Mitigation Of Greenhouse Gas Emissions: The Impacts On A Developed Country Highly Dependent On Agriculture.

Caroline Saunders and Anita Wreford

AERU, PO Box 84, Lincoln University, Canterbury, New Zealand

saunderc@lincoln.ac.nz
wreforda@lincoln.ac.nz

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Abstract

This paper focuses on the impact of mitigating greenhouse gases (GHG) on agricultural trade. In particular, the paper assesses the impact on New Zealand (NZ), which is highly reliant on agricultural trade, with a high percentage of its total GHG emissions are originating in the agricultural sector. The paper also analyses the impact of mitigation strategies in the European Union (EU), which has a low proportion of GHG coming from agriculture, a highly protected agriculture sector, and is a major market and competitor for NZ. Results from a partial equilibrium trade model, the LTEM, show clearly that while these mitigation strategies achieve the goal of GHG reduction, producer returns are also negatively affected. The value of these changes in emissions are then calculated, based on US$15/tonne of carbon dioxide (CO_2), and producer returns adjusted for this. Although this value of CO_2 goes some way towards offsetting the reduction in producer returns, it would need to be considerably greater in order to provide any significant compensation.

Key words: Agricultural production system, greenhouse gas emissions, partial equilibrium trade model

F18, Q17

1. Introduction

The Kyoto Protocol requires developed countries to reduce their emissions of greenhouse gases (GHGs). Agriculture is a source of GHGs, particularly methane (CH_4) and nitrous oxide (N_2O), and concern exists regarding the effects of mitigation strategies on the economies of participating countries. However, little is known regarding the impact of mitigation on the agricultural sector and trade. This research provides a link between physical science and economic effects, through the modification of a partial equilibrium (PE) trade model. Selected GHG mitigation options are simulated, and an analysis of their predicted impact on GHG emissions, trade and producer returns is presented.

The paper begins with brief overviews of the contribution of GHG to climate change, policies to reduce emissions and how these may affect agriculture. Possible mitigation options are then identified, followed by a description of the model used, the Lincoln Trade and Environment Model (LTEM). Scenarios and their results are presented in sections 5 and 6, followed by a discussion and conclusion.

2. Climate Change

Increased levels of GHG in the atmosphere are predicted to cause climate change. In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) was adopted, with the objective to achieve 'stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.

The third conference of the parties to the UNFCCC was held in Kyoto, Japan in 1997, and resulted in the Kyoto Protocol, which will come into force after being ratified by at least 55 countries, accounting for 55 percent of developed countries' carbon dioxide (CO_2) emissions (MfE 1999). It is expected that the Protocol will come into effect relatively soon.

Under the Kyoto Protocol, developed countries must reduce total amounts of GHGs to a target level over the period 2008 –2012 (the first commitment period). All countries must demonstrate progress towards their targets by 2005.

3. The role of agriculture in climate change

Agriculture is both an emitter and a sink of GHGs (Saunders et al. 2002b). The primary GHGs produced from the livestock sector are CH_4 and N_2O. These are significant, as using CO_2 as a base (ie.1), CH_4 has a global warming potential of 21, and N_2O 310 (MfE 1999).

In most developed countries, agricultural emissions are a relatively small percentage of total emissions and therefore not likely to be a major focus of mitigation policy. Compensation for any lost income is likely to be provided. However, NZ differs in that agriculture not only accounts for 55 percent of GHG emissions, but is important to the economy, accounting for nearly 50 percent of export earnings. NZ supports the Kyoto protocol, yet any policy designed to limit emissions is likely to have a significant impact on the country's economy. Moreover, mitigation strategies of trading partners and/or competitors, in particular the EU, are likely to have significant effects on NZ.

3.1 Mitigation options for agriculture

There are a number of mitigation strategies for agriculture, as identified in Clark et al. (2001), AEA Technology Environment (1998), many of which 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. The purpose of this paper is to simulate the impact of two of these strategies: a reduction in stocking rate and a limit of nitrogen (N) fertiliser, to analyse the impact not only on GHG emissions, but also on trade and producer returns from livestock, using a partial equilibrium net trade model, LTEM. The key countries included in this analysis are NZ, a country with agriculture as its main sector, and the EU, which has the likelihood of using mitigation policies which may affect the world market.

4. The LTEM

The LTEM is a 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 mitigation and other policies, applied either as physical or financial criteria. A detailed review of the literature linking GHG with agriculture and trade is presented in Saunders et al. (2002b).

4.1. General features of the LTEM

A detailed description of the LTEM and its characteristics are presented in Cagatay (2001). 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 type, 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 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 LTEM is used to derive the medium- to long-term (until 2010) policy impacts in a comparative static fashion using 1997 as the base year.

In general there are six behavioural equations and one economic identity for each commodity in 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 these are determined endogenously.

The model solves 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.

4.2. 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.

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 $\beta i1$ and $\beta i2$ 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 $\beta i2$ 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.

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

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' decision to increase their livestock is 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 increase (invest in) their livestock. The $\gamma i1$ is expected to be positive since an increase in own-price may change farmers' incentives to increase 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 instead of feeding. Two major sources were used for the livestock data: the FAO agricultural statistics database, and the USDA database.

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

4.3 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). All of these sources associated with livestock agriculture are summarised into an 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.

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

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.

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

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

5. Scenarios

Two scenarios representing GHG mitigation strategies 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 simultaneous reduction in the EU of stocking rate, as well as a reduction in application of N fertiliser and concentrate use. This scenario is a low-input production system, and represents a significant difference in system for many regions in the EU. This reflects current agri-environment policies, and possible GHG mitigation strategies. This scenario is of interest to NZ, because the change to a less intensive system is likely to affect production and therefore also NZ's opportunities for trade internationally, as the EU is both a major market and competitor, especially in the livestock sector. Scenario 3 simulates a GHG mitigation policy in NZ, where stocking rates and fertiliser application are also considerably lower. Concentrate use remains at the original low level. The EU system remains the same as in scenario 2. This last scenario is of key importance in understanding the overall effect on NZ of this GHG emission reduction strategy.

6. Results

6.1 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

6.2 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 due to 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

6.3 Valuing carbon emissions

According to the NZ climate change project (2002), current predictions of an emissions price in the international trading market during the first commitment period lie in the range of US$15 per tonne of CO2 equivalent. Assuming that any increase in emissions above the base scenario would be charged at this rate, and any decrease in emissions below the base scenario level could be sold, and the revenue returned to producers, the new producer returns may be calculated. Comparing the change in emissions in scenarios 2 and 3 with the base scenario by 2010, the EU would save around 386 million US$ in both scenarios as a result of the reduction in GHG gases. This would bring the total reduction in producer returns from dairy from ten percent to 8.7 percent in scenario 2 and 8.4 percent in scenario 3. NZ would have to pay an extra one million in scenario 2 as a result of the increased GHG emissions, while it would save 25.6 million in scenario 3. This would hardly affect the producer returns in scenario 2. The change in scenario 3 would bring the percentage fall in producer returns from 30.7 percent, to 29.8 percent. These changes are shown in table 3.

Table 3: Value of CO_2 emissions (based on US$15/tonne of CO2) and new percentage change in producer returns

	EU		NZ	
	2	**3**	**2**	**3**
Value of the change in emissions (US$m)	386	386	1	25.6
producer returns adjusted for value of CO_2 (% change)	-8.7	-8.4	2.1	-29.8

7. Discussion and conclusion

The results presented in the previous section illustrate that while the primary aim of GHG reduction in the EU and NZ is being met through the two strategies simulated here, it is accompanied by a predicted decrease in producer returns. Some of these reductions are reasonably significant and could have an important effect on producers. However, if carbon emissions were traded, the amount saved by reducing emissions could potentially help to offset the fall in producer returns. The values of CO_2 used in the previous calculations however, do not balance the reduction in producer returns significantly, although they do provide some compensation. The value placed on CO_2 in the international market is clearly vital in determining the total economic effect of climate change policies. In a situation where CO_2 was worth more, the improvement in producer returns would be more significant.

The results in this paper illustrate that reducing GHG emissions through a change to a less intensive production system will have a negative effect on the returns received by producers. However it is also worth noting that the shift to a less intensive system has associated benefits, such as reduced ground-water contamination (an important problem facing NZ at present) as well as potential animal welfare improvements. Similar changes in production systems are occurring in the EU under agri-environment schemes at present, independent of any greenhouse gas 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.

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