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Trade liberalisation and greenhouse gas emissions: the case of dairying in the European Union and New Zealand*

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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 its association with greenhouse gas emissions. Agriculture is a sector of the economy that both contributes to, and will be affected by, climate change. This paper models the impact of agricultural trade liberalisation on greenhouse gas emissions from agriculture around the world, focusing particularly on the effects on New Zealand, a small economy highly dependent on agricultural trade. A partial equilibrium agricultural multicountry, multicommodity trade model is used for the analysis, extended to include physical production systems and their greenhouse gas emissions. Two simulations are performed: removal of agricultural policies in the EU and in all OECD countries. The results indicate that although producer returns in New Zealand increase, greenhouse gas emissions also increase significantly. EU producers face lower returns but also lower greenhouse gas emissions.

Key words: agricultural production systems, greenhouse gas emissions, trade liberalisation.

1. Introduction

Current negotiations under the Doha Development Agenda of the World Trade Organization (WTO) (the Doha Round) are likely to lead to changes in international agricultural trade policy, causing possible shifts to global production patterns. Countries such as New Zealand, relying heavily on exports of agricultural products, are highly likely to be affected by these policy changes. Probable outcomes may be changing quantities of production, shifts in production systems and inputs, and as a consequence of the above, changes in environmental impacts. This paper is an attempt to quantify one such environmental impact of trade liberalisation, greenhouse gas (GHG) emissions from agriculture, using a partial-equilibrium (PE) agricultural trade model.

Published work analysing the interactions between trade and the environment has increased in recent years (for example, Leuck *et al.* 1995; OECD 2000; Strutt and Anderson 2000; Rae and Strutt 2001). However, there are still

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relatively few studies investigating the impacts of trade liberalisation on GHG emissions from agriculture. This paper intends to supplement the published work in this area, and uses New Zealand as the focus of the study, as it is unusual among Organisation for Economic Co-operation and Development (OECD) countries in its dependence on agriculture.

Typically, developed countries' agricultural emissions comprise a relatively small percentage of total emissions, and therefore, are not likely to be a major focus of a GHG mitigation policy, and compensation for any financial losses is likely to be provided by the government. However, New Zealand differs in that around 50 per cent of GHG emissions originate from agriculture, but the agricultural sector is very important to the economy, accounting for nearly 50 per cent of export earnings. New Zealand has ratified the Kyoto Protocol, and is therefore bound to meet the commitments agreed under the protocol. Moreover, changes in trade policies of major markets and/or competitors are also likely to have an important effect on New Zealand.

It is argued that trade liberalisation will deliver not only improved economic efficiency, but will cause production and associated resource usage to revert to a more environmentally benign pattern. Anderson and Strutt (1996) use the example of fertiliser and pesticide use, which is sometimes used ten times as much per hectare in the highly protected countries than in Australasia and most developing countries. In essence, 'the relocation of (particularly crop) production from densely populated protectionist countries to the rest of the world would cause a much larger reduction in degradation in the former compared with any increased degradation in the latter, where chemical use would expand from a low base and still to modest levels' (Anderson and Strutt 1996, p. 157).

Identifying the trade-off between environmental damage and economic efficiency gains across different trading nations is therefore an important task. Representing production and environmental heterogeneity requires careful consideration not only of trade flows arising from international market and policy interactions, but also the production structures and constraints underpinning domestic supplies and environmental susceptibility to changes in both the levels and mixes of outputs generated and inputs used.

The Lincoln Trade and Environment Model (LTEM) has been used to analyse various trade policy changes and their subsequent impacts on agricultural sectors around the world. It was previously modified to include the environmental indicator of groundwater nitrates, with the introduction of three separate production systems in four main countries in the model. Previous modelling scenarios with the LTEM have included changes in trade policy and the effect on groundwater nitrate production from the dairy sector (Saunders *et al.* 2000), and the economic implications of commercial release of genetically modified organisms in New Zealand (Saunders and Cagatay 2003). For this paper, the LTEM has been further extended to include GHG emissions, using the dairy sector as an example.

The analysis in this paper will consist of a reference-case simulation and two further scenarios: the reference or 'base' scenario assumes no change in trade policy out to 2010; the first scenario involves a complete liberalisation of European Union (EU) agricultural trade policy, and the second assumes an OECD-wide trade policy liberalisation. These two scenarios were chosen because the highly subsidised EU is both a competitor and a major trading market for New Zealand, and changes in support policies are likely to have important implications for the New Zealand agriculture sector. An OECD-wide liberalisation is a more widespread liberalisation of the world's most protected markets. The results from these scenarios will be discussed in the context of climate change and the implications for countries such as New Zealand.

The remainder of the paper is organised in the following manner. Section 2 provides a brief background to the climate change issue and discusses the relevance of agriculture in this context. This background is followed by a review of the relevant published work and a description of the model used in the analysis, the LTEM. Section 4 presents the simulations run and the results obtained, whereas section 5 provides a discussion of the consequences of these results, and concludes the paper.

2. Background

2.1 Climate change and greenhouse gas emissions from agriculture

In response to the threat of serious changes to the world's climate, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992. The objective of the UNFCCC is to achieve 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. The convention embraces the precautionary principle, in that it promotes action despite scientific uncertainty as to the likely magnitude and impacts of climate change.

The Third Conference of the Parties to the UNFCCC held in Kyoto, Japan, and in 1997 resulted in the Kyoto Protocol. In this protocol, developed countries agreed to reduce their collective greenhouse gas emissions to at least 5 per cent below 1990 levels, averaged over the period 2008–2012. The Kyoto Protocol became legally binding in February 2005, when at least 55 countries, representing 55 per cent of developed countries' carbon dioxide (CO_2) emissions, signed and ratified the Protocol. At the time of writing, both the EU and New Zealand (the two countries of particular relevance to this paper) have ratified the protocol, whereas Australia and the USA have refused to sign the agreement. The Kyoto Protocol is important in the context of this research, because if changes to international trade policy cause current levels of production to change, this will have a flow-on effect on GHG emissions, which will in turn affect countries' abilities to meet their Kyoto Protocol commitments. Furthermore, countries who are not ratifiers of the Protocol do not have to meet any commitments and may therefore have some advantage over ratifying countries.

2.2 The link between agriculture and climate change

Agriculture is both an emitter of and a sink for greenhouse gases. The primary gases produced from agriculture are methane (CH_4) and nitrous oxide (N_2O). The relative climatic effects of non-CO_2 gases can be compared with CO_2 through the use of global warming potentials (GWP) (Intergovernmental Panel on Climate Change (IPCC) 2001). Methane has a GWP of 21,[1] and nitrous oxide 310 (IPCC 1996). Methane is produced both as a by-product of the digestive process of ruminant animals, and from the decomposition of livestock manure under anaerobic conditions. Nitrous oxide is emitted directly from the soil as a result of nitrification and denitrification, and indirectly following the application of synthetic fertilisers. Nitrous oxide is also emitted directly from soils as a result of animal production. Emissions of methane or nitrous oxide from arable agriculture are not considered here. The sources of these gases in the context of this paper include enteric fermentation, manure management and agricultural soils.

3. Observations from the published work

Studies linking the impact of trade policies with environmental effects have become more common only relatively recently, following the high profile of the issue in the World Trade Organization (WTO). There is still a dearth of published work on the impact of liberalisation on agricultural GHG emissions, however. Economic studies in the area of climate change focus generally on impact assessment, the cost of complying with the Kyoto Protocol, and management of climatic risk. Studies combining GHG emissions or climate change with some form of economic analysis, such as Randhir and Hertel (2000), Burniaux (2000), ABARE (2001), and De Cara and Jayet (2000, 2001) have become more widespread in recent years, although they generally focus on one country without considering the trading interactions. The impact of trade liberalisation on environmental factors such as nitrogen pollution and animal numbers has been examined in more detail (e.g., Leuck *et al.* 1995; OECD 2000). Other studies use computable general equilibrium (CGE) models to assess the impact of trade liberalisation on the whole economy, sometimes including the environment, such as Strutt and Anderson (1999), Rae and Strutt (2001, 2005), and Beghin *et al.* (1997). McQuinn and Binfield (2002) and Wier *et al.* (2002) do simulate GHG emissions following trade policy reform; however, their analysis is limited to a single country.

[1] For the Kyoto Protocol, the time horizon was set at 100 years, with a resultant GWP for CH_4 of 21. Different time horizons would result in different GWP. However, these values are currently used by the IPCC.

There is a larger body of published work analysing the impacts of trade liberalisation on price and trade effects of one or more countries, without considering the environmental consequences, such as Bouamra-Mechemache *et al.* (2002), Langley *et al.* (2003), Shaw and Love (2001), Cox *et al.* (1999), and Zhu *et al.* (1999). These types of studies can provide a useful verification of the predicted economic effects from this research.

The approach used in this paper is unique in that it simulates at the world trading level, but has the additional advantage of providing a greater level of insight than many other trade models. This is due to the disaggregation of four main countries in the model (Australia, the EU, New Zealand and the USA) into three separate production systems, and the simulation of GHG from each system. The empirical model and methodology used in this paper is described in the following section.

4. The empirical model: LTEM

The LTEM is a partial-equilibrium (PE) model based upon VORSIM[2] (Roningen 1986; Roningen *et al.* 1991; Roningen 2005), and focuses on the agricultural sector, but has been extended to allow the link through supply to production systems and physical and environmental impacts to be modelled. It is thus possible to simulate mitigation and other policies, applied either as physical or financial criteria. Although, as discussed in section 3, much of the trade and the environment published work uses a CGE modelling methodology, this paper does not intend to replicate that work. Rather, an innovative approach using a PE model is taken to allow a greater depth of analysis and understanding of the issue to be carried out. The LTEM is very flexible and transparent, allowing scientific linkages to be relatively easily established. The detail of the agricultural sector in the LTEM is much greater than could be easily achieved with a CGE model. For example, the dairy sector in the LTEM consists of five products (liquid milk, butter, cheese, skim milk powder, whole milk powder). In addition, this model has been used extensively in trade policy analysis (Saunders and Wreford 2002, 2004), focusing particularly on New Zealand and the EU.

4.1 General features of the LTEM

A detailed description of the LTEM and its characteristics is presented in Cagatay and Saunders (2003). The LTEM includes 19 agricultural commodities (7 crop and 12 livestock products) 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.

[2] VORSIM is a partial equilibrium agricultural trade model, evolved from SWOPSIM, which was developed by the USDA during the Uruguay Round of trade negotiations to provide trade policy analysis.

Therefore, commodities are perfect substitutes in consumption in international markets. Based on these assumptions, the model is built as a non-spatial type, which emphasises the net trade of commodities in each region.

The LTEM is a synthetic model, with parameters of the standard equations adopted mostly from VORSIM. However, the parameters of the newly introduced behavioural equations (such as nitrogen fertiliser demand, number of animals, and regional supply of raw milk) are estimated econometrically. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities that reflect the symmetry condition. Therefore, own- and cross-price elasticities are consistent with the theory. The model is used to quantify the price, supply, demand, and net trade effects of various policy changes. The medium- to long-term (until 2010) policy impacts are derived 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 this demand is determined endogenously.

The dairy sector in the LTEM is modelled explicitly, in contrast to the two other major approaches to modelling this sector.[3] Explicitly modelling the five dairy products as well as raw milk ensures they come under the effect of their respective border and domestic policies, as well as ensuring the domestic supply of raw milk is fully exhausted into various demand categories.

The model solves by simulating the world market-clearing price of each commodity 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).

Various unilateral and bilateral agricultural and border policies can be simulated in the LTEM through the modification of the behavioural equations. In general, any policy measure that creates a per-unit wedge between domestic and trade prices can be incorporated through the price functions, whereas supply-related policies such as production quotas, set-aside policies, and acreage reduction are simulated through the supply functions. Bilateral

[3] The more traditional approach to modelling dairy products is in terms of raw milk equivalents. Another approach allocates raw milk to various product categories in a hierarchical fashion (Lariviere and Meilke, 1999).

policies such as preferential access, including trade quotas and in- and out-of-quota tariff rates, can also be incorporated in the LTEM through modifications to the supply, price, and net trade equations of the two countries in question. Details on the modelling of these policies are provided in Cagatay and Saunders (2003).

The sectoral focus of this study is the dairy sector. The dairy sector in particular is influenced by agricultural policy, especially in the EU, and involves the use of a number of complex policy instruments. Dairy products are one of New Zealand's largest exports and have suffered perhaps the most from trade barriers and subsidised competition from other producers. The dairy sector is also a significant emitter of GHG around the world. Further work will involve including emissions from the beef and sheep sectors. However, the detailed focus on the dairy sector in this paper illustrates the implications of policy changes on the environment. The equation representing the link between dairy production and GHG emissions in the LTEM is presented in the following section.

4.2 Environmental submodule: 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, New Zealand, and the USA are separated into three production system types, and supply in each type is then modelled (Saunders *et al.* 2003). The production effects of agricultural trade liberalisation will vary within countries as well as between them, and capturing the spatial heterogeneity of production developments at a greater level of detail than the national level yields more precision of the effects of changes in policy. Data on production systems were taken from a number of sources, including farm advisory recommendations, census and survey reports, and field trials. Systems are differentiated based on the intensity of inputs, yield, and stocking rate, and are subsequently referred to as A, B, or C (see Appendix). However, in terms of GHG emissions, national and regional totals are also of interest; therefore the systems are aggregated to the regional and national level as well. In the other livestock sectors, an aggregate production system in each country is modelled at present. Second, 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, as a result, extended to incorporate the link to physical production systems and then consequently extended further to assess the impact on GHG emissions.

In order to endogenise the amount of N fertiliser used (N/ha) for production, a conditional input demand function for N is estimated for each production system, Equation (1). In this equation, the demand for N use per hectare, for example from raw milk production in system A (Na_m), is specified as a function of the relative prices of the feed concentrates (pc_{mk}) to the N (pc_{mN}), and the quantity of raw milk supplied per hectare in system A (qsa_{mi}). The variable

pc_{mk} 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 qsa_{mi} is included as an exogenous shift factor that proxies the technological changes in the production process and/or irregular effects that affect the amount supplied of raw milk (Burrell 1989). Any technological change that allows production to increase without increasing the factors of production can be simulated in the model through exogenously changing qsa_{mi} (for further details regarding this please refer to Cagatay and Saunders 2003). The coefficients β_{i1} and β_{i2} show the elasticity of fertiliser demand in system A with respect to the change in raw milk supply in system A and relative prices. The β_{i2} is expected to be positive and an increase in pc_{mk} is expected to result in an increase in N demand, as N fertiliser and feed concentrates are expected to be gross substitutes.

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

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 (NAa_{mi}) is endogenised by specifying it as a function of various product and input prices such as feed concentrates and N fertiliser, shown in Equation (2).

The livestock number equation specification is based on Jarvis's (1974) livestock supply response model in which the farmer's decision to increase their livestock is dependent on the expected value of future meat and/or milk production. The estimation was carried out using ordinary least-squares reqression on the log-linear form of the equations. In Equation (2), the parameters γ_{i1} and γ_{ij} (own- and cross-price elasticities) reflect the response of farmers to various prices on deciding to build up (invest in) their livestock. The γ_{i1} is expected to be positive as an increase in own-price may change farmers' incentives to increase stock, whereas the γ_{ij} is expected to be negative as an increase in producer prices of other livestock products may change farmers' incentives to invest in other types of livestock. A negative elasticity between animal numbers and input prices ($\gamma_{ik,n}$) is also expected as rising prices of either fertiliser 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.

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

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 New

Zealand, the emission factors are based on more accurate research, and differ from the default IPCC values (Clough and Sherlock, pers. comm., 2001).

Emissions of N_2O and CH_4 are generated by a number of complex processes in agriculture, as identified in IPCC (1996). All of these sources associated with livestock agriculture are summarised into a form able to be included in the LTEM (Clough and Sherlock, pers. comm., 2001), see Equation (3). A single coefficient for the N_2O emitted from N fertiliser 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 GWP. Technological change or developments, or changes made in quantifying emissions can be incorporated through the exogenous modification of the coefficients.

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

The domestic supply functions include the price of N fertiliser (pc_{mN}) and number of animals (NAa_{mi}), as well as the producer (pp_{mi}, pp_{mj}) and consumer (pc_{mk}) 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)

$$qsa_{mi} = \alpha_{i0}\, pp_{mi}^{\alpha_{ii}}\, pp_{mj}^{\alpha_{ij}} \prod_k pc_{mk}^{\alpha_{ik}};\ \ \alpha_{ii} > 0, \alpha_{ij} < 0, \alpha_{ik} < 0 \tag{4}$$

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

The α_{ii} and α_{ij} are expected to be positive and negative, respectively, as an increase (decrease) in own (cross-commodity) price may create an incentive (disincentive) for raw milk producers. A negative sign on α_{iN} (price of N fertiliser) and α_{ik} (price of other inputs) is also expected as a rise in input prices would yield a fall in raw milk production. Finally, α_{iNAa} should represent a positive relationship between number of animals and raw milk supply.

5. Scenarios and results

Baseline scenario

The baseline scenario comprises historic data from 1979 to 1997, and a projection out to the year 2010. This scenario assumes trade policies in 1997 remain in place from 1997 until 2010. The scenario provides a useful reference case for comparison with policy change scenarios, as it represents a steady developmental course with classic long-term economic properties.

EU liberalisation

This scenario is based on EU agricultural reform, and assumes a sudden unilateral liberalisation of all agricultural products in the base year of 1997,

Table 1 Percentage change from base scenario in 2010 of selected trade variables for the European Union (EU) and New Zealand (NZ)

	1		2	
Scenario†	EU	NZ	EU	NZ
Producer price				
Raw milk	–14.9	23.5	–0.9	38.7
Butter	–19.9	15.1	–9.3	24.0
Cheese	–26.7	33.7	–9.2	49.7
Whole milk powder	–34.7	27.8	–25.6	35.2
Skim milk powder	–31.3	20.5	23.7	73.2
Production				
Raw milk A	–12.9	24.3	–11.7	36.9
Raw milk B	–18.4	23.8	–17.4	41.0
Raw milk C	–17.5	20.5	–15.6	31.4
Raw milk total	–16.5	22.6	–15.1	35.3
Butter	–22.4	27.0	–17.8	46.7
Cheese	–22.6	30.3	–17.3	47.5
Whole milk powder	–39.0	29.4	–38.1	45.3
Skim milk powder	–22.4	27.0	–17.8	46.7
Producer returns (raw milk)	–28.9	51.4	–15.9	87.6

Note: †Scenario 1 refers to a complete liberalisation of all agricultural commodities in the EU; scenario 2 refers to a complete OECD liberalisation.

continuing out to 2010. This includes the complete removal of internal dairy quotas, export subsidies, and import tariffs, with no compensation provided to farmers. Although this is an extreme scenario, it illustrates the effects of EU policy reform and shows unambiguously the direction of change. These scenarios are not necessarily aiming to simulate reality but rather to illustrate the expected relative changes between the scenarios and the baseline.

OECD liberalisation

This scenario assumes agricultural policy reform throughout all OECD countries in the model. As in the previous scenario, it simulates a sudden unilateral liberalisation beginning in the base year, 1997, and simulating out to 2010. Again, this simulation assumes the removal of internal dairy quotas, export subsidies, and import tariffs, without compensating farmers for these reforms.

5.1 Economic consequences of EU liberalisation

5.1.1 Prices

Changes to the agricultural trade variables, such as prices, production quantities, and amounts traded, are standard trade model results and will only be discussed briefly here. Selected results for these trade variables are presented in Table 1 for New Zealand and the EU as sample countries, for dairy products only. The total model coverage is too large and not immediately relevant to be presented here. In terms of the effects on New Zealand, the trade results from OECD liberalisation generally follow a similar pattern to those from EU liberalisation, so they will be discussed together. Following either of these liberalisations, producer prices in New Zealand increase, ranging from 15 per cent for butter under an EU liberalisation, to 73 per cent for skim milk powder (SMP) following OECD liberalisation. EU prices fall under both these scenarios, generally at lower amounts under total OECD liberalisation compared with the EU-only liberalisation. The largest decline in the EU is predicted for whole milk powder (WMP) as a result of EU liberalisation, at 35 per cent below the base scenario in 2010.

It may be helpful at this stage to compare these results with studies mentioned in the published work reviewed earlier in this paper. In terms of New Zealand, only Langley *et al.* (2003) and Shaw and Love (2001) specifically mention effects for New Zealand. Langley *et al.* (2003) simulate a full international dairy liberalisation, whereas Shaw and Love (2001) simulate a reduction in subsidies around the world, and a separate scenario of increased market access. The results from these studies can therefore be compared with the OECD liberalisation scenario in this paper in order to establish plausibility. Unfortunately, Shaw and Love (2001) present results only for the year following liberalisation, and Langley *et al.* (2003) do not specify how long after the base the results are for, whereas the results presented in this paper are for 2010, 13 years after the initial liberalisation. This study generally predicts higher values than Shaw and Love (2001), probably as a result of their shorter simulation horizon. The comparisons with Langley *et al.* (2003) vary – for butter, their prediction is an increase of 61 per cent, whereas this study predicts an increase of 24 per cent; however, for SMP and WMP this study predicts increases of 73 per cent, whereas Langley *et al.* (2003) predict increases of 10 and 20 per cent, respectively. Cheese prices are more aligned: this study predicts an increase of 49 per cent, whereas Langley *et al.* (2003) predict an increase of 33 per cent.

With respect to the EU results, the most comparable study for the EU liberalisation scenario here is the Bouamra-Mechemache *et al.* (2002) study, and their ‘quota removal and WTO export limit removal’ scenario. They predict a 10 per cent reduction in producer prices in the EU for butter (compared with the 20 per cent fall in this study); a 32 per cent fall for SMP (31 per cent from this study); and a 21 per cent fall for WMP (35 per cent from this study). Cheese is more difficult to compare as the cheese in their study is disaggregated into three classes; taking the average of these three gives a fall of nearly 10 per cent – this study predicted a fall of 27 per cent. Taking into account slightly different modelling and policy tools, these results are not inconsistent.

In terms of the impact of the OECD liberalisation on the EU, the results may be compared with both Langley *et al.* (2003) and Shaw and Love (2001). Again the results are comparable. The main trend is that the results from this study are of a slightly greater magnitude. However, even this does not hold across all commodities.

5.1.2 Production

Production for all dairy commodities in the EU decreases under both the EU and OECD liberalisation scenarios. The largest decrease is predicted for WMP, at 39 per cent following EU-only liberalisation. The smallest decrease is shown in raw milk production in system A, at just over 11 per cent following OECD liberalisation. Production in New Zealand increases in both scenarios 1 and 2, ranging from an increase of 20.5 per cent in system C's raw milk production as a result of EU-only liberalisation, to a considerably larger increase of 47.5 per cent in cheese following OECD liberalisation.

These scenarios do simulate a complete liberalisation across EU and OECD agricultural sectors, not only in the dairy sector. However, the effects on production responses in different commodities vary. Within the EU, production levels of wheat, coarse grains and oilseeds, and pig meat increase in both these scenarios, ranging from 1.4 per cent for coarse grains following EU liberalisation, to 11.6 per cent for oilseeds following both EU and OECD liberalisation. In general, these increases in production are of a greater magnitude following OECD liberalisation. In the case of New Zealand, although production of most agricultural commodities modelled here is predicted to increase following both liberalisation scenarios, the production of wheat, pig meat and poultry is expected to decline following EU liberalisation, and pig meat and poultry following OECD liberalisation.

Table 1 shows changes in prices, production, and producer returns for the EU and New Zealand for these two scenarios. Producer returns fall in both scenarios for the EU, and rise significantly for New Zealand.

5.1.3 Trade

Quantities exported from the EU fall across each scenario for dairy products. In these scenarios, the EU changes from being a net exporter, to a net importer for butter and cheese. The EU remains an exporter of WMP and SMP, but by reduced amounts. New Zealand remains an exporter of all dairy products for the scenarios simulated here, increasing for all dairy products.

5.2 Environmental results

5.2.1 Fertiliser application and animal numbers

Fertiliser application and animal numbers are important factors in the calculation of GHG emissions; their results will therefore be discussed here briefly before the GHG results are presented. Fertiliser application is predicted to fall for all production systems in the EU for both these scenarios. The reductions range from 14.8 to 24 per cent. Fertiliser application is predicted to rise in New Zealand for both scenarios, from 21 per cent in system C in the EU-only liberalisation, to a significant 45 per cent in system B under OECD liberalisation. Rae and Strutt (2001) predict changes in N-waste outputs following a Uruguay Round liberalisation – their N-waste is not only from fertiliser application, so is not a direct comparison. However, their directions of change

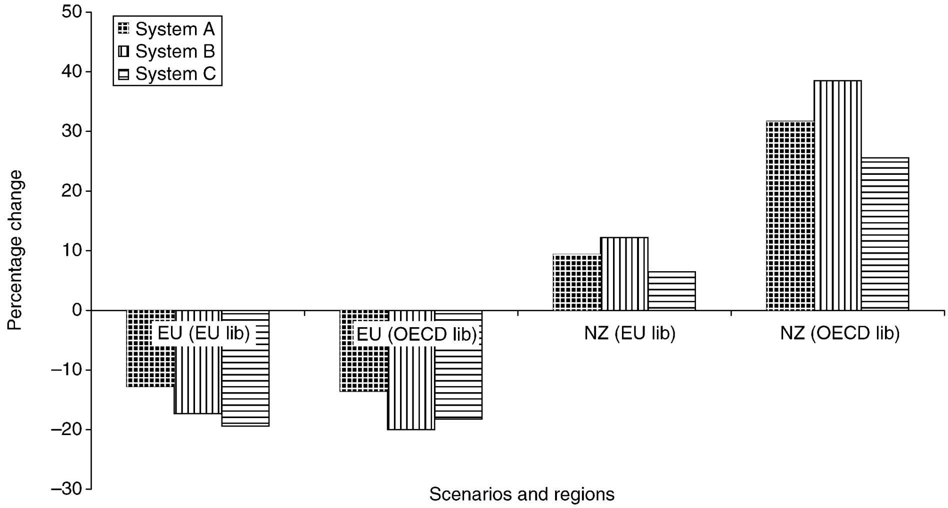

Figure 1 Percentage change in GHG emissions from the base scenario in 2010 for the European Union and New Zealand dairy sectors.

for New Zealand and the EU following liberalisation are comparable to those in this study. Leuck *et al.* (1995) find that CAP reform reduces nitrogen levels in the EU by around 5 per cent.

Animal numbers are predicted to decrease across all production systems of the EU for both simulations shown here. The largest decreases in animal numbers are actually shown under OECD liberalisation – ranging from 12.6 per cent in system A to 20.6 per cent in system B. Animal numbers increase in New Zealand, with larger increases under OECD liberalisation than the EU-only scenario. Rae and Strutt (2001) also predict an increase in New Zealand dairy numbers following their Uruguay Round simulation, and a decrease in EU dairy numbers.

5.2.2 Greenhouse gas emissions

Emissions from dairy cows in the EU are predicted to fall in both scenarios, as a consequence of the predicted decreases in animal numbers and fertiliser application. Figure 1 shows the predicted decreases for the different production systems and scenarios. The largest decrease is predicted in system B under OECD liberalisation, of 20 per cent, with the smallest being in system A under EU-only liberalisation, at 12.7 per cent. Production system A shows the smallest decrease in both scenarios; however, systems B and C vary, with C showing the largest decrease in the EU-only liberalisation, and B in the OECD liberalisation. The mean decreases in the EU are 16.5 and 17.3 per cent for EU and OECD liberalisation, respectively.

Behan and McQuinn (2002) and McQuinn and Binfield both predict reductions in GHG emissions from Irish agriculture (although Ireland is only one region in the EU it may be seen as loosely representative in this context), following changes in international trade policy.

New Zealand's emissions are predicted to increase under both scenarios from between 6.5 per cent in system C under EU liberalisation, to a massive increase of 38.5 per cent in B under OECD liberalisation. Emission increases are considerably higher under OECD liberalisation than the EU-only liberalisation, from between 25.6 to the 38.5 per cent, in comparison with the more modest 6.5–12.2 per cent increase under the EU-only scenario. The mean increases predicted for New Zealand range from 9.3 to a considerably larger 31.9 per cent for EU and OECD liberalisation, respectively.

Although GHG emissions are not at present modelled for other sectors in the LTEM, the increased production in New Zealand, particularly in the beef and sheep sectors, will also affect New Zealand's GHG emissions. The only livestock sectors from which production is expected to decrease in New Zealand are pig meat and poultry, which are non-ruminants and therefore their reduction will not offset New Zealand's increase in methane from the increased numbers of ruminants. The reduced production of pigs and poultry will offset nitrous oxide emissions. However, the reduction is likely to be very small in comparison with the increased emissions from the dairy, beef, and sheep sectors. Wheat production is also predicted to decrease in NZ but the effect of this on emissions is also likely to be very small.

Similarly, in the EU, production is projected to switch towards the wheat, coarse-grain, and oilseed crops, which emit no methane and small amounts of nitrous oxide. Pig meat production is also projected to increase but as stated above, is only a source of nitrous oxide in terms of its manure management; therefore unlikely to increase the EU's GHG emissions significantly.

The net environmental effect is not possible to determine without an analysis of other countries. However, the impact per hectare of N application on the two countries in this study can be discussed. In terms of fertiliser use, the reduction in fertiliser application on average across the three EU production systems following EU liberalisation was 47.5 kg per hectare, whereas the average increase of the three systems in New Zealand was only 11.2 kg per hectare. This comparison supports the theory that the relocation of production from highly intensive systems following liberalisation would cause a greater reduction in degradation in the initial country compared with any increased degradation in the country where production increases. However, in the case of OECD liberalisation, the average decrease in fertiliser application per hectare in the EU production systems was 7.5 kg per hectare, whereas the average application across New Zealand's systems was predicted to increase by nearly 72 kg per hectare. In spite of this significant increase in New Zealand, it is most likely that a number of other countries will have reduced their average fertiliser application in this scenario. It does, however, indicate that New Zealand's systems would become considerably more intensive following such a widespread liberalisation, although the environmental harm from fertiliser run-off is not necessarily linearly proportional to the application rate.

The results also highlight the different responses within the dairy sectors of both countries. All three production systems are responding to the same price

Table 2 Percentage changes in fertiliser use and animal numbers from the base scenario in 2010 for the European Union (EU) and New Zealand (NZ)

	1		2	
Scenario	EU	NZ	EU	NZ
Fertiliser use				
System A	−20.1	25.0	−14.8	44.3
System B	−21.5	24.3	−18.7	45.4
System C	−24.0	21.1	−18.4	37.1
Animal numbers				
System A	−7.2	6.7	−12.6	29.5
System B	−15.5	6.2	−20.6	35.0
System C	−14.1	2.1	−18.1	22.2

change. However, as can be seen in Table 2 and Figure 1, the impact on fertiliser use, animal numbers, and ultimately, GHG emissions, varies considerably between production systems of the same country (or bloc as in the EU), reflecting the differences in physical constraints, responsiveness, and resilience to changes in price.

6. Discussion

The results presented in the previous section can be divided into the two categories of economic estimates and environmental estimates. The first group represents standard outputs from a trade model, and may be compared with those from other studies of agricultural trade liberalisation. These results correspond broadly with expectations from trade theory. If the EU removes its border policies, their prices and production fall, whereas prices and production rise for most other countries in the model, and likewise for the OECD liberalisation. New Zealand could potentially gain significantly due to its comparative advantage in dairy production.

The second group of results show an environmental impact of trade liberalisation, GHG emissions from agriculture. As a result of the fall in animal numbers and applied nitrogen fertiliser, emissions in the EU fall, and the opposite occurs in New Zealand.

These results are particularly important for New Zealand agriculture. As discussed previously, agriculture accounts for approximately 50 per cent of the country's greenhouse gas emissions. Under New Zealand's commitment to the Kyoto Protocol, emissions must be reduced to 1990 levels. Any change in the predicted emission levels, such as simulated here following EU liberalisation, will increase the burden faced by the agricultural sector to reduce emissions, and consequently, also the reductions required in other sectors.

Under current EU protection policies, New Zealand agricultural producers face lower prices and are unable to export in a free-market situation. If these policies were removed, producers would receive higher prices and may be able to export greater volumes, but as a consequence may face some form of financial penalty for their increased greenhouse gas emissions. Although the New Zealand government has agreed that farmers will not pay a carbon tax or any penalty for their GHG emissions during the first commitment period of the Kyoto Protocol, it is possible that in the future, producers would face a charge on their emissions.

Conversely, the EU, as an example of a highly protected agricultural market, and a major trading partner for New Zealand, has been operating with significant support systems for its producers, who have been able to enjoy the associated higher prices. Although the EU faces reasonably serious reductions in producers' returns following liberalisation, they will at least be able to go some way towards meeting their commitments under the Kyoto Protocol with the resultant decline in GHG emissions.

Although these results provide insights into the implications of trade reform for meeting Kyoto Protocol commitments, limitations of the model and assumptions should be borne in mind. First, the model at this stage only simulates emissions from the dairy sectors and the analysis would be made richer by the inclusion of at least beef and sheep. Second, the two scenarios chosen were particularly extreme and more realistic policy changes would in all likelihood generate changes of smaller magnitude. Further research is needed to investigate these issues and to probe more deeply into the global environmental effects of changes in trade policies.

Appendix

Technical data for production system differentiation

Region	Production per cow (litres)	Average stocking rate/ha	Area (000 ha)
EU (15)			
West EU (A)	5310	2.4	3174.8
East EU (B)	4680	1.8	6639.6
Other EU (C)	4991	2.3	3302.2
Australia:			
Victoria (A)	4715	1.0	1267.9
NSW (B)	4972	0.5	504.02
Rest of Australia (C)	4608	0.5	1046.0
USA:			
California (A)	8439	10	149.2
WI, MI, MN, PA, NY (B)	7182	3	1251.2
Rest of USA (C)	6770	2.7	1727.8
New Zealand			
Auckland (A)	3278	2.8	494.6
South Island (B)	3874	2.6	274.8
Rest of NZ (C)	3300	2	570.4

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