Values of Ecosystem Services Associated with Intense Dairy Farming in New Zealand[1]

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Abstract:

The increase in greenhouse gas emissions and degradation of water quality and quantity in waterways due to dairy farming in New Zealand have become of growing concern. Compared to traditional sheep and beef cattle farming, dairy farming is more input intensive and more likely to cause such environmental damage. Our study uses choice modeling to explore New Zealanders' willingness to pay for sustainable dairy and sheep/beef cattle farming. We investigate respondents' level of awareness of the environmental degradation caused by dairy farming and their willingness to make trade-offs between economic growth and improvements in the level of ecosystem services associated with pastoral farming.

Key Words: ecosystem services; greenhouse gas emissions; dairy farming; choice modeling

1. Introduction

Currently nearly 90% of total agricultural land in New Zealand is used for pastoral farming. Sheep and beef cattle farming occupies nearly 85% of the pastoral land, and dairy farming uses about 15% of the pastoral land. Dairy farming and the amount of New Zealand land used for dairy farming have been growing rapidly over the last decade. Land used for dairy farming and the number of dairy cows increased by 12% and 34%, respectively, from 1994 to 2002 (Statistics New Zealand, 2003). The growth of dairy farming led to increased export of agriculture products of NZ$3.7 billion during the period and increased dairy product's share of total agricultural exports from 34 to 42% (MAF Policy, 2005). These developments in dairy farming have contributed strongly to New Zealand economic growth. However, increases in the amount and intensity of dairy farming also have some harmful environmental effects including increased nitrate leaching to streams and rivers, increased methane gas emissions, increased demands for surface and ground water for irrigation and reduced variety in pastoral landscapes (Parliamentary Commissioner for the Environment, 2004). These effects of increased, intense dairy farming reduce the ability of pastoral land to provide some important ecosystems services.

There is clear evidence that many New Zealand residents are concerned about the rapid development of intense dairy farming because of its adverse effects on part of the natural environment (Cullen et al. 2006). We believe that policies can be introduced to influence pastoral farming practice and achieve improvements in the environmental attributes that impact selected ecosystem services. Our study aims to estimate values for improvements in selected environmental attributes that are linked to intense dairy and traditional beef/sheep farming. As the values attached to improvement in environmental attributes reflect individual's marginal utilities, the estimations allow us to quantify the social benefits of the changes. Thus the study surveys randomly selected New Zealand residents to determine their willingness to pay for some environmental attributes: improved water quality, reduced methane gas emissions, reduced demands by agriculture for surface and groundwater, and more diverse pastoral landscapes associated with dairy farming if the area and number of dairy farms are decreased. The paper also studies respondents' level of awareness of the environmental degradation caused by dairy farming and the trade-off between economic growth and increases in ecosystem services associated with pastoral farming.

2. Method

Choice modeling is utilized to calculate individual's willingness to pay for various environmental attributes. The model is formulated in a random utility framework, which allows measurement of values of non-market goods and services. The utility function, U, is composed of an observable component, (indirect utility function), V, and an unobservable (stochastic) error component, ε:

$$U = V(v) + \varepsilon\ . \tag{1}$$

Here, we assume that the indirect utility, v, takes a linear form,

$$v_i = \beta_k X_{ki} + \alpha_i y_i = \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_k x_{ki} + \alpha_i y_i , \tag{2}$$

where X_{ki} (= {x_1, $x_{2,\ \ldots,}$ x_k}) is vector of k attributes associated with alternative i, β is a coefficient vector, y_i is income for a respondent choosing the alternative i^{th} bundle, and α is the coefficient vector of income. If the stochastic error term is logistically Gumbel distributed (Type I extreme value distributed), the choice probability for alternative i is given by,

$$\Pr(i) = \frac{\exp(\rho v_i)}{\Sigma_{j\in C}^{J} \exp(\rho v_i)} , \tag{3}$$

where ρ is a positive scale parameter, and C is the choice set for an individual. For convenience, we make the assumption of ρ =1 (Ben-Akiva and Lerman, 1985).
To estimate the welfare impacts, i.e., willingness-to-pay, for a change from the status quo state of the world to the chosen state, the following formula is used:

$$v_i(X_i, y) + \varepsilon_i = v_j(X_j, y - CV) + \varepsilon_j , \tag{4}$$

where v_i and v_j represent utility before and after the change and CV is compensating variation, the amount of money that makes the respondent indifferent between the status quo and the proposed scenario.

A multinomial logit model or conditional logit model can be applied to estimate the welfare measure in Eq. (4). With the multinomial logit model, the effects of the attribute variables are allowed to vary for each outcome. Equation (4) can be restated as:

$$\beta_i X_{ki} + \alpha_i y + \varepsilon_i = \beta_j X_{kj} + \alpha_j (y - CV) + \varepsilon_j, \quad (5)$$

where α_t and α_j are assumed to be equal (Haab and McConnel, 2003) if marginal utility of income for a respondent is constant. The welfare change is estimated by:

$$CV = -\frac{1}{\alpha}\left[(\beta_i X_{ki} - \beta_j X_{kj}) + (\varepsilon_i - \varepsilon_j)\right]. \quad (6)$$

For the multinomial logit model, the coefficient vector of *k* attribute variables differ for each alternative, and $\beta_i \neq \beta_j$. On the other hand, in the conditional logit model, coefficients of *k* attributes across all of the alternatives are the same (Greene, 2002), and $\beta_i = \beta_j$; only the attribute levels differ across the alternatives. Under this condition, welfare change is estimated by the following:

$$CV = -\frac{1}{\alpha}\left[\beta(X_{ki} - X_{kj}) + (\varepsilon_i - \varepsilon_j)\right]. \quad (7)$$

In this paper, the conditional logit model (Eq. 7) is used to estimate welfare changes in ecosystem services, since the impact of the attributes of ecosystem services is assumed to remain the same across all choice alternatives.

3. Survey Design

Our surveys contained four sections: (1) general questions on the environment in New Zealand; (2) general questions on pastoral farming in New Zealand; (3) specific questions on alternative management scenarios for pastoral farming, which contained choice model questions (sets); and (4) questions on respondent's social characteristics and backgrounds. The questions in the last section ask respondents their age (AGE), gender (GENDER), education (EDU), income (INC), and residential area, i.e. rural or urban area (UEB).

Choice modeling is utilized to calculate individual's willingness to pay for each of the environmental attributes of interest. Each choice set contains three alternative scenarios (options A, B, and C). Respondents were asked to choose the best option among the three scenarios (figure 1).

Each of the scenarios includes various levels of selected environmental attributes associated with pastoral farming. These attributes are the levels of methane gas emissions from pastoral farms, the amount of nitrate leaching to surface and groundwater, the amount of water used for irrigation on pastoral farms, and the diversity of scenery in pastoral landscapes. The first three environmental attributes have three levels in the scenarios. Methane gas emissions from pastoral farms were set at 30% reduction, 10% reduction, or no change from the current emission level. Nitrate leaching to waterways from pastoral farms were presented as 30% reduction, 10% reduction, or maintenance of the current level of nitrate leaching. The levels for the third attribute, water used for irrigation on pastoral farms, were set at 30% reduction, 10% reduction or maintenance of the current level of water used for irrigation. The scenic view attribute is limited to two levels; 30% more trees, shelterbelts, and plantations on pastoral farms or no change from the current pastoral farming landscape. Since the study aims to analyze New Zealand residents' behaviors by comparing dairy farming to other pastoral farming, the scenarios in options A and B provide two routes to achieve environmental outcomes in the selected attributes by decreasing the area and number of dairy farms while increasing the area and number of sheep and beef cattle farms. Option C is the "status quo" or no change from the current levels of pastoral farming and environmental quality, which is a reference level for the data analysis.

The payment vehicle is loss of household incomes. Our study assumes that policies, which lead to reduced water for irrigation, reduced methane emissions, reduced nitrate leaching to waterways, and more trees and shelterbelts, may decrease the profitability of dairy farming and affect the short-term growth of the New Zealand economy and employment. The slower economic growth could reduce a typical household's income for the next five years and increase the likelihood of household members being unemployed. The losses of income and employment are the cost of our policy scenarios in options A and B. The discrete range of the costs provided to the respondents is NZ$10, $30, $60 and $100 per year per household for the next five years. The assigned cost of the status quo is $0.

Respondents were asked to answer similar types of choice sets nine times in a survey questionnaire. There are 3^3x2x4 factorial designs (Louvier et al., 2000) since we consider three levels for each of the methane gas emissions, nitrate leaching to water and water use for irrigation, two levels in the scenic view attribute, and four levels in the cost to household. For statistically efficient choice designs, a D-efficient design excluding unrealistic cases was adapted (Huber and Zwerina, 1996; Terawaki et al., 2003). One hundred and four designs were selected from them, which constituted 72 choice sets, and allocated them to eight groups (versions) of nine choice sets.

In the beginning of November, 2005, pilot surveys were tested on randomly selected residents in both the South and North Islands. During late November and early December 2005, 1008 pre-survey cards, survey questionnaires, cover letters, and reminder cards were mailed nationwide to randomly selected residents, who were registered on the New Zealand electoral roll. Half of the residents were selected from the South Island population roll, and the other half from the North Island.

4. Survey Analysis and Results

4.1 Descriptive Statistics

We received a total of 312 responses with completed questionnaires out of 1008 mailed survey questionnaires. The total effective response rate was 31%.

The average social characteristics for the respondents are shown in table 1. In our data, 48% of the respondents are female and 70% are living in urban areas. The average respondent is 53 years old and has lived in the same region for approximately 20 years. He/she graduated from high school and has a technical/trade qualification, and his/her household income is between NZ$40,000 and NZ$50,000.

The regional distribution of the data set is presented in table 2. More than half of the survey respondents reside in Canterbury. The second largest number of responses was from Auckland. North Island except Auckland, then Northland follow in that order.

4.2 Conditional Logit Model

Choice modeling results are analyzed using a conditional logit model. Rather than employing dummy variables (1 or 0 coding), effect coding (1, 0 or -1 coding) are used (Louvier, 2000) for the attribute variables in our model. Definitions of the effect coding for the variables are presented in table 3. The advantage of using effect coding over dummy variables is the ability to observe a respondents' comparison of one level with other levels in an attribute (Takatsuka, 2004).

For simplicity, no social characteristics and no regional variables are introduced in the first model (Model 1). This model includes an alternative specific constant (ASC) which captures unobserved factors on respondents' choices between options A, B and C (Morrison et al., 2002). Our study sets the ASCs for options A and B to be identical, since our interest is in determining differences in respondents' behaviors to select between proposed policies (option A or B) and the status quo situation (option C). To estimate a utility function (eq. 2), the following conditional logit model is regressed in Model 1:

$$[\mathit{UTILITY\ 1}] = f\,[\mathrm{COST}, \mathit{ME10, ME30, NL10, NL30, WU10, WU30, ASC}].$$

The results are presented under columns of Model 1 in table 4. All variables are significant at the 0.10 level. COST is negative, which indicates that higher costs of proposed policies would lower respondents' utilities. Positive signs for all of the environmental attribute variables indicate that improvement in the level of the attributes increases respondents' utility. In this model, another notable sign is the negative ASC. It indicates that unobserved factors affect respondents' utilities negatively when the respondents choose option A or B compared to the status quo.

Regional analysis is operated in the second model (Model 2). Regional variables are interacted with ASC and included in the conditional logit model. Regions tested in the model are Auckland (AUC), Northland (NORTHLA), other areas in the North Island outside Auckland and Northland (OTHERNI), and Canterbury (CANTER). Definitions of the variables are shown in table 5. Model 2 is regressed in the following fashion:

[*UTILITY 2*] = f [*COST, ME10, ME30, NL10, NL30, WU10, WU30, ASC, ASC*AUC, ASC*NORTHLA, ASC*OTHERNI, ASC*CANTER*].

The results (table 4) show that all variables are significant at the 0.05 level except ASC. Similarly to Model 1, all environmental attributes have positive signs, while COST is negative. The negative signs of regional interaction terms indicate that if a respondent selects a proposed policy (option A or B) with no improvement in any environmental attribute, then the respondents suffer a loss of utility. This is rational since they incur the burden of a loss of income without enjoying higher levels of environmental quality.

4.3 Willingness-to-Pay Analysis

Implicit prices for the ecosystem attributes are estimated from both models 1 and 2. Table 6 shows the results. In model 1, the prices are estimated mean marginal willingness to pay for each environmental attribute for New Zealand. In model 2, the implicit prices are calculated for a reference region, which is the South Island outside the Canterbury region. The implicit prices between the two models do not show large differences. In both models, reductions in nitrate leaching are the most highly valued by respondents. Reduction in water use for irrigation, enhanced pastoral landscape, and reduced methane emissions from pastoral farming follow in order as valued environmental attributes.

Based on these results, marginal respondent willingness to pay or utilities from the base scenario, status quo situation (SQ), to the various proposed scenarios are estimated. The varied scenarios are listed below:

1. From the SQ to a situation in a selection of an offered policy A or B, but no improvement in any selected ecosystem attributes.
2. From the SQ to a situation with 30% reduction in methane gas emissions (ME) under a policy A or B.
3. From the SQ to a situation with 30% reduction in nitrate leaching to waterways (NL) under a policy A or B.
4. From SQ to a situation with 30% reduction in water use for irrigation (WU) under policy A or B.
5. From SQ a situation with 30% more variety of scenic views (SV) under policy A or B.
6. A scenario combining 2 and 3.
7. A scenario combining 2, 3, and 4.
8. A scenario combining 2, 3, 4, and 5 (improvement in all attributes).

The resulting effects on marginal utilities in Model 1 are expressed in table 7. In scenario 1, respondent's marginal utility is NZ$ -127.49. This negative value can be interpreted as a case of the government employing a policy which reduces dairy farming and increases beef/sheep farming while not improving any selected environmental attribute associated with pastoral farming. In this situation, the average New Zealand resident will have lower utility valued at $127.49 per year. However, if New Zealand residents know that the policy leads to improvement in environmental attributes associated with pastoral farming, their utilities rise compared to the situation with no improvement. For example, in scenarios 2, 3, 4, and 5, in which a single environmental attribute is improved via a policy, higher marginal utilities are observed compared to the case in scenario one, although the signs are still negative. If reductions in methane gas emissions and nitrate leaching to waterways are achieved via a policy, then respondent's marginal utilities are observed to be positive.

Similar results are seen from model B. In the four regions studied in our survey, (Auckland, Northland, other North Island regions, and Canterbury) respondent's willingness to pay are negative for a policy which achieves no improvements in environmental quality. If any single environmental attribute is improved in Auckland, Northland, or other North Island regions, then respondent's willingness to pay for the policies are still negative. In Auckland, reductions in methane gas emissions, in nitrate leaching to waterways, and in water use for irrigation can bring the residents higher utility. In Northland and other regions in the North Island, residents will enjoy higher utility levels if policies lead to 30% reductions in methane gas emissions and nitrate leaching to waterways from pastoral farming. In Canterbury, policies which lead pastoral farming to any environment improvement, except solely reduced methane gas emissions, would increase respondents' utility.

This study also shows that Canterbury respondent's marginal utility is NZ$249.18 per year per household if policy change pushes pastoral farming to 30% improvement in all of the selected environmental attributes. In other regions of the North Island, Northland, and Auckland respondents' utilities are also increased by scenarios that lead to improvement in all four environmental attributes.

5. Summary

Our study uses choice modeling to explore New Zealanders' willingness to pay for sustainable dairy and sheep/beef cattle farming. We assumed that reductions in dairy farming and increases in beef and cattle farming would improve selected environmental attributes associated with pastoral farming although they may result in slower economic growth rates. The results of our study indicate that implicit prices of each of the selected environmental attributes in pastoral farming are positive. Reductions in nitrate leaching to waterways from pastoral farming are at national level the highest valued attribute among our selected attributes. Reductions in water use for irrigation, improvement in scenic views, and reduction in methane gas emissions from pastoral farming follow in order as valued attributes.

This study also investigates respondents' willingness to make trade-offs between economic growth and improvement in ecosystem attributes associated with pastoral farming. It can be noted that respondents in Auckland will have increased utility if pastoral farming systems change and three environmental attributes improve (methane gas emissions, nitrate leaching to waterways, and water use for irrigation) while economic growth slows. In Northland, and regions in the North Island except Auckland and Northland, the trade-off between economic growth and 30% reductions in environmental attributes, which combined methane gas emission and nitrate leaching, will bring society increased utility.

In Canterbury, respondents' utilities are improved by a policy increasing only a single environmental attribute (nitrate leaching, water use for irrigation, or pastoral scenic views). This result shows that Canterbury residents value each single attribute higher than do residents in other regions. In other words, Canterbury residents may be more aware of the serious environmental degradation caused by dairy farming, and their willingness to make trade-offs between economic growth and improvements in the level of ecosystem services associated with pastoral farming is much stronger than that observed in other regions.

Overall our study found that with some provisos, any region in New Zealand can enjoy higher social benefits if policy decreases the number of intensely farmed dairy farms and there is a shift to traditional beef/sheep farming. Based on the present investigation, the requirement for increased social benefit is to improve at least three out of the four environmental attributes considered in this research. The approach used in this study could be applied to other cases to determine how policy might achieve both enhancement of environmental attributes and increase in social utility.

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Appendixes:

Table 1 Descriptive Statistics

	Mean	Std.Dev.	Skewness	Minimum	Maximum
GEND	0.48	0.50	0.10	0	1
URBAN	0.70	0.46	-0.86	0	1
YRSLIV	20.36	18.24	1.15	0	90
NOHH	2.79	1.42	1.02	0	8
NOCHI	0.60	1.04	1.91	0	6
EDU	4.00	1.66	0.27	1	7
INCO	5.48	2.48	-0.04	1	9
BORN	53.05	18.43	0.00	17	97

Variable	Definitions
GEND	1 if male; 0 if female
URBAN	1 if residence in urban area; otherwise 0
YRSLIV	Number of years of living in the same district
NOHH	Number of household members
NOCHI	Number of children in a household
EDU	1 if primary school; 2 if high school without qualifications; 3 if high school wit qualifications; 4 trade/technical qualification; 5 undergraduate diploma; 6 bachelors degree; 7 postgraduate
INCO	Household income: 1 if less than \$10,001; 2 if \$10,001 to \$20,000; 3 if \$20,001 to \$30,000; 4 if \$30,001 to \$40,000; 5 if \$40,001 to \$50,000; 6 if \$50,001 to \$60,000; 7 if \$60,001 to \$70,000; 8 if \$70,001 to \$100,000; 9 if more than \$100,000
BORN	Age

Table 2 Regional Distribution of the Survey Respondents

	Region	%
North Island	Auckland	27.4
	Northland	3.0
	Other regions	14.8
South Island	Canterbury	52.2
	Other regions	2.6
Total		100.0

Table 3 Attributes in Choice Modeling (Effect Coding)

Attributes	Variables	Definitions
Methane gas emissions	ME10	1 if 10% reduction; 0 if 30% reduction; -1 if no change
	ME30	1 if 30% reduction; 0 if 10% reduction; -1 if no change
Nitrate Leaching	NL10	1 if 10% reduction; 0 if 30% reduction; -1 if no change
	NL30	1 if 30% reduction; 0 if 10% reduction; -1 if no change
Water use for irrigation	WU10	1 if 10% reduction; 0 if 30% reduction; -1 if no change
	WU30	1 if 30% reduction; 0 if 10% reduction; -1 if no change
Scenic views	SV30	1 if 30% more variety; -1 if no change
Cost to household	COST	NZ$10;$30;$60;$100 per year
Alternative specific constant	ASC	

Table 4 Conditional Logit Model

	Model 1 Coeff.		Std.Err.	t-ratio	P-value	Model 2 Coeff.		Std.Err.	t-ratio	P-value
COST	-0.01	**	0.00	-6.16	0.00	-0.01	**	0.00	-6.32	0.00
ME10	0.10	**	0.05	2.12	0.03	0.10	**	0.05	2.12	0.03
ME30	0.13	**	0.04	2.92	0.00	0.12	**	0.04	2.82	0.00
NL10	0.11	**	0.04	2.50	0.01	0.13	**	0.05	2.80	0.01
NL30	0.32	**	0.04	7.59	0.00	0.33	**	0.04	7.66	0.00
WU10	0.09	*	0.05	1.88	0.06	0.09	**	0.05	2.00	0.05
WU30	0.18	**	0.04	4.31	0.00	0.18	**	0.04	4.25	0.00
SV30	0.22	**	0.03	6.85	0.00	0.23	**	0.03	6.98	0.00
ASC	-0.81	**	0.12	-7.03	0.00	0.42		0.37	1.12	0.26
ASC*AUC						-1.93	**	0.37	-5.24	0.00
ASC*NORTHLA						-1.51	**	0.44	-3.46	0.00
ASC*OTHERNI						-1.42	**	0.38	-3.78	0.00
ASC*CANTER						-0.82	**	0.36	-2.25	0.02
Number of observation	2404					2404				
Chi-squared	132.12					46.70				
Log-likelihood	-2553.05					-2486.28				
R-squared adj.	0.03					0.05				

** Significant at the 0.05 level

* Significant at the 0.10 level

Table 5 Regional Variables

Variables	
AUC	1 if residents in Auckland; otherwise 0
NORTHLA	1 if residents in Northland; otherwise 0
OTHERNI	1 if residents in North Island except Auckland and Northland; otherwise 0
CANTER	1 if residents in Canterbury; otherwise 0

Table 6 WTP (Implicit price): NZ$ per household per year

Variables	ME30%	ME10%	NL30%	NL10%	WU30%	WU10%	SV30%	ASC	AUC	NORTHLA	NIWOAN	CANTER
Model 1												
Implicit price												
NZ	**55.04**	**50.35**	**119.60**	**86.29**	**70.75**	**55.80**	**69.45**	**-127.49**				
Model 2												
Implicit price												
South Island except Canterbury	**52.40**	**48.56**	**120.06**	**89.09**	**69.08**	**55.66**	**68.93**	63.81	**-293.52**	**-229.37**	**-216.39**	**-125.10**

Bold - Significant at the 0.10 level

Table 7 Changes in Utility in Varied Scenarios: NZ$ per household per year

	Model A	Model B			
	NZ	Auckland	Northland	Others in North Island	Canterbury
Scenarios					
1. From SQ to a selection of a proposed policy but no improvements	-127.49	-229.72	-165.56	-152.58	-61.29
2. From SQ to 30% reductions in ME	-72.44	-177.32	-113.16	-100.18	-8.89
3. From SQ to 30% reductions in NL	-7.88	-109.36	-45.20	-32.22	59.07
4. From SQ to 30 reductions in WU	-56.74	-160.64	-96.48	-83.50	7.79
5. From SQ to 30% more variety in SV	-58.04	-160.79	-96.63	-83.65	7.64
6. From SQ to 30 % reductions in ME & NL	47.15	-57.26	6.90	19.88	111.17
7. From SQ to 30% resuscitations in ME, NL, & WU	117.90	11.82	75.98	88.96	180.25
8. Total Improvements of scenarios from 1 to 4	187.36	80.75	144.91	157.89	249.18

Figure 1 A Example of Choice Modeling Questions

Please tick the option that you most prefer:

	Option A	**Option B**	**Option C**
	Less dairy farming and more sheep/beef farming	**Less dairy farming and more sheep/beef farming**	**No change from the current dairy farming level**
Methane emissions	30% reduction	10% reduction	No change
Nitrate leaching	30% reduction	No change	No change
Water use for irrigation	No change	10% reduction	No change
Scenic views	30% more trees, hedges, plantations	30% more trees, hedges, plantations	No change
Loss of your household income ($ per year for the next 5 years)	$100	$60	$0

Option A ☐ Option B ☐ Option C ☐