Estimating Values of Environmental Impacts of Dairy Farming in New Zealand

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Abstract

New Zealand is the world's largest exporter of dairy products, supplying about one third of global trade. The dairy sector strives to maintain international competitiveness by continued increases in productivity and intensification in the use of inputs. Increasing intensity of dairy farming and unsustainable agricultural activities contribute to degradation of several Ecosystem Services such as clean air and water. The New Zealand dairy industry receives widespread public criticism of its environmental impacts. This paper provides a case study of the intensification of dairy farming in New Zealand and its detrimental environmental impacts such as nitrate leaching to streams and rivers, methane gas emissions, demands for surface and groundwater for irrigation and reduced variety in pastoral landscapes. To design efficient policies that will incentivise farmers to adopt more environmentally friendly practices, resource managers and decision makers need information on the relative values attached by the public to these detrimental environmental impacts. The study uses choice modelling method, in particular Mixed Logit model, to evaluate these relative values (willingness to pay), incorporating sources of preference heterogeneity (both observed and unobserved heterogeneity) within a sampled population. The research provides information for policy makers that will be useful in designing policy instruments to encourage farmers to reduce the principal harmful effects of dairy farming on the environment.

Key Words: choice modelling, willingness to pay, New Zealand dairy farming, environmental impacts

JEL Classification: Q1, Q2, Q5

INTRODUCTION

New Zealand is the largest dairy exporter in the world at present, and the eighth largest milk producer, averaging 2.2 per cent of world milk production for 2005 to 2007. The dairy industry in New Zealand is a significant contributor to the national economy, earning NZ$10 billion and generating 25% of export revenue for the year ending March 2008 (MAF 2008). Export value is projected to rise 14 per cent to $12 billion in the year ending 31 March 2012. This expansion reflects a depreciated exchange rate, rising cow numbers and increasing milk solids production per cow (MAF 2008). The dairy sector strives to maintain international competitiveness by continued increases in productivity and intensification in the use of inputs. Exclusionary trade practises by North American and European countries, and the high proportions of exports which go to the middle and low income countries, mean that the dairy sector is constrained to maintain a strategy of low-cost production (Jay & Morad 2007). For example, growth in demand for milk powders especially, has come from China and other developing economies and particularly from oil-exporting countries. For the year ended 31 March 2008, the Organization of Petroleum Exporting Countries (OPEC) accounted for 21 percent of New Zealand’s total dairy export value (up from 17 percent the previous year), (MAF 2008). The intensification of production is a part of this strategy which leads to unsustainable agricultural activities and contributes to the degradation of several Ecosystem Services (ES) such as clean air and water.

The environmental consequences of dairying include pollution of surface and groundwater; destruction of wetland and native lowland forest for farm development; indirect damage to freshwater and estuarine habitat through contamination and nutrient pollution of surface and groundwater; loss of native biodiversity (through damage or destruction of native habitat); soil erosion, soil contamination, and damage to soil structure; and discharge of greenhouse gases (PCE 2004; MfE 2007; Clark et al. 2007; Collins et al. 2007; Jay & Morad

2007; Monaghan et al. 2007; Flemmer & Flemmer 2008; Moller et al. 2008). As a result, the New Zealand dairy industry receives widespread public criticism of its environmental impacts.

However, neither the exact nature of this threat nor the extent of its impact has received adequate reporting from public perspective. A major problem for New Zealand society is how to weigh the economic benefits (and the lifestyle implications) of increased intensification of dairy production against the costs of environmental degradation. Environmental costs tend to be regionally localized, and many of the environmental costs remain subtle, complex, long-term, and hard to quantify (Jay & Morad 2007).

This paper provides a case study of the intensification of dairy farming in New Zealand and its detrimental environmental impacts such as nitrate leaching to streams and rivers, methane gas emissions, demands for surface and groundwater for irrigation and reduced variety in pastoral landscapes. The study estimates the relative values (i.e., marginal willingness-to-pay (WTP)) attached by the society in order to reduce these detrimental environmental impacts. Understanding the mechanisms underlying public perception of improvements in ES can contribute important information about the impacts of agricultural intensification. It is also a prerequisite to gaining public support for protecting and enhancing ecosystem services and the landscapes that provide them. This paper uses the estimated values to provide a novel approach to designing and describing policy solutions that will incentivise farmers to reduce their environmental footprint, while operating profitable businesses. The information from this research could be used as criteria for assessing policy approaches by the dairy industry and resource managers who are involved in the policy development process.

ENVIRONMENTAL IMPACT OF DAIRY FARMING

It is a well established that New Zealand dairy farms have a significant environmental impacts due to their intense farming practices (PCE 2004; MfE 2007; Clark et al. 2007; Collins et al. 2007; Jay & Morad 2007; Monaghan et al. 2007; Flemmer & Flemmer 2008; Moller et al. 2008). The scale and intensity of dairy farming in New Zealand are driven by global economic circumstances that influence the industry to increase their productivity and profitability by increasing the use of production inputs (e.g., stocking rates and fertiliser use). According to Dairynz (2008), farms in the South Island are, on average, larger than those in the North Island, in terms of farm area and cow numbers. The average herd size in both islands continues to increase. Within the South Island, North and South Canterbury has the largest average herd sizes (710 and 711 cows respectively). North Canterbury has the highest average cows per hectare (3.28), followed by South Canterbury (3.23) and South Auckland (3.03).

The intensification and expansion of dairy farms have contributed many environmental problems such as the contamination of ground and surface water, insufficient water for irrigation during droughts, excess nutrients losses from farms, larger emissions of greenhouse gases particularly methane (CH_4) and nitrous oxide (N_2O) from animal waste, and ongoing threats to biodiversity.

The allocation of surface and groundwater for irrigation is controlled by regional council consents for water abstraction. Future demands for irrigation water are likely to increase because of the profitability of irrigation for many land-use options, as well as increasing water demand from industry, and a growing population. The significant increase in groundwater abstraction associated with land use intensification has contributed to a decline in groundwater levels and reduced flows in rivers and lowland streams. For example, Environment Canterbury (ECan) records show a 260 per cent increase in the amount of irrigated land from 1985 to 2005, and some 70 per cent 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. This increase comes primarily from increased groundwater takes. There has been a significant increase in irrigation in the last 20 years, a demand which is expected to continue in the near future. Use of water for irrigation can reduce river flows, reduce ground water levels and harm wetlands. Excessive extraction of water for dairy farming can lead to water shortages and to the destruction of aquatic ecosystems.

A key water quality issue for dairy farmers is the significant amounts of excess nutrients, particularly nitrogen (N) and phosphorus (P) that leach into waterways. The transfer of these pollutants from land to water can result in significant water quality impairment. The N content of consumed pasture is often in excess of the cow's capacity to incorporate the N into milk protein. This excess results in high N excretion and concentrations in urine (94%), which combined with the use of N fertilizer to increase pasture, have increased surplus N. About 39 percent of monitored groundwater in New Zealand has nitrate levels that are elevated above natural background levels and there are areas where concentrations exceed the drinking water standard of 11.3 milligrams per litre (MfE 2007). Fertiliser use and the amount of animal waste are expected to continue increasing in dairy farming and will accordingly impact on water quality.

Most recently, greater attention has been focused on some of the off-site impacts of farming activities, particularly the contribution of greenhouse gases (GHG) such as methane and nitrous oxide to global warming. In New Zealand, agriculture is the largest source of emissions, contributing 48 per cent of New Zealand's total GHG emissions in 2007 (methane

(66%) and nitrous oxide (34%)).[1] Methane emissions produced by enteric fermentation from livestock increased 1.5 Mt CO_2-e (7 per cent) since 1990. Emissions from livestock waste (dung and urine) deposited on soil and the use of nitrogenous fertilizers increased 2.3 Mt CO_2-e (22 per cent) since 1990. The main reasons for the increase are the expansion of dairy farming and an increase in the use of nitrogen fertiliser (MfE 2009).

Agriculture intensification is an ongoing threat to biodiversity where structural complexity and diversity of indigenous vegetation and natural habitats have declined within New Zealand's agricultural landscapes over the past four decades (Moller et al. 2008). Recent measures of habitat extent and diversity have demonstrated the importance of habitat and landscape quality and quantity in determining bird abundance and community composition. Some pastoral landscapes contain only pasture, livestock, post and wire fences, but no trees or hedges. Land use conversion from sheep farming to dairy farming often leads to removal of shelter belts. Tait and Cullen (2006) note that the area of shelter belts in Te Pirita region of Canterbury reduced by 46% between 1984 and 2004 as a result of dairy conversions.

Society is becoming less accepting of negative impacts of farming, notwithstanding any recognition of the important economic and social contribution that agriculture makes to society. A major problem for New Zealand society is lack of information to guide policy solutions that address economic incentives or internalize the environmental costs of increased dairy production. As the benefits provided by many ecosystem services are neither priced nor marketed, resource managers do not take into account the degradation of these services in their resource management decisions. Being able to estimate values for the main environmental impacts of dairy farming is fundamental to designing policies to induce

1 This figure underlines the importance of the farming activities in achieving the New Zealand commitment of the Kyoto protocol of reducing its GHG emissions back to the 1990 level. Agriculture in 2013 will enter in the Emissions Trading Schemes (ETS), although farmers will not be required to pay the full cost of their emissions until 2030. The sector will be allocated a number of emissions units from 2013 through to 2030. From 2013 to 2018, the annual allocation will equate to 90 percent of the sector's total 2005 emissions. The allocation will phase out gradually from 2019 to 2030 (http://www.maf.govt.nz/climatechange/agriculture).

farmers to manage their activities so that they provide (or improve) ecosystem services at levels that are demanded by society. This paper focuses primarily on valuing the environmental impacts of dairy farming on four key environmental issues: water quality (pollution) and quantity (depletion), air quality (methane gas emissions) and landscape (loss of native biodiversity). Nonmarket valuation using choice modelling was used to assess and elicit New Zealand's public perception of the environmental impacts associated with dairy farming.

METHODS

Choice Modelling

This paper reports on use of a survey-based method Choice Modelling (CM), to elicit households' willingness to pay (WTP) for improvements in ecosystem service quality. CM models are used to study people's choices and behavioural changes in hypothetical scenarios involving a quality change. The theoretical basis of CM is random utility model (RUM) developed by McFadden (1974). Assumptions about respondents' behaviour are introduced into RUM theory through specification of a utility function. The utility function measures the level of satisfaction an individual experiences as a result of consuming particular goods and services. Under the RUM framework, the utility function for each respondent can be expressed as:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where U_{ij} is individual i's true but unobservable utility of choosing alternative j, V_{ij} is the observable systematic component of utility (indirect utility function) and ε_{ij} is an error term that represents unobservable (to the researcher) influences on individual choice. RUM assumes that the individual acts rationally (i.e., utility maximizer) and chooses the alternative with the highest level of utility. As the researcher cannot observe the individual's true utility function, a probabilistic approach is used in the estimation. In a given choice set, C with the set of all J possible alternatives, the probability that alternative j is chosen is given by:

$$P_j = \Pr ob(U_j > U_k) = \Pr ob(V_j + \varepsilon_j > V_k + \varepsilon_k) = \Pr ob(\varepsilon_k - \varepsilon_j < V_j - V_k) \forall k \neq j \in C$$
$$P_j = \int_{\varepsilon} I(\varepsilon_k - \varepsilon_j < V_j - V_k \ \forall k \neq j \in C) f(\varepsilon) d\varepsilon \qquad (1)$$

where I (.) is the indicator function, equalling 1 when the expression in parenthesis is true and 0 otherwise (Train 2003). In order to derive an explicit expression for these probabilities, assumptions are made about the distribution of the error terms, $f(\varepsilon)$. Different discrete choice models are obtained from different specification of the distribution of the error terms depending on the researcher's analytical convenience. For instance, assuming that the error terms is Type I Extreme Value distribution, the integral in equation (1) will have a close form and the probability that a respondent chooses alternative j is given by:

$$P_{ij} = \frac{e^{\mu V_{ij}}}{\sum_{k \in C} e^{\mu V_{ik}}} \qquad (2)$$

This formulation is known as the conditional logit (CL) model (McFadden 1974), where μ is a scale parameter, inversely proportional to the standard deviation of the error distribution, and typically assumed to be one.

The individual indirect utility function (V_{ij}) can be modelled in different specifications. The simplest functional form which only includes attributes from the choice sets is an additive structure:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} \qquad (3)$$

where ASC is an alternative specific constant for alternative j, β_k is a vector of coefficients associated with the kth attribute, and X are attributes that describe the environmental good under study. The CL model (eq. 2) assumes preference homogeneity across respondents where a single parameter estimate is generated for each attribute. If one interprets the parameter associated with any attribute as its marginal utilities, this implies that all respondents have the same tastes for that attribute. In order to extract more information and to allow for respondents preference heterogeneity, socioeconomic as well as attitudinal variables can be added into the utility functions as interactions with attributes or ASC.[2] The utility function now becomes:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_m \omega_{jm} ASC_j * S_{mi} + \sum_n \delta_{kn} X_{ijk} * S_{ni} \qquad (4)$$

where ω_{jm} is the vector of coefficients of the interactions between the *ASC* and the *m*th socioeconomic characteristics of individual *i* (S_{mi}) and δ_{kn} is the vector of coefficients of the interactions between the *k*th attribute and the *n*th socioeconomic characteristics of individual *i* (S_{ni}).

Given that two respondents with the same socioeconomic characteristics can hold different preferences for the environmental impacts of interest, a mixed logit (ML) model, also known as Random Parameter Logit, was considered in this study. The utility function for ML model is generally described by:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_k \eta_{ki} X_{ijk} + \sum_m \omega_{jm} ASC_j * S_{mi} + \sum_n \delta_{kn} X_{ijk} * S_{ni} \qquad (5)$$

where η_{ki} is a vector of *k* deviation parameters which represents how the individual *i* tastes differ from the average taste (β_k). In contrast to CL, ML model allows respondents taste, β_{ki}, to vary among respondents, hence letting $\beta_{ki}=\beta_k+\eta_{ki}$. In addition to respondents' taste heterogeneity for the studied attributes, it is important to consider that there may be unobserved factors which are common across alternatives and increases the respondents likelihood of choosing a particular choice. For instance, respondents who live in areas with a high underground nitrate concentration or that were taught about the ongoing effects of climate change may be more prone to support the reduction of the environmental impact of

[2] Note that these variables cannot be included directly into the model since being invariant across alternatives they cause Hessian singularities and forbid model estimation.

dairy farming.[3] These unobserved effects can be included in the utility specification by creating a correlation structure in the alternative of the choice set. The utility specification now becomes:

$$V_{ij} = ASC_j + \sum_k \beta_k X_{ijk} + \sum_k \eta_{ki} X_{ijk} + \sum_m \omega_m ASC_j * S_{mi} + \sum_n \delta_n X_{ijk} * S_{ni} + \sigma_j E_{ij} \qquad (6)$$

where E_{ij} are additional alternative specific individual error components distributed normally with zero mean and variance (σ^2), which allow for correlation patterns between the unobservable portions of the utility of the alternatives.[4] In this paper, the study allows for correlation in the unobserved effects of the improvement alternatives (alternatives 1 and 2 in the choice cards, see Figure 1) since they may have common unobserved effects that may lead respondents to choose the policy outcomes.

Finally, as pointed out by Scarpa et al. (2007) additional information can by obtained by disaggregating the additional error component into the socioeconomics determinants of the error. In particular, a larger variation of errors can be made by certain categories of respondents than others. To take this into account, the variance of the error component terms, σ_j^2, can be specified as a function of a set of individual socioeconomic or attitudinal variables:

$$\sigma_{ij} = \sigma_j \exp(\gamma_j h_i) \qquad (7)$$

where h_i are the individual characteristics that produce heterogeneity in the variances of the error components and γ_j are parameters to be estimated which represent the importance of each individual characteristics in explaining the heteroscedastic structure of the error component terms.

[3] As researchers, we do not often have information about whether an individual lives in a vulnerable nitrate area or knows about the ongoing effects of climate change. Thus, it is considered as unobservable information from the analyst point of view on this study.

[4] Note that σ_j is the standard deviation of the E_{ij} which is distributed as N (0, 1).

Prior to estimating the model, it is necessary to assume how the β_k coefficients are distributed over the population. The most common distributional functional forms 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 or double to the mean. The decision on "how much" to constrain the spread was taken by observing the spread of the distribution in an unconstrained model. This will allow the study to incorporate respondents' preference heterogeneity avoiding the presence of behaviourally irrational WTP measures (Hensher & Green 2003).

The error component mixed logit model is estimated by simulating the maximum likelihood function. The log likelihood function is as follows:

$$L_i = \int_{E_{i1}} \cdots \int_{E_{ij}} \prod_{t=1}^{T} \frac{\exp(V_{ijt})}{\sum_{q=1}^{J} \exp(V_{iqt})} \quad (8)$$

where V has been defined in equations (6) and (7), and the product over T is included to take into account the panel structure of the data.[5] The integral of equation (8) cannot be expressed in a closed form; however, it is easily approximated by simulating draws from the distributions involved in the utility function. In particular, it is necessary to take a draw for each random coefficient from its distribution and a draw from each error component from the standard normal distribution, calculate the logit probability and averaging the results. The individual likelihood function to be maximised is as follows:

[5] As explained in Section 3, each respondent has 9 choices to choose from and by including the product of the logit probabilities for each choice, we let the coefficients vary over respondents but are constant over choice situations for each respondent.

$$L_i = \frac{1}{R}\sum_{r=1}^{R}\prod_{t=1}^{T}\frac{\exp(ASC_j + \sum_k \beta_k X_{ijkt} + \sum_k \eta_{ik,r} X_{ijkt} + \sum_m \omega_m ASC_j * S_{mi} + \sum_n \delta_n X_{ijkt} * S_{ni} + \sigma_{ij} E_{ij,r})}{\sum_{q=1}^{J}\exp(ASC_q + \sum_k \beta_k X_{iqkt} + \sum_k \eta_{ik,r} X_{iqkt} + \sum_m \omega_m ASC_q * S_{mi} + \sum_n \delta_n X_{iqkt} * S_{ni} + \sigma_{iq} E_{iq,r})}$$

(9)

where *R* is the number of draws, $\eta_{ik,r}$ is the rth draw for individual *i* and attribute k (from the triangular distribution), $E_{ij,r}$ is the rth draw from the standard normal distribution and all other terms have been previously defined.

Welfare Analysis

The results of the CM estimation can be used to estimate marginal WTP or Implicit prices. The implicit prices express the marginal WTP for a discrete change in an attribute level, and thus allow some understanding of the relative importance that respondents give to attributes within the study design. Given the assumption that utility is linear in parameters, the marginal willingness to pay for attribute *a* will be:

$$\text{Marginal WTP}_a = -\left(\frac{\beta_a}{\beta_{cost}}\right) \quad (10)$$

If the interaction effects with socioeconomic variables are considered, the marginal value of a particular attribute depends on the level of the interacting variables. For example, if income is interacted with the cost attribute, being β_{incost} the estimated coefficient, the marginal value of an attribute *a* will be given by the expression:

$$\text{Marginal WTP}_a = -\left(\frac{\beta_a}{\beta_{cost} + \beta_{incost} * Income}\right) \quad (11)$$

Data Collection

The CM surveys were designed to contain multiple choice questions (choice cards) about alternative policies for improving the environmental outcome of dairy farming. The questionnaire consisted of three parts. The first part contained questions regarding respondent’s opinions and their awareness of environmental impacts caused by dairy farming. These questions had the objective of introducing the respondent to the subject of the relation between environment and dairy farm production. The second part of the survey contained the choice situation questions. In the choice cards, respondents were asked to select the option they favoured the most out of the three alternatives provided. Each option contains different combinations and levels of the attributes as well as the cost to the household of the action or policy. The cost to the household (the payment vehicle) was defined as an additional annual payment to the regional council responsible for the management of the environment over the next five years.

Attributes discussed were the levels of methane gas emissions from dairy farms, the amount of nitrate leaching to surface and ground water, the amount of water used for irrigation on dairy farms, and the diversity of scenery in dairy landscapes. Following focus group discussion on ease of understanding of changes, each attribute was presented to respondents as three discrete levels. For example, methane gas emissions from dairy farms was presented as: 30% reduction from current emission level; 10% reduction from current level; and ‘no change’ from current emission level. These levels were selected after reviewing responses to a pilot study and by considering the technical feasibility of achieving change in attribute levels.

The study preferred to use effects coding instead of dummy coding due to the identification problem. The advantage of using effects coding is that the effect of all attributes levels are estimated and are uncorrelated with the intercept (Louviere et al. 2000; Hensher et al. 2005). Table 1 provides a more complete description of all explanatory variables and their specified effects coding based on the levels. All of the attributes selected are factors that a policy maker can affect, directly or indirectly. They are contentious issues within New Zealand, and are the subject of many articles (White 2007; Ford and Taylor

2006; Cullen *et al*. 2006). The last part of the survey contained questions regarding respondents' socioeconomic status.

Insert Table 1 here

The experimental design was used to build the choice cards to quantify the effects of marginal changes (reduction) in the environmental impacts. There are three attributes with three levels, two levels for scenic views, and the cost attribute with four levels (3^3 x 2^1 x 4^1) which were combined in a fractional factorial main effects experimental design (Louviere et al. 2000). For statistically efficient choice designs, a D-efficient fractional factorial designs excluding unrealistic cases was adapted to each of the choice questions (Terawaki *et al*. 2003). This was performed with linear D-optimal using SAS statistical software (Kuhfeld 2002). The programme created 72 choice sets which were then allocated into 8 sets of 9 choices each. Each respondent was presented with 9 choice sets and was asked to choose among the status quo (current condition) and 2 improved environmental management alternatives. Figure 1 illustrates an example of the choice cards shown to respondents.

Insert Figure 1 here

During November to December 2005 a pre-survey card, survey booklet, cover letter, and a reminder post-survey card were mailed to 1008 Canterbury region respondents selected from the New Zealand electoral roll using a random sampling design. The study received 155 completed questionnaire responses and had an overall effective response rate of 15 per cent. This response rate is relatively low compared to the usual average of 35 per cent in similar studies. This may be due to the complexity of scenarios and lack of awareness of ES that might have discouraged many of the people sampled. A sample size of 1375 useable observations was used in the data analysis.

RESULTS AND DISCUSSION

Tables 2 and 3 present the descriptive statistics of the Canterbury sample for the socio-demographic and attitudinal variables. The sample shows greatest differences in comparison to regional population census data in the income and education categories. For example, the respondent sample contains a significantly larger proportion of higher educated and higher income people than the population from which the sample was drawn. It is evident that the mail survey induced some self-selection bias where a substantial proportion of the questionnaires were not returned.

Insert Table 2 here

The results in Table 3 show that 46 per cent of the sample are satisfied with the environmental quality in the region and about one third are not satisfied at all. Respondents were asked how often they worry about air quality, water quality in rivers, drinking water quality, water usage for irrigation, water level in the rivers and greenhouse gas emissions from dairy farming. More than 50 per cent of the respondents stated that they were worried (always or very often) about the quantity and quality of water quality. About one third of the respondents do worry a lot (always or very often) about air quality and its greenhouse gas emissions. Regarding the present impacts of diary farming on the natural environment, about 85 per cent of the respondents rated them slightly harmful to very bad. Respondents were also asked whether they are aware of environmental issues such as methane gas emissions, water use for irrigation, synthetic fertiliser and pesticides use, river buffer zones, animal urine and faeces leaching into streams associated with dairy farming. A majority of the respondents stated they knew about the issues and the way dairy farming is currently managed.

Insert Table 3 here

The choice data were analysed using NLOGIT 4.0 statistical software. In the ML models, all random parameters are assumed to follow a constrained triangular distribution. Estimates were obtained using 100 Halton random draws to simulate the sample likelihood and the random parameters were considered to be independent. Table 4 shows the estimated model coefficients.

Insert Table 4 here

A base ML model (ML 1) including the socioeconomic and attitudinal characteristics of respondents has been estimated first. In this model, the signs of the random parameters are consistent with *a priori* expectations, and all of the attributes (except ME10 and WU10) are significantly different from zero at the 1 per cent confidence level. The preferred changes in dairy farming management are related to water use and quality where 30 per cent reductions in water use for irrigation and nitrate leaching to waterways are considered to be the most important attributes. The COST variable with negative sign indicates improved environmental conditions with a higher cost contributes negatively to utility and is therefore less likely to be selected. In order to check a differential impact of cost attribute according to income level, the study introduced the interaction of cost attribute with an income variable, INCOST. The INCOST variable reveals that higher income respondents are less concerned about cost (payment vehicle) increases.

The coefficients of the interactions between the ASC and the individual attitudinal characteristics reveal (everything else equal) that people who are worried about the environmental qualities have higher probability of choosing the options which proposed changes to dairy farm management. The coefficients of the ASCAQ and ASCWU interactions suggest that respondents who worry about air quality and water usage for irrigation tend to choose the improvement alternatives relative to the status quo. The negative sign of ASCIMPDF reveals that respondents are willing to choose the improvement alternatives to curtail the higher rate of environmental degradation caused by dairy farming. It is surprising to find that respondents who are concerned about drinking water quality are more likely to choose the status quo option. Possible reasons could be that respondents do not believe dairy farming is the main cause of the problem, or they are confident there is a regulatory body that assures the quality of drinking water. The results show that ME30, NL10, NL30, WU30, SV, and COST have statistically significant standard deviations of the parameters implying the existence of heterogeneity around the mean in the sampled respondents.

The second model shown in Table 4 is a mixed logit error component (MLEC) model where we defined a common error component structure to the varying alternatives and allowed the variance of the error component to be a function of the degree of satisfaction the respondents declared about the environmental conditions in the Canterbury region. The addition of the error component model and the heterogeneity in the variances provide greater improvements in terms of significant coefficients, log-likelihood function, higher McFadden R^2, Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC). All three criteria, log-likelihood function, AIC, and BIC have lower values for the MLEC compared to the base model. The lower the values the better the models. Similar to ML 1, attribute ME10 in MLEC is insignificant. The MLEC also resulted in an additional attribute being significant. For example, the WU10 which was found to be insignificant in ML 1 appeared to be statistically significant at the 5% level in MLEC. This implies that respondents' get increased utility from a 10% reduction in water usage for irrigation. The standard deviations of parameters distributions for all the random parameters (except for ME10) are statistically significant indicating heterogeneity exists among sampled respondents in choosing those ES levels.

The MLEC combined Alternatives 1 & 2 as a specific nest of alternatives that share relative commonalities in attribute improvement plans compared to the status quo. The error component is statistically significant, which shows that indeed there are unobserved effects common to the improvement plans which drive respondents to choose these alternatives. Note that this form of preference heterogeneity is additional to the one already explained in the systematic part of the utility by the random parameters. The larger coefficient indicates that there is greater alternative specific variance heterogeneity (heteroscedasticity) in the unobserved effects for the improvement plan alternatives compared to the status quo option. The MLEC also extends ML 1 by controlling for error component heteroscedasticity using respondents' self reported satisfaction with environmental quality (SATIS) levels. The estimated coefficient is positive and highly statistically significant suggesting that respondents who are highly satisfied with the environmental quality levels have greater unobserved utility variance than respondents who are not satisfied.

Estimation of Marginal WTP (Implicit Prices)

Overall, these results suggest the public appreciates higher levels of environmental provision from dairy management and support environmentally friendly agricultural programs. Estimates of marginal WTP derived from the estimated models are presented in Table 5. The estimated values are marginal WTP annually for a period of five years for a change (improvement) in the environmental attributes described assuming all other attribute levels (except those under consideration) are held constant. Since MLEC has better results statistically compared with ML 1, the study uses MLEC in the following discussion for its marginal WTP estimates.

Insert Table 5 here

In the second column of Table 5, the marginal WTP are calculated based on the mean income of the sampled respondents. The marginal WTPs for all attributes are positive, implying that respondents derive positive utilities from reducing the environmental impacts of dairy farming.[6] For example, Table 5 shows on average respondents would be willing to pay $15.85 annually for a period of five years for a reduction in methane gas emissions of 30 per cent. These marginal WTP estimates offer some insights on the relative importance of each environmental impact, and can be used by policy makers to assign more resources to improving those dairy farming effects that have higher values, such as 30 per cent levels of Nitrate Leaching and Water Usage. As mentioned, the sample shows greater differences in comparison to regional population census data, especially in the income and education categories. To correct for this self-selection bias, the study calculated the marginal WTP for different income bands.[7] According to Census 2006, 65 per cent of Canterbury region resident population have an annual income of less than $40,000, 17 per cent have $40-$70,000, 6 per cent have more than $70,000 and 12 per cent have zero or loss income. Columns 3 to 5 in Table 5 show the marginal WTP for each income band, whilst column 6 describes the weighted marginal WTP according to the proportion of each income band in the population. Two observations are noteworthy. Firstly, the marginal WTP values increase as the income categories increase. This indicates that the higher income group are willing to pay more for the improvement of the environmental conditions. As can be seen in the second last column of Table 5, people who belong to the highest income category have WTP around 1.5 times more than people who belong to the lowest income category. Second, from a methodological point of view, it stresses the importance of including the interactions between key socioeconomic variables and the studied attributes to provide extra information to policy

[6] In Table 5, in the parenthesis, the study reports the 2.5 and 97.5 percentiles of the empirical WTP distribution. The negative values of the 2.5 percentile represent a small proportion of the sample who hold "negative" preferences or do not care about improving the quality of the attribute in question.

[7] The income and the education variables are highly correlated. The information contained in these two variables can be fairly described by the income variable by way of interacting with the cost attribute.

makers on the effect in the estimated welfare measures for a particular group of people. For instance, the different marginal WTP between income groups suggests to policy makers that a socially acceptable way to fund a policy aiming to reduce the dairy farming environmental effects would be to increase taxes proportional to income levels. Even if the sample were to represent the population, it would not be possible to extract this information from the sample average WTP. However, the question whether those in different income groups have different preferences for a proposed change in ES levels requires further analysis and is beyond the scope of this paper. If the preferences of income groups diverge, then this information is important for policy makers.

POLICY IMPLICATIONS

A clear understanding of the public's perceptions of the benefits and the availability of better information about their WTP for the reduction in dairy farming environmental effects can improve development and implementation of sustainable agricultural programs. The marginal WTP values estimated in this study can be useful to the dairying sector and policy makers to justify and prioritise programmes, policies, or actions that protect or restore ecosystems and their services. First, the estimated values offer some insights on the relative importance of each environmental impact and can be used to assign more resources (i.e., funding, training and manpower) to improve those impacts that have higher social values, such as 30 per cent reduction in Nitrate Leaching and Water Usage. Information on the potential benefits of alternative management strategies such as Nutrient Management Plans and the Restorative Programme for Lowland Streams is crucial for the regional council in Canterbury.

Second, from a policy perspective, when results from a benefit-cost analysis are the key to decisions, then the estimates of the benefits (the WTP values) from the alternative management practices should be contrasted against the policy implementation costs. For example, groundwater from aquifers provides untreated drinking water for some residents in Canterbury. Since some of the aquifers exceed New Zealand Drinking-Water Standards of 11.3 mg/L nitrate-nitrogen and the findings from the survey reveal that majority of the respondents worry about the quality of the drinking water in their region, their aggregate benefit for a 30 per cent reduction in nitrate concentrations is around $7.5 million ($17.90 x 419,340) from Table 5.[8] If Environment Canterbury were planning to implement a nitrates management plan at a cost of $6 million, then the net benefit to society is the sum of the present value of the benefits less the present value of the costs, which is $1.5 million. Protecting aquifers from contamination ensures natural water purification can occur at lower cost than if water treatment is needed. If the residents understand that their drinking water originates from protected aquifers, they will more likely see the value in protecting aquifers from contamination. The community might come to the conclusion that aquifer protection is more cost-effective than introducing an expensive nutrient management plan. It allows regional government more ability to pay for other social services that it provides. Nevertheless, caution is advisable before using these values for major policy decisions, in particular concerning public health and safety.

Despite the effort to promote new environmental management policies and practices by the Fonterra Co-operative Group and regional government, the continuing decline of environmental conditions linked to dairy farming suggest that persuasion and the regulatory frameworks used have not prevented environmental deterioration in areas used for dairying and intensive farm production.[9] The reasons for this decline are that first, it is not easy to

[8] The estimation assumes that non-respondents (those who have not return the survey questionnaire) have the same mean WTP as respondents. However, the values based on this assumption need to be taken with caution as it will lead to an overestimation of the aggregate WTP for the population even though adjusted for income band.

[9] Fonterra Co-operative Group is the largest of New Zealand's three extant dairy companies, with more than 11,000 farmer members. To improve on-farm environmental management, the company has adopted initiatives designed to encourage farmers to improve on-farm environmental management. These have consisted of videos

ensure compliance with regulations by all farmers, and secondly, improvements in environmental management by farmers are invariably offset by intensification of production, or the conversion of lower intensity land uses such as sheep and beef farming to higher intensity uses such as dairying, cropping, and horticulture (Jay & Morad 2007).

Perhaps, one way of solving this problem is to create appropriate economic incentives for the farmers that will motivate them to reduce the negative impacts on environment. The economic incentives could take the form of compensation paid to farmers who adopt environmentally sustainable production (e.g., native habitat conservation) or rewards for meeting management controls (e.g., stocking rate or best management practice programmes). This approach is known as Payment for Ecosystem Services (PES). These payments can be linked to farming practices and provide annual payments if farmers adopt less input intensive production systems. The PES approach depends on valuing an ecosystem service, identifying how additional amounts of that service can be provided most cost-effectively, deciding which farmers to compensate for providing more of the service and determining how much to pay them (FAO 2007). A regulatory approach, in contrast, would require costly compliance but provide no compensation for changed practices.

Finally, the estimated WTP values can be used to calculate the maximum sum that government should dedicate to specific agri-environmental schemes to promote "environmental friendly" dairy farming management. In doing so, it can facilitate policy development to incentivise dairy farmers by way of PES to maintain or improve ES (Baskaran et al. 2009). For example, PES can be made to farmers to offset the cost of establishing or maintaining farms with more native vegetation, native scrub, riparian vegetation, introduced native birds, shelterbelts and windbreaks, maintaining, improving or

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and pamphlets on cleaning production methods for farmers, and for river catchment monitoring studies in the major dairying regions. The company has also been partner to an agreement with central and regional governments to introduce policies encouraging farmers to fence off streams and rivers, encouraging appropriate disposal of dairy-shed effluent, and management of nutrients applied to farm soils.

creating hedges and building biodiversity trails. A challenge for New Zealand is to develop management strategies that integrate pest management goals with the need to maintain or enhance populations of native and beneficial introduced species in its production landscapes (Moller et al. 2008). The estimated mean weighted WTP value of $8.78 per household for improved dairy landscape in Table 5 could be considered when generating PES to enhance dairy landscapes with the development of Integrated Pest Management (IPM) protocols. Government could allocate grants based on the population benefiting from the enhanced landscape. Government for example could offer farmers PES totalling $3.7 million ($8.78 x 419,340) per year to enhance landscape on farmland in the Canterbury region. If IPM saves costs for farmers in terms of reducing reliance on hazardous pesticides and biological control of pests, PES may incentivise biodiversity conservation and sustainable land management. It is important to stress that the range of policies dealing with payment is limited to those that do not conflict with New Zealand's continuing opposition to use of agricultural production subsidies.

CONCLUSION

Dairy farming intensification has led to severe degradation of several ES. The main reason is the price paid for dairy products does not reflect the external costs of depleting environmental resources or causing environmental degradation. CM has been used as the nonmarket valuation method to determine households' WTP for improving the degraded ES associated with dairy farming. The study found that accounting for variance heterogeneity within the random parameter distributions, conditioned on person specific variables, produces better model fits as well as behaviourally sensible outputs in terms of the means of WTP distributions. There is a significant increase in New Zealand residents' marginal utilities from the reduction of the environmental impacts of dairy farming. Water quality and quantity are considered the most important attributes and are highly valued by respondents. The WTP magnitudes for improvement in the level of the impacts considered can be used to develop policy solutions that provide economic incentives to internalize the environmental costs of intense dairy production. The information from this research could be used to assess policy approaches by the dairy industry and resource managers who are involved in the policy development process.

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Table 1 Definition and coding of variables

Variable	Description
Attribute variable	
ME10	10% reduction in Methane gas emissions from the current level Effect Coding: 1 if 10% reduction; 0 if 30% reduction; -1 if no change
ME30	30% reduction in Methane gas emissions from the current level Effect Coding: 1 if 30% reduction; 0 if 10% reduction; -1 if no change
NL10	10% reduction in Nitrate leaching to waterways from the current level Effect Coding: 1 if 10% reduction; 0 if 30% reduction; -1 if no change
NL30	30% reduction in Nitrate leaching to waterways from the current level Effect Coding: 1 if 30% reduction; 0 if 10% reduction; -1 if no change
WU10	10% reduction in water use for irrigation from the current level Effect Coding: 1 if 10% reduction; 0 if 30% reduction; -1 if no change
WU30	30% reduction in water use for irrigation from the current level Effect Coding: 1 if 30% reduction; 0 if 10% reduction; -1 if no change
SV	30% more in scenic views (i.e. trees, plantations) on pastoral farms Effect Coding: 1 if 30% more variety; -1 if no change
COST	Loss of household income during the next 5 years - NZ$0, 30, 60, 100
ASC	Alternative-specific constant on value of 1 for Alternative 1 and 2 in the choice sets, and 0 for the current level
Non-attribute variable	
INCOST	Interaction between income and cost
SATIS	How satisfied respondents with environmental quality (1 = not satisfied; 4 = highly satisfied)
AQ	How often respondents worry about air quality (1 = never; 5 = always)
DW	How often respondents worry about drinking water quality (1 = never; 5 = always)
WU	How often respondents worry about water use for irrigation (1 = never; 5 = always)
IMPDF	Respondents rate the impacts of dairy farming on the environment (1 = very bad; 7 = very good)

Figure 1 Example of a choice card from the questionnaire

	Alternative 1	Alternative 2	Status Quo
Methane emissions	10% reduction	30% reduction	No change
Nitrate Leaching	10% reduction	30% reduction	No change
Water Use for Irrigation	10% reduction	10% reduction	No change
Scenic Views	No change	30% more trees, hedges, plantations	No change
Loss of your household income ($ per year for the next 5 years)	$30	$60	$0

Option A ☐ Option B ☐ Option C ☐

Table 2: Principal socio-economic characteristics of survey samples

	Canterbury	**Population Census (2006)**
Total number of respondents	155	521,832
Genders (%)		
Males	49	49
Females	51	51
Age (mean)	56	37.6 (median)
Education (%)		
No qualification	1	23
Secondary/High School	38	33
Technical/diploma	37	22
Degree/professional	23	19
Occupation (%)		
Agricultural/resource	16	5
Manufacturing and transportation	23	20
Banking/financial	12	2
Education	19	7
Health services	11	11
Accommodation, retail, and leisure	13	22
Government and defence services	4	3
Others	0	29
Income (%)		
Less than $20000	12	41
$20001 to $40000	24	28
$40001 to $60000	26	9
$60001 to $70000	12	9
$70001 to $100000	13	3
More than $100000	13	3

Source: Census 2006 (Statistics New Zealand)

Table 3: General environmental attitudes and beliefs on dairy farming

How satisfied are you with environmental quality in the region (%)?

Highly satisfied	Satisfied	Neutral	Not satisfied
4	42	21	32

How often do you worry about the following environmental aspects of your region (%)?

Attribute	Always	Very often	Sometimes	Rarely	Never
Air quality	10	28	43	13	6
Water quality in rivers	21	34	33	11	1
Drinking water quality	27	31	16	15	11
Water use for irrigation	19	24	29	15	13
Water level in rivers	26	25	32	13	4
Greenhouse gas emissions	9	23	39	19	10

Management of the following compare with 5 years ago (%)

Attribute	Much better	Better	No change	Worse	Much worse
Pesticides and fertilizer	15	52	23	8	2
Greenhouse gas emissions	3	37	46	13	2

How do you rate the impacts of dairy farming on the natural environment (%)?

Very bad	Bad	Slightly harmful	No impact	Slightly helpful	Good	Very good
27	24	34	8	2	4	1

Are you aware on the following environmental issues on dairy farming (%)?

Attribute	Yes	No
Methane gas emissions	76	24
Water use for irrigation	95	5
Synthetic fertilizer	40	60
Pesticide	67	33
River buffering zones	54	46
Animal urine and faeces leaching to streams and lakes	81	19

Table 4 RPL model results

Variable	ML 1		MLEC	
Random Parameters				
ME10	0.0539	(0.0882)	0.0326	(0.0954)
ME30	0.6995***	(0.1129)	0.4673***	(0.0985)
NL10	0.2501***	(0.0841)	0.2182***	(0.0846)
NL30	0.7635***	(0.0927)	0.6616***	(0.0824)
WU10	0.0820	(0.0838)	0.2285**	(0.0956)
WU30	0.9229***	(0.1158)	0.6779***	(0.0929)
SV	0.6020***	(0.0789)	0.4985***	(0.0721)
COST	-0.0861***	(0.0125)	-0.0744***	(0.0077)
Non-random Parameters				
INCOST	0.0096***	(0.0018)	0.0084***	(0.0013)
ASCAQ	0.6278***	(0.1528)	1.6128***	(0.6106)
ASCDW	-0.4645***	(0.1302)	-1.4034***	(0.4831)
ASCWU	0.3824***	(0.1369)	1.9913***	(0.6731)
ASCIMPDF	-0.6436***	(0.1032)	-1.2794***	(0.4376)
Standard Deviation of Parameter Distributions				
TsME10	0.1079	(0.1764)	0.0652	(0.1907)
TsME30	1.3990***	(0.2258)	0.9345***	(0.1969)
TsNL10	0.2501***	(0.0841)	0.2182***	(0.0846)
TsNL30	0.7635***	(0.0927)	0.6616***	(0.0824)
TsWU10	0.0820	(0.0838)	0.2285***	(0.0956)
TsWU30	1.8459***	(0.2315)	1.3558***	(0.1858)
TsSV	1.2040***	(0.1579)	0.9970***	(0.1443)
TsCOST	0.0861***	(0.0125)	0.0744***	(0.0077)
Error Components				
σ_j			2.7090***	(1.0045)
Heterogeneity around the Std of the Error Components				
γ_j (SATIS)			0.3663***	(0.1272)
Model Statistics				
N (Observations)	1375		1375	
Log Likelihood	-1040.367		-899.175	
McFadden Pseudo-R^2 (%)	31.1		40.5	
AIC	1.53		1.33	
BIC	1.58		1.39	
χ^2 (degrees of freedom)	940.45*** (13)		1222.83*** (15)	

Notes: Standard errors in parentheses; single (*), double (**) and triple (***) asterisks denote significance at the 10%, 5% and 1% levels respectively.

Table 5 Annual mean WTP (NZ$) per household for the attributes

Attribute	MLEC	Income <$40,000	Income $40 – 70,000	Income >$70,000	Weighted WTP
ME10	8.72 (-3 – 19)	5.29	4.69	7.73	4.70
ME30	15.85 (-6 – 34)	9.62	16.69	26.09	10.66
NL10	22.67 (3 – 39)	14.15	14.66	22.15	13.02
NL30	31.82 (4 – 54)	19.87	19.14	28.92	17.90
WU10	20.54 (-3 – 40)	12.64	10.86	16.67	11.06
WU30	26.93 (-8 – 56)	16.44	15.73	24.29	14.82
SV	16.34 (-6 – 35)	9.92	8.85	13.72	8.78

Note: Confidence intervals (CIs) in parentheses at 95% level; the mean WTPs and CIs are calculated based on the unconditional parameter distribution estimates.