Valuing agricultural externalities in Canterbury rivers and streams

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Summary

Water quality and quantity concerns in Canterbury are intrinsically related to agriculture. Monetary values for impacts on streams and rivers is lacking in policy debate. This paper employs choice modelling to estimate values of three impacts on rivers and streams in Canterbury associated with agriculture: health risks of E coli from animal waste, ecological effects of excess nutrients, and low-flow impacts of irrigation. This study provides a valuation of outcomes for public policy implemented in Canterbury such as The Dairy and Clean Streams Accord, Living Streams, and The Restorative Programme for Lowland Streams.

Keywords: non-market-valuation, choice experiment, agricultural externalities, New Zealand

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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 environmental resources. The trend of increasing dairy farm conversions will exacerbate tensions over property-rights to use water resources. Current water allocation and pricing mechanisms are generally inadequately designed for achieving economic efficiency. The majority of New Zealand territorial authorities employ a first-in first-served water allocation design which provides an incentive to race to the bottom of the well. The absence of water pricing is common in New Zealand, this provides no incentive to minimise water use, and leads to inefficiently high levels of water demanded. Add to this a legal framework that ties water extraction rights to land and the result is that the value of the water is captured in the price of land.

Economic efficiency is achieved when limited water is allocated across different uses so that the marginal social benefits of each use are equal. If private marginal benefit and social marginal benefit are equal then markets alone will achieve the efficient allocation of water between uses. A shift to a market based mechanism will require all economic values associated with a particular use to be included in the mechanism. Externalities of water use and public good properties of environmental allocation mean that markets alone cannot provide the efficient allocation of water. A mixture of competitive market forces and selected government intervention to correct for market failures seems the way of the future.

A role of non-market valuation is to provide estimates of the differences between private and social marginal benefit of differing water uses. Typically valuation exercises are framed in a benign manner so as to underscore the objectivity and unbiased nature of the study. To tie values to uses requires that the framing of the valuation exercise should take place within the context of the resource allocation issue.

Canterbury

Canterbury's primary sector provides about 8.7% of all Full Time Equivalent jobs in the region, contributing approximately 6.6% of the Gross Domestic Product. Geographically the region's size is over three million hectares of which about fifty percent is plains land; 2.45 million hectares in pastoral use, 0.2 million in arable use, 0.015 million in horticultural use and 0.1 million in production forest. There are just over 0.5 million beef cattle; 0.75 million dairy cattle; just over 7.1 million sheep; 0.2 million pigs and just under 0.4 million deer. Beef cattle numbers are going against the falling national trend by increasing 16% over 2002 to 2007; sheep and pig numbers have fallen over the same period; dairy cattle numbers have increased 39% (SNZ, 2007)

Increasing substitution of arable dry land farming for water intensive dairy farming is a significant current trend in the Canterbury plains. Dairy stock unit numbers in Canterbury have increased far more than other stock types. The environmental implications are well understood 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 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 (PCE, 2004). Agricultural interests seeking rights to extract water from major rivers for irrigation. Applicants such as Central Plains Water have seen many scientific arguments challenged formally in the Environment Court.

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.

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 (MfE, 2003). 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 principle 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).

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 (ECan, 2007b).

Although progress is being made it is likely that funding these policies will be ongoing. In the 2006/2007 39.6% were assessed as being fully compliant with consents to apply effluent to land., 42.7% did not comply with discharge conditions in minor ways, 17.7% required re-inspection visits due to incidents of significant or major non-compliance In general, on-site visits indicated that many farmers still do not have sound dairy shed effluent management plans. (ECan, 2007). Bewsell and Kaine (2005) identify the factors that influence dairy farmers' propensity to adopt sustainable management practices. The attitudes of dairy farmers to sustainability and the environment have at best a limited role in influencing their propensity to adopt sustainable management practices. That is, like any commercial enterprise most producers only react significantly to those values that they can capture in the markets for their products.

For export oriented industries such as agriculture, environmental image is a substantial driver of the value New Zealand can derive for goods in international markets. This observation has been given scant empirical attention in New Zealand and yet what little study has been completed indicates that it is significant and measured in hundreds of millions of dollars per annum (MfE, 2001).

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. The stated preference method of choice modelling is one tool that allows the analyst to estimate values for multiple outcomes of environmental policy within one survey. The respondent is presented with several alternatives and each alternative is made up of combinations of policy outcomes, known as attributes. Each attribute has at least two levels and they are varied systematically according to an experimental design. 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.

Statistical model

Choice experiments are an application of both Lancaster's characteristics theory of value and 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,

$$U_i = V_i + \varepsilon_i$$

Where U_i is the unobservable true utility of offering I; V_i is the systematic (i.e. known) component of utility; and ε_i is the random component.

Individuals are asked to choose between alternative goods, which are described in terms of their attributes, one of which is price (or a proxy).

$$Prob_i(j|\boldsymbol{C}) = Prob(V_{ij} + \varepsilon_{ij} > V_{ik} + \varepsilon_{ik})$$

Different probabilistic choice models can be derived depending on the specific assumptions that are made about the distribution of the random error component. If errors are assumed to be distributed according to a type 1 extreme value distribution, a conditional or multinomial logit model (McFadden, 1974) can be specified:

$$Prob_i(j|\mathbf{C}) = exp(\mu(\theta_0 + \alpha P_j + \beta' \mathbf{X}_j))/ \sum_C exp(\mu(\theta_0 + \alpha P_C + \beta' \mathbf{X}_C)$$

This equation can be estimated by conventional maximum likelihood procedures. The implicit price (WTP) associated with an individual attribute, a is:

$$wtp = -\beta_a/\alpha$$

where α is the parameter estimate of the price variable P and β_a is the parameter estimate of the specific attribute X_a.

For this specification, selections from the choice set must obey the independence from irrelevant alternatives' (IIA) property. This property states that the relative probabilities of two options being selected are unaffected by the introduction or removal of other alternatives. This property follows from the independence of the error terms across the different options contained in the choice set. If the IIA assumption is violated then 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, the nested logit, the random parameters logit, and the heterogeneous extreme value logit. The most widely used test for violations of IIA is provided by Hausman and McFadden (1984).

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 Environment Canterbury with several meetings conducted and a survey was sent to relevant Environment Canterbury staff. Table 1 shows the main questions contained in that survey.

Table 1: Expert opinion ECan 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:

- Ecoli measured in mpn/100ml
- Nitrate measured in mg/L
- Phosphate mg/L
- 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 phone listings. One was held in central Christchurch and was aimed at gaining an urban perspective; 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.

Three environmental attributes were indentified to be valued in the choice experiment and these are shown in Table 2. The cost attribute is defined as an annual household payment via rates or rent. 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). The magnitude of changes in levels was guided by Ball (2006) and McBride (2002).

Table2: Attributes used in choice sets

Attributes	Base alternative	Levels in other alternatives
Health Risk	60	10, 30 and 60 people/1000/year
Ecology	Poor	Poor, Fair, Good
Low Flow	5	1, 3 and 5 months/year
Cost	$0	$15, $30, $45, $60, $75, $90/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 ECan (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: ECan (2003), Stark (1998), Stark and Maxted (2007), and Stark and Maxted (2007b). Table 3 shows the descriptions used.

Table 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 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.

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 ECan (2001).

The experimental design used is an orthogonal main effects fractional factorial design constructed utilising procedures from Street and Burgess (2005). The experimental design consisted of 18 treatments which were randomly blocked into 3 blocks of 6 choice sets. Figure 1 provides an example choice set. The constant base alternative (Option 1) was assumed to be a worsening condition of rivers and streams 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.

Figure : 1 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	5	1
Annual cost to Canterbury households	$0	$15	$75

☐ I would choose option 1

☐ I would choose option 2

☐ I would choose option 3

The survey consisted of three parts, first some questions designed to elicit measures of attitude to agri-environmental policy in Canterbury were asked, second the choice experiment was presented, and the survey concluded with socio-demographic questions. The first and third parts are designed to capture preference heterogeneity not captured by the attributes in the choice sets. The first set of questions presented respondents with statements that they were asked to indicate agreement or disagreement with on a likert scale (disagree strongly, disagree, agree, agree strongly, and don't know). Table 4 provides the statements used.

Table 4: Agri-environmental attitudinal statements measured on Likert scale

- 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
- A price should be charged for water for irrigation
- Agriculture should fully convert to organic farming methods

The second set of questions presented in Section One of the survey asked respondents to indicate how rivers and streams are important to them. Table 5 shows the options respondents had to choose from. They were able to select more than one.

Table 5: Importance of Canterbury rivers and streams to respondents

- 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

Survey Logistics

During July and August of 2008 1500 survey instruments were mailed to a stratified random sample of Canterbury residents. The sample was stratified by Territorial Local Authority. The instrument consisted of a covering letter and survey booklet along with a free-post reply envelope. A reminder postcard was sent also. The mail-out procedure yielded 363 usable responses for an effective response rate of 25%.

Table 6 contains sample characteristics for socio-demographics, attitude and importance variables. The attitudes of the respondents for agri-environmental issues were elicited through a series of likert measures, these were recoded as binary variables (1 if agree or strongly agree, 0 otherwise).

Table 6 : Respondent socio-demographics, attitudes, importance indicators

Variable description	Sample characteristics
Socio-demographics	
Gender	46% female
Average age	57
Education	30% completed high school
	24% had a trade/technical qualification
	31% had undergraduate diploma/certificate/degree
	14% had postgraduate degree
Income	9% loss to $20,000
	34% $20,001 to $50,000
	36% $50,001 to 100,000
	21% $100,001 or more
Employed	78% employed
Children	35% have children
Own home	89% own the home they live in
Use	52% use rivers and streams directly for recreation
Attitudes	
Agreed or strongly agreed with statement	24% Agricultural production today is environmentally safe
	12% Canterbury ratepayers as a whole should pay the costs of cleaning up and preventing agriculture's impact on water resources
	58% Farmers should pay for the costs of cleaning up and preventing agriculture's impact on water
	65% The agricultural landscape is important in Canterbury
	54% A price should be charged for water for irrigation
	30% Agriculture should fully convert to organic farming methods
Importance	
Reasons why rivers and streams are important	59% Resource for future generations
	49% Recreational opportunities
	55% Habitat for plants and animals
	9% Resource for commercial development
	19% I like knowing its there
	49% Drinking water for public

Model estimation

The ecological attribute is effects coded into two variables, 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). The risk and flow attributes are assumed to be cardinal and linear. The non-attribute variables were interacted with the alternative specific constant to be included in modelling. The variables used in model estimation are summarised in Table 7.

Table 7 : Summary of explanatory variables

ASC	alternative specific constant, 1 if alternative 2 or 3, 0 if base alternative
Risk	number of people out of 1000 who get sick from recreational contact each year
Ecology Fair	ecological quality fair
Ecology Good	ecological quality good
Flow	the number of low-flow months per year
Cost	annual cost per household
Education	education level of respondent
Gender	gender of respondent (1 if male)
Use	respondent has recreational use (1 if yes)
Safe	respondent agrees that agriculture is environmentally safe
Organic	respondent agrees that agriculture should convert to organic methods
Commercial	respondent indicates commercial important
Future	respondent indicates future resource important
Habitat	respondent indicates habitat is important

The pseudo-R^2 values given here are calculated using:

$$\text{Psuedo-}R^2 = 1 - LL_{\text{estimated model}} / LL_{\text{base model}}$$

The base model contains a constant only. Two specifications of the Conditional Logit model are presented in Table 8. The first contains only the attributes used in the choice sets. The second model contains the socio-demographic, attitudinal and importance variables. A likelihood ratio test easily rejects the null hypothesis that the extended model is no better than the attributes only model.

Table 8: Conditional Logit Models

Variable	Model 1 Base model	Model 2 Extended model
ASC	0.0508	-2.45***
Risk	-0.0216***	- 0.0219***
Ecology Fair	0.345***	0.346***
Ecology Good	0.563***	0.557***
Flow	-0.0877***	- 0.084***
Cost	-0.00969***	-0.00939***
Education		0.235**
Gender		0.694***
Use		0.353*
Safe		-0.601***
Organic		0.878***
Commercial		-0.459**
Future		0.98***
Habitat		0.74***
Log-likelihood	-1120.348	- 1070.094
Psuedo-R^2	0.22	0.26
Iterations	5	5

***significance at the 1% level, ** significance at the 5% level, * significance at the 10% level

Each of the attributes is statistically different from zero at a p-value of 0.01. All have signs that are consistent with our *a priori* expectations, that is: an increase in the risk of getting sick, an increase in the number of low-flow months and an increase in the cost, all lower the probability of that alternative being chosen; an increase in ecological quality increases the probability of that alternative being chosen. A Wald test of the linear restriction that the parameters of both ecology variables are equal retained the null hypothesis of inequality. Model 2 includes demographic and attitudinal variables. Higher education levels increase the probability of choosing an alternative with improvements in water quality. Males are more likely to choose alternatives with improvements. Respondents who use rivers and streams for recreation are more likely to choose an alternative with improvements. Agreeing with the statement that agricultural production today is environmentally safe lowered the probability of choosing an alternative with water quality improvements. Agreeing with the statement that agriculture should fully convert to organic methods increased the probability of choosing an alternative with improvements. Respondents who indicated that they valued rivers and streams as a resource for commercial development were less likely to choose an alternative with improvements. Respondents who indicated that they valued rivers and streams as a resource for future generations and as habitat for plants and animals were more likely to choose an alternative with water quality improvements than those who do not hold such values.

The statistical assumption of individually and identically distributed error terms has the implication that the probability of choosing any alternative should be independent from the remaining probabilities, a property called independence from irrelevant alternatives. To test this assumption Hausman-McFadden tests were conducted. This involves removing an alternative from the choice set and testing whether the parameter estimates differed.

Table 9 shows that the null hypothesis of IIA/IID is retained, hence the CL model is the appropriate model for estimation of this data and it is not necessary to use discrete choice models with more flexible error term structures such as Random Parameters Logit.

Table 9: Hausman and McFadden test of IID/IIA

Excluded alternative	$X^2_{4\text{ d.f.}}$	Probability
Option 1:no change	4.0736	0.396142
Option 2	4.2079	0.378605
Option 3	6.3385	0.175255

WTP and Compensating Surplus Estimates

Welfare measures in the form of marginal willingness-to-pay can be 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 coefficient of the payment vehicle (Birol et. al., 2006).

$$WTP = -1(\beta_{\text{attribute}}/\beta_{\text{cost}})$$

Using Model 1 Table 10 shows that respondents are: wtp \$2.26 to reduce the risk of getting sick by one person per year; wtp \$35.60 for an improvement in ecological quality to Fair; wtp \$58.10 for an improvement in ecological quality to Good; wtp \$9.05 for each month that isn't in low-flow conditions.

Table 10: Implicit prices of attributes

Risk	\$2.26
Ecology Fair	\$35.60
Ecology Good	\$58.10
Flow	\$9.05

Estimates of compensating surplus are calculated using:

Compensating surplus = $(-1/\beta_{cost})\ (V_{base} - V_{management})$

Where V_{base} is the utility derived from the 'No change' base alternative and $V_{management}$ is the utility derived from the management alternatives. Table 11 shows the compensating surplus estimates.

The 'no change' base and two 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 11: Compensating surplus estimates

Scenario	Compensating surplus	Canterbury surplus
Management Fair	$125.82	$12,686,431
Management Good	$211.00	$21,275,130

Following Morrison (2000) this study assumes that 50% of households in the sampling frame have the same preferences as the study sample. Multiplying this by the 201,660 households (Census, 2006) and then by the household compensating surplus yields the value of improvements to water quality for Canterbury. These figures are shown as Canterbury surplus in Table 11 above.

Concluding remarks

The objective of this paper was to use choice modelling to quantify some of the external effects of agriculture on Canterbury streams and rivers. More specifically, flow, ecology and risk attributes of agri-environmental policy are valued by Canterbury residents. Survey and model results show that there is support amongst residents for protection and improvement of rivers and streams in Canterbury.

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 critical debate.

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