New Zealand Agricultural and Resource Economics Society (Inc.)

Modelling the effects of climate change policy on the NZ livestock sector

Caroline Saunders
Professor, AERU, PO Box 84, Lincoln University, Canterbury, New Zealand
e-mail: saunderc@lincoln.ac.nz

Anita Wreford
Research Associate, AERU, PO Box 84, Lincoln University, Canterbury, New Zealand
e-mail: wreforda@lincoln.ac.nz

Paper presented at the 2004 NZARES Conference
Blenheim Country Hotel, Blenheim, New Zealand. June 25-26, 2004.

Modelling the effects of climate change policy on the NZ livestock sector.

Caroline Saunders* and Anita Wreford**

Prepared for the annual NZARES meeting – Blenheim , June 25th -26th, 2004.

Abstract

The link between trade and the environment has aroused considerable interest both in terms of the impact of trade liberalisation on the environment, and also the impact of environmental policy on production and trade. Of key environmental concern at present is global warming and greenhouse gas (GHG) emissions. Global attempts to limit GHG emissions will also impact on agricultural trade and producer returns, particularly in countries such as NZ, where relatively large proportions of GHG emissions originate from the agricultural sector. This study uses a partial equilibrium agricultural trade model, extended to include production systems and GHG emissions, to analyse the effects of GHG mitigation policies on agricultural production and trade.

*Professor, AERU, PO Box 84, Lincoln University, Canterbury, New Zealand
saunderc@lincoln.ac.nz

** Research Associate, AERU, PO Box 84, Lincoln University, Canterbury, New Zealand
wreforda@lincoln.ac.nz

1. Introduction

Agriculture is an important source of greenhouse gas (GHG) emissions, particularly methane (CH_4), and nitrous oxide (N_2O). Therefore countries who have ratified the Kyoto Protocol and are consequently committed to reducing their GHG emissions, may be assessing methods of reducing emissions from the agricultural sector. For most developed countries however, agricultural emissions are a small proportion of their total emissions and this sector is therefore not a primary concern. New Zealand (NZ) is unusual amongst developed countries though, with more than half of its GHG emissions originating from agricultural processes, and the sector's emissions are as a consequence likely to be targeted in some form. For comparison, European Union (EU) agriculture contributes around 10 percent of EU total emissions (IPCC 2000).

Complying with Kyoto Protocol requirements is likely to come at a cost for many sectors and agriculture is no exception. There is concern among participating countries regarding the effects of mitigation strategies on the economies concerned. The NZ agricultural sector contributes significantly to the economy, with land-based industries comprising around 70 percent of the country's export earnings (MFAT 2002). The impact of mitigating agricultural GHG emissions on producer returns and trade in the agricultural sector is very important.

The purpose of this paper is to illustrate the linking of natural and social science in this context through the extension of a partial equilibrium (PE) trade model, to include emissions of methane and nitrous oxide. This model is important in that it provides a means to analyse the economic impact of GHG mitigation strategies, in the form of producer returns to agriculture, as well as other mechanisms for meeting Kyoto requirements, such as carbon taxes and/or tradeable emission permits.

The structure of the paper is as follows: the next section briefly describes methane and nitrous oxide emissions from agriculture and their major sources. This is followed by a description of the economic model used in the research, the LTEM, and the methodology used in the extension to include GHGs. An example of a GHG mitigating strategy will be presented, along with some preliminary results. These will be followed by a discussion and the direction of further research.

2. Methane and Nitrous Oxide

Direct emissions of carbon dioxide (CO_2) from the agricultural sector are low and New Zealand is no exception in this regard. Emissions of methane and nitrous oxide from agriculture are much more significant (MAF 2001). Moreover, both methane and nitrous oxide have much higher global warming potentials than CO_2. Consequently, the two greenhouse gases which will be considered in this study are methane and nitrous oxide.

With the relatively large ruminant animal population in New Zealand, methane production is particularly significant. Methane from livestock is produced from two possible sources: that produced during the digestion process ("enteric fermentation") and that from the decomposition of ruminant faecal waste ("manure management"). The amount of methane produced depends on the amount of feed intake as well as the type and quality of the feed.

Nitrous oxide, although emitted in much smaller quantities than either CH_4 or CO_2, is important because of its relative impact in terms of global warming potential. There are a number of sources of this gas arising from agricultural production, broadly relating to animal waste management, agricultural soil processes and fertiliser application.

There are a number of mitigation strategies for agriculture, as identified in O'Hara et al (2003), Clark et al. (2001), AEA Technology Environment (1998), many of which may affect production. Furthermore, as stated by the IPCC (2001), there is a need to identify the extent to which the impacts of climate change mitigation policies create or exacerbate inequities across nations and regions. This paper will illustrate the capability of the model through simulating the impact of two such strategies: a reduction in stocking rate and a limit on nitrogen (N) fertiliser, to analyse the impact not only on GHG emissions, but also on trade and producer returns from livestock. This paper focuses primarily on NZ, a country with agriculture as its main sector, and the European Union (EU), whose mitigation policies have the potential to affect the world market.

3. The LTEM

The LTEM is a partial equilibrium (PE) model based upon VORSIM (Roningen, 1986; Roningen et al., 1991). which has been extended to allow the link through supply to production systems and physical and environmental impacts to be simulated. Through this it is possible to model climate change policies, such as mitigation strategies or carbon taxes, applied either as physical or financial criteria, or trade policy changes to analyse their impact on GHG emissions. A detailed review of the literature linking GHG with agriculture and trade is presented in Saunders et al. (2002b).

3.1 General features of the LTEM

A detailed description of the LTEM and its characteristics are presented in Cagatay and Saunders (2002). The LTEM includes 19 agricultural (7 crop and 12 livestock products) commodities and 17 countries. The commodities included in the model are treated as homogeneous with respect to the country of origin and destination and to the physical characteristics of the product. Therefore commodities are perfect substitutes in consumption in international markets. Based on these assumptions, the model is built as a non-spatial model, which emphasizes the net trade of commodities in each region.

The LTEM is a synthetic model, with parameters adopted from the literature. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities which reflect the symmetry condition. Therefore, the own- and cross-price elasticities are consistent with theory. The model is used to quantify the price, supply, demand and net trade effects of various policy changes. The model is used to derive the medium- to long-term (until 2010) policy impact in a comparative static fashion based on the base year of 1997.

In general there are six behavioural equations and one economic identity for each commodity under each country in the LTEM framework. The behavioural equations are domestic supply, demand, stocks, domestic producer and consumer price functions and the trade price equation. The economic identity is the net trade equation, which is equal to excess supply or demand in the domestic economy. For some products the number of behavioural equations may change as the total demand is disaggregated into food, feed, and processing industry demand, and are determined endogenously.

The model works by simulating the commodity based world market clearing price on the domestic quantities and prices, which may or may not be under the effect of policy changes, in each country. Excess domestic supply or demand in each country spills over onto the world market to determine world prices. The world market-clearing price is determined at the level that equilibrates the total excess demand and supply of each commodity in the world market by using a non-linear optimisation algorithm (Newton's global or search algorithm).

The sectoral focus of this study is dairy. The relationship calculating GHG emissions and the linkage between the dairy sector and GHG emissions are presented in the next section. In future, beef and sheep will also be included in the estimations.

3.2 Environmental sub-module: Linking agricultural output through production systems with GHG emissions

To incorporate GHG into the model the LTEM structure is extended in two directions. First, the dairy sectors in Australia, the EU, NZ and the United States are separated into three production types, and supply in each type modelled explicitly (Saunders et al. 2002a). Data on production systems were taken from a number of sources, including farm advisory recommendations, census and survey reports, and field trials. Secondly, in order to reflect the effect of livestock production on GHG emissions, an environmental damage function is introduced, measuring the CH_4 and N_2O emissions. The model is extended to incorporate the link to physical production systems and then secondly through to the impact on GHG emissions.

In order to endogenise the amount of N fertilizer used (N/ha) for production, a conditional input demand function for N is estimated for each region, equation 1. In this equation, the demand for N use per hectare, for example for raw milk in region A (*Nam*), is specified as a function of relative prices of the feed concentrates (*pcmk*) to the N (*pcmN*) and quantity supplied per hectare in region A (*qsami*). The variable *pcmk* is calculated as a weighted average of consumer prices of wheat, coarse grains, oil seeds and oil meals. The weights are found by calculating the percentage share of each feed product in total feed use. The variable *qsami* is included as a shift factor which proxies the technological changes in the production process and/or irregular effects that effect supplied amount of raw milk (Burrell, 1989). The coefficients *βi1* and *βi2* show the elasticity of fertilizer demand in region A with respect to the change in raw milk supply in region A and relative prices. The *βi2* is expected to be positive and an increase in *pcmk* is expected to result in an increase in N demand, as N fertilizer and feed concentrates are expected to be gross substitutes.

$$Na_m = \beta_{m0}\left(qsa_{mi}\right)^{\beta_{i1}}\left(\frac{pc_{mk}}{pc_{mN}}\right)^{\beta_{i2}} ; \qquad \beta_{i1} > 0 , \; \beta_{i2} > 0 \qquad 1$$

Animal numbers are of critical importance in determining the CH_4 and N_2O emissions for each country. The number of animals used for production in each region (*NAami*) are endogenised by specifying them as a function of various product and input prices such as feed concentrates and N fertilizer, shown in equation 2. The specification is based on Jarvis's (1974) livestock supply response model in which farmers' decisions to increase their livestock are dependent on the expected value of future meat and/or milk production. The estimation was carried out using OLS on the log-linear form of the equations. In equation 2, the parameters $\gamma i1$ and γij (own- and cross- price elasticities) reflect the response of farmers to various prices on deciding to build up (invest in) their stock of livestock. The $\gamma i1$ is expected to be positive since an increase in own-price may change farmers' incentives to increase their stock whilst the γij is expected to be negative since an increase in producer prices of other livestock products may change farmers' incentives to increase other types of livestock. A negative elasticity between animal numbers and input prices ($\gamma ik,n$) is also expected since rising prices of either fertilizer or feed concentrates may change the incentives towards slaughtering them instead of feeding. Two major sources were used for the livestock data: the FAO agricultural statistics database, and the USDA database.

$$NAa_{mi} = \gamma_{m0}\, pp_{mi}^{\gamma_{i1}} \prod_j pp_{mj}^{\gamma_{ij}} \prod_{k,n} pc_{mk,n}^{\gamma_{ik,n}} \; ; \; \gamma_{i1} > 0 \, , \; \gamma_{ij} < 0 \, , \gamma_{ik,n} < 0 \qquad 2$$

3.3 Calculation of coefficients for GHG production.

The calculation of coefficients for CH_4 and N_2O production from livestock systems is based on the IPCC methodology for GHG inventories. Default emission factors provided by the IPCC are used for the calculation of coefficients in most countries (IPCC 1996). In the case of N_2O production in NZ, the emission factors are based on more accurate findings, and differ from the default IPCC values (Clough and Sherlock 2001).

Emissions of N_2O and CH_4 are generated through a number of complex processes in agriculture, as identified in IPCC (1996). The sources associated with livestock agriculture are summarised into one equation, able to be included in the LTEM (Clough and Sherlock 2001) (equation 3). A single coefficient for the N_2O emitted from N fertilizer was also calculated, constant across animals and countries. In equation 3, GHG is specified as a function of applied N and number of animals, and CH_4 and N_2O emissions from these sources are multiplied by their respective CO_2 weightings.

$$GHG_j = 21(\alpha NA) + 310(\beta N, \gamma NA) \qquad 3$$

The aNA term symbolises methane, and calculates this by applying a coefficient to the number of animals, the coefficient developed from the IPCC methodology. Similarly, the $\beta(N, NA)$ term represents nitrous oxide, with N being nitrogen fertiliser application, and NA again being animal numbers. The coefficient β is a standard coefficient on the nitrogen fertiliser, and the γ coefficient is derived from the source of N_2O relating to animal numbers. Both methane and N_2O are multiplied by their respective weightings to give CO_2 equivalents.

The domestic supply functions include the price of N fertiliser and number of animals, as well as the producer and consumer commodity prices, in order to analyse the supply effect of changes in N usage in raw milk production and number of animals, as in equations 4 and 5.

$$qsa_{mi} = \alpha_{i0}\, shf_{qs}^{\;1}\, pp_{mi}^{\alpha_{ii}}\, pp_{mj}^{\alpha_{ij}} \prod_k pc_{mk}^{\alpha_{ik}} \qquad 4$$

$$qsa_{mi} = \alpha_{i0}\, shf_{qs}^{\;1}\, pp_{mi}^{\alpha_{ii}}\, pc_{mN}^{\alpha_{iN}}\, NAa_{mi}^{\alpha_{iNAa}} \prod_j pp_{mj}^{\alpha_{ij}} \prod_k pc_{mk}^{\alpha_{ik}} \; ; \; \alpha_{iN} < 0 \, , \; \alpha_{iNAa} > 0 \qquad 5$$

4. Simulation example

For the purposes of this paper, potential mitigation strategies will be simulated, with their effect on GHG emissions as well as producer returns and trade.

4.1 Mitigation Strategies

Two scenarios representing GHG mitigation strategies in the dairy sector are simulated along with a base scenario, scenario 1, which assumes current policies and production systems are in place and represents a baseline from which the two other scenarios may be compared against. Scenario 2 represents a reduction in the EU of stocking rate, to reflect current agri-environment policies, as well as a reduction in application of N fertiliser and concentrate use in the EU. This scenario is a low-input production system, and represents a significant difference in system for many regions in the EU. This scenario is of interest to NZ, because the change to a less intensive system is likely to affect EU production and trade and therefore also NZ's opportunities for trade internationally, as the EU is both a major market and competitor, especially in the dairy sector. NZ systems remain as in the base scenario.

Scenario 3 simulates a GHG mitigation policy in NZ, where stocking rates are reduced to the EU agri-environment scheme levels, and fertiliser application is considerably lower than the base level. Concentrate use remains at the original low level. The EU system remains the same as in scenario 2.

5. Results

5.1 Trade results

Changes in producer returns from the base scenario are shown in table 1 for raw milk in NZ and the EU. These are predicted to fall by ten percent in the EU, following the change to a less intensive production system in both scenarios. This fall in producer returns is mainly brought about by the reduction in production following a lower stocking rate and less fertiliser application. NZ producer returns increase by two percent in scenario two, where NZ producers benefit somewhat from the reduction in EU production and the associated price effect on the world market. In scenario 3, raw milk returns to NZ producers decrease by a significant 31 percent, following the changes in NZ. This loss of producer returns is considerably larger than the reduction in the EU, despite similar changes in production system.

Table 1. Percentage changes in raw milk producer returns for the EU and NZ, in 2010

	Raw Milk producer returns (Percentage change from base in 2010)	
scenario	**EU**	**NZ**
2	-10.0	2.2
3	-9.7	-30.7

5.2 GHG emissions

Changes in GHG emissions from the base scenario can be seen in table 2. Following the change in production system in the EU in scenario 2, the reduction in stocking rate and N fertiliser application, GHG emissions from dairy livestock in the EU decrease, as expected. The reductions are reasonably large, with total emissions from dairy in the EU falling by 35 percent. It can be seen from table 2 that not all regions in the EU experience the same changes in emissions – region B is hardly affected, while region C emissions decrease by over 60 percent. This is because of the difference in production system to begin with; region C was very intensive and therefore the change had a greater effect than in region B which had a lower stocking rate and rate of fertiliser application to begin with.

Under scenario 2, emissions from NZ dairy livestock generally increase, but these increases are relatively insignificant (one percent). It is interesting to note the minor effect the change in EU policy has on NZ emissions.

In scenario 3, where NZ also reduces stocking rate and N application, emissions from the EU are predicted to decrease by similar amounts as in scenario 2. Emissions from NZ are quite different however, decreasing for all regions and by a total of 22 percent. Again, the reductions vary across the regions, reflecting the different original production systems. Region A shows the largest decrease in emissions, while region B is affected least by the change to a less intensive system, as this region already has a lower stocking rate.

Table 2: Percentage changes in GHG emissions from dairy in 2010 for the EU and NZ

Percentage changes in GHG emissions from the base scenario				
	EU		**NZ**	
	2	**3**	**2**	**3**
MKA	-34.15	-34.15	0.85	-31.22
MKB	-0.89	-0.89	0.91	-11.77
MKC	-61.65	-61.65	0.87	-19.14
Total	-34.68	-34.68	0.87	-21.89

5.3 The economic effect of the mitigation strategies

For countries who have reduced their GHG emissions, trading the credits may be an option. For those countries who have not managed to reduce their emissions, they may be required to pay either a tax, or purchase credits in order to meet their Kyoto Commitments. This section uses varying values of carbon to place a value on the GHG emissions that have been avoided as a result of policies. Table 3 shows these values in million US dollars, with the different values of CO_2 equivalents in the left hand column.

Table 3: Value of the reduction in emissions at different levels of carbon prices (US$m)

	EU		**NZ**	
scenario / **($/000t CO_2-eq)**	**2**	**3**	**2**	**3**
10	257.1	257.1	0.7	17.1
15	385.1	385.7	1.0	25.6
50	1285.7	1285.7	3.4	85.5
100	2571.3	2571.4	6.8	170.9

This value of the change in emissions is then either added or subtracted to the original producer returns, depending on whether the GHGs were more or less than the base scenario, and the new change from the base scenario is calculated. Table 4 shows these results, with the original change in the two mitigation simulations shown in the first two rows for comparison. It is clear from this table that even relatively large carbon prices (such as 50 and 100 US$) do not offset the fall in producer returns resulting from the mitigated GHG emissions. The EU fares better than NZ, in that some of the larger values of CO_2 go some way towards offsetting their reduced producer returns. NZ however, whose producers do not receive any minimum prices or price support, still faces reductions in producer returns of 25 percent at the highest value of CO_2 equivalent (US$100). For comparison, the NZ government has proposed a value of approximately US$15 per tonne of CO_2 equivalent (NZ Climate Change Project 2002). On the other hand, in scenario 2, where NZ must pay the value of its increased emissions, an increase in producer returns from the base scenario is still shown, even at the highest value of carbon.

Table 4: Percentage change in producer returns including the value of CO_2 at different levels of carbon pricing

		EU	NZ
Original change	**2**	-9.9	2.19
	3	-9.7	-30.72
$ Value of CO_2-eq			
Scenario 2	$10	-9.08	2.16
	$15	-8.66	2.15
	$50	-5.70	2.07
	$100	-1.47	1.96
Scenario 3	$10	-8.82	-30.15
	$15	-8.40	-29.87
	$50	-5.44	-27.89
	$100	-1.21	-25.05

6. Discussion and conclusion

There are a number of uncertainties and assumptions in this research. The variability of biological systems make their emissions intrinsically more difficult to measure than other sectors, for example. The major point relating to this for NZ is animal numbers, as CH_4 is such a significant proportion the country's emissions, primarily originating from ruminant animals. Uncertainty in the numbers of animals will lead to under- or over-estimation of NZ's GHG emissions, which would have important implications for meeting Kyoto targets. Similarly, but even more complex to measure, are the emission factors for each source of gas. Default IPCC values are clearly too broad to be accurate for each country and will therefore again be over- or under-estimating total emissions. These vary in importance, however indirect N_2O emissions is the major uncertainty in NZ (Clough 2004).

The second major limitation is that in this analysis, producers bear the whole price of the carbon pricing, and do not transfer it to consumer prices, as would occur in reality. As a result, there is no modification in consumption patterns. Thirdly, agricultural sinks are not considered in this analysis, and the dairy sector is the only sector considered. The intention is to expand the analysis to include the beef and sheep sectors, however this has been hampered until now by data availability. Further analysis will be to simulate and investigate the impact of carbon taxes and/or carbon trading schemes. Ongoing work will include collecting more accurate data and re-estimating coefficients.

Notwithstanding these limitations, the results indicate clearly for NZ that the best economic path for the livestock sector is to continue with business as usual and if required, purchase carbon credits to cover the increase in GHG emissions. The loss in producer returns following these mitigation paths would be devastating for producers and the economy as a whole. Clearly there are other mitigation options which are not so production focused and would not have the resulting effect on producer returns, and this should be the area where research is focused. In terms of GHG abatement and the Kyoto Protocol, the results are not quite so clear. The EU is a significant emitter of GHGs and therefore every attempt to reduce their emissions may have an important impact on global emissions. While NZ is a small scale emitter, it must be seen to be making attempts to reduce its emissions. However, the forms of mitigation used in this analysis would not be advised for NZ, particularly given the value of agricultural production to the economy. It is also worth noting that the shift to a less intensive system has associated environmental benefits. Similar changes in production systems are occurring in the EU under agri-environment schemes at present, independent of any GHG mitigation programme. New Zealand producers may benefit from an international perception that dairy products from this country are produced in a more “environmentally-friendly” system and may gain consumers who are willing to pay extra for this type of product. The model does not take such effects into account at this stage.

References

AEA Technology Environment, 1998. Options to reduce N2O emissions (Final Report). A report produced for DGXI. AEAT-4180: Issue 3.

Burrell, A., 1989. The Demand for Fertilizer in the United Kingdom. Journal of Agricultural Economics, Vol. 40, No. 1.

Cagatay, S., Saunders, C., 2002. Lincoln trade and environment model: an agricultural multi-country, multi-commodity partial equilibrium framework. Discussion Paper, AERU, NZ.

Clark, H., de Klein, C., Newton, P., 2001. Potential management practices and technologies to reduce N_2O, CH_4 and carbon dioxide emissions from NZ agriculture. Report prepared for Ministry of Agriculture and Forestry, NZ.

Clough, T (2004). Personal Communication, Lincoln University

Clough, T., Sherlock, R., Personal Communication, Lincoln University, NZ, 2001.

Intergovernmental Panel on Climate Change, 2001a. Climate Change 2001, Third Assessment Report of the IPCC, Cambridge University Press.

Intergovernmental Panel on Climate Change, 2001b. Summary for policymakers. Climate Change 2001: Mitigation. A report of working group III of the Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change, 2000. Greenhouse Gas Inventory Data http://www.ghg.unfccc.int

Intergovernmental Panel on Climate Change, 1996. Revised 1996 Guidelines for National Greenhouse Gas Inventories. www.ipcc-nggip.iges.or.jp/public/gl/invs5c.htm

Jarvis, L.S., 1974. Cattle as Capital Goods and Ranchers as Portfolio Managers: An Application to the Argentine Cattle Sector. Journal of Political Economy, May/June, p. 489-520.

MAF 2001 website: www.maf.govt.nz

Ministry of Foreign Affairs and Trade, 2002. New Zealand external trade statistics. Wellington, NZ.

NZ Climate Change Project, 2004 http://www.climatechange.govt.nz/sectors/agriculture/index.html

NZ Climate Change Project, 2002. Climate Change: the government's preferred policy package. Department of the Prime Minister and Cabinet, NZ.

O'Hara, P.; Freney, J.; Ulyatt, M. 2003: Abatement of Agricultural Non-Carbon Dioxide Greenhouse Gas Emissions. A Study of Research Requirements. Report prepared for the MAF.

Roningen, V.O., 1986. A Static Policy Simulation Modeling (SWOPSIM) Framework, Staff Report AGES 860625, Economic Research Service. Washington.: USDA.

Roningen, V.O., Dixit P,. Sullivan, J., and Hart, T., 1991. Overview of the Static World Policy Simulation (SWOPSIM) Modeling Framework, Staff Report AGES 9114, Economic Research Service. Washington: USDA.

Saunders, C.M., Moxey, A., Roningen, V., Cagatay, S., 2002a. Trade and the Environment. Linking a Partial Equilibrium Trade Model with Production Systems and Their Environmental Consequences, Forthcoming.

Saunders, C.M, Wreford, A., Cagatay,. 2002b. Agricultural Trade Liberalisation and Greenhouse Gas Emissions: Modelling the Linkages in the Dairy Sector, Presented at the UK Annual Conference of the UK Agricultural Economics Society, April, Aberystwyth