influenced by respondent's local river flow rates.

H2.2. H_0: WTP for improvements in ecological quality is influenced by respondent's local river ecological quality.

H2.3. H_0: WTP for reductions in the risk of sickness from pathogens is influenced by respondent's local river *E. coli* levels.

H2.4. H_0: Welfare aggregation incorporating the effects of local water quality is significantly different to aggregation using sample mean willingness-to-pay.

1.4. Justification of Study

Three distinct groups may benefit from the current study; policy advisers, choice experiment practitioners and Canterbury residents. Measurement of public preferences over agricultural impacts on rivers and streams are perceived to be valuable information for policy advisers to assess the overall sustainability of agricultural activities, to improve international competitiveness of our agricultural products, to provide policy makers and planners with measures with which to assess the best use of future land use. In this regard the current study contributes important information to policy development processes and will be directly beneficial to policy advisers. The estimation of monetary values for water quality is an important item for management as it reveals both the level and relative importance of public preferences for outcomes that can be pursued by introduction of agri-environmental policies.

This study is one of the first applications of the choice experiment technique to address the relationship between marginal implicit prices and respondent's local water quality. By modelling the relationship between the GIS based water quality data, applying the method developed in this paper, policy advisers will be able to use biophysical data collected on water quality and flow rates as part of ongoing monitoring programmes to evaluate policy actions. This approach means that the spatial distribution of benefits from specific policy actions can be assessed. This information will enable policy advisers to target policies to specific locations to maximise the value of welfare gains to Canterbury residents.

Practitioners of choice experiments will benefit from this study as it adds to the literature applying choice experiments to value river water quality employing a contemporary econometric specification. The comparison of mail and internet survey modes is of benefit to nonmarket valuation practitioners as it adds to the survey mode literature by examining impacts of survey mode on data collected. This study represents the first application of choice experiment to valuing agricultural impacts on rivers and streams in Canterbury. As such it particularly benefits practitioners conducting research within the New Zealand context.

The residents of Canterbury can benefit twofold from the current research, by having their rates spent more affectively, and through the enhancement of democracy within agri-environmental policy formation. Typically the only influence that a resident located in a policy target area can exert over policy content is indirect through voting for political representatives. The choice experiment survey provides residents with the ability to explicitly express their individual preferences over policy outcomes in an un-politicised context. As such it provides a unique mechanism for improving societal representativeness in policy formation.

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Chapter 2: Valuation of Agricultural Impacts on Rivers and Streams Using Choice Modelling: A New Zealand Case Study

Abstract

Many water quality and quantity concerns in New Zealand (N.Z.) are intrinsically related to agriculture. Valuation of preferences for mitigating agricultural impacts on rivers and streams is lacking in policy debate. This paper employs a choice experiment (CE) to estimate economic values of agricultural impacts on rivers and streams in the Canterbury region of the South Island of New Zealand where increasing substitution of dry land pastoral and arable farming for water intensive practices have placed pressure on water resources. Three impacts are considered: health risks of pathogens from animal waste, ecological effects of excess nutrients, and low-flow impacts of irrigation. This study provides a valuation of outcomes for public agri-environmental policy implemented in Canterbury such as The Dairy and Clean Streams Accord, Living Streams, and The Restorative Programme for Lowland Streams. Significant differences are found between willingness-to-pay (WTP) estimates derived from multinomial logit (MNL) and random parameter logit (RPL) models for some water quality attributes. Based on results from the RPL model, the average five year discounted compensating surplus (CS) for improvements to rivers and streams in Canterbury provided by agri-environmental policy is over $185,000,000.

2.1. Introduction

Agricultural impacts on rivers and streams in New Zealand are well understood with a sound scientific basis demonstrating that intensification of production continues to put growing pressure on many environmental resources. The trend of increasing dairy farm conversions exacerbates tension over property-rights to use water resources in a management environment in which allocation and pricing mechanisms are generally inadequately designed for achieving economic efficiency.

Increasing substitution of dry land pastoral and arable farming for water intensive dairy farming is a significant current trend in Canterbury. Dairy stock unit numbers in Canterbury have increased rapidly and the trend is continuing. The environmental implications of these land uses changes have been well researched with a growing body of scientific literature outlining the impending consequences if inadequate action is taken. Minimum water flow levels to maintain environmental and recreational values are threatened by increasing irrigation demand (PCE, 2004). Studies of trends in water quality and contrasting land cover indicate a clear relationship between dairy stock numbers and decreasing water quality (Larned et al., 2004). Increases in water borne pathogens such as Campylobacter have been reported (Ross and Donnison, 2003, 2004), as have increases in nitrogen and dissolved reactive phosphorous in water-ways (Cameron et al., 2002; Cameron and Di, 2004; Hamill and McBride, 2003). The long term consequences of land application of animal effluent are uncertain (Wang and Magesan, 2004). The rates of fertiliser and pesticide applications have increased dramatically over the past decade and are forecast to continue increasing (ECan, 2008b).

In the application of agri-environmental policy some progress has been made in reducing point sources of pollution such as from dairy sheds or animal processing plants, however it is the non-point sources of pollution that remain the most difficult to manage. Environment Canterbury launched the Living Streams project in 2003 aimed at encouraging sustainable land use and riparian management practices to improve the quality of Canterbury's streams. Each year the programme selects a number of areas of focus for its efforts. Stream care initiatives, education programmes in schools and the Environment Enhancement Fund (EEF) support this work and the protection of wetlands and bush habitat. A policy targeting dairying is The Dairying and Clean Streams Accord. This is a co-operative agreement between Fonterra Co-operative Group, Regional Councils, Ministry for the Environment and Ministry of Agriculture and Forestry. The accord focuses on reducing the impacts of dairying on waterways by including targets for excluding animals from waterways, requiring farmers to have effluent management systems and achieving unanimous Resource Management Act (RMA) consent adherence (MfE, 2003). Regional councils will be carrying out work to monitor the environmental effects of implementing the targets of the Accord. In 2006 Environment Canterbury announced its Restorative Programme for Lowland Streams Policy. The principal purpose of the restorative programme is to return water to dry streams and to ensure environmental flows that will preserve the intrinsic values of lowland aquatic ecosystems (ECan, 2008).

While the costs of environmental policies aimed at reducing agriculture's impact on Canterbury's waterways are relatively straight-forward to measure, the benefits are diffuse and much more difficult to quantify. Choice experiments are a stated preference method that allows the analyst to estimate values for multiple outcomes of environmental policy within one survey. The aim of this study is to provide policy makers with estimates of the benefits to mitigating agricultural impacts on rivers and streams in Canterbury. It is hypothesised that Canterbury residents are willing to pay for river and stream quality improvements provided by regional agri-environmental policies and that values will differ across alternate aspects of policy outcomes. These values can be incorporated into policy formation processes to aid in determining the level of implementation. This study contributes to the development of choice experiment application literature in New Zealand by providing a case study valuing agricultural externalities. It also contributes to choice experiment literature generally by formally testing the hypothesis that welfare estimates derived from the traditional MNL model are equal to those of the increasingly established RPL model.

The remainder of the paper is organised as follows. The next section presents an introductory overview of choice experiment methodology. This is followed by a description of the application in section three. Model specifications are detailed in section four. Welfare estimates from the different model specifications are presented and compared in section five. The paper concludes with a discussion of the policy implications of the results.

2.2. Choice Experiments

Choice experiments are a stated preference technique for collecting preference data. The questions involved in a choice experiment are very similar to those contained in contingent valuation (CV) exercises. In CV applications respondents are typically presented with one question regarding one proposed policy situation. In a CE respondents are presented with a sequence of choices. Each choice is between a constant status quo situation (referred to as the constant base) and a number of different proposed situations describing policy outcomes. The groupings of status quo and proposed alternatives are known as choice sets, and Figure 2.1 shows an example of a choice set. The proposed alternatives in each choice set are all different in terms of the condition of the environment described to respondents and the financial burden they impose. The descriptors of the environment and the financial burden are known as the attributes of the alternatives. Variation across proposed alternatives in the choice sets are achieved by assigning different levels of the attributes. Different levels are assigned to attributes to create the proposed alternatives for inclusion in the choice sets according to a systematic process known as experimental design (see Rose and Bliemer, 2009 for a review of this literature). The respondent is asked to indicate the alternative they prefer. The variation generated between the attributes and the choice variable is modelled using a discrete choice probabilistic model, where the dependent variable is the probability of choosing an alternative given the levels of attributes. Marginal rates of substitution between attributes can be calculated by modelling how people change their preferred option in response to changes in the levels of attributes. By including a monetary attribute in choice sets, WTP for environmental attributes can be estimated. These values are known as implicit prices. Compensating surpluses can be estimated for shifts from the status quo to specifically defined combinations of attribute levels.

In the environmental non-market valuation literature stated preference methods appear to be on the rise (Adamowicz, 2004). This possibly reflects the inability of revealed preference methods to provide measures of passive use value, and the fact that stated preference methods offer researchers more control over the experimental design and eliminate collinearity usually present in revealed preference data. Contingent valuation (Mitchell and Carson, 1989) has been the dominant valuation methodology employed in terms of numbers of applications, perhaps a result of being relatively easy to apply compared with other valuation methods.

The conception of CE was in marketing and transport literature. Initially CE were useful to marketing researchers to predict market shares when a new product or variation of existing product was being contemplated. It was also useful to transport economists for forecasting market share of alternate transport modes. Their consistency with welfare economic assumptions of utility maximisation and demand theory has motivated a movement towards their use over conjoint approaches in which interpersonal comparisons were not possible. Contrary to typical conjoint approaches of rating or ranking exercises that depart from the contexts of choice actually faced by consumers, CE required respondents to choose between alternatives. This approach results in a sequence of choice outcomes enabling the probability of an alternative being chosen to be modelled in terms of the attributes used to describe the alternatives. The higher the level of a desirable attribute, *ceteris paribus,* the higher the utility, and so the greater the probability of that alternative being chosen.

There is a growing use of choice experiments instead of CV due to a number of advantages they offer that have been widely discussed (Boxall et al., 1996; Hanley et al., 1998; Golberg and Roosen, 2007; Tuan and Navrud, 2007; Hanley et al., 1998, 2001; Adamowicz et al., 1998; Louviere, 2001; Bennett and Adamowicz, 2001; Jin et al., 2006; Mogas et al., 2005). As opposed to CV in which a single bundle of attribute levels describes the good, CE infers which attributes significantly influence choice, can determine the implied ranking of these attributes, marginal WTP for changes in an attribute and WTP for programmes changing more than one attribute. It is argued that CV places too much attention on the case being valued; that is respondents place a level of importance on a case that may be beyond its real significance. Framing effects can be lessened in CE compared with CV, in part by the inclusion of a range of substitute and complementary goods. In CEs, framing effects have been observed from varying the choice set complexity: such as changing the number of choice sets per survey, alternatives per set, attributes per alternative or levels per alternative (Kragt and Bennett, 20011). However researchers have found evidence that suggests that respondents stated and actual preferences are consistent, thus refuting the presence of hypothetical market bias (Loureiro et al, 2003). CV value estimates have been found to be invariant to the scope of the good involved whereas in CE the scope of provision of the good being valued is varied as part of the survey design. Strategic behaviour by respondents is made more difficult relative to the case of doing so in CV. The higher degree of representation of consumers' utility functions requires more of both respondent and analyst. The greater complexity of the survey instrument increases respondent burden and the statistical analysis is more complex relative to CV.

The theoretical foundations of choice experiments are in Lancaster's characteristics theory of value and in random utility theory (RUT). Lancaster proposed that utility is not derived directly from the purchase of a good, but from the attributes that the good possesses (Lancaster, 1966). This means that utilities for goods can be decomposed into separable utilities for their attributes. Thurstone (1927) proposed RUT as the basis for explaining dominance judgements among pairs of offerings. As conceived by Thurstone, consumers should try to choose the offerings they like best, subject to constraints such as time and income following usual economic theory. A consumer may not choose what appears to be the optimal alternative. Such variations in choice can be explained by proposing a random element as a component of the consumer's utility function. That is,

$$U_i = V_i + \varepsilon_i \qquad \textbf{\textit{(1)}}$$

Where U_i is the unobservable true utility of alternative i; V_i is the systematic observable component of utility; and ε_i contains a stochastic component as well as possible individual and alternative specific correlates. Individuals are asked to choose between alternative goods, which are described in terms of their attributes, one of which is price (or a proxy). This inherently stochastic problem naturally leads to formulating expressions for the probability of choice. The probability that individual i will choose alternative j over alternative k is:

$$Prob_i(j|\mathbf{C}) = Prob[(V_{ij} + \varepsilon_{ij}) > (V_{ik} + \varepsilon_{ik})] \qquad \textbf{\textit{(2)}}$$

where **C** is the complete set of alternatives and ε_{ij} and ε_{ik} are error terms.

In order to derive an explicit expression for this probability it is necessary to know the distribution of the error terms. A typical assumption is that they are independently and identically distributed (IID) with an extreme value (Gumbel) distribution. This distribution for the error term implies that the probability of any particular alternative being chosen as the most preferred can be expressed in terms of the logistic distribution, which results in a specification known as the conditional or multinomial logit model (MNL) (McFadden, 1974):

$$\text{Prob}_i(j|\mathbf{C}) = \exp (\mu V_{ij})/\sum_C \exp (\mu V_{iC}) \qquad \textbf{\textit{(3)}}$$

where μ is a scale parameter which is inversely proportional to the standard deviation of the error distribution and cannot be seperately identified and is therefore typically assumed to be one. Equation (3) can be estimated by conventional maximum likelihood procedures. If the deterministic part of the individual indirect utility function is linear in its agruments and additive then a typical general functional form is:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_m \omega_{jm} ASC_j * S_{mi} \qquad \textbf{\textit{(4)}}$$

where ASC is an alternative specific constant for alternative j, β_k is a vector of coefficients associated with the kth attribute, X are attributes of the choice set, ω_{jm} is the vector of coefficients of the interactions between the ASC and the mth socioeconomic characteristic of individual i (S_{mi}). The MNL model has three main assumptions that may be practically over restrictive. First, the utility weights are the same for all respondents, second, the errors in each respondent's series of answers are uncorrelated, and third the IID error distribution assumption implies that all information in random components of unobserved attributes is identical in quantity and relationship between and across all alternatives. This means that the ratio of the choice probabilities of any pair of alternatives must be independent of the presence or absence of any other alternative in a choice set. This behavioural property is called the independence of irrelevant alternatives (IIA) assumption. Hausman and McFadden (1984) proposed a specification test for the MNL model to test the IIA assumption. If IIA does not hold then the parameter estimates are considered biased and other models must be used that relax this assumption by employing more complex specifications of the covariance matrix of the error distribution. These include the multinomial probit, nested logit, latent class, random parameters logit, and heterogeneous extreme value logit. The first three of these possibilities offers merely a partial relaxation of the IID assumption and only accommodates limited heterogeneity amongst respondents. The random parameter logit (RPL) model represents a full relaxation of the IID assumption and addresses the two other behaviour limits of MNL reported above by accommodating correlations among panel observations and accounting for uncontrolled heterogeneity in tastes across respondents (Train, 2003). The parameter vector can be expressed as the population mean β and the individual specific deviation from the mean η_i. Hence the above utility function can be rewritten as:

$$U_i = \beta X_i + \eta_i X_i + \varepsilon_i \qquad \textit{(5)}$$

The stochastic part of utility now may be correlated among alternatives and across the sequence of choices via the common influence of η_i (Hensher and Greene, 2003). Including an individual specific error term that is correlated across the sequence of choices made by an individual takes into account the panel structure of the choice data. Specifying additional error component terms can further capture error correlation between alternatives in a choice set (Scarpa et al. 2005). This extension of the model captures additional unobserved heterogeneity that is alternative rather than individual specific (Greene and Hensher, 2007). The RPL model can also extend beyond an estimator in which the covariance matrix of the random parameters is diagonal, by allowing parameters to be freely correlated. In this way the modeller can account for correlation of preferences across attributes. The choice probability resulting from this specification does not have a closed form solution and requires estimation by simulated maximum likelihood (ML). The ML algorithm searches for a solution by simulating m draws from distributions with given means and standard deviations. Probabilities can then be calculated by integrating the joint simulated distribution (the mixture distribution of the IID distribution of ε_i and the specified distribution for η_i). It is this fact that gives the alternative name for this model, the mixed logit. These model forms can be used to generate welfare estimates of respondent's marginal WTP for a change in attributes as the ratio of attribute and cost parameters:

$$WTP_a = -(\beta_{a\ attribute}/\beta_{cost}) \quad \textbf{\textit{(6)}}$$

The welfare estimate of a combination of policy outcomes can be calculated as compensating surplus using:

$$CS_{management} = (-1/\beta_{cost})\,(V_{base} - V_{management}) \quad \textbf{\textit{(7)}}$$

Where V_{base} is the utility derived from the 'No change' base alternative and $V_{management}$ is the utility derived from the environmental improvement management scenarios. Those researchers contemplating applying CE will find the following texts useful sources of practical direction, Louviere et al. (2000), Bennett and Blamey (2001), and Hensher et al. (2005).

2.3. Application Details

2.3.1. Questionnaire Design

The development of the set of attributes to be valued consisted of two main procedures. First a survey of relevant policy documents and expert based opinion, and second focus groups and cognitive interviews (Dillman, 2007) of Canterbury residents. To elicit expert opinion on which impacts were the most significant from a policy maker perspective a dialogue was begun with the regional policy authority, Environment Canterbury, and several meetings were conducted and a survey sent to relevant Environment Canterbury staff. The main questions contained in that survey are presented in Table 2.1, Appendix one contains the full survey.

Table 2.1 Environment Canterbury expert opinion survey

Q1	What agricultural impacts on rivers and streams are you familiar with in your general activities at Environment Canterbury?
Q2	Please rank the 4 most significant impacts in order by placing a number next to the list above with 1 representing the most significant impact
Q3	How are these impacts measured?
Q4	What is the range of typically observed values for these measurements?

This survey revealed that the variables that are most relevant to the policy process are scientific and technical in nature. In terms of Q2 the top four were: *E. coli* (mpn/100ml), Nitrate (mg/L), Phosphate (mg/L) and Pesticides (mg/L). The challenge is to take the scientific measures and match them up with descriptions of impacts that are salient to Canterbury residents. A starting point is to recognise that it is not the pollutant per se that has disutility for Canterbury residents but the values for rivers and streams held by those residents that are impinged on by the presence of pollutant. For example, the quantity of nitrate measured in micrograms per litre has meaning to scientists but it is the description of excess weed growth and other ecological effect that have meaning to Canterbury residents.

Two focus groups were conducted with Canterbury residents. Participants for focus groups and cognitive interviews were randomly selected from telephone directory listings. One was held in central Christchurch and was aimed at gaining an urban perspective and the other was conducted in Lincoln and recruited a rural sample of participants. Cognitive interviews were conducted in central Christchurch and Lincoln, 10 in each location. Materials used as focus groups and interview discussion guides are contained in Appendix two.

Three river and stream quality attributes were indentified to be valued in the choice experiment and these are shown in Table 2.2. The first environmental attribute is the risk of people getting sick from microorganisms in animal waste that end up in waterways. The risk considered here is from recreational contact, and is measured as the number of people out of one thousand that would become sick annually. Level definition was guided by Adamowicz (2007) and Environment Canterbury (2007b). The magnitude of changes in levels was guided by Ball (2006) and McBride (2002).

Table 2.2 Attributes and levels used in choice sets

Attribute	***Base level***	***Improvement level***
Health Risk	60	10 and 30 people/1000/year
Ecology	Poor	Fair and Good
Flow	5	1 and 3 months of low-flow/year
Cost	$0	$15, $30, $45, $60, $75, $90 per domicile per year

The second attribute allows the analyst to value the impact of excess nutrients on the ecological quality of rivers and streams. The descriptions of the ecological levels were guided by the policy outcomes for water quality as defined in Environment Canterbury (2007), a document representing current policy. Elements of these defined outcomes were used to construct the levels. This also involved taking elements of the Quantitative Macroinvertebrate Index used by Environment Canterbury in defining outcomes, using the following publications: Environment Canterbury (2003), Stark (1998) and Stark and Maxted (2007a, 2007b). Table 2.3 shows the descriptions used.

Table 2.3 Ecology attribute level definitions

Poor Quality	Weeds are the only aquatic plants present and cover most of the stream channel. The stream-bed is covered mostly by thick green algae mats. Only pollution tolerant insect populations are present. No fish species are present.
Fair Quality	About 50% of stream channel covered by plants. Few types of aquatic plants, insects and fish. Algae cover about 20% of stream bed. Population densities are reduced.
Good Quality	Less than 50% of stream channel covered by plants. Algae cover less than 20% of stream-bed; there is a diverse and abundant range of aquatic plants, fish and insects. Insect communities are dominated by favourable species with pollution sensitive populations present.

The third environmental attribute allows us to value the impact of low-flow conditions. The description of the impact of low-flow conditions on rivers and streams was guided by Ministry for the Environment (2008, 2008b). The range in levels was guided by flow rate data from the Environment Canterbury website (www.ecan.govt.nz) and Environment Canterbury (2001). These types of attributes were chosen in part because they are considered to precede those attributes that are more explicitly tied to a use of a water body such as swimmable or fishable. For example, a waterway that has a Fair level of Ecological quality provides angler services, while a Poor level does not. The cost attribute is defined as an annual household payment via rates or rent. This payment time frame was chosen as focus group and interview participants considered that ongoing funding would be required for the foreseeable future given agricultural trends.

The experimental design used is a linear D-efficient main effects fractional factorial design constructed utilising procedures from Street et al. (2005). This design aims to minimise the standard error of parameter estimates. It has been argued that the main effects typically account for 70 to 90 percent of explained variance (Louviere et al., 2000). This approach has become the mainstream method in CEs. Dominant and implausible alternatives were removed from the design. The experimental design consisted of 18 treatments which were randomly blocked into three blocks of six choice sets. Figure 2.1 provides an example choice set.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	10
Ecological quality of local streams and rivers	Poor	Good	Good
Number of low flow months	5	1	1
Annual cost to Canterbury households	$0	$15	$75

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

Figure 2.1 Example choice set

The constant base alternative was assumed to be a worsening condition of rivers and streams if no change in management occurs. There would be no annual tax payment by the household, however it is assumed the risk of getting sick will be at its greatest, ecological quality will be poor, and the number of low-flow months will be at its highest. The survey consisted of three sections. The first section seeks to measure respondents' attitudes towards agri-environmental policy, and how rivers and streams are important to them. The second section consists of description of the impacts of agriculture on Canterbury rivers and streams being considered in the survey and policies that could be funded to mitigate these impacts followed by choice sets. The third section concludes with household socio-demographic questions. The first and third sections are designed to capture preference heterogeneity that is not captured by the attributes in the choice sets. The complete survey instrument, including covering letter and reminder postcard, is contained in Appendix three.

2.3.2. Sampling Procedures

The policy target population is all residents in Canterbury. During the months of July and August 2008, 1500 surveys were mailed to Canterbury residents using a stratified random sampling method. The sample was stratified by Territorial Local Authority to achieve a geographically representative sample. A reminder postcard was sent two weeks later. A week later surveys were sent to non-respondents. The mail-out procedure yielded 360 usable responses for an effective response rate of 25 percent. This response rate is slightly lower than that of similar studies in Canterbury. Three Canterbury CE studies applied in an agricultural context, achieved responses rates of 37% (Baskaran etal. 2009a), 36% (Takatsuka etal. 2009) and 31% (Baskaran etal. 2010b).

2.4. Results and Discussion

2.4.1. Socio-demographics of Respondents

In order to assess if the sample is representative of the Canterbury population, a Chi-square test was conducted. If the null hypothesis is rejected, it can be concluded that the Census 2006 population data are statistically significantly different from the sample data. Table 2.4 presents the Chi-square tests. In the instance of an unrepresentative sample being found, modelling results, and in particular the derived welfare estimates must be considerd with reference to observed bias. For example, welfare estimates derived from a sample exhibiting a disproportionately high number of high income households may be inflated realtive to the true population value. The underlying concern must consider whether preferences over policy outcomes differ across demographic segments.

Table 2.4 Sample representativeness

Characteristic		*Mail Survey (%)*	*Census 2006 (%)*	*p-value*
Income	<20k	13	26	<0.01
	20k to 70k	54	55	
	70k <	34	20	
Household size	One	13	26	<0.01
	Two	44	24	
	Two <	43	40	
Age	20 to 29	7	19	<0.01
	30 to 59	65	63	
	60 <	28	18	
Education	High School	33	65	<0.01
	Trade	27	22	
	Undergraduate	28	9	
	Postgraduate	12	4	
Employment	Unemployed	2	2	0.11
	Employed	74	66	
	Not in Labour Force	24	32	
Gender	Female	48	51	0.55

P-value is for Chi-square test under the null hypothesis of no difference between distributions.

Comparison of sample demographics with Census 2006 data (SNZ, 2006) reveals that the sample represents the middle portion of policy target demographic distributions well but falls short at the upper and lower tails. Considering income, the sample under represents households with low income while over representing those with the highest income, it does however contain roughly the same proportion of middle income households as is in the policy target. Although those households with one occupant are underrepresented and those with two are somewhat overrepresented, the sample does come very close to the proportion of two or more occupant households. Those population members aged less than thirty are underrepresented while those over sixty are overrepresented, however the middle aged sample and population proportions are almost identical. Bearing in mind the previous observation on sample income distribution, it is not surprising that the sample over represents the proportion of those with higher education levels. Interestingly the sample does have nearly the same amount of trade educated people as the policy target. There are no significant differences (at a 10 percent level) between the sample and target population for labour force status or gender. To consider the geographical representation of the sample, a Chi-square test is conducted for the distribution of respondents according to the region's ten Territorial Local Authorities (TLA). Although there is under representation of the Christchurch TLA (by approx 20 percent) and therefore over representation of the remaining TLA, the distributions are not statistically significantly different.

2.4.2. Agri-environmental Attitudes and River and Stream Resource Importance

Looking at Table 2.5 we can see that the vast majority of respondents disagree that agriculture is environmentally safe. The next two statements attempt to gauge the contentious issue of who should pay to clean up and prevent agricultures' impact on water resources. The results suggest some conflicted respondents as 64 percent agree that the burden should fall to ratepayers collectively while 84 percent agree that costs should be borne by farmers. Although more respondents agree that farmers should pay, this means that some respondents have agreed with both statements. Perhaps this reflects the public nature of the resource and indicates that ratepayers are prepared to contribute but that farmers must bear a proportionately greater cost. This argument is supported by the next two statements. Almost all respondents agree that the Canterbury agricultural landscape is important and so there are public benefits from the private actions of farmers. However 75 percent of respondents agree that a price should be charged for water for irrigation reflecting that some of the private benefits enjoyed from the extensive use of a public resource as essentially a free production input should be channelled into the public domain. This result is also a reflection of public desire to see their valuable resource used efficiently and is a condemnation of the current allocation mechanism that incentivises a race to the bottom of the well. A third of respondents agree that organic farming methods should be employed across the sector. This could be considered reasonable support for "sustainable production" policies.

Table 2.5 Agri-environmental attitudes and river and stream resource importance

Agri-environmental Attitudes (%)	*Disagree Strongly*	*Disagree*	*Agree*	*Agree Strongly*	*Don't Know*
Agricultural production today is environmentally safe	21	48	20	4	7
Canterbury ratepayers as a whole should pay the costs of cleaning up and preventing agricultures' impact on water	3	22	35	29	11
Farmers should pay for the costs of cleaning up and preventing agricultures' impact on water	3	10	43	41	3
The agricultural landscape is important in Canterbury	2	2	41	54	1
A price should be charged for water for irrigation	5	13	43	32	7
Agriculture should fully convert to organic farming methods	13	43	21	12	11

River and Stream Resource Importance (%)	
Resource for future generations	88
Habitat for plants and animals	83
Recreational opportunities	75
Drinking water resource for public	74
I just like knowing that they are there	28
Resource for commercial development	14

Table 2.5 also shows which uses of rivers and stream resources are important to respondents. This is an attempt to indicate the relative weights given to use and non-use values by respondents. We can see that intergenerational equity is important to respondents. This is not really considered a use per se but instead reflects the sentiment of sustainability; the resource should not be degraded for the short term gain of present generations at the cost of those to come. "Habitat for plants and animals" is very important as is "recreational opportunities". There is some overlap here as healthy habitat provides enhanced recreational opportunities particularly for game hunting and fishing enthusiasts. Also very important is

"use for drinking water". The next statement could be considered to reflect existence values and just over a quarter of respondents consider these to be important. Finally, "use as a resource for commercial development" is considered important by only 14 percent of respondents. This may reflect the view that the maintenance of public property rights is crucial, however it must be noted that only a small portion of respondents would actually require water resources for commercial uses and that the 14 percent support recognises that agriculture does provide income for the region.

2.4.3. Multinomial Logit and Random Parameter Logit Models Estimates

As mentioned previously the experimental design was randomly blocked into three surveys. The statistical properties of the experimental design are fully maintained only if the researcher receives the same number of responses to each block. With this in mind a staggered sampling design was used to collect the mail sample achieving a distribution of the three blocks of 33 percent, 32 percent and 34 percent.

The choice data were analysed using NLOGIT 4.0™ statistical software. To examine nonlinear preferences the attributes are effects coded with the lowest level of quality for each attribute being the base comparator. The attitudes of the respondents towards agri-environmental issues, the resource importance questions and demographic variables are recoded and interacted with the alternative specific constant (ASC) for inclusion in modelling. The variables included in final model specifications are given in Table 2.6.

Table 2.6 Model variables

Risk 10	10 people/1000/year sick from recreational contact
Risk 30	30 people/1000/year sick from recreational contact
Ecology Good	Ecological quality is good
Ecology Fair	Ecological quality is fair
Flow 1	1 month of low-flow/year
Flow 3	3 months of low-flow/year
Cost	$15, $30, $45, $60, $75 and $90 per household per year
ASC	Alternative specific constant 1 if alternative 2 or 3, 0 otherwise
Income	Household gross annual income (nine categories)
Gender	1 if respondent female, zero otherwise
Safe	Respondent agrees that agriculture is environmentally safe
Commercial	Respondent indicates commercial use of water is important
Businesses	Respondent indicates farms should pay for water improvement policy

To examine if the effects coded variables for an attribute should be combined into a single linear variable, a Wald test was conducted to observe whether the two parameters (one for each of the two effects coded attribute levels) are equal. The null hypothesis of inequality is retained for all attributes. Thus, preferences for the two attribute levels are statistically significantly different and we can conclude that preferences are not the same across different attribute levels. The MNL model is estimated first and presented in Table 2.7. Considering the attribute variables, all attribute means are significantly different from zero at a 99 percent level except Flow 3 which is not significant. All attributes have a priori signs with improvements in the levels of the attributes increasing the probability of that option being chosen. The magnitude of the probability increases as the attribute level improves indicating that respondents are sensitive to the scope of provision. The Psuedo-R^2 is of an acceptable level. Respondents derive the most utility from Ecology

Good, followed by Risk 10, Ecology fair, Flow 1, and Risk 30. The Cost variable is negative indicating that alternatives with higher cost are less likely to be chosen. The ASC is not significant indicating that the sample is not subject to status quo bias. The ASC interactions reveal that respondents who; agree that agriculture is environmentally safe, agree that farmers should pay to clean up and prevent agricultures' impacts on rivers and streams, indicate that rivers and streams are an important resource for commercial development, and are male, are less likely to choose an alternative with improvements to water quality. Respondents with higher household income are more likely to choose an alternative with improvements in water quality.

Table 2.7 Multinomial Logit and Random Parameter Logit models

Attributes	***MNL***	***RPL***
RPL Random Parameters		
Risk 10	0.437 (0.052)***	0.592 (0.066)***
Risk 30	0.107 (0.049)***	0.072 (0.058)
Ecology Fair	0.269 (0.053)***	0.356 (0.681)***
Ecology Good	0.626 (0.054)***	0.805 (0.078)***
Flow 1	0.217 (0.051)***	0.346 (0.074)***
Flow 3	0.023 (0.057)	0.032 (0.085)
Cost	-0.009 (0.001)***	-0.016 (0.002)***
RPL Non-random Parameters		
ASC	-0.356 (0.297)	0.086 (0.337)
Safe	-1.341 (0.187)***	-1.229 (0.208)***
Commercial	-1.009 (0.246)***	-1.071 (0.293)***
Gender	-0.495 (0.184)***	-0.518 (0.204)***
Income	0.195 (0.043)***	0.179 (0.048)***
Businesses	-0.884 (0.051)***	-0.945 (0.058)***
Derived Standard Deviations of Random Parameter Distributions		
Risk 10		0.592 (0.066)***
Risk 30		0.072 (0.058)
Ecology Fair		0.356 (0.681)***
Ecology Good		0.805 (0.078)***
Flow 1		0.346 (0.074)***
Flow 3		0.032 (0.085)
Cost		0.016 (0.002)***
Model statistics		
Log Likelihood	-1552	-1410
McFadden Pseudo R^2	0.26	0.37
AIC	1.44	1.35
BIC	1.48	1.39
Observations	2160	2160

, **, * indicates significance at 10, 5 and 1 percent level. Standard errors in parenthesis*

To test the IID/IIA assumption Hausman-McFadden (1984) tests were conducted. This involves removing an alternative from the choice set and testing whether the parameter estimates differ between the models with all alternatives present and with an alternative removed. Table 2.8 shows that the null hypothesis is rejected across all of the excluded alternatives.

Table 2.8 Hausman and McFadden test of IIA assumption

Excluded option	$X^2_{8\,d.f}$	***p-value***
Option 1: no change	28.31	0.003
Option 2	26.21	0.001
Option 3	25.20	0.001

The second specification presented in Table 2.7 is an RPL model. The most common distributional functional forms for the random parameters are normal, lognormal, uniform and triangular. In this paper, I tested for different distributions, and finally chose a bounded triangular distribution for all attributes. The bounds were set to take into account the degree of heterogeneity whilst obtaining meaningful WTP estimates, with the spread of each random parameter distribution restricted to be equal to the mean. Five hundred shuffled Halton draws are used in maximising the simulated Log-likelihood function. All parameters are specified as correlated.

In terms of parameter significance, sign and preference ordering, the RPL model is identical to the MNL model except that Risk 30 is not significant. The estimated standard deviations for the water quality attributes indicate significant heterogeneity in respondents' preferences for these attributes. The RPL specification provides improvements over the MNL model in terms of improved Log Likelihood function, higher McFadden Psuedo-R^2, lower Akaike Information Criteria (AIC) and lower Bayesian Information Criteria (BIC).

2.5. Welfare Estimates

The WTP estimates for water quality attributes are derived using the MNL and RPL models. These are calculated by estimating the marginal rate of substitution between the change in the river and stream management attribute in question and the marginal utility of income represented by the coefficient of the payment vehicle. Results are shown in Table 2.9.

Table 2.9 WTP estimates (NZ$ 2008) and tests for differences between MNL and RPL

Attribute	***MNL***	***RPL***	***Poe test p-value***
Risk 10	78 (56-101)	27 (3-51)	0.00
Risk30	46 (27-65)	-	-
Flow 1	41 (24-58)	52 (13-92)	0.72
Ecology Good	124 (81-165)	84 (18-148)	0.14
Ecology Fair	95 (69-120)	64 (16-111)	0.11

95 percent confidence intervals in brackets calculated from unconditional parameter distributions for RPL model and Krinsky and Rob (1986) method for MNL model.

For the MNL model confidence intervals are constructed using the Krinsky and Robb (1986) parametric bootstrapping technique to draw a vector of 1000 parameter estimates from the multivariate normal distribution with mean and variance equal to the parameter mean vectors and the covariance matrix of the estimated model. For the random parameters, confidence intervals are constructed using the unconditional parameter estimates (population moments) (Hensher et al., 2005). Estimates of WTP derived from these models are presented in Table 2.9. These represent the annual payments respondents indicated they are willing to pay for marginal changes in river and stream improvements. These payments were framed as ongoing as this view was strongly endorsed in focus groups and interviews during questionnaire development. These estimates show that Canterbury respondents are willing to pay for river and stream quality improvements under public agri-environmental policy such as those described in the introduction.

To assess whether there are significant differences between WTP estimates derived from the MNL and RPL models the convolutions method of Poe et al. (2001) is employed. This test estimates the average proportion (over 100 random draws) of WTP differences that were negative. This proportion approximates a p-value for the null hypothesis of no difference between the distributions of WTP derived from the MNL and RPL models. The results presented in Table 2.9 show that the MNL and RPL models generate annual WTP for most attributes that are not statistically significantly different from each other. However, WTP for the risk of becoming sick (Risk 10 and Risk 30) are statistically different between the two models at the 5 percent level and the Ecology attribute variables are close to being different at the 10 percent level. The WTP for the random parameters all have wider confidence intervals compared to corresponding MNL WTP, demonstrating the heterogeneity of peoples' preferences for these attributes that is included in the RPL model.

It is considered that the welfare estimates derived from the RPL model should be the basis for further policy analysis for two reasons. First, the introduction of individual preference heterogeneity improved the diagnostic statistics presented in Table 2.7 above. Second, the IIA assumption of the MNL model was rejected and therefore estimates may well be biased.

Different combinations of attribute outcomes are valued as compensating surplus estimates. These estimates represent household's overall WTP for improvements in policy outcomes from the 'no change' alternative. The 'no change' base and two improvement scenarios are as follows:

No change	60 people per 1000 get sick from recreational contact each year, ecological quality is poor, and there are 5 months of low-flow conditions.
Management Fair	30 people per 1000 get sick from recreational contact each year, ecological quality is fair, and there are 3 months of low-flow conditions.
Management Good	10 people per 1000 get sick from recreational contact each year, ecological quality is good, and there is 1 month of low-flow conditions.

Table 2.10 Compensating surplus estimates (NZ$ 2008)

Scenario	*Annual Household*	*5-year Canterbury*	*Non-response adjusted*
Management Fair	154 (58 – 250)	133,872,980	80,969,948
Management Good	213 (68 – 350)	185,026,964	111,946,872

95 percent confidence intervals in brackets calculated from unconditional parameter distributions.

Table 2.10 shows that on average Canterbury households are willing to pay $154.00 per annum for the middle levels of water quality improvement and $213.00 per annum for the best outcomes considered. Household level CS is aggregated across Canterbury for a five year period reflecting the definition of the payment vehicle. To aggregate the CS across the population an assumption has to be made about the non-respondents who did not return the survey. Mitchell and Carson (1989) propose employing an equation of the following form to calculate the annual individual CS:

$$\overline{CS_a} = \frac{1}{r+m}\left[\sum_r CS_i + \sum_m (a) CS_i\right] \qquad \textbf{\textit{(8)}}$$

where there are *r* respondents who have answered the survey and *m* non-respondents who have not, and *a* is the multiplier that expresses the non-respondents CS in relation to the CS of the respondents. Using different multipliers in place of *a*, I can calculate the appropriate CS estimates for different assumptions of non-respondents' CS. To obtain the Canterbury region CS, this individual CS is then multiplied by the number of households in the policy target 201,660 (SNZ, 2006). I calculated the aggregate CS under two assumptions: non-respondents CS is half that of a sample respondent and non-respondents have the same CS as sample respondents (Mitchell and Carson, 1989). I use the declining discount rate (DDR) approach (Birol et al., 2010; Gollier, 2008) to calculate the present value of the five year horizon. The choice of a five year horizon partially captures the trait of the ongoing annual cost framing of the payment vehicle. The benefits of policy were considered to be realised in the medium term but would be at risk of being undone if policy implementation ceased. Declining discount rates should be used when evaluating projects or policies with long-term impacts. In comparison with the use of a constant discount rate, the use of a DDR increases the weight attached to the welfare of future beneficiaries of water quality improvements. For a review of discounting for public policy see Hepburn (2009). I use a DDR structure of 10, 9, 8 and 7 percent in the fifth year. The Canterbury region five year discounted CS assuming non-respondents have the same preferences as the sample is about $185,000,000 for the outcomes of the best management scenario and about $134,000,000 for the middle level of policy outcomes. Assuming half the respondent CS for non-respondents the values fall to about $112,000,000 and $81,000,000 respectively.

2.6. Conclusions

This paper uses a choice experiment to provide welfare estimates for external effects of agriculture on Canterbury streams and rivers. More specifically, the number of low-flow months caused by abstraction of river water for irrigation, the impact of excess nutrients on ecology quality and the risk of becoming sick from contact with pathogens from animal waste are attributes of agri-environmental policy valued by Canterbury residents. Survey and model results show that there is strong support amongst residents for protection and improvement of rivers and streams in Canterbury from these effects. The five year present value of welfare benefits for Canterbury residents is considerable and could be as high as $185 million.

Environmental valuation employing choice experiment methodology is experiencing a shift in model specification. Practitioners who have become established using traditional modelling approaches may feel uneasy about adopting newer less well-known methods. A secondary objective of this paper is to present an introduction to the basics of using choice experiments for environmental valuation and to compare the long-established MNL model with the increasingly established RPL model. The restrictions of the MNL model are discussed and contrasted with their benefits. In comparing welfare estimates of the two models some WTP estimates are statistically different between the two model specifications. Based on diagnostic statistics the RPL model is proposed as a superior model specification and is recommended as the basis for policy evaluation.

A major element of the debate over water quality and quantity centres on the perceived property rights of differing user and non-user groups in the community. Focus groups and interviews revealed that residents have informed awareness of the general issues involved. This is not surprising given the regular media coverage that water rights, water quality and related issues receive. Extractive water use, often accompanied by the subsequent disposal of agricultural waste back into the environment, versus alternative uses for Canterbury's water resources by other groups within the region is at the heart of this sensitive and essential debate. A collaborative management strategy that encompasses the values held by diverse interests is crucial to forming policies that are acceptable to the general public. The newly initiated Canterbury Water Management Strategy proposes such an approach. This strategy aims to avoid the adversarial and legalistic approaches used to date. The inclusion of monetary values for water quality is an important management component as it reveals both the level and relative importance of public preferences for policy outcomes that can be used to allocate resources efficiently.

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Chapter 3: Comparing Internet and Mail Survey Modes in Environmental Valuation: Implications for Welfare Estimates

Abstract

This paper presents a comparison of internet and mail survey modes for non-market valuation. The aim of the paper is to investigate the capability of internet surveying to provide robust welfare estimates of environmental goods. Results from a choice experiment (CE) valuing agricultural impacts on rivers and streams in Canterbury, New Zealand are compared based on three main testing procedures. Chi-square tests of respondent characteristics provide an indication of the impact of sample frame and self-selection bias. A test of parameter equality across mail and internet Random Parameter Logit models (RPL) is then conducted employing the Swait and Louviere (1993) approach. Finally, differences in the derived welfare estimates are assessed using the Poe (2005) Complete Combinatorial method. Some evidence of framing and additional self-selection bias in the internet sample is found. The null hypothesis of parameter equality across survey modes is rejected; however this difference in cognitive processes between samples does not translate into significantly different willingness-to-pay (WTP) or compensating surplus (CS) estimates. Overall this case study supports the use of internet sampling to obtain viable welfare estimates of environmental policy.

3.1. Introduction

Collection of quality primary data is critically important to nonmarket valuation practitioners. The data collection procedure used can influence both the quality of the data and the subsequent reliability of the results. One central consideration is the survey mode. The steadily increasing cost of in-person interviews and decline in reliability of telephone interviews are driving a trend toward self-administered forms of survey research (Dillman and Bowker, 2001; Couper, 2005). Information technology offers new avenues for nonmarket valuation practitioners to conduct self-administered surveys on the internet. This survey administration mode is gaining widespread use in the environmental valuation literature (e.g. Tsuge and Washida, 2003; Lindhjam and Navrud, 2009; Vista et al., 2009; Viscusi et al., 2008; Johnstone and Markandya, 2006).

A central problem when conducting internet surveys for non-market valuation of public goods is sample frame bias (i.e. the exclusion of individuals who do not have access to the internet)[1]. The problem of lack of representativeness of internet based samples has been widely discussed in various literatures (Evans and Mathur, 2005; Wilson and Laskey, 2003) suggesting that internet samples are generally wealthier, more educated and male. If preferences of those within the sampling frame are different than those outside, this possible disparity may impact on welfare estimates. Therefore, there is a crucial need to investigate the reliability of internet surveys and its biasness in terms of welfare estimates.

Only a handful of published studies comparing internet with other survey modes exist in the environmental non-market valuation literature. The internet survey mode has been compared with the

[1] A sample frame is a list of individuals from which a sample is drawn. Generally, the sample frame covers the entire population, and any discrepancy between the frame and the policy target population is called the sample frame bias.

telephone mode (Berrens et al., 2003), in-person interviews (Marta-Pedroso et al., 2007; van der Heide et al., 2008), intercept-mail (Fleming and Bowden, 2009) and onsite sampling (Hynes and Hanley, 2006). These papers do not formally test differences in welfare estimates between modes. To the best of the authors knowledge, Olsen (2009) is the only paper published until now which explicitly compares traditional mail and internet samples in a choice experiment. Our paper differs crucially from Olsen's study in the method of sample recruitment. There are many internet sample recruitment approaches evident in the literature, each of which introduces potentially distinct framing and self-selection processes; Olsen recruits from a pre-recruited internet panel whereas I use a method that places survey links on suitable host sites. The findings across recruitment methods are an important contribution to environmental valuation literature.

To establish a clearer understanding of survey mode effect, in particular, from a perspective of welfare estimates, further case studies are required. The objective of this paper is to provide such a case study by comparing welfare estimates from a choice experiment valuing the effects of agricultural pollution on rivers and streams in New Zealand conducted using a traditional mail-and return survey mode and an internet mode. This paper contributes to the current survey mode literature by addressing three important statistical tests that need to be conducted in order to validate the survey mode effect. First, a hypothesis is proposed to test whether there are differences among respondents' personal characteristics including socio-demographics between the survey modes. This will give an indication of sample frame bias and additional self-selection processes. The second hypothesis tests whether there are preference structure differences between the survey modes. Finally, a third hypothesis will be tested to examine whether there are differences in welfare estimates between the mail and internet survey modes. Collectively, the working null hypothesis is of no differences in these elements between survey modes.

The remainder of the paper is organised as follows. Section 2 outlines some concerns when using internet surveys for public policy valuation. Section 3 describes the CE method and sampling procedure. In Section 4 the results of hypotheses testing procedures are discussed. Section 5 concludes.

3.2. Some Concerns When Using Internet Surveys

There are several potential benefits of internet-based surveys that make this mode an attractive data collection method across many disciplines. They include flexible survey format, shorter response time (Griffis et al., 2003), automated data storage and lower costs of dissemination (Wilson and Laskey, 2003; Evans and Mathur, 2005). Outcomes for responses rates are not so certain with studies reporting lower (Converse et al., 2008) and higher (McCabe, 2004) internet response rates compared to mail mode surveys.

The effectiveness of employing an internet based survey mode has been extensively researched using many different populations and in many different settings. Considered to have first been led by those most familiar with the technology (Kiernan et al., 2005), marketing researchers in particular have focused on this area (Ilieva etal. 2002; Wilson and Laskey, 2003; Deutskens et al., 2006). Researchers have found outcomes from employing the internet mode to be mixed (Cole, 2005). While some studies have found that internet-based surveys produce similar responses to those obtained from mail surveys (e.g. Deutskens et al., 2006; Griffis et al., 2003), others have shown evidence of significant differences (e.g. Ilieva etal. 2002; Cole, 2005). Generally, findings suggest that the usefulness of internet surveys is largely population specific (Cole, 2005). These indecisive outcomes indicate that the reliability of internet surveying for non-market valuation must be empirically assessed with case studies specific to the policy target.

Internet sampling for public policy suffers from two sources of sample frame bias. The first is a result of not everyone having internet access and so the population of internet users is smaller and possibly characteristically different than the policy target population. The second source results from the inability to obtain a sample frame of those who do have internet access. This problem of how to make contact with internet users is not a trivial consideration. Internet respondents self-select into the limited sampling frame by processes dependent on the recruitment method employed. Therefore internet samples generally suffer from self-selection biases that are additional to those present using a mail survey mode. Sample members familiar or having some degree of affinity with the survey content are considered more likely to respond. This effect is called avidity bias and is likely to occur for both the mail and internet survey modes in the same way.

In 2006 approximately 67.2 percent of Canterbury households had access to the internet. Overall in New Zealand only 65.3 percent of households with access had used the internet within the last month. The use of the internet in New Zealand is greater for individuals who are younger, have higher income, educated and employed (SNZ, 2007). Only a handful of environmental studies employing internet survey modes have compared respondent characteristics. Olsen (2009) found that an internet sample had higher income and is more educated than a mail mode sample but was similar in terms of gender and age. Authors comparing contingent valuation data from internet and in-person-interviews have found internet samples to be younger, better educated and have higher income (Marta-Pedroso et al., 2007) but also are representative of the general population (van der Heide, 2008). Fleming and Bowden (2009) found no differences in socio-demographics of an internet sample and a intercept-mail sample. In Berrens et al., (2003) comparing internet and telephone samples using CV, age and gender were similar but the telephone sample was more educated and the internet sample had lower income. These varied findings reinforce the view that the characteristics of internet samples have to be assessed specific to the policy target.

The choice of internet sample recruitment method is primarily dictated by what approach is feasible for contacting the policy target population. Within the environmental economics literature three main methods are used to obtain internet samples intended to represent general populations. A growing number of studies employ specialist recruited panels maintained by third party entities (eg Viscusi et al., 2008; van der Heide et al., 2008; Olsen 2009). Many are of a voluntary opt-in nature however panels are able to obtain probabilistic samples if the initial sample for recruitment to the panel is recruited probabilistically with all respondents provided with the ability to participate (Lee, 2006). Two other methods are used primarily where panels are unavailable or budget constraints prohibit their use. The first is to place links to the survey on web sites of organisations that experience a high volume of hits from the target population (eg. Fleming and Bowden, 2009; Johnstone and Markandya, 2006; Tsuge and Washida, 2003). The second is to obtain lists of email address that are considered extensive enough to facilitate representative samples of the target population (e.g. Marta-Pedroso et al. 2007). There is the possibility that respondents to a web site linked survey will not belong to the target population, likewise email addresses per se do not indicate respondent residence. Therefore both these approaches require efforts to mitigate the risk of including respondents from outside the target population in the sample.

Each of these recruitment methods induce distinctive self-selection processes that are additional to those encountered using the mail mode. Consideration of these processes is important as they can influence the characteristics of internet samples. How panels are initially recruited and the dynamic of belonging to an ongoing surveying environment are possible sources of additional bias in internet panels (Olsen, 2009). Links from web sites to the survey, first require that respondents visit the site hosting the link which may induce self-selection based on the information available on that particular site. Lists of email addresses obtained from Internet Service Providers (ISP) first require that respondents use that particular ISP which is likely to have a customer base formed on characteristics of the service provided and so may be distinct from the target population. The degree to which these additional sources of self-selection bias compromise internet samples is an empirical consideration that is difficult to estimate without comparative research employing different internet sample recruitment methods.

The above issues contrast with traditional mail probability based sampling procedures which are facilitated by the ability to sample from population databases that correspond to the policy target. In this application the New Zealand electoral roll data provides an almost complete list of people within the policy target[2] from which to draw a sample.

The primary concern for environmental valuation practitioners employing internet surveys is how sample frame and self-selection processes may bias welfare estimates. If the internet sample is over represented by high income respondents then it could be argued that any welfare estimates will be higher than those produced from a sample which is representative of the income distribution within the policy target population. This does not preclude the same problem occurring during traditional mail sampling, but seems probable to increase the likelihood of this outcome given the findings of previous research. If the self-selection processes are similar between modes then any additional source of welfare bias may be mitigated but this is an empirical issue, one that this study intends to shed light on.

[2] *Registration for the Electoral roll is mandatory for all citizens aged 18 years and older.*

3.3. Method

To assess the internet survey mode effect this study employs data from a CE estimating the benefits of environmental policies aimed at reducing agricultural impacts on waterways in Canterbury, New Zealand. Three environmental attributes were indentified to be included in the CE and these are shown in Table 3.1. The cost attribute is defined as an annual household payment via local council rates. This payment vehicle is framed as an ongoing annual cost as participants in resident focus groups and interviews indicated that they considered that funding would be required continuously for activities such as monitoring and enforcement.

Table 3.1 Attributes and levels used in choice sets

Attribute	***Base level***	***Improvement level***
Health Risk	60	10 and 30 people/1000/year
Ecology	Poor	Fair and Good
Flow	5	1 and 3 months of low-flow/year
Cost	$0	$15, $30, $45, $60, $75, $90 per domicile per year

The first water quality attribute is the risk of people getting sick from pathogens in animal waste that end up in waterways. Exposure is via recreational contact, and risk is measured as the number of people out of one thousand that would become sick annually. The second water quality attribute allows the analyst 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 (2007) measurement of water quality. The third water quality attribute allows us to value the impact of low-flow conditions. This attribute is 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 of the impact of low-flow conditions on rivers and streams was recommended by Ministry for the Environment (2008, 1998).

The experimental design used is a linear D-efficient main effects fractional factorial design constructed utilising procedures from Street et al. (2005). The experimental design consisted of 18 treatments which were randomly blocked into 3 blocks of 6 choice sets. The constant base alternative was assumed to be a worsening condition of rivers and streams if no change in management occurs. There would be no annual rate payment by the household, however it is assumed the risk of getting sick will be at its greatest, ecological quality will be poor, and the number of low-flow months will be at its highest. The survey consisted of three sections. The first section seeks to measure respondents' perception of environmental quality, attitudes towards agri-environmental policy, and how rivers and streams are important to them. The second section consists of choice sets and the third section concludes with household socio-demographic questions. The first and third sections are designed to capture preference heterogeneity that is not captured by the attributes in the choice sets.

This study fits a RPL model to the data obtained in the CE. Readers who are interested in the theoretical underpinnings of RPL can refer to Train (2003). The deterministic part of the individual indirect utility function estimated takes the general functional form:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_k \eta_{ki} X_{ijk} + \sum_m \omega_{jm} ASC_j * S_{mi} + \sum_n \delta_{kn} X_{ijk} * S_{ni} \qquad \textbf{\textit{(1)}}$$

where ASC is an alternative specific constant for alternative j, β_k is a vector of coefficients associated with the kth attribute, X are attributes that describe the water quality, η_{ki} is a vector of k deviation parameters which represents how the tastes of individual i differ from the average taste (β_k), ω_{jm} is the vector of coefficients of the interactions between the ASC and the mth socioeconomic characteristic of individual i (S_{mi}) and δ_{kn} is the vector of coefficients of the interactions between the kth attribute and the nth local water quality characteristic of individual i (S_{ni}).

3.3.1. Sampling Procedures

During the months of July and August 2008, 1500 surveys were mailed to Canterbury residents using a stratified random sampling method. The sample was stratified by Territorial Local Authority to achieve a geographically representative sample. A reminder postcard was sent two weeks later. The mail-out procedure yielded 360 usable responses for an effective response rate of 25 percent.

Concurrent with the mailing procedure, the internet survey was served up to www.ecosurveys.co.nz (this website was only used for this survey) with links on the websites of Environment Canterbury, North Canterbury Fish and Game and several Canterbury District Councils. The internet and Mail surveys are identical in all regards except delivery mode. To replicate the mail survey, the internet survey was presented as a single page that the respondent could scroll through. This meant that they could go back and forward through the survey, as is the case in the mail survey. It is considered that the timing of the internet survey has no effect on the type of resident responding as the range of information and therefore types of users of the sites are very diverse. The website of Environment Canterbury contains information on all aspects of regional municipal management from public transport, household energy efficiency to swimming quality grades and irrigation restrictions. Similar information with a more localised purpose is available on sites of District Councils. Fish and Game councils are the statutory managers of sports fish and game bird resources and their sustainable recreational use by anglers and hunters.

The Environment Canterbury web site has the highest visitor rate of the sites hosting the survey link with twenty to thirty thousand visitors a month. Links were up for approximately four weeks. The internet-based survey procedure yielded 345 usable responses. As it was not possible to count the number of possible internet respondents who saw the survey link but decided not to partake, no reliable estimate of response rate can be calculated. The internet survey was cheaper per usable response ($4.41 vs. $10.75) and had a faster response time. A third of the internet sample had completed the survey after 48 hours and the total sample was obtained after three weeks, whereas the mailing procedure lasted twice as long. The internet data format was readily imported into statistical software whereas the mail data took about 30 hours to enter.

The additional self-selection processes present in the current sample stem from the selection of web sites chosen to host the survey link. These processes are motivated by the reasons that possible respondents have to visit the sites and how these condition the type of individual so as to form a distinct population that may or may not be representative of the target population. The website of Fish and Game provides information primarily of use to game-bird and fishing enthusiasts such as license applications and habitat management issues. The diverse range of information present across the survey link host sites helps to mitigate this source of self-selection bias. This strategy of diversifying the link host sites aims to mitigate sources of additional self-selection processes by ensuring that collectively the website users are varied and representative of the target population.

3.4. Results and Discussion

The results section is presented in two main sections. The first section tests the hypothesis of no differences in personal characteristic between survey modes and is separated into sub-sections containing analysis of personal characteristics and then socio-demographics. The second main section presents econometric modelling estimates with subsequent sub-sections first testing the hypotheses of preference equality and welfare estimates between modes.

3.4.1. Testing the Equality of Personal Characteristics Hypothesis

It could reasonably be assumed that both the mail and internet modes have similar non-response and avidity processes. Under these assumptions, Chi-square tests identifying differences in the personal characteristics of the two samples can give an indication of the combined effect of sampling frame and additional self-selection bias in the internet sample. This study employs Pearson's Chi-square test as it is by far the most common type of Chi-square significance test. Used to test the non-directional hypothesis that two variables are related only by chance, the test statistic is calculated as the sum of observed minus expected count squared, divided by the expected. If the null is rejected then I can say that the variables of interest are related (Steel and Torrie, 1980).

3.4.1.1 Environmental Perceptions, Agri-environmental Attitudes and Water Use Priorities

Analysis of differences in respondent's environmental perceptions, attitudes towards agri-environmental policy and water use priorities can illuminate possible sampling frame and self-selection processes not necessarily revealed by divergence of socio-demographics such as age or income often used to convey such bias.

Table 3.2 reveals a dire perception of surface and groundwater quality in the internet sample compared to the mail sample. It could be argued that this reveals a more realistic view of general river and stream water quality currently in Canterbury. This divergence may be an indication of recruitment method self-selection bias as it could reasonably be expected that users of link host sites for water related information may have a greater understanding and knowledge base that reflects current water quality conditions and trends in Canterbury. The majority of both samples consider air and soil quality to be good with no statistically significant differences between samples.

Table 3.2 Comparing perceptions of Canterbury environmental quality: Mail vs. Internet (%)

Do you think the quality of…..?		***Very bad***	***Bad***	***Adequate***	***Good***	***Very good***	***Don't know***	***p-value***
Air is	Mail	4	17	28	30	20	1	0.595
	Internet	2	13	30	33	21	1	
Water in lakes and rivers is	Mail	3	22	34	27	19	2	0.004
	Internet	9	36	25	19	12	2	
Groundwater is	Mail	1	12	22	28	29	8	0.018
	Internet	5	16	30	21	24	4	
Soils is	Mail	1	5	33	34	20	7	0.762
	Internet	1	6	36	31	16	10	

P-value is for Chi-square test under the null hypothesis of no difference between distributions.

Significant differences in attitudes towards agri-environmental issues exist between internet and mail mode samples, as shown in Table 3.3. Overall the majority of both samples disagree that agricultural production is environmentally safe, with the internet sample more so. Overall there are opposing views as to who should pay to clean up and prevent agricultural impacts on water resources. Funding from Canterbury ratepayers as a whole is favoured in the mail sample while the view that farmers should pay is favoured in the internet sample. The polluter-pays implication from this observation is reinforced by overwhelming support for a price being charged for irrigation water in the internet sample, although support for this policy is also evident in the mail sample. The agricultural landscape is important in both samples. Overall the view that agriculture should convert to organic methods is not supported by the majority of respondents from both samples. Although at least 40 percent of each sample does support this policy view.

Table 3.3 Comparing Agri-environmental attitudes: Mail vs. Internet (%)

		Disagree strongly	***Disagree***	***Agree***	***Agree strongly***	***Don't know***	***p-value***
Agricultural production today is environmentally safe	**Mail**	21	48	20	4	7	<0.01
	Internet	35	48	13	3	1	
Canterbury ratepayers as a whole should pay the costs of cleaning up and preventing agriculture's impact on water resources	**Mail**	3	22	35	29	11	<0.01
	Internet	54	31	9	5	1	
Farmers should pay for the costs of cleaning up and preventing agriculture's impact on water	**Mail**	3	10	43	41	3	<0.01
	Internet	4	3	26	64	3	
The agricultural landscape is important in Canterbury	**Mail**	2	2	41	54	1	0.23
	Internet	2	6	47	43	2	
A price should be charged for water for irrigation	**Mail**	5	13	43	32	7	<0.01
	Internet	5	6	28	55	6	
Agriculture should convert to organic farming methods	**Mail**	13	43	21	12	11	0.73
	Internet	16	44	21	8	11	

P-value is for Chi-square test under the null hypothesis of no difference between distributions.

How internet and mail respondents consider Canterbury rivers and streams to be important to them is shown in Table 3.4. For the most part, rivers and streams as a resource for future generations, a source of public drinking water, habitat, and existence values are most important in the mail sample. Recreational opportunities and commercial development are of prominent importance in the internet sample. Taken as a whole this suggests that mail respondents favour intergeneration equity and non-use values while internet respondents are focused primarily on the direct use of the resource. The perceptions, attitudes and priorities results combined could be indicative of internet self-selection processes that condition agri-environmental policy attitudes towards differing property rights perspectives. Respondents in the mail sample appear to have a public property rights lean whereas respondents in the internet sample have a stronger private property rights outlook. The processes that led to these outcomes are not well understood and require additional focused research.

Table 3.4 Comparison of river and stream resource Importance: Mail vs. Internet (%)

	Mail	***Internet***
Resource for future generations	88	66
Recreational opportunities	75	88
Habitat for plants and animals	83	81
Resource for commercial development	14	24
I just like knowing that they are there	28	13
Drinking water resource for public	74	55

3.4.1.2. Socio-demographics

The p-values of Chi-square tests between the distributions of selected respondent demographics of the internet and mail samples and Census (SNZ, 2006) data are shown in Table 3.5.

Table 3.5 Comparison of respondent demographics: Mail vs. Internet

Characteristic		***Mail***	***Internet***	***Census 2006***	***p-value***
Income	Less than 20k	13	9	26	**< 0.01,** < 0.01, < 0.01
	20k to 70k	54	41	55	
	More than 70k	34	50	20	
Household size	One	13	9	26	**0.82,** < 0.01, < 0.01
	Two	44	49	34	
	More than 2	43	41	40	
Age	20-29	7	6	19	**0.85,** < 0.01, < 0.01
	30-59	65	63	63	
	60 or more	28	31	18	
Education	High School	33	19	65	**0.02,** <0 .01, < 0.01
	Trade	27	29	22	
	Undergraduate	28	33	9	
	Postgraduate	12	19	4	
Employment	Unemployed	2	1	2	**0.78,** 0.09, 0.02
	Employed	74	79	66	
	Not in Labour Force	24	20	32	
Gender	Female	48	30	51	**< 0.01,** 0.55, < 0.01

P-*values are for Chi-square test under the null hypothesis of no difference between distributions. The first p-value is for* ***Mail vs. Internet****, the second p-value is for Census vs. Mail, the third p-value is for Census vs. Internet.*

Looking at the income distribution, the internet and mail samples differ significantly from each other as well as from the survey population. Both samples are over represented by high income households with the internet sample even more so with 50 percent of the sample earning more than $70,000 each year. There is no difference in the distribution of household size between the survey modes however both samples over represent two person households and under represent one person households compared to the policy target population. Considering the distribution of age, there is no difference between the survey modes although both samples are skewed towards older respondents compared to the policy target population. There is a strong over representation of university educated people in both samples compared to the policy target population, the internet sample even more so with a significant difference between the samples at a 5 percent level. The distribution of labour force status is not significantly different between the two samples, but both over represent the employed. The internet sample is heavily over represented by males compared to both the mail sample and the survey population. The distribution of gender in the mail sample does not differ significantly from the survey population. Overall the direction of bias relative to the survey population is the same for both survey modes but the internet sample is further off target. The over representation of males in the internet sample could be indicative of self-selection bias stemming from the survey link host sites as fishing and hunting are dominated by male participants, although this outcome is also consistent with a traditional view of sample-frame bias. The higher income and education levels of the internet sample relative to the mail sample could be interpreted as evidence of sample frame affects.

3.4.2 Random Parameter Logit Models, Utility Weights and Welfare Estimates

As mentioned previously the experimental design was randomly blocked into three surveys. The statistical properties of the experimental design are fully maintained only if the researcher receives the same number of responses from each block. With this in mind a staggered sampling design was used to collect the mail sample achieving a distribution of blocks, 0.33, 0.32 and 0.34. The internet survey facilitated the ability to serve up each survey block one version after another reiterating continuously thus attaining a sample in which each block is represented the same number of times.

The choice data were analysed using NLOGIT 4.0™ statistical software. To examine nonlinear preferences the attributes are effects coded with the lowest level of quality for each attribute being the base comparator. This model specification includes two demographic variables, gender (1 if Male) and annual Household Income. Also included is a variable indicating whether the respondent agrees that water quality in Canterbury is Good. These non-attribute variables were interacted with the alternative specific constant. The most common distributional functional forms for the random parameters are normal, lognormal, uniform and triangular. In this paper, we tested for different distributions, and finally chose a bounded triangular distribution for all attributes. To take into account the degree of heterogeneity whilst obtaining meaningful WTP estimates, the spread of each random parameter distribution was restricted to be equal to the mean. Five hundred shuffled Halton draws are used in maximising the simulated Log-likelihood function.

Table 3.6 Mail and internet random parameter logit model estimates

Attributes	***Mail***	***Internet***
Random Parameters		
Risk 10	0.789 (0.07)***	0.561 (0.06)***
Risk 30	-0.013 (0.06)	-0.073 (0.06)
Ecology Fair	0.723 (0.06)***	0.449 (0.07)***
Ecology Good	0.748 (0.08)***	0.986 (0.09)***
Flow 1	0.193 (0.07)***	0.349 (0.06)***
Flow 3	0.179 (0.07)*	0.253 (0.07)***
Cost	-0.025 (0.00)***	-0.027 (0.00)***
Non-random Parameters		
ASC	-0.427 (0.31)	-1.926 (0.28)***
Safe	-1.114 (0.19)***	-0.443 (0.14)***
Gender	-0.146 (0.18)*	-0.636 (0.16)***
Income	0.201 (0.04)***	0.276 (0.03)***
Derived Standard Deviations of Random Parameter Distributions		
Risk 10	0.789 (0.07)***	0.561 (0.06)***
Risk 30	-0.013 (0.06)	-0.073 (0.06)
Ecology Fair	0.723 (0.06)***	0.449 (0.07)***
Ecology Good	0.748 (0.08)***	0.986 (0.09)***
Flow 1	0.193 (0.07)***	0.349 (0.06)***
Flow 3	0.179 (0.07)*	0.253 (0.07)***
Cost	-0.025 (0.00)***	-0.027 (0.00)***
Model statistics		
Log Likelihood	-1703	-1956
McFadden Pseudo R^2	0.30	0.28
Observations	2160	2070

, **, * indicates significance at 10, 5 and 1 percent level respectively. Standard errors in parenthesis.*

To examine if the effects coded variables for an attribute should be combined into a single linear variable, a Wald test was conducted to observe whether the two parameters (one for each of the two effects coded attribute levels) are equal. The null hypothesis of inequality is retained for all attributes. Thus, preferences for the two attribute levels are statistically significantly different and I can conclude that preferences are not the same across different attribute levels.

The Psuedo-R^2 shows that both the specified models have an acceptable level of explanatory power. Looking at the attribute variables shows that an improvement in the levels of the attributes increases the probability of that option being chosen, with the magnitude of the probability increasing as the attribute level improves. For both models all attribute means are significantly different from zero at a 10 percent level except Risk 30. The internal ranking is almost the same across samples. Both samples value both the good level of ecological quality and the lowest level of risk of sickness, either first or second followed by the fair level of ecological quality, one month of low flow conditions and lastly three low-flow months.

The ASC is negative for both samples, although not significant for the mail sample, indicating that the internet sample is subject to status quo effects not present in the mail sample. For both models higher household income increased the probability of choosing an alternative with improvements in water quality. Respondents who agreed that agriculture is environmentally safe were less likely to choose an alternative with improvements in water quality. Male respondents in both samples were less likely to choose an alternative with improvements in water quality. The estimated standard deviations for the water quality attributes indicate significant heterogeneity in respondents' preferences for these attributes.

3.4.2.1. Testing the Utility Weight Equality Hypothesis

The parameters produced as the primary model output represent the relative utility weights of each attribute (and non-attribute) to respondents. To investigate potential differences in parameter vectors between samples a Swait and Louviere (1993) likelihood ratio (LR) test for nested models is conducted of the null hypothesis of parameter equality. This test requires that both models have identical specifications. Direct comparison of utility weights between models is not possible as each weight includes the influence of a scale parameter which is not separately identifiable within a single data set. This testing procedure accounts for the confoundment of the scale parameter with utility weights by rescaling one data set relative to the other. The mail and internet data sets are stacked and the internet data is scaled relative to the mail data. The log likelihood (LL) of the pooled scaled model is optimised at -3712 and the test statistic is thus -2(-3712-(-1936-1703)) = 146. This value exceeds the critical value of 36.19 (Chi-square distributed on 19 d.f.at $\alpha = 0.01$) and so the null hypothesis is rejected and the conclusion is that the utility weights of the mail and internet models are statistically significantly different. This implies that data generating processes for utility weights are different for each survey mode.

An estimate of the relative scale parameter of 1.71 for the internet data is obtained and is significantly different from 1 at a 1 percent level. As the scale factor in the logit model is inversely related to the variance of the error term, this captures the variance of the unobserved effects in the internet sample relative to that in the mail sample (Louviere et al., 2000). The relative scale parameter tells us that the variance of the mail sample is about $(1/1.71)^2 \approx 34$ percent that of the internet sample. This means that there is far more variance in the way internet respondents choose an alternative from a choice set relative to respondents from the mail mode. This may indicate that there is greater heterogeneity in preferences in the internet sample relative to the mail survey sample.

3.4.2.2. Testing the Welfare Valuation Equality Hypothesis

To evaluate if differences in utility weights between modes translate into differences in welfare estimates the Complete Combinatorial method (Poe et al., 2005) is employed to test the null hypothesis that the difference in WTP between modes, and the difference in CS between modes, is equal to zero. This is a non-parametric test that involves comparing differences in welfare measures for all possible combinations of estimates calculated from unconditional parameter estimates. The complete combination of two 1000 element vectors (as is the case here) results in a vector of one million differences. Two scenarios are constructed to test differences in compensating surplus estimates. The base comparison and two management options:

No change	60 people per 1000 get sick from recreational contact each year, ecological quality is poor, and there are 5 months of low-flow conditions.
Management Fair	30 people per 1000 get sick from recreational contact each year, ecological quality is fair, and there are 3 months of low-flow conditions.
Management Good	10 people per 1000 get sick from recreational contact each year, ecological quality is good, and there is 1 month of low-flow conditions

Table 3.7 Welfare estimates: Poe (2005) tests for differences between internet and mail (NZ$ 2008/ annum)

Mean Willingness-to-pay	***Internet***	***Mail***	***p-value***
Risk 10	29 (7-49)	41 (11-71)	0.76
Flow 3	21 (5-37)	13 (1-26)	0.24
Flow 1	24 (6-42)	15 (3-26)	0.20
Ecology Fair	42 (1-84)	49 (6-104)	0.61
Ecology Good	59 (10-108)	54 (5-101)	0.43
Mean Compensating Surplus			
Management Fair	68 (3-131)	117 (33-202)	0.81
Management Good	101 (17-184)	143 (50-236)	0.75

95 percent confidence intervals in brackets calculated from unconditional parameter distributions

The utility equations are calculated with all socio-demographic variables set at their means and include ASCs. The utility associated with the fixed comparator level of each effects coded attribute is assumed to be the negative sum of the other two levels (Louviere et al. 2000). Table 3.7 reveals that the value order between samples are identical with ecological quality valued highest followed by health risk reductions and alleviation of low-flow conditions. Improvements in low-flow conditions have higher value in the internet sample compared to the mail sample. A reduction in health risk is valued higher in the mail sample compared to the internet sample. The values for ecological quality are very close between the two samples. The Poe (2005) test results reveal that there are no statistically significant differences between the WTP of the attributes, and neither of the CS estimates between survey modes. This may come as a surprise as some disparity between estimates is apparent; the management fair CS estimates for example seem quite different. However, it is important to note that the testing procedure considers the entire distribution of values and so viewing the mean in isolation gives a false picture of true differences in values.

3.5. Conclusions

The future of non-market valuation surveys seems likely to involve a greater reliance on self-administered survey methods and less on interview methods. Self-administered questionnaires are now poised to benefit enormously from information age technologies utilising the internet. The reliability of this relatively new survey mode for environmental valuation needs to be determined. Using data from a choice experiment valuing the effects of agricultural pollution on rivers and streams in New Zealand, this paper examines differences between internet and traditional mail-and-return survey modes in terms of the characteristics of the people who answered them and the estimates derived from models using their responses. While some important disparities are found in personal characteristics between modes these are not replicated in welfare estimates. Therefore this study finds that the use of internet surveying in environmental non-market valuation has a promising future as an alternative to traditional mail-and-return surveys. Moreover this study contributes to the literature by examining an internet sample recruited through the commonly used approach of placing survey links on host sites. The finding that our results are consistent with those of Olsen (2009) suggests that researchers can have some flexibility in choosing sample recruitment methods while maintaining the ability to obtain useable samples.

In terms of personal characteristics, internet respondents have a more realistic appreciation of river and stream water quality compared to the mail respondents. The view that farmers should pay for any pollution clean-up is more strongly favoured by internet respondents, a view contrary to the public funding stance endorsed in the mail sample. This sentiment is reflected in the mail sample orientation towards the importance of rivers and streams as public resources whereas private use plays a more significant role for internet respondents. These disparities in personal preferences could be a result of additional self-selection processes in the recruitment of the internet sample. Considering respondent demographics both samples do not represent the policy target population adequately however the internet sample performs worse than the mail sample. This is likely to be a result of the inability to obtain an internet sampling frame containing the policy target population. Econometric modelling reveals significant divergence in preference weights across the two samples however a comparison of unconditional willingness-to-pay and compensating surplus estimates fails to find any significant differences.

Overall this paper has demonstrated that samples collected via the internet and traditional mail and return samples are not drastically different. An encouraging contribution for environmental valuation from this study is that even though the mail model and internet model parameters are different, the resulting welfare estimates are not. This finding supports the conclusion that non-market valuation practitioners seeking to take advantage of internet-based surveying will not jeopardise the validity and reliability of their results. Although the results of the few comparative studies to date generally support the adoption of internet surveys for non-market valuation, further research is needed to build a reliable body of literature on this topic. Of relevance is examining the effect of different sample recruitment methods and better understanding of subsequent additional self-selection processes on results. Support for use of the internet for environmental valuation would also benefit from research programs designed to identify any pure mode effects, an issue that has not received adequate attention in this literature. Clearly the development of best practice in the field will require many more comparative studies to be undertaken.

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Chapter 4: Nonmarket Valuation of Water Quality: Addressing Spatially Heterogeneous Preferences Using GIS and a Random Parameter Logit Model

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 programs in Canterbury, New Zealand. Results show that those respondents who live in the vicinity of low quality waterway are willing to pay more for improvements relative to those who live near to high quality waterways. The study also finds that disregarding the influence of respondents' local water quality has a significant impact on the magnitude of welfare estimates and causes substantial underestimation of aggregated benefits.

4.1. 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 et al., 2006). Analysis of how values differ spatially within the population being aggregated can mitigate biases by identifying values conditional on spatially related variables that are hypothesised to influence individual benefits.

This paper employs 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 programs 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 (MacDonald et al. 2010; Agee and Crocker, 2010; Kong et al., 2007). 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 residence 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 programs (Naidoo and Ricketts, 2006; Egoh et al., 2008; Nengwang et al., 2009, Jenkins et al., 2010).

This approach is a rudimentary form of benefits transfer and more sophisticated forms use valuation functions that vary across spatial as well as socio-demographic variables (Bateman et al., 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 (Hanley et al., 2003; Bateman et al., 2006; Concu, 2007). Bateman et al. (2006) provides a review of literature regarding the aggregation of benefit estimates for nonmarket goods. The authors find highly significant distance decay in values and show that reliance on sample mean WTP can result in biased estimates. This is consistent with the findings of Hanley et al. (2003) who employ contingent valuation and GIS. Concu (2007) is one of the first authors to conduct a distance decay analysis using CE method. The author concurs that distance omission produces underestimation of aggregate benefits and losses. Other sources of spatial preference heterogeneity have also been identified in a somewhat limited pool of studies outside of the revealed preference and distance decay literature. Brouwer et al. (2010) use 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 the 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 are estimated. Results indicate that respondents' value the change of water quality significantly more for their respective sub-basins, but only for the highest level of water quality considered. The authors find that not accounting for spatial preference heterogeneity results in an underestimation of around 30 percent of the estimated value for the highest water quality level in the whole river basin.

In an application employing a random parameter logit model, Condon et al. (2007) examine the influence of respondents' geographical location on values for rural land conservation programs in Florida. The study uses a 20 kilometre (km) radius around respondents and four variables hypothesised to affect individual values which are constructed using a GIS. Results reveal that the share of agricultural land and distance to the coast are statistically significant influences on respondents' values. The authors find that compared to using sample mean values, aggregate values incorporating the respondents' geographic information are approximately 17 percent and 50 percent lower for the highest and lowest valued programs respectively. Comparing this outcome with that of Brouwer et al. (2010) emphasises that the direction of aggregation bias from using sample mean values may not always be apparent *a priori*.

In a more recent application, Moore et al. (2011) provide a good example of spatial influences on WTP in the context of water quality. These authors demonstrate that because current water clarity is spatially variable, the value that a household places on a universal improvement depends on the distance of the household's residence from the policy target and on the particular geospatial location of the residence. The authors conclude that aggregate benefits are much larger when resident's spatial location is included in modelling. The role of respondent's spatial variation in relation to environmental attributes being valued is a theme examined by Ferreira and Moro (2010). They use a Subjective Well-Being approach to look at the effects of spatial variation in several factors including environmental quality. The authors find significant local and regional effects.

This study considers respondents' local water quality conditions as a source of spatial preference heterogeneity in valuing stream and river conservation programs 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 incorporation of biophysical data into the valuation process to enhance reliability of welfare estimates. The rest of the paper is organised as follows. Section 2 describes the Canterbury water quality problem. In Section 3, the valuation and GIS methods are presented. Section 4 presents model estimation and welfare estimates incorporating the influence of respondents' local water quality. Conclusion and policy implications are summarized in Section 5.

4.2. Background

Canterbury is New Zealand's largest region, with an area of 45,346 km^2. It has a population of approximately 550,000 (SNZ, 2006). 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 of 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 Campylobacter have been reported (Ross and Donnison, 2003, 2004), as have increases in nitrogen and dissolved reactive phosphorous in waterways (Cameron and Di, 2004). There are risks of irreversible damages in some instances as long term consequences, such as land application of animal effluent (Wang and Magesan, 2004). The rates of fertiliser and pesticide applications have increased dramatically over the past decade and are forecast to continue increasing (PCE, 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 percent increase in the amount of irrigated land from 1985 to 2005, and some 70 percent of consumptive use of water in the region is for pastoral purposes (Sage, 2008). Increased irrigation also means increased agricultural production and more intensive use of land.

In the application of agri-environmental policy some progress has been made in reducing point sources of pollution such as from dairy sheds or animal processing plants, however it is the non-point sources of pollution that remain the most difficult to manage. Three public policies aimed at protecting and improving streams and rivers in Canterbury are: the Dairying and Clean Streams Accord; the Restorative Programme for Lowland Streams; and the Living Streams project. Environment Canterbury launched the Living Streams project in 2003 aimed at encouraging sustainable land use and riparian management practices to improve the quality of Canterbury's streams. Each year the programme selects a number of areas of focus for its efforts. Stream care initiatives, education programmes in schools and the Environment Enhancement Fund (EEF) support this work and the protection of wetlands and bush habitat (Environment Canterbury, 2007b). The Dairying and Clean Streams Accord is a co-operative agreement between Fonterra Co-operative Group, Regional Councils, Ministry for the Environment and Ministry of Agriculture and Forestry. The Accord focuses on reducing the impacts of dairying on the quality of New Zealand streams, rivers, lakes, groundwater and wetlands. Regional councils will be carrying out work to monitor the environmental effects of implementing the targets of the Accord (MfE, 2007). In 2006, Environment Canterbury announced its Restorative Programme for Lowland Streams Policy. The principal purpose of the restorative programme is to return water to dry streams and to ensure environmental flows that will preserve the intrinsic values of lowland aquatic ecosystems (Environment Canterbury, 2008).

4.3. Method

This study employs a CE to estimate the benefits of environmental policies aimed at reducing agricultural impacts on Canterbury's waterways.[3] The respondent is presented with several alternatives and each alternative is made up of combinations of environmental attributes commonly referred to as policy outcomes. Combinations of attributes and levels are varied systematically in the alternatives according to experimental design theory. The respondent is asked to indicate the combination of the attributes in an alternative they prefer most.

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 indentified to be included in the CE and these are shown in Table 4.1. The cost attribute is defined as an annual household payment via local council rates. This payment vehicle is 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 activities such as monitoring and enforcement.

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

Table 4.1 Attributes and levels used in choice sets

Attribute	***Base level***	***Improvement level***
Health Risk	60	10 and 30 people/1000/year
Ecology	Poor	Fair and Good
Flow	5	1 and 3 months of low-flow/year
Cost	$0	$15, $30, $45, $60, $75, $90 per domicile per year

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, 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 (Ball, 2006; McBride et al., 2002).

The second water quality attribute allows the analyst to value the impact of excess nutrients on the ecological quality of local rivers and streams. The descriptions of the ecological levels for water quality were in accord with Environment Canterbury (2007) policy descriptions. For example, the ecological levels were constructed using the Quantitative Macro Invertebrate Index developed by Environment Canterbury (2003) and studies relevant to the index (Stark and Maxted, 2007). Table 4.2 shows the descriptions used.

Table 4.2 Ecology attribute level definitions

Poor Quality	Weeds are the only aquatic plants present and cover most of the stream channel. The stream-bed is covered mostly by thick green algae mats. Only pollution tolerant insect populations are present. No fish species are present.
Fair Quality	About 50% of stream channel covered by plants. Few types of aquatic plants, insects and fish. Algae cover about 20% of stream bed. Population densities are reduced.
Good Quality	Less than 50% of stream channel covered by plants. Algae cover less than 20% of stream-bed; there is a diverse and abundant range of aquatic plants, fish and insects. Insect communities are dominated by favourable species with pollution sensitive populations present.

The third water quality attribute allows us to value the impact of low-flow conditions. This attribute is 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 of the impact of low-flow conditions on rivers and streams was recommended by Ministry for the Environment (2008a, 2008b). The range in levels was guided by flow rate data from the Environment Canterbury website (www.ecan.govt.nz) and Environment Canterbury (2001).

The experimental design involved three attributes with three levels and the cost attribute with six levels (3^3 x 6^1) which were combined in a D-efficient fractional factorial main effects experimental design, providing 18 profiles in order to form the choice sets. The choice sets were constructed following the procedure proposed by Street et al. (2005) which were then randomly blocked into 3 versions of 6 choice sets. Each choice question has three alternatives and the third alternative was always a constant base alternative (current condition). In other words, each respondent in each choice set has to choose either an improved environmental management plan (Alternative 2 or 3) or the current plan (Alternative 1). The constant base alternative was assumed to be a worsening condition of rivers and streams if no change in management occurs. In this alternative, there is no additional payment by the household, however it is assumed that the risk of getting sick will be at its greatest level, ecological quality will be at its lowest level, and the number of low-flow months will be at its highest level.

The survey consisted of three sections. The first section seeks to measure respondents' attitudes towards agri-environmental policy in Canterbury, and to indicate how rivers and streams are important to them. The second section consisted of the choice sets and the third section concludes with household socio-demographic questions. The first and third sections are designed to capture preference heterogeneity that is not captured by the attributes in the choice sets.

The variation generated between the attribute levels and the alternative chosen is modelled using a discrete choice probabilistic method where the dependent variable is the probability of choosing an alternative given the levels of attributes in that chosen alternative. This study fits a Random Parameter Logit (RPL) model to the data obtained in the CE.[4] The deterministic part of the individual indirect utility function estimated takes the general functional form:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_k \eta_{ki} X_{ijk} + \sum_m \omega_{jm} ASC_j * S_{mi} + \sum_n \delta_{kn} X_{ijk} * S_{ni} \qquad \textbf{(1)}$$

where *ASC* is an alternative specific constant for alternative *j*, β_k is a vector of coefficients associated with the *k*th attribute, *X* are attributes that describe the water quality, η_{ki} is a vector of *k* deviation parameters which represents how the tastes of individual *i* differ from the average taste (β_k), ω_{jm} is the vector of coefficients of the interactions between the *ASC* and the *m*th socioeconomic characteristic of individual *i* (S_{mi}) and δ_{kn} is the vector of coefficients of the interactions between the *k*th attribute and the

[4] *Readers who are seeking an in-depth discussion of this model can refer to Train (2003).*

*n*th local water quality characteristic of individual *i* (S_{ni}). This last element of the utility function contains the respondents' local water quality data that is hypothesised to influence their WTP for the attributes contained in *X*.

The choice data were analysed using NLOGIT 4.0™ statistical software. Model variables are summarised in Table 4.3. The attributes are effects coded into two variables for each attribute with the lowest level of quality being the fixed comparator for each attribute; Ecology Fair (coded 1 if Fair, 0 if Good, -1 if Poor) and Ecology Good (coded 1 if Good, 0 if Fair, -1 if Poor); Risk10 (1 if Risk10, 0 if Risk30, -1 if Risk60) and Risk30 (1 if Risk30, 0 if Risk10, -1 if Risk60); Flow1 (1 if Flow1, 0 if Flow3, -1 if Flow5) and Flow3 (1 if Flow3, 0 if Flow1, -1 if Flow5). The non-attribute variables were interacted with the alternative specific constant.

Table 4.3 GIS Model variables

Risk 10	10 people/1000/year sick from recreational contact
Risk 30	30 people/1000/year sick from recreational contact
Ecology Good	Ecological quality is good
Ecology Fair	Ecological quality is fair
Flow 1	1 month of low-flow/year
Flow 3	3 months of low-flow/year
Cost	$15, $30, $45, $60, $75 and $90 per household per year
ASC	Alternative specific constant 1 if alternative 2 or 3, 0 otherwise
Income	Household gross annual income
Safe	Respondent agrees that agriculture is environmentally safe
Commercial	Respondent indicates commercial use of water is important
Businesses	Respondent indicates farms should pay for water improvement policy
SRG	Measure of pathogen presence
SQMCI Score	Measure of ecological quality
Flow Change	Change in flow conditions

The most common distributional functional forms for parameters are normal, lognormal, uniform and triangular. After evaluating the results from various distributional functional forms, I follow Hensher and Greene (2003) and opt for a bounded triangular distribution for all attributes. In order to take into account the degree of heterogeneity whilst obtaining meaningful WTP estimates, the spread of each random parameter distribution was restricted to be equal to the mean.[5] Five hundred shuffled Halton draws are used in maximising the simulated Log-likelihood function. To examine if the effects coded variables for an attribute should be combined into a single linear variable, a Wald test was conducted to observe whether the two parameters (one for each of the two effects coded attribute levels) are equal. The null hypothesis of equality is rejected for all attributes. Thus, preferences for the two attribute levels are statistically significantly different. This nonlinear preference finding would be ignored if the attribute was assumed to be linear.

4.3.1 Water Quality Data and GIS

Three spatially related water quality datasets hypothesised to influence respondents' values of attributes were obtained from Environment Canterbury. The three datasets consist of Suitability for Recreation Grade (SRG), Semi Quantitative Macroinvertebrate Community Index (SQMCI) scores, and daily flow rates. These datasets and respondents' Geocoded addresses were imported into the Geographical Information System ArcView 9™. The geographically closest water quality data points, one for each of the three water quality variables, were obtained for use in the econometric models. Figure 4.1 shows the spatial distribution across Canterbury of the recorder sites for the data and respondent locations. Table 4.4 shows the current distribution of respondents' local water quality measures.

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[5] *See Hensher and Greene (2003) and Hensher et al. (2005) for a description of the triangular distribution in this context.*

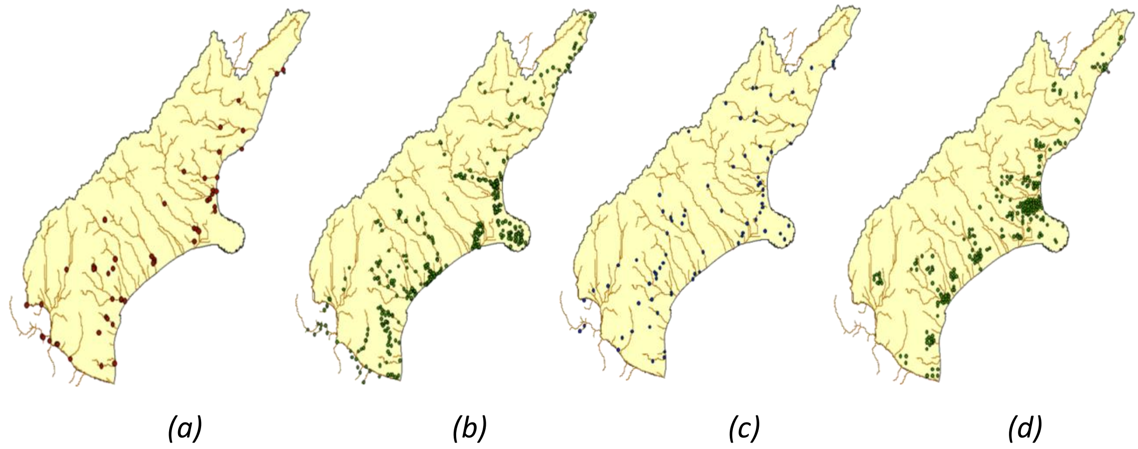

Figure 4.1 Distributions of Water Quality Recorder Sites and Respondents

Key (a) Suitability for Recreation Grade Recorder Sites (b) SQMCI Score Recorder Sites (c) Flow Rate Recorder Sites (d) Respondents Geocoded residential addresses.

The first water quality dataset relates to the Health Risk attribute and contains Suitability for Recreation Grades for 56 sites for the 2007-2008 summer (Environment Canterbury 2008b). The grades are based on Ministry for the Environment guidelines (MfE, 2003) with two components to grading an individual site; the Sanitary Inspection Category generates a qualitative risk assessment of the susceptibility of a water body to faecal contamination, the second component is a measurement of the faecal indicator, *E. coli* (a type of bacteria that can get into food). All sites were sampled weekly during the summer of 2007-2008 (November to February). The 95th percentile value from the last five years sampling are used to construct the current summer grade. There are five grades altogether in the sample: very good, good, fair, poor and very poor. The risk of becoming sick from contact recreation increases from sites graded very good to very poor. Sites graded very good, good and fair are considered suitable for contact recreation, although good and fair sites may at times not be suitable (e.g., after heavy rain). Sites graded poor and very poor are generally considered unsuitable for contact recreation and therefore, public notification is recommended (Environment Canterbury, 2008b). Table 4.4 shows the distribution of respondent's closest grades. For example, as shown in Table 4.4, 70 percent of respondents' closest Suitability for Recreation Grade was very poor.

Table 4.4 Distribution of respondent's local water quality

SRG	% of Sample	***SQMCI Median Score***	% of Sample	***Flow Change***	% of sample
Very Poor	70	0 to 2	13	Increase	6
Poor	4	2 to 3	26	0 to 10% decrease	44
Fair	7	3 to 4	17	10% to 20% decrease	9
Good	4	4 to 6	24	20% to 30% decrease	14
Very Good	15	6 to 7	11	30% to 40% decrease	18
		> 7	9	> 50% decrease	9

The inclusion of this data facilitates the testing of the spatial hypotheses that respondents' local Suitability for Recreation Grade influences their WTP to decrease the risk of becoming sick. This hypothesis is tested by interacting the cost attribute with the recreation grade in the model. This modelling approach follows the literature (see for example; Birol etal. 2006; Scarpa etal. 2003). Moreover this approach is appropriate as respondent's marginal utility of income spent on water improvement is considered to be influenced by their level of local water quality. The parameter of this variable is then employed in the estimation of respondent's WTP for reductions in the risk of becoming sick from contact recreation using equation 2 as shown below:

$$\boldsymbol{Marginal\ WTP_{Health\ Risk}} = -\left(\frac{\beta_{Health\ Risk}}{\beta_{Cost} + \beta_{SRG_i*Cost} \times \boldsymbol{Recreation\ Grade}} \right) \qquad \textbf{(2)}$$

The second water quality dataset relates to the Ecology attribute and consists of Semi Quantitative Macroinvertebrate Community Index scores. The index will be used as indicators for ecological quality on 431 sites. The abundance and diversity of aquatic invertebrates are often used as an indicator of ecosystem health. Biotic indices rely on the fact that biological communities are a product of their environment where different kinds of organisms have different habitat preferences and pollution tolerances. Thus, when an organic effluent is discharged into a stream, intolerant organisms reduce in number or disappear, while those that can tolerate such stresses increase in number. Ideally a healthy body of water will hold an abundant and diverse macroinvertebrate population. The presence of pollution sensitive macroinvertebrates indicates that the body of water is healthy. Alternatively the excessive presence of pollution tolerant macroinvertebrates indicates poor water quality. Each site has at least three observations over at least two hydrological years (the hydrological year is 1 October to 30 September). The medians of scores from January 2006 to December 2008 are used. Table 4.4 shows the distribution of respondent's closest score. Almost a third of respondents closest SQMCI scores are above the Environment Canterbury's objective score of five or more. The inclusion of the data facilitates testing of the spatial hypothesis that respondents' local SQMCI score influences their WTP for improvements in ecological quality. This hypothesis is tested by interacting the cost attribute with the median SQMCI score in the model. The parameter of this variable is then employed in the estimation of respondent's WTP for improvements in ecological quality using equation 3 as below:

$$\textbf{\textit{Marginal WTP}}_{Ecology} = -\left(\frac{\beta_{Ecology}}{\beta_{Cost} + \beta_{SQMCI\ Score_i *Cost} \times \textbf{\textit{SQMCI Score}}} \right) \qquad \textbf{\textit{(3)}}$$

The third water quality dataset relates to the Flow attribute and contains daily flow rate measures for 70 sites. To indicate which rivers are experiencing low flows relative to historical trends, the flow sites were categorised into stratum according to daily median flow for the last hydrological year relative to the median daily flow rate over the entire data series, which is typically three hydrological years. This is a novel approach developed to facilitate variable construction over the 70 sites without the need for in-depth hydrological analysis and recognises that the natural states of particular waterways are characterised by different flow rates. This created six strata describing how flow levels have changed. Table 4.4 presents the definitions of these strata and the distribution of respondent's closest flow change conditions. For example, the table shows that 41 percent of the respondents experienced a decrease in flow associated with their local waterway of 20 percent or more. The inclusion of this data facilitates the testing of the spatial hypotheses that respondents' local flow changes influence their WTP to decrease the number of low-flow months. This hypothesis is tested by interacting the cost attribute with the median flow change in the model. The parameter of this variable is then employed in the estimation of respondent's WTP for improvements in flow conditions using equation 4 as follows:

$$\textbf{\textit{Marginal WTP}}_{Flow} = -\left(\frac{\beta_{Flow}}{\beta_{Cost} + \beta_{Flow\ Change_i *Cost} \times \textbf{\textit{Flow Change}}} \right) \qquad \textbf{\textit{(4)}}$$

The value of benefits from combinations of attribute level changes conditional on respondents' local water quality can be calculated as Compensating Surplus (CS) estimates. Estimates of CS are calculated using a modified standard Hanemann utility difference expression (Hanemann, 1984).

$$CS_i = -\left(\frac{1}{\beta_{Cost} + \sum_r \left(\beta_{Water\ Quality\ Measure_{rl}*Cost} \times \ \textbf{Water Quality Measure}_{rl} \right)} \right) \left(V_{ij}^0 - V_{ij}^1 \right) \qquad \textbf{(5)}$$

where V_{ij}^0 is the utility derived from 'No change' base alternative, and V_{ij}^1 is the utility derived from new management alternatives. The following are the 'No Change' (V_{ij}^0) and the two new management scenarios (V_{ij}^1) employed in this study:

No change 60 people per 1000 get sick from recreational contact each year, ecological quality is poor, and there are 5 months of low-flow conditions.

Management Fair 30 people per 1000 get sick from recreational contact each year, ecological quality is fair, and there are 3 months of low-flow conditions.

Management Good 10 people per 1000 get sick from recreational contact each year, ecological quality is good, and there is 1 month of low-flow conditions.

4.3.2. Survey Logistics

During the months of July and August 2008, 1500 surveys were mailed to Canterbury residents using random sampling stratified by Territorial Local Authority to achieve a geographically representative sample. The mail-out procedure yielded 349 usable responses with an effective response rate of 25 percent. In order to assess if the sample is representative of the Canterbury population, Chi-square tests were conducted. If the null hypothesis is rejected, it can be concluded that the Census 2006 population data are statistically significantly different from the sample data. It is apparent that the null hypotheses are rejected for income, education and house tenure. This means that the sample respondents have higher income, are more highly educated and have a higher home ownership rate.This may indicate sample selection bias toward affluent and educated groups and thus, caution should to be taken when using these variables in the WTP estimation. However, the combination of employing an RPL model and water quality data should be able to account for this bias in terms of individual heterogeneity within income groups and spatial differences amongst respondents when valuing the attributes.

To consider the geographical representation of the sample, a Chi-square test is conducted for the distribution of respondents according to the regions ten Territorial Local Authorities (TLA). Results reveal that the Census and sample distributions are not statistically significantly different.

A relevant concern when conducting a CE in which the experimental design is blocked is whether a sample contains a sufficient representation of the choice sets. The distribution of the three blocks of the experimental design used in this survey was 32, 33 and 34 percent, and therefore, the returned surveys represent the choice sets adequately.

4.4. Results and Discussion

All parameters except Flow 1 are highly statistically significant and of the expected signs. The standard deviation parameters for all attributes except Flow 1 are statistically significant suggesting significant taste heterogeneity exists within the data for these attributes. These factors alongside the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) and McFadden Pseudo R^2 form the basis for a test of relative model fit. The Psuedo-R^2 in Table 4.5 shows that the fully specified model has an acceptable level of explanatory power. Improvements in the levels of the attributes increase the probability of that option being chosen, with the magnitude of the probability increasing as the attribute level improves. All attributes except Flow3 are statistically significant at the 1 percent level. This indicates that respondents did not prefer the medium level of improvement of three months of low-flow but would rather see the highest level of improvement of one month of low-flow conditions. Respondents with higher household income and being a female increased the probability of choosing an alternative with improvements in water quality. Respondents who agreed that agricultural practice is environmentally safe were less likely to choose an alternative with improvements in water quality. Respondents who concurred that farmers should pay for water quality improvement programs were less likely to choose an alternative with improvements in water quality. Similarly, respondents who indicated that commercial use of water is important were less likely to choose an alternative with improvements in water quality. In view of interactions between the water quality and cost attributes, it is apparent that the estimated coefficients for SRG, Flow Change and SQMCI are significant at the 1, 5 and 10 percent levels, respectively.

Table 4.5 Random Parameter Logit model including local water quality

Random Parameters	***Coefficient***	***Standard error***
Risk 10	0.496***	(0.06)
Risk 30	0.201***	(0.06)
Ecology Fair	0.249***	(0.66)
Ecology Good	0.701***	(0.08)
Flow 1	0.329***	(0.07)
Flow 3	-0.108	(0.07)
Cost	-0.057***	(0.01)
Non-random Parameters		
ASC	0.317	(0.41)
Safe	-1.28***	(0.25)
Commercial	-1.23***	(0.37)
Gender	0.699***	(0.25)
Income	0.183***	(0.06)
Businesses	-6.13***	(0.46)
SRG x Cost	0.0046***	(0.001)
Flow Change x Cost	0.0056***	(0.001)
SQMCI x Cost	0.0018*	(0.0001)
Derived Standard Deviations of Random Parameter Distributions		
Risk 10	0.496***	(0.06)
Risk 30	0.402***	(0.13)
Ecology Fair	0.249***	(0.06)
Ecology Good	0.701***	(0.08)
Flow 1	0.329***	(0.07)
Flow 3	0.108	(0.07)
Cost	0.057***	(0.01)
Model statistics		
Log Likelihood	-1464	
McFadden Pseudo R^2	0.37	
AIC	1.41	
BIC	1.45	
Observations	2094	

, **, * indicates significance at 10, 5 and 1 percent level.*

4.4.1. WTP and CS Estimates

Table 4.6 shows WTP for three bands of water quality data for each attribute. The water quality data are averaged within the three bands.

Table 4.6 Willingness-to-Pay incorporating local water quality (NZ$ 2008 per annum)

Water Quality / *Attributes*	***WTP ($) with Inclusion of Local Water Quality***			***Overall Sample Mean WTP ($) Without Local Water Quality data:***
SRG	***< 2***	***2 ≤ grade ≤ 4***	***4 <***	
Risk 10	20.5 (0.6 - 0.3)	16.6 (1.3 - 31.9)	14.1 (1.6 - 6.5)	19.1 (2.2 - 34.6)
Risk 30	16.1 (2.3 - 4.5)	13.1 (1.4 - 27.5)	11 (0.9 - 22.9)	14.9 (2.4 - 20.9)
SQMCI	***≤ 2***	***2 < score < 5***	***5 ≤***	
Ecology Good	27.4 (6.4 - 49)	24.7 (5.8 - 43.4)	23.1 (5.7-0.6)	25.6 (8.5 - 41.3)
Ecology Fair	18.9 (4.5 - 4.1)	17 (3.7 - 30.3)	15.9 (3.6-8.2)	16.1 (4.7 - 26.6)
Flow Change	***> 30% less***	***Up to 30% less***	***Increase***	
Flow 1	15 (4.7 - 27.5)	9.6 (2.7 - 18.8)	5.7 (1.7-12.9)	7.1 (1.6 - 13.4)

95 percent confidence intervals in brackets calculated from unconditional parameter distribution.

Respondents' WTP increases as the water quality deteriorates. For either level of the 'Risk' attribute, respondents with low SRG have higher WTP in order to reduce the risk of getting sick relative to respondents with high SRG (scores shown are coded from 1 = Very Poor to 5 = Very Good). For either level of the 'Ecology' attribute, respondents with low SQMCI scores have higher WTP in order to improve ecological quality relative to respondents with high SQMCI scores. Respondents who experience a high number of low-flow months are willing to pay more so as to reduce the number of low-flow months relative to respondents who experience a low number of low-flow months. It is also interesting to note that there is a substantial difference in terms of absolute mean WTP values between the respondents' local water quality grades and the overall sample mean estimates. Thus, accounting for respondents' local water conditions in nonmarket valuation can differ considerably suggesting that valuing water quality attributes by stratifying individuals based on close proximity to rivers and streams provides more plausible welfare measures than asking respondents the overall qualities of rivers and streams in a region. As mentioned, the sample is biased towards affluent and more educated respondents and as a result, may over or under estimate the 'true' WTP if reliance is placed on the traditional sample mean WTP estimation approach.

Included in the surveys preliminary section was a set of questions that elicited respondent's perceptions of environmental quality in Canterbury on a likert scale. There is an interesting relationship between what respondents consider the quality of Canterbury surface water to be, and there actual local biophysical water quality. To describe this relationship, Pearson's Correlation Coefficients are calculated. This reveals that a respondent's perceived quality of surface water is positively correlated with both the SRG, and the SQMCI, at 0.18 and 0.38 respectively.

Compensating Surplus (CS) measures policy outcomes that indicate WTP for a change in water quality from the 'No Change' option presented in the choice sets to a combination of attributes that depict water quality improvements (Fair and Good Management Scenarios). Calculating Canterbury spatially weighted aggregate CS that takes into account the influence of respondents' local water quality involves the percentage of respondents who live in the combinations of three water quality variables (SRG, SCMI Flow Change) multiplied by both the number of households in Canterbury and average CS estimates as shown in Table 4.7. For example, for the first row 24 percent of the sample faced this combination of water quality variables and associated CS values calculated using equation 3. To form an estimate for the Good Management scenario for Canterbury I first assume that 24 percent of the policy target also face this combination and multiply the $141 individual household estimate by 24 percent of the 201,660 households in the Canterbury region (SNZ, 2006), yielding $6.7 million annually. Estimates of this calculation for each combination of water quality variables are shown in Table 4.7 as weighted aggregates. Summing these values produces the $27.4 million estimate presented in Table 4.8.

Table 4.7 Individual Compensating Surplus incorporating local water quality ($NZ 2008 /annum)

Local Water Quality			***Respondent Distribution***	***Individual Compensating Surplus ($)***		***Weighted Aggregate CS ($000's)***
SRG	***Flow change***	***SQMCI***		***Fair Management***	***Good Management***	***Good Management***
< 2	up to 30% less	2 < Score < 5	**24%**	118 (33 - 203)	141 (20 - 262)	6,730
< 2	up to 30% less	5 ≤	**16%**	106 (39 - 174)	127 (28 - 225)	4,050
< 2	> 30% less	2 < Score < 5	**11%**	147 (33 - 260)	177 (20 - 330)	4,044
< 2	up to 30% less	≤ 2	**10%**	132 (30 - 236)	158 (14 - 304)	3,043
2 ≤ grade ≤ 4	up to 30% less	2 < Score < 5	**7%**	100 (42 - 160)	119 (32 - 208)	1,765
< 2	> 30% less	5 ≤	**5%**	132 (30 - 236)	158 (13 - 304)	1,565
4 <	up to 30% less	2 < Score < 5	**4%**	83 (44 - 122)	98 (37 - 160)	851
4 <	> 30% less	2 < Score < 5	**3%**	97 (43 - 152)	115 (33 - 197)	744
4 <	up to 30% less	5 ≤	**3%**	77 (44 - 111)	91 (37 - 146)	683
2 ≤ grade ≤ 4	> 30% less	2 < Score < 5	**3%**	124 (31 - 217)	147 (16 - 280)	776
2 ≤ grade ≤ 4	up to 30% less	5 ≤	**2%**	92 (43 - 141)	109 (35 - 185)	531
2 ≤ grade ≤ 4	> 30% less	5 ≤	**2%**	111 (38 - 184)	132 (27 - 238)	560
< 2	Increase	5 ≤	**2%**	77 (44 - 111)	91 (37 - 146)	314
< 2	Increase	2 < Score < 5	**2%**	83 (44 - 122)	98 (37 - 160)	417
< 2	> 30% less	≤ 2	**1%**	168 (16 - 322)	201 (8 - 396)	244
2 ≤ grade ≤ 4	up to 30% less	≤ 2	**1%**	111 (38 - 184)	132 (27 - 238)	232
4 <	> 30% less	5 ≤	**1%**	89 (44 - 135)	106 (36 - 176)	321
4 <	Increase	5 ≤	**1%**	61 (40 - 82)	72 (36 - 109)	87
4 <	Increase	2 < Score < 5	**1%**	64 (42 - 87)	76 (36 - 116)	88
4 <	up to 30% less	≤ 2	**1%**	89 (44 - 135)	106 (36 - 176)	306

95 percent confidence intervals in brackets calculated from unconditional parameter estimates.

Table 4.8 also shows estimates using sample mean values where CS estimates do not account for respondents' close proximity to rivers and streams water quality characteristics. This enables a comparison of the CS estimates with and without local water quality data. In order to aggregate the CS across the population, assumptions have to be made about the non-respondents who did not return the survey. For illustrative purpose, I calculate the average aggregate CS based on different multiplier assumptions as suggested by Mitchell and Carson (1989). I calculated the aggregate CS based on the multipliers 0, 0.5 and 1. If 0 is used as a multiplier, I assume that non-respondents are not willing to pay anything. If the multiplier is 0.5, I assume that each non-respondents' WTP is half of the WTP of a sample respondent. The third assumption is that non-respondents have the same mean WTP as respondents and the multiplier is 1. The results of these calculations are presented in Table 4.8.

Table 4.8 Canterbury Compensating Surplus incorporating local water quality (2008 NZ$ millions/annum)

Aggregation multiplier	α = 1		α = 0.5		α = 0	
Management scenario	Fair	Good	Fair	Good	Fair	Good
Spatially weighted CS aggregation	22.9	27.4	13.7	17.1	5.6	6.7
Sample mean CS aggregation	10.2	11.9	6.3	7.4	2.5	2.1

In Table 4.8, it is noticeable that the aggregation that takes into account the respondents' local water quality data is 125 percent higher for the Fair Management scenario ((22.9 - 10.2)/10.2) and 130 percent higher for the Good Management scenario ((27.4 - 11.9)/11.9) assuming non-respondents have the same mean WTP as sample respondents. This suggests that water management programs in Canterbury would be undervalued if the traditional sample mean CS was used to assess aggregate benefits. Using respondents' local water quality data facilitates a better capture of the distribution of benefits and thus a more appropriate estimation method. The increase in CS from base to Fair and Good Management scenarios indicate that where respondents' local rivers and streams are generally poor in quality they are willing to pay more for higher levels of improvements in water quality.

4.5. Policy Implications and Conclusions

The results reported in this paper have important implications for both agri-environmental policy managers and for choice modelling practitioners. For policy managers, practical application of policies with strict budget constraints inevitably necessitates trade-offs being made. The trade-offs could be based upon aspects of water quality, which rivers and streams are to be targeted, and which one to choose first. The results of this study may help to answer these questions. First, recognising the importance of the selected attributes that require great attention can be considered. Based upon the results from this study, Canterbury residents will benefit most by improving the ecology quality, followed by reducing the risk of sickness and finally, reducing the number of months that a river is in low-flow. Secondly, by showing that further benefit is gained by targeting the relatively lower quality rivers and streams initially. For policy practitioners, by modelling the relationship between the GIS based water quality data applying the method developed in this paper, they will be able to use the estimated values as proxies of benefits to evaluate policy actions across rivers and streams within Canterbury.

Implications for choice modelling practitioners stem from the finding that individual welfare is spatially sensitive, and that omission of this facet from aggregate CS calculations may bias results. The primary purpose of this paper is to test spatial hypotheses regarding respondents' local water quality and quantity, and their WTP for improvements in water quality attributes. Respondents' WTP for improvements in ecological quality is influenced by the ecological quality of their local rivers and streams.

The lower the ecological quality, the higher is their WTP to improve it. Respondents' WTP for fewer low-flow months is influenced by flow conditions in their local rivers and streams. The poorer the flow condition, the higher is their WTP to reduce the number of low-flow months. Respondents' WTP to decrease the risk of getting sick is influenced by the SRG of their local rivers and streams. The lower the grade the higher is their WTP to decrease the risk of becoming sick. These findings suggest that regional water management authorities can improve allocation of their limited resources by targeting relatively low quality waterways. Overall, the respondents valued improvements in ecological quality the most, followed by decreasing the risk of sickness and lastly, decreasing the number of low flow months.

This paper presents aggregate benefit values that are suitable for cost benefit analysis. Benefits of combinations of policy outcomes can be assessed using CS estimates. This study finds that inclusion of the respondents' local water quality data has a significant impact on the magnitude of CS estimates. Aggregate CS estimates that incorporate the spatially distributed water quality data are more than 100 percent larger than the overall sample mean traditional CS estimates.

The main contribution of this paper is the development of a method to incorporate respondents' local water quality data via GIS in estimating WTP and CS for agri-environmental policy. By including respondents' local river and stream water quality data, the analyst is able to form a range of estimates dependent on the specific areas water quality. In short, the spatially distributed WTP estimates for highest (lowest) levels of improvements in water quality attributes are greater (smaller) than the sample average WTP. Therefore, benefit aggregation based on sample average WTP with no spatially distributed water quality information may result in biased estimates. Further research investigating the spatial impact of policies is needed to form a better understanding of how individual benefits relate to the costs of policy implementation. That analysis could also be conducted in a GIS and, combined with spatial WTP data, could aid in indicating where policy is achieving a net benefit.

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Chapter 5: Summary, Limitations and Future Directions

5.1. Introduction

The costs of environmental policies aimed at reducing the impact of agriculture on Canterbury's waterways are relatively straight-forward to measure, while the benefits are diffuse and more difficult to financially quantify. This study set out to help fill this information gap and aid policy makers in prioritising agri-environmental policy resources.

Internet surveys for non-market valuation are emerging as the dominant survey mode. There are concerns about the ability of this survey mode to provide reliable welfare estimates. This thesis aimed to provide an examination of these concerns.

Aggregate welfare measures often rely on sample mean values. This reliance is problematic in a spatially diffuse policy setting and could lead to biased estimates. This thesis aimed to examine this issue by testing spatially explicit hypotheses concerning effects on welfare measures.

The study undertaken is important for three main reasons: agri-environmental policy valuation is imperative for development of efficient policies, the use of internet sampling for non-market environmental valuation is inadequately covered in survey mode literature, and aggregate welfare measures of environmental values that rely on sample mean values may bias results.

This study consists of three empirical manuscripts where each focuses on a particular technical element of nonmarket valuation. The first manuscript examines the core valuation exercise applying a random utility theorem via a choice experiment modelling. The second manuscript assists in the assessment of the viability of the internet survey mode. The third manuscript uses a GIS method exploring the role of spatially heterogeneous preferences among the respondents who live in the vicinity of or in the areas of degraded water quality.

In this final chapter a succinct summary of the key findings are made that leads to a discussion on the study limitations that exist in each of the three manuscripts. The chapter also makes some suggestions on how to overcome the limitations as a matter for future research. The following sections explain each manuscript's key points, limitations and suggest future directions for research.

5.2. Manuscript 1 titled 'Valuation of Agricultural Impacts on Rivers and Streams using Choice Modelling: A New Zealand Case Study'

Rural water quality and quantity concerns in New Zealand are in most cases intrinsically related to agriculture. Valuation of preferences for mitigating agricultural impacts on rivers and streams is lacking in policy debate. This paper employed a choice experiment to estimate economic values of agricultural impacts on rivers and streams in the Canterbury region of New Zealand where increasing replacement of dry land pastoral and arable farming by water intensive farm practices have placed pressure on water resources. Three impacts were considered: health risks of pathogens from animal waste, ecological effects of excess nutrients, and low-flow impacts of irrigation. This study provided a valuation of outcomes for public agri-environmental policy implemented in Canterbury such as The Dairy and Clean

Streams Accord, Living Streams, and The Restorative Programme for Lowland Streams. Significant differences are found between willingness-to-pay estimates derived from multinomial logit and random parameter logit models for some water quality attributes. Based on the results from the RPL model, the five year present value of compensating surplus for a management programme that achieves good ecological quality, one month of low-flow conditions per year and ten people out of a thousand getting sick each year is estimated at $186,000,000.

A limitation of the research is the response rate of the survey that could be considered relatively low at twenty-five percent. The burden of relatively high cognitive demands on respondents to complete the choice experiment may be a contributing factor although each respondent was asked to complete just six choice sets which could be considered to be a relatively low number. The use of the self-administered mail-and-return survey mode could also be a contributing element, given that choice experiments are not commonplace in New Zealand. It is unlikely that respondents would have previously been exposed to this survey method, and so they may have benefited from a personal interview survey mode where questions and concerns could be addressed directly. Given the limited budget of the project no financial inducement was offered. There were a relatively low number of respondent contact times - first mail out, reminder and second follow-up mail out. This three contact procedure was not in line with Dillman (2007) recommendations who suggest more contacts including a pre-survey notification, and a financial inducement.

A low response rate does not necessarily indicate the presence of non-response bias, where the inclusion of those who did not answer the survey would significantly affect model estimates. However, in general the lower the response rate the more likely that there is some non-response effect. Combined with the relatively unrepresentative nature of the sample, the present research could be enhanced by a non-response analysis. That analysis would involve contacting and surveying those in the sample who did not respond. The primary focus would be to identify reasons for non-participation and to collect variables that could be used to match the non-respondents with those that did respond. This would facilitate an adjustment of the modelling method to incorporate the preferences of non-respondents. The ability to conduct such an analysis is hampered by the lack of telephone numbers for the sample. Any contact with non-respondents must be made using the mail system which is costly. Unfortunately the added expense of financial inducements, increased respondent contact, personal interviews and non-respondent analysis were beyond the budget for this research. Future study in this area would benefit from research design incorporating non-response bias analysis as this would give more validity to results.

The valuation frame for this study is regional as this was considered by regional water policy makers to be the most beneficial approach. This method contrasts with a valuation frame that is site-specific where respondents are asked to express their preferences over a particular river for example. Employing a regional valuation frame, respondents are asked to express preferences for water quality changes in all rivers and streams in Canterbury. In doing so an assumption is implied that changes in water quality are valued the same irrespective of which waterway the change took place in. This assumption may not hold as some waterways have greater significance than others. For example, a small lowland stream that has few direct users may hold less value than a major river with many direct users. The concern is that this assumption may influence aggregate welfare measures for the Canterbury region. Future research in this area could contrast the welfare estimates generated in this study with those generated employing site-specific valuations that have been scaled up to regional level. This could be achieved using benefit transfer methodology that has an established literature to draw on. That approach could perform several valuation exercises focused on distinct river and stream types, possibly disaggregated based on biophysical characteristics. Once the individual river and stream type values were obtained, a weighted aggregate regional value could be formed by apportioning values relative to the number of river and stream types (corresponding to the types valued) that occur in Canterbury.

5.3. Manuscript 2 titled 'Comparing Internet and Mail Survey Modes in Environmental Valuation: Implications for Welfare Estimates'

This paper presented a comparison of internet and mail survey modes for non-market valuation. There are concerns that internet mode effects such as sample frame bias and self-selection processes undermine the ability of this mode to collect reliable data. The aim of the paper was to investigate the capability of internet surveying to provide robust welfare estimates of environmental goods. Results from a choice experiment valuing agricultural impacts on rivers and streams in Canterbury, New Zealand are compared based on three main testing procedures. Chi-square tests of respondent characteristics provide an indication of the impact of sample frame and self-selection bias. A test of parameter equality across mail and internet Random Parameter Logit models is then conducted employing the Swait and Louviere (1993) approach. Finally, differences in the derived welfare estimates are assessed using the Poe (2005) Complete Combinatorial method. Some evidence of framing and additional self-selection bias in the internet sample is found. The null hypothesis of parameter equality across survey modes is rejected, however this difference in cognitive processes between samples does not translate into significantly different willingness-to-pay (WTP) or compensating surplus (CS) estimates. Overall this case study supports the use of internet sampling to obtain viable welfare estimates of environmental policy.

A limitation of this paper stems from the respondent recruitment method. As there is no complete list of internet users from which to draw a sample, a method of making contact with possible respondents is required. Email lists, pre-recruited panels and host site survey links are common methods in environmental valuation literature. The thesis uses links to the survey placed on host sites. The concern is that this choice may limit the ability to generalise results over different respondent recruitment methods. The collection of demographic information of people in the internet sampling frame actually employed could aid in identifying self-selection processes across respondent recruitment methods. For the thesis this means collecting demographic data of the usual users of Environment Canterbury web site, information that is currently unavailable. Useful future research could investigate the impact of alternative sample recruitment methods on samples. Specifically, attention could be focused on identification of self-selection processes distinctive to the recruitment method. In this way practitioners may be able to identify favourable recruitment methods.

The capabilities of an enhanced survey interface afforded by use of computers have not been explored here. However it seems inevitable that presentation formats not typically used in surveying will become evident. These are likely to include audio-visual information that could not otherwise be presented to respondents. The effects of these elements are avenues for future research, in particular how they might influence welfare measures.

Further research contributing to the survey mode literature could conduct direct empirical analysis of self-selection processes and sample-frame bias under different internet sampling approaches. This could involve a parallel surveying procedure wherein identical surveys are administered to different samples based on varying sample recruitment methods. This would facilitate an examination of how different recruitment methods characterise a sample. A complementary avenue of research could examine these issues in a controlled environment wherein survey participants are given the option of which survey mode they would prefer to complete a survey with, and this choice is observed and modelled with explanatory variables elicited directly from participants. This vein of research could contribute to isolating pure survey mode effects, those effects of using a computer rather than verbal or written provision of responses, from the effects of sampling limitations. Currently there is a lack of insight in this area for non-market valuation.

This paper demonstrated the growing role of information technology in environmental valuation highlighting the advantages of the internet mode to collect usable samples. The use of computer technology also facilitates the ability to collect data that is not otherwise able to be collected in traditional survey methods. Typically in self-administered surveys self-reported data is used to analyse decision processing questions, however the use of computer technology allows for unreported data to be measured and captured that may shed light on respondent strategies (Kaye-Blake et al., 2009). These measures could include the time to complete the entire survey as well as each section, amount of information read and order of answer completion. Future research could explore the types of relevant measures that can aid in the identification of choice processing strategies. To employ computer administration requires either a computer laboratory or interviews using laptops, and both approaches are typically expensive. The current research indicates the potential for such surveys to be conducted on the internet using a respondent's own computer, therefore lowering surveying costs.

5.4. Manuscript 3 titled 'Nonmarket Valuation of Water Quality: Addressing spatial heterogeneous Preferences using GIS and Random Parameter Logit Model'

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 was to test spatial hypotheses regarding respondents' local water quality and quantity and their willingness-to-pay for improvements in water quality and quantity attributes. This paper combined choice experiment and spatially related water quality data via a Geographical Information System to develop a method that evaluates the influence of respondents' local water quality on willingness-to-pay for river and stream conservation programs 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 finds that disregarding the influence of respondents' local water quality has a significant impact on the magnitude of welfare estimates and causes substantial underestimation of aggregated benefits.

A limitation of the spatial heterogeneity paper stems from some characteristics of the biophysical data used. The three biophysical data sets used are; Suitability for Recreation Grade (SRG), Semi Quantitative Macroinvertebrate Community Index (SQMCI) scores, and daily water flow rates. The only practical source of geographically referenced biophysical data was Environment Canterbury. The main concerns about the validity of these data sets centre on issues of distance between respondents and monitoring sites. There were 56 monitoring sites for the SRG, 70 sites for SQMCI scores and 431 sites measuring daily flow rates. The location of the SRG sites reflects the public use of the site as a popular swimming location. Flow rate monitoring sites are primarily chosen to provide data used for water allocation management such as irrigation restrictions. SQMCI sites are reasonably evenly distributed across Canterbury to provide information for land use and water resource management. The ideal data sets would contain measurements taken from rivers or streams geographically closest to respondents' residence and therefore most relevant to their decision making process in the CE. This would also enable the formation of a consistent definition of what is to be considered as local water quality across respondents. Unfortunately this is not the case and the outcome is that for a number of residents the biophysical data matched to their location is not the geographically closest possible. To improve on this situation requires accurate monitoring of sites closer to respondent's addresses. To achieve quality monitoring data comparable with that collected by Environment Canterbury is expensive and requires an extensive time frame. Investigation of different approaches to defining what is considered local is an opportunity for future research.

A further limitation concerns the possibility that other spatial correlates of WTP have been un-observed and therefore emitted from the analysis. The exploration of covariates is not undertaken in this thesis. However since the biophysical covariates chosen for modelling are directly related to the attribute variables modelled they are considered to be the most significant determinants of possible spatial variation.

An interesting extension of the GIS based analysis involves the role of biophysical information provision to respondents. Perceptions of health risks in particular may be effected by the provision of information to respondents (Poe and Bishop, 1999). Providing respondents with water quality measurements from their local rivers and streams prior to undertaking a CE may influence their WTP compared to respondents who are not informed. In the current research, householders were not informed in the surveys of local water quality measurements. The use of GIS facilitates such research by being able to identify possible respondent's local water quality prior to the surveying procedure. These water quality measures can then be included in the survey instrument respondents receive.

A useful extension of the current work that utilises the spatially related dataset generated for this paper would be to construct spatial and temporal water quality value grids using geostatistical programming. This facilitates the formation of water quality value maps to illustrate spatial distribution. These maps could then be combined with spatial modelling of the implementation of agri-environmental policies, that is, where do pollution mitigating-water quality enhancing activities take place and what is their efficacy. The result is a GIS map with values in one layer and implementation activities over layered, thus showing the junction of where policy is efficiently deployed. This method of spatially combining non-market values with policy activities could aid water policy makers in targeting resources efficiently.

5.5. Additional Future Directions

This section briefly describes several additional research streams that may be undertaken relevant to the junction of policy valuation and discrete choice modelling. The sophistication of discrete choice models are constantly evolving. Over the study period, there have been three developments in the choice experiment literature that have not been addressed in this study. It is noteworthy that these developments are mentioned as additional future research directions for environmental valuation. The following developments are as follows:

a) ***WTP space modelling;***
b) ***Efficient design of experiment technique;***
c) ***Respondents' choice processing strategies;***

An emerging method to generate distributions of WTP is the so-called WTP-space model. This method could be another option for exploring welfare measures. WTP-space modelling allows estimated parameters to be directly interpreted as parameters of implied WTP distributions (Train and Weeks, 2005; Sonnier et al., 2007; Scarpa et al., 2008, Fiebig et al., 2009; Thiene and Scarpa, 2009). The usual approach to obtaining welfare measures is indirectly through the distributions of utility weights that are then used to derive WTP distributions in a secondary process. This method is not altogether new. Contingent valuation data has in the past been analysed with this approach (Cameron and James, 1987; Cameron, 1988). Its reappearance is primarily in response to the complications in deriving WTP distributions from RPL models (Das et al., 2009). The role of this approach for choice modelling has yet to be determined in the literature and further case studies are required. Currently, mainstream econometric software does not allow the estimation of WTP-space models. Research examining possible sensitivities of WTP distributions to alternate specifications of random parameter distributions is particularly important.

In this study attribute level combinations forming alternatives were varied using a D-efficient main effects fractional factorial experimental design. Widely employed in choice experiments across many disciplines, this approach corresponds to minimising on average the elements of the expected asymptotic variance covariance matrix including standard errors. This leads to the smallest possible confidence intervals around parameter estimates and the maximisation of asymptotic t-ratios for each parameter, characteristics that are undoubtedly important. The recent public release of N-gene™ experimental design software has now made it possible for mainstream choice experiment practitioners to explore the role of many experimental design techniques. One of which is the C-efficiency criterion that minimises the variance in WTP values derived from parameter estimates (Kanninen, 1993; Scarpa and Rose, 2008). Further research is required to determine the importance of this approach to experimental design and, in particular, the impact on WTP distributions.

In non-market environmental valuation applications, advantages may be found in taking into account respondents' decision making strategies, in particular discontinuous preferences and attribute non-attendance. The ability to incorporate information use into modelling procedures may add validity to welfare estimates. If respondents act as though more of one good cannot be measured against less of another then this may demonstrate non-compensatory or discontinuous preferences. The implications of discontinuous preferences for empirical estimation of welfare estimates have been investigated (McIntosh and Ryan, 2002). However, they remain relatively unexplored in environmental valuation literature (Scarpa et al., 2009). The ignoring of attributes in the choice task has been empirically analysed (Scarpa et al., 2009, Hensher and Greene, 2009) although is again, remains relatively unexplored in non-market environmental valuation literature. The restricted Latent Class model approach operationalises attribute non-attendance, and therefore discontinuous non-compensatory preferences by allowing some respondents to belong to latent classes with zero utility weights for ignored attributes (Scarpa et al., 2009). This method of assessing preference structures has the advantage of being able to be applied retrospectively to data sets. The implications for WTP from accommodating discontinuous preferences in the econometric specification requires further case study. Future research using the current data set could provide an illustration to this end that forms a comparison with traditional modelling approaches.

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Appendix 1: *Environment Canterbury Expert Opinion Survey*

Along with policy document review, this survey formed part of the qualitative phase of attribute determination to identify policy relevance in application of study output as well as attribute level definitions and sensible attribute level ranges. It was administered via email to those staff considered relevant to water management in relation to agriculture including scientists and managers.

Agricultural impacts on surface and groundwater

Thank you for taking the time to look at this survey, it should take about 5-10 minutes to complete.

This survey is part of PhD study at Lincoln University that aims to estimate economic values of agricultural impacts on surface and groundwater in Canterbury. The information that you provide will aid in the formation of a survey instrument to be administered to Cantabrians later this year.

Part of the first stage in implementing the valuation methodology requires surveying those involved in the policy making process to identify those agricultural water impacts that are relevant to policy makers and the policy process. How these impacts are measured (i.e. measurement units), and observed ranges of those measurements are also required. For example, faecal contamination of waterways is measured by *E. coli* levels that are described as parts per million, then compared with a quality/safety standard. Similarly with nitrogen contamination.

Q1: What agricultural impacts on surface and/or groundwater are you familiar with in your general activities at Environment Canterbury?

Q2: Please rank the 4 most significant impacts in order by placing a number next to the list above with 1 representing the most significant impact.

Q3: How are these impacts measured?

Q4: What is the range of typically observed values for these measurements?

Q5: What is your job description at Environment Canterbury?

Thanks again. Please return completed questionnaires to myself Peter Tait, email: taitp1@lincoln.ac.nz .
Feel free to add any questions, concerns or comments.

Appendix 2: *Focus Group Discussion Guide*

Section 1

Greeting, purpose, ground rules,

Welcome I'm Peter Tait and I'll be conducting the discussion we're here for today.

We're here to discuss your opinions and experiences of the environmental performance of agriculture in Canterbury. We'll discuss any problems from your perspective, and any possible solutions that your might have.

Your comments are confidential. I will ask a question and each participant will give a response one at a time, then the group can discuss interactively. It all comes down to individual opinions, there are no wrong or right answers.

Get participants to introduce themselves and describe their job or profession.

Section 2

Focus statement assessing informational requirements

We are designing a questionnaire, and we are interested in what needs to go in the questionnaire. What do people think is important about the issue we are interested in.
I'll just mention the bare basics about the issue and then I'll ask you what you think you need to know to be able to answer the sort of questions we'll be asking in the questionnaire.

So I'd like you to think about an environmental issue in Canterbury. Here is a map of Canterbury, and we're interested in the types of agricultural pollution and their effects, that are occurring within this area.

[Show map, either on paper or ohp or ppt]

Canterbury is a fertile farming province with a diverse range of agricultural practices operating. The main land use is arable farming. The main livestock operations are dairy, beef, deer and sheep. There are about 600,000 dairy stock units, 530,000 beef stock units, 450, 000 deer stock units and 430,000 sheep stock units.

[Show graphs of sector trends; land use change, stock unit number change]

The issue concerns pollution from agricultural. There are various options the regional authorities can adopt for managing agricultural pollution and the authorities would like to know what the community thinks about the various options it has….

Let's suppose that regional authorities are thinking about 2 different ways of managing agricultural pollution. There are 2 different management options. They might involve different amounts of pollution in waterways. Or in different areas, or whatever. Without telling you anymore, can you give me an idea of what you would need to know to be able to say something like 'management option A is better than management option B.'

[Facilitator draws an A and a B on the whiteboard]

In the questionnaire we are going to ask people which option they prefer. What sort of information would you need to know?

Section 3

General discussion questions

Q: What types of agricultural pollution are familiar to you, either thru personal experience or media exposure?

Q: Agriculture also provides positive values that farmers do not get paid for, these are values such as scenic views, open space, and a ecosystem services such as flood protection and carbon sequestration. Are you aware of any of these values, either thru your own experience or thru media exposure?

Q: Monitoring data for Canterbury freshwater sites (rivers and lakes) indicate that approx 70% of freshwater sites monitored in Canterbury are not suitable for contact recreation. Do you find this acceptable?

Q: Have any of you been to a freshwater site and seen a sign warning of pollution and/or health risks?

Q: Does agriculture have the right to use waterways to dispose of farm effluent?

Q: Agriculture is a main exporter in Canterbury; do think that agriculture benefits from the clean green image?

Q: In what way? By how much? (A quarter of total value, half etc)

Q: Do Canterbury residents have the right to expect to be able to use a fresh water site of their choice?

Q: What types of policies do you think would help reduce agricultural pollution?

Section 4

Draft instrument test

[Distribute draft instrument]

Discuss draft survey

Use this set of likert questions to prompt discussion.

Thinking about questions 7 to 12, and the information presented earlier in Section B, please indicate how strongly you agree or disagree with each of the following statements:

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
I felt I needed more information than was provided					
I thought the information was biased in favour of continued pollution					
I thought the information was biased in opposition to continued pollution					
I found questions 7 to 12 extremely difficult					
I did not like questions 7 to 12					

Closing comments

Q: Any final suggestions?

Thank you for your time and input.

Appendix 3: *Survey Instrument*

Agricultural environmental values survey
P.O. Box 84
Lincoln University
Canterbury, New Zealand

Agriculture and Water in Canterbury

Dear sir/madam

My name is Peter Tait, I am studying for a PhD degree in economics at Lincoln University. My research focuses on ways to manage agricultural pollution. The goal is to help improve pollution minimisation programmes in Canterbury.

Recent debate has highlighted some important concerns about management of agriculture in Canterbury. Agricultural production systems produce environmental costs and benefits that are not transmitted through markets for the goods produced - they are externalities. Environmental costs are borne by society at large, and are not taken into consideration when farmers make profit maximising decisions. As agricultural output increases and production methods industrialise and intensify, the amount of agricultural by-products such as pollution increases. The pressures that this creates are felt environmentally as well as socially. The primary purpose of this research is to estimate economic values for various environmental externalities of Canterbury agriculture.

Agricultural exporters gain significant values from a "clean green" image, as do many other sectors of the economy. Recent research has estimated that approximately half the value of many agricultural exports will be lost if the clean green image is harmed. The emphasis must shift to pollution minimisation.

By completing and returning this survey you will provide information that will help assess the benefit of introducing, and continuing, strategies to minimise agricultural pollution in Canterbury.

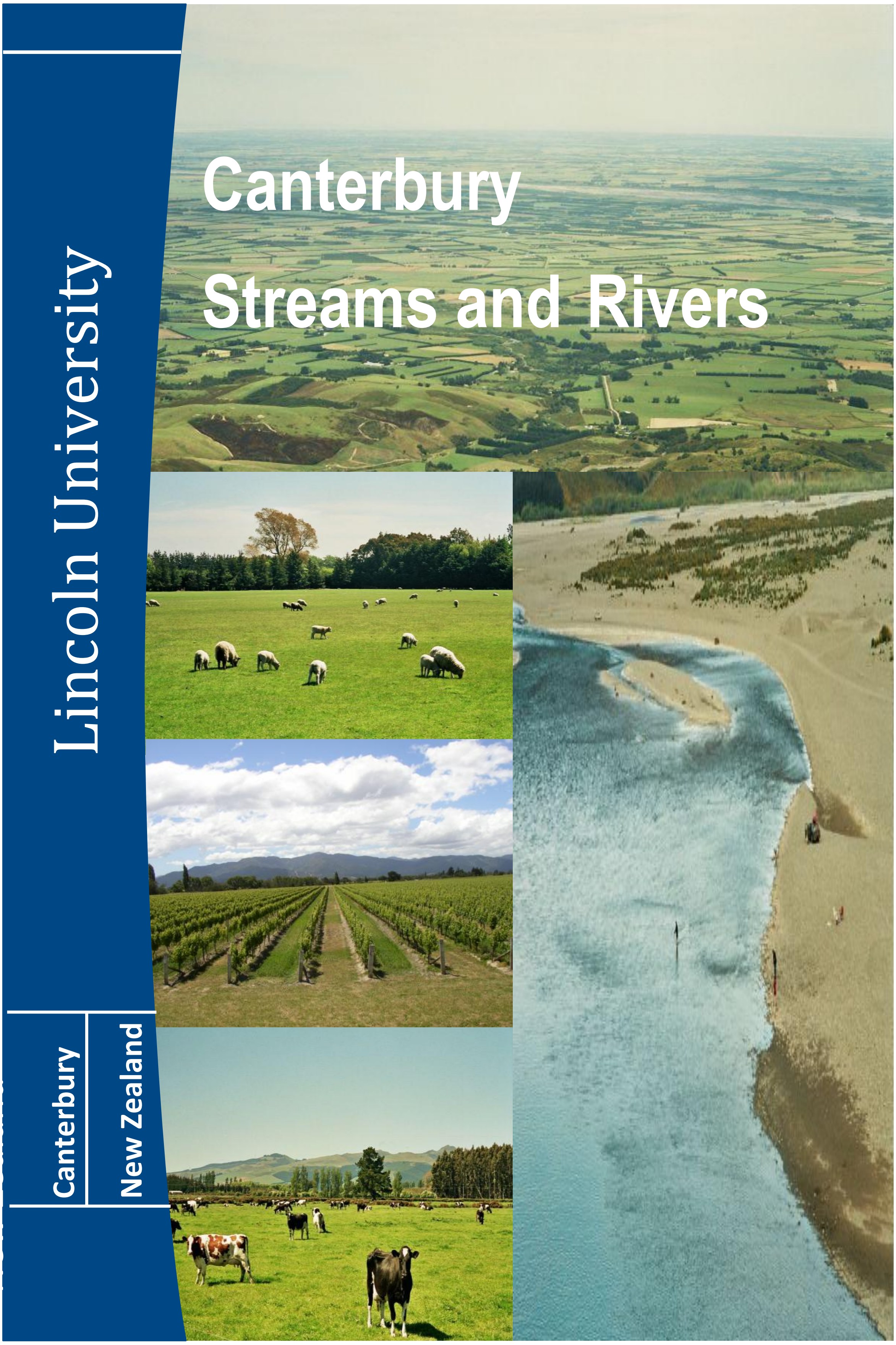
The Human Ethics Committee at Lincoln University has approved this research. Participation in this survey is totally voluntary. All information you provide is entirely anonymous and confidential, and as such your name will never be associated with your response.

Please complete this survey if you want to and understand the information in this letter, and the content of the questions. Do not hesitate to contact me or my supervisor Dr Ross Cullen, if you have any questions or concerns. By completing and returning this survey you are consenting to your response being used for this research project. There are no right or wrong answers to any of the questions. The survey will take about 15 minutes to complete.

Kind regards

	Peter R Tait	Dr Ross Cullen
Email:	taitp1@lincoln.ac.nz	Cullenr@lincoln.ac.nz
Phone :	03 3252811 extn 8607	03 3252811 extn 7807

Canterbury Streams and Rivers



You are invited to participate in a project called:

Assessing the Role of Agricultural Impacts on Canterbury Streams and Rivers

by completing the following questionnaire.

We want to know your views on different options of how best to manage your local streams and rivers. This will help to manage this water resource the way Cantabrians want.

Please complete this questionnaire, even if you think you don't know much about agriculture or streams and rivers. We need answers from all types of people to ensure we are representing the views of most Cantabrians. There are no wrong or right answers.

1 What is your perception of the quality of the Canterbury environment? Please indicate your choice by ticking the appropriate box.

Do you think the quality of…..	**Very bad**	**Bad**	**Adequate**	**Good**	**Very Good**	**Don't know**
air in Canterbury is						
water in lakes and rivers in Canterbury is						
groundwater in Canterbury is						
soils in Canterbury is						

2 Please indicate your level of agreement with the following statements by ticking the appropriate box.

	Disagree strongly	**Disagree**	**Agree**	**Agree strongly**	**Don't know**
Agricultural production today is environmentally safe					

Canterbury ratepayers as a whole should pay the costs of cleaning up and preventing agriculture's impact on water resources					
Farmers should pay for the costs of cleaning up and preventing agriculture's impact on water					
The agricultural landscape is important in Canterbury					
The agricultural landscape is of no importance for my nature experiences					
A price should be charged for water for irrigation					
Agriculture should fully convert to organic farming methods					

3

Do you use Canterbury streams and rivers directly? What activities do you engage in? Examples include fishing, picnicking, swimming, kayaking, hiking, water skiing.

____

____

4

At what location(s) do you participate in the above activities? Please be as specific as possible, giving the name of the waterway and local area if possible.

____

____

____

5

Rivers and streams in Canterbury are important to people for a number of reasons. Which of the following reasons are most important to you?

- Resource for future generations ☐
- Recreational opportunities ☐
- Habitat for plants and animals ☐
- Resource for commercial development ☐
- I just like knowing that they are there ☐
- Drinking water resource for public ☐
- Other, please specify ☐ ______________________

Effects of agriculture on streams and rivers in Canterbury

An issue facing people in Canterbury is the impact that agricultural practices have on streams and rivers. Run-off from paddocks can carry animal waste, fertiliser, or pesticide residues into streams and rivers harming plants and animals and creating health impacts for people and restrictions on recreational activity, food gathering and aesthetic pleasure.

There are three impacts that we are going to consider in this survey. **(1)** The first is the risk of people getting sick from microorganisms in animal waste that end up in waterways. **(2)** The second is excess nutrients from fertilisers impacting on the ecology of waterways. **(3)** The third is the effect of low-flow conditions on rivers and streams.

(1) Livestock produce large quantities of **waste** containing microorganisms that cause disease such as Campylobacter and Salmonella. Most of this waste is deposited directly on the land by the animal, while a significant amount is collected and either sprayed onto paddocks, or discharged directly into waterways. The risk of people becoming sick increases with the amount of animal waste in the waterway. If we can limit the amount of waste that ends up in waterways then we can decrease the risk of people becoming sick. The risk considered here is from **recreational contact** with rivers and streams. Risk is represented by the **number of people out of one thousand** that become sick in a year. In the following questions you will be asked to consider three levels of risk associated with rivers and streams local to you:

Low risk	**10 per 1000 people**	**(1%)**
Medium risk	**30 per 1000 people**	**(3%)**
High risk	**60 per 1000 people**	**(6%)**

(2) Run-off containing nitrogen and phosphate from **fertilisers** and **pesticides** impacts on the ecological quality of the waterway. The excess nutrients cause choking weed growth that decomposes and lowers oxygen levels in the water which leads to declining aquatic plant and insect populations. The appearance of the waterway is degraded and recreational activities such as swimming and fishing are impaired. In the following questions you will be asked to consider three levels of ecological quality of streams and rivers local to you.

Poor quality	**Weeds** are the only aquatic plants present and cover **most** of the stream channel. The stream-bed is covered **mostly** by thick green algae mats. Only pollution tolerant insect populations are present. **No fish** species are present.
Fair quality	**About 50%** of stream channel covered by plants. **Few** types of aquatic plants, insects and fish. Algae covering **about 20%** of stream bed. Population densities are **reduced**.
Good quality	**Less than 50%** of stream channel covered by plants. Algae cover **less than 20%** of stream-bed, there is a **diverse** and **abundant** range of aquatic plants, fish and insects. Insect communities are dominated by favourable species with pollution sensitive populations present.

(3) The amount of water used for **irrigation** can impact on the **flow rates** of rivers and streams. Minimum flow levels are designed to protect the ecological and recreational quality of the waterway. A waterway is experiencing **low-flow conditions** when flow falls below this minimum level. Ecological damage can include; less habitat for all aquatic species, impeded fish passage for migration, increased algae that smothers habitat for fish, reduced oxygen for aquatic insects fish and plants, less food source for fish and birds. Recreational activities such as boating, kayaking, swimming and fishing are not possible during low-flow periods. The appearance of streams is also substantially altered. As the amount of water used for irrigation increases the number and duration of low-flow occurrences increases. In this survey you will be asked to consider three levels of low-flow duration in streams local to you. As rivers and streams can run dry naturally, we assume that there is at least one month of low-flow:

1 month of low-flow per year

3 months of low-flow per year

5 months of low-flow per year

There are many policy **options** for **managing** agricultural impacts on Canterbury streams and rivers.

Examples include:

- Fencing to prevent farm animals from entering streams, rivers and lakes and providing bridges or culverts over regular crossing points
- Stricter enforcement of resource consents or regional plan rules for effluent management
- Habitat restoration
- Nutrient budgeting to minimise the amount of nutrient that can make its way into waterways
- Promotion of Organic agricultural systems
- Planting buffer zones around waterways to reduce run-off getting into waterways
- Nitrification inhibitors to aid in reducing the amount of excess nitrogen in run-off
- Irrigation restrictions to minimise low-flow conditions

These management options will cost money and a contribution will be sought from Canterbury residents through rates to households and landowners.

What do you think?

To help determine how the community would like to see the effects of agriculture on streams and rivers managed, we have prepared six sets of management options. We would like to know which management option you prefer the most in each set of options. Each management option is described in terms of four outcomes:

- The number of people who would get sick from recreational contact annually
- Ecological quality of waterways
- The number of low-flow months each year
- The annual contribution that each Canterbury household would make either via rates or rent increase to ensure that management policies are put into practice

Option 1 is the same in each set and shows the outcomes if no change in management occurs. In the 'No change' scenario there would be no annual cost, however it is assumed the risk of getting sick will be at its greatest, ecological quality will be poor, and the number of low-flow months will be at its highest.

As you answer the following questions remember that you can find the meaning of the outcome levels on pages 4 and 5.

6 Now we would like you to indicate by ticking the box below, which option you prefer

Block A

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	10	60
Ecological quality of local streams and rivers	Poor	Good	Poor
Number of low flow months	5	1	1
Annual cost to Canterbury households	$0	$90	$60

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

7 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	10
Ecological quality of local streams and rivers	Poor	Poor	Fair
Number of low flow months	5	3	5
Annual cost to Canterbury households	$0	$30	$30

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

8 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	30
Ecological quality of local streams and rivers	Poor	Poor	Good
Number of low flow months	5	1	5
Annual cost to Canterbury households	$0	$75	$90

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

9 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	10	60
Ecological quality of local streams and rivers	Poor	Fair	Fair
Number of low flow months	5	5	3
Annual cost to Canterbury households	$0	$45	$45

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

10 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	30
Ecological quality of local streams and rivers	Poor	Fair	Poor
Number of low flow months	5	3	3
Annual cost to Canterbury households	$0	$60	$15

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

11 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	10
Ecological quality of local streams and rivers	Poor	Good	Good
Number of low flow months	5	3	1
Annual cost to Canterbury households	$0	$15	$75

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

6 Now we would like you to indicate by ticking the box below, which option you prefer

Block B

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	10	30
Ecological quality of local streams and rivers	Poor	Poor	Fair
Number of low flow months	5	5	3
Annual cost to Canterbury households	$0	$60	$75

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

7 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	60
Ecological quality of local streams and rivers	Poor	Fair	Good
Number of low flow months	5	1	1
Annual cost to Canterbury households	$0	$15	$15

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

8 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	10
Ecological quality of local streams and rivers	Poor	Good	Good
Number of low flow months	5	3	3
Annual cost to Canterbury households	$0	$30	$60

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

9 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	30
Ecological quality of local streams and rivers	Poor	Fair	Poor
Number of low flow months	5	3	1
Annual cost to Canterbury households	$0	$90	$30

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

10 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	10
Ecological quality of local streams and rivers	Poor	Poor	Poor
Number of low flow months	5	1	5
Annual cost to Canterbury households	$0	$45	$45

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

11 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	10	60
Ecological quality of local streams and rivers	Poor	Good	Fair
Number of low flow months	5	3	1
Annual cost to Canterbury households	$0	$75	$90

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

6 Now we would like you to indicate by ticking the box below, which option you prefer

Block C

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	30
Ecological quality of local streams and rivers	Poor	Fair	Good
Number of low flow months	5	5	1
Annual cost to Canterbury households	$0	$30	$45

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

7 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	10
Ecological quality of local streams and rivers	Poor	Good	Poor
Number of low flow months	5	3	3
Annual cost to Canterbury households	$0	$45	$90

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

8 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	60
Ecological quality of local streams and rivers	Poor	Good	Poor
Number of low flow months	5	1	5
Annual cost to Canterbury households	$0	$60	$15

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

9 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	10	60
Ecological quality of local streams and rivers	Poor	Fair	Good
Number of low flow months	5	1	3
Annual cost to Canterbury households	$0	$30	$30

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

10 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	60	30
Ecological quality of local streams and rivers	Poor	Poor	Fair
Number of low flow months	5	5	5
Annual cost to Canterbury households	$0	$30	$60

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

11 Here are some more management options, please choose one.

Outcomes	Option 1: No change	Option 2	Option 3
For every 1000 people, the number who become sick from recreational contact each year would be	60	30	60
Ecological quality of local streams and rivers	Poor	Good	Fair
Number of low flow months	5	3	1
Annual cost to Canterbury households	$0	$15	$90

- ☐ I would choose option 1
- ☐ I would choose option 2
- ☐ I would choose option 3

12 If in the previous six questions you selected 'No change' for every question, which statement below most closely describes your reason for making this choice?

- I believe that agriculture is already well managed ☐
- I support the improvements but can't afford to contribute to the cost ☐
- I am opposed to additional rates ☐
- I am prepared to pay for improvements but am concerned that my payments will not be spent wisely ☐
- I didn't know which option was best so I stuck with 'No change' ☐
- I support the improvements but farms are businesses so they should pay for the changes ☐
- Other reason, please state

____

____

____

You and your background

To finish up we would like to ask a few questions about you. These questions allow us to check that we have a representative sample of people. Remember your responses are anonymous.

13 Are you **Male** ☐ **Female** ☐

14 What is your year of birth? ______________________________

15 What country were you born in? ______________________________

16 What ethnic group(s) do you identify with? ______________________________

____

17 Does your household **Rent** the house you are currently living in? ☐

Own this property? ☐

18 How many adults (18 and over) ________ and children________ live in your household?

19 Please circle the highest level of formal **education** you have completed (or the equivalent outside of New Zealand)

High school	1
Trade/technical qualification or similar	2
Undergraduate diploma/certificate/degree	3
Postgraduate degree	4

20 Please circle the option that best describes your **current** situation.

Unemployed	1
Retired	2
Unpaid voluntary work	3
Student	4

Paid employment	5
Home duties	6
Self-employed	7
None of the above	8

21 Please circle your household **yearly income** from all sources before tax.

Loss	1
$0 to $10,000	2
$10,001 to $20,000	3
$20,001 to $30,000	4
$30,001 to $40,000	5
$40,001 to $50,000	6
$50,001 to $70,000	7
$70,001 to $100,000	8
$100,001 or more	9

Thank you very much for your cooperation and contribution to this project. If you have any questions or comments please feel free to contact the author or write them below. Please return this survey by placing it in the freepost envelope provided as soon as possible.

Lincoln University
Te Whare Wānaka O Aoraki

Follow-up reminder postcard

Lincoln University
New Zealand
Canterbury

Canterbury Streams and Rivers Survey

Dear Householder

About 2 weeks ago we sent you a survey about Canterbury rivers and streams. The information you can contribute by completing this survey is very important for us, and for Canterbury. If you have not already completed and mailed the survey then please do so. Remember the survey came with a postage free reply envelope. If you cannot find the survey please contact Peter Tait at Lincoln University, 03 3252 811 (between 8am and 5pm), or email taitp1@lincoln.ac.nz.