Agricultural Trade Liberalization and Greenhouse Gas Emissions: Modeling the Linkages Using a Partial Equilibrium Trade Model

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Global attempts to limit greenhouse gas (GHG) emissions may impact on agricultural trade and producer returns, particularly in countries such as New Zealand, where a relatively large proportion of GHG emissions originate from the agricultural sector. This study uses an extended partial equilibrium agricultural trade model to analyze the effects of trade policy liberalization on agricultural production and trade, as well as on GHG emissions. Further analysis combines trade liberalization with GHG mitigation policy in the New Zealand and European dairy sectors, and the effects on producer returns and GHG emissions are predicted. As expected, full trade liberalization in the OECD (Organization for Economic Cooperation and Development) countries enhances producer returns in New Zealand's dairy sector, but reduces returns in the European Union's dairy sector.

Key Words: partial equilibrium trade model, agricultural production system, greenhouse gas emissions

The link between trade and the environment has aroused considerable interest, both in terms of the impact of trade liberalization on the environment, and also the impact of environmental policy on production and trade. This interest is expressed at the global level, especially in the World Trade Organization (WTO) round of negotiations, but also at the micro level, where local governments and agencies are concerned about the impacts of policies on production and trade, as well as on the local environment. This paper analyzes the effects of trade liberalization on greenhouse gas (GHG) emissions from agriculture, as climate change is an increasingly important environmental concern. An extension of this analysis will simulate the combined impact of trade liberalization and a GHG mitigation policy. This second part of the analysis will focus particularly on the impact on New Zealand, a country highly reliant on agricultural trade and which has a high percentage of its total GHG emissions originating in the agricultural sector.

The analysis in this paper simulates the removal of all European and OECD (Organization for Economic Cooperation and Development) export subsidies, import tariffs, and internal dairy quotas, focusing specifically on the impact of this on the dairy sector. Trade policy reform, such as liberalization, will significantly reduce the system of support for livestock production. Studies that analyze trade policy such as the Uruguay Round Agricultural Agreement or the CAP (Common Agricultural Policy) reform generally show that production in countries whose support is removed decreases, while other countries' production may increase (Cox et al. 1999, Shaw and Love 2001, Rae and Strutt 2001). International trade offers an important vehicle for adapting to climate change. By permitting the geographic relocation of world

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food supplies according to changing comparative advantage, spatial diversification of the climatic risk associated with global warming may be achieved (Randhir and Hertel 2000). By facilitating the transfer of output from regions with possible environmentally harmful production to regions where production may be less environmentally damaging, international trade can play a valuable role in mitigating the global cost of climate change. However, the potential for trade to play this buffering role is often hampered by restrictive trade policies. Furthermore, as stated by the Intergovernmental Panel on Climate Change (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. Changes to trade policies of trading partners and/or competitors, in particular the European Union (EU) and the United States, are likely to have significant effects on the GHG emissions from New Zealand agriculture. Following possible and likely liberalization of international agricultural trade policies, New Zealand producers are likely to respond by increasing production to target the newly liberalized markets, further increasing emissions from New Zealand.

The Role of Agriculture in 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 of achieving "stabilization 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 went into force in February 2005, having been ratified by 55 countries, including ones accounting for 55 percent of developed countries' carbon dioxide (CO_2) emissions (New Zealand Ministry for the Environment 2004). Under the Kyoto Protocol, developed country ratifiers 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.

Agriculture is both an emitter and a sink of GHGs, with the primary GHGs produced from the livestock sector being methane (CH_4) and nitrous oxide (N_2O). 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, New Zealand differs in that agriculture not only accounts for 55 percent of GHG emissions, but is more important to the economy, accounting for nearly 50 percent of export earnings. This is significant for New Zealand, because according to the Ministry for the Environment estimates, total GHG emissions for that country could be between 14 and 20 percent above the Kyoto Protocol target during the first commitment period, and emissions from agriculture around 12 percent above this level (New Zealand Ministry for the Environment 2004). Any policy designed to limit emissions is likely to have a significant impact on the country's economy.

In comparison, the agricultural sector in the EU is responsible for 10 percent of all the EU's GHG emissions. The European Union's GHG emissions from the agricultural sector have declined by 6.4 percent in the period from 1990 to 2000 (Gugele, Strobel, and Taylor 2004). Recent agricultural policy reforms include proposals and incentives that may have a mitigating effect on GHG emissions through agri-environment measures, without directly targeting these emissions.

Many of the mitigation strategies for agriculture (AEA Technology Environment 1998; Clark, de Klein, and Newton 2001) affect production. Two of these strategies—a reduction in stocking rate and a limit of nitrogen (N) fertilizer—are simulated in this paper in order to analyze the impact not only on GHG emissions, but also on trade and producer returns from livestock, using the partial equilibrium net trade model, LTEM (the Lincoln Trade and Environment Model).

Methods

The impacts of trade and climate change policies are estimated with an international partial equilibrium (PE) model that incorporates GHGs into a set of scenarios that isolate policies and thus help to explain the interaction between them. This section describes the model used in this analysis, the LTEM. The sectoral focus of this study is the dairy sector. The equation calculating GHG emissions, as well as the methodology linking the dairy sector with GHG emssions, is presented in the following section, with the scenario descriptions concluding the section.

Model Description: The Lincoln Trade and Environment Model (LTEM)

The LTEM is a PE model using VORSIM modeling software (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 liberalization as well as mitigation and other policies, applied either as physical or financial criteria.

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 18 countries. The LTEM's country and commodity coverage is shown in Appendix Table A1. 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 that 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 behavioral equations and one economic identity for each commodity in each country in the LTEM framework. The behavioral equations are domestic supply, demand, stocks, domestic producer and consumer price functions, and the trade price equation. The interdependencies between primary and processed products and/or between substitutes are reflected by cross-price elasticities, and producers are able to substitute between types of production. 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 behavioral 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 into 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 optimization algorithm (Newton's global or search algorithm).

Linking Agricultural Output with GHG Emissions

Emissions of N_2O and CH_4 are linked with nitrogen (N) fertilizer and the number of animals used in agricultural production. Applications of N fertilizer vary by type of dairy production system. Different systems are simulated by dividing dairy sectors in Australia, the EU, the United States, and New Zealand into three regions—A, B, and C (Cagatay and Saunders 2003) (see Appendix Table A1).

Nitrogen fertilizer is applied in varying quantities depending on the intensity of the production in each region, as well as on the physical characteristics of the soil. In order to endogenize 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, all of which are endogenous to the model. 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 that proxies the technological changes in the production process and/or irregular effects that affect the 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:

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

where $\beta_{i1} > 0$ and $\beta_{i2} > 0$.

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*) is endogenized 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 ordinary least squares (OLS) on the log-linear form of the equations. In Equation 2, the parameters γi1 and γij (own- and cross-price elasticities) reflect the decision of farmers, as a response to various prices, to build up (invest in) their stock of livestock. The γi1 is expected to be positive since an increase in own-price may change farmers' incentives to increase their stock, while 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 (γik, n) is also expected, since rising prices of either fertilizer or feed concentrates may favor the incentive to slaughter rather than to feed them. Two major sources were used for the livestock data: the Food and Agriculture Organization (FAO) agricultural statistics database (Food and Agriculture Organization 2005) and the U.S. Department of Agriculture (USDA) database (U.S. Department of Agriculture 2005).

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

where $\gamma_{i1} > 0$, $\gamma_{ij} < 0$, and $\gamma_{ik,n} < 0$.

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 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 summarized 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:

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

The domestic supply functions include the price of N fertilizer and number of animals, as well as the producer and consumer commodity prices, in order to analyze the supply effect of changes in N usage in raw milk production and number of animals, as in Equations 4 and 5. These are the equations used in the model with the α constants generated by the model to develop a solution:

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

and

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

where $\alpha_{iN} < 0$ and $\alpha_{iNAa} > 0$.

Scenarios

We simulate six scenarios, including scenario 1, the baseline scenario, which assumes that current

Table 1. Scenario Description

Scenario	Trade Policy[a]	New Zealand stocking rate / Nitrogen (N) application[b]	European Union stocking rate / Nitrogen (N) application[b]
1	Base scenario	No change	No change
2	OECD liberalization	No change	No change
3	Base	Stocking rate and fertilizer reduction	No change
4	Base	Stocking rate and fertilizer reduction	Stocking rate and fertilizer reduction
5	OECD liberalization	Stocking rate and fertilizer reduction	Stocking rate and fertilizer reduction
6	OECD liberalization	Stocking rate and fertilizer reduction	No change

[a] Trade policy consists of a removal of tariffs and support policies in the OECD countries in the model.

[b] Stocking rate is reduced by 25 percent and fertilizer application is reduced by 20 percent.

policies and production systems are in place (see Table 1 for a summary of the six scenarios). The scenarios involve changes in trade policies around the world, in the form of an OECD liberalization, which simulates the removal of agricultural support policies in the OECD countries in the LTEM. Scenario 2 simulates OECD liberalization in isolation from any environmental policy, in order to provide the impact of trade liberalization alone. Scenarios 3 and 4 simulate GHG mitigation strategies in the absence of any change in trade policy, so comparison of these with the base scenario provides the impact of GHG mitigation alone.

OECD liberalization is then simulated in conjunction with both the EU and New Zealand simultaneously imposing reductions on stocking rates[1] and N fertilizer application in the dairy sectors. This scenario, scenario 5, is simulated in order to investigate the impact these reductions in stocking intensity may have on GHG emissions, as well as on producer returns, so that the simultaneous impacts of trade liberalization and GHG mitigation policies are able to be predicted. The last scenario, scenario 6, simulates an OECD liberalization with only New Zealand reducing its stocking rate and fertilizer application, as the EU may well be able to meet its Kyoto requirements using easier and/or less costly measures in other sectors. These changes to production systems will henceforth be referred to as GHG "mitigation strategies"; however, it must be stressed that they are a crude GHG mitigation tool and are more likely to be implemented as part of an agri-environment scheme, such as those in place in the EU.

[1] In the LTEM, stocking rate restrictions are modeled through changes in animal numbers as opposed to changes in land area.

Both the trade policy changes and the stocking rate and fertilizer reductions are initiated in the base year of 1997 and simulated out to 2010. Stocking rates were reduced by just over 25 percent in both the EU and New Zealand in their mitigation strategies, and fertilizer application rates were decreased by 20 percent in both regions, in the base year; however, they are not bound at that lower rate. The EU was specifically chosen as a comparison because of its importance in influencing the world market for dairy products, as well as its being a major competitor and destination for New Zealand dairy products. Australia and the United States are not likely to change their N application or stocking rates, as they are not participating in the Kyoto Protocol.

Results

This section presents selected results for the scenarios described above. The simulated scenario results are summarized in Tables 2 and 3. Although results are generated for all countries in the model, for all years up to 2010, they are presented and discussed here in terms of their predicted changes by 2010 in relation to the base scenario.

Trade Results

Changes to the agricultural trade variables, such as prices, production quantities, and amounts traded, are standard trade model results and will be discussed only briefly here, because the main focus of interest is the impact on GHG emissions.

Table 2. Percentage Change in 2010 from Base Scenario for Producer Returns for Raw Milk for the European Union and New Zealand

Scenario	2	3	4	5	6
European Union	-15.93	0.00	-25.98	-37.58	-15.94
New Zealand	87.64	-25.90	-25.97	39.73	41.16

Table 3. Percentage Change in 2010 from Base Scenario for Fertilizer Use and Animal Numbers for the European Union and New Zealand

Scenario	2	3	4	5	6
European Union					
dairy cows region A	-12.6	0.0	-25.0	-34.5	-12.7
dairy cows region B	-20.6	0.0	-28.5	-43.4	-20.7
dairy cows region C	-18.1	0.0	-25.0	-38.6	-18.2
fertilizer region A	-14.7	0.0	-57.1	-63.5	-14.8
fertilizer region B	-18.7	0.0	-20.0	-35.0	-18.8
fertilizer region C	-18.3	0.0	-20.0	-34.7	-18.4
New Zealand					
dairy cows region A	29.5	-28.5	-28.6	-19.4	-19.9
dairy cows region B	35.0	-28.6	-28.6	-16.1	-18.2
dairy cows region C	22.2	-23.1	-23.1	-18.2	-19.1
fertilizer region A	44.3	0.0	0.0	44.6	45.3
fertilizer region B	45.4	-25.4	-25.4	8.9	7.8
fertilizer region C	37.1	-33.3	-33.4	-8.4	-8.4

Note: Region delineations are determined by typical production systems for those regions; their definitions can be seen in Appendix Table A1.

The total model coverage is too large and not immediately relevant enough to be presented here.

Prices. Following the liberalization-only scenario (scenario 2), producer prices in New Zealand increase across commodities, the largest increase being 73 percent for skim milk powder. EU prices fall in this scenario. In the scenarios involving international trade policy liberalization combined with a New Zealand mitigation strategy (i.e., scenarios 5 and 6), New Zealand dairy prices increase, while prices for dairy commodities in the EU fall. The only scenarios which show a decrease in New Zealand prices are scenarios 3 and 4—mitigation strategies with no international trade policy changes. However, these decreases are minimal. EU prices do not change in scenario 3, the mitigation strategy in New Zealand only; and only marginal changes follow the reductions in both EU and New Zealand stocking rate and fertilizer in scenario 4.

Production. Production for all dairy commodities in the EU decreases under the OECD liberalization scenarios. Production in New Zealand increases in scenario 2, up to 47.5 percent in cheese, as a result of the OECD countries liberalizing their trade policies.

Production for the scenarios involving mitigation strategies generally decreases, the exception being in New Zealand in scenarios 5 and 6, where mitigation is combined with OECD liberalization. Despite the initial decrease in production of raw milk as a result of the mitigation strategy, in these two scenarios the increased access to other markets results in a very small increase in raw milk production above the base scenario (less than one percent). These production declines are a direct result of the lower stocking rate and reduced fertilizer application. The combination with OECD liberalization helps offset these losses in production.

Table 2 shows the predicted changes in producer returns for raw milk in the EU and New Zealand across all scenarios. EU producer returns for raw milk fall across all scenarios, with the exception of scenario 3, the New Zealand mitigation strategy scenario. Conversely, producer returns in New Zealand increase in all scenarios except 3 and 4, which simulate mitigation strategies against a base trade policy with no liberalization occurring.

Trade. Quantities exported from the EU fall for dairy products across most scenarios. In most scenarios the EU is predicted to change from a net exporter to a net importer for butter and cheese, although it remains a net exporter of whole milk powder and skim milk powder across the scenarios, by reduced amounts. New Zealand remains a net exporter of all dairy products—increasing its exports of most of them—for all the scenarios except 3 and 4.

Environmental Results

This section presents and discusses the simulated results for the environmental variables in the model, particularly the predicted GHG emissions following the various policy changes. The summarized results of these environmental variables are shown in Table 3, and the GHG emission changes, together with producer returns, are illustrated in Figures 1 and 2 in order to clearly show both the economic and the environmental effect of each scenario.

Fertilizer Application and Animal Numbers. Fertilizer application and animal numbers are important factors in the calculation of GHG emissions; therefore, their results will be discussed here briefly before the GHG results are presented. Fertilizer application is predicted to be lower than in the base scenario across all regions in the EU across all scenarios except scenario 3 (which shows no change), whereas N application is predicted to increase in scenario 2 in New Zealand, and also in some regions in scenarios 5 and 6.[2]

[2] The reductions in stocking rate and fertilizer application are made in 1997 and continued out to 2010 in the base data of the model. They are not binding, however; therefore, as a result of changes in trade policies stimulating increased production in New Zealand, the stocking rates and application of fertilizer are able to increase above their initial reduced rate again.

Animal numbers are predicted to be lower across all regions of the EU for all the simulations shown here (except for in scenario 3, where there is no change). Animal numbers increase from the base in New Zealand in scenario 2; but, following the reduction in stocking rate as a climate change policy tool, numbers are lower in the other simulations. In scenarios 5 and 6, animal numbers decrease below the base scenario; however, fertilizer application in these scenarios increases in regions A and B, as a result of changes in production and input prices. These changes in animal numbers and fertilizer application are presented in Table 3.

Greenhouse Gas Emissions. Emissions from dairy cows in the EU are predicted to fall across all scenarios (again with the exception of scenario 3, where there is no change) as a consequence of either the liberalization of support policy (scenarios 2, 5, and 6), the reduction in stocking rate and fertilizer application (scenario 4), or both (scenario 5). These reductions vary across the production systems, and between scenarios, from a relatively low 13.5 percent in region A, scenario 2, to the more substantial 36–46 percent in scenario 5 (see Figure 1).

New Zealand's emissions are predicted to increase above the base in scenario 2 but to decline in the other scenarios. The largest decreases are shown in scenarios 3 and 4, where the percentage reductions are around 25 percent. Scenario 2 (OECD liberalization) shows a large increase in emissions, an average of 32 percent. Reductions from scenarios 5 and 6, where mitigation strategies are combined with OECD liberalization, result in smaller declines in emissions than under scenarios with no liberalization, as the increased access to international markets encourages increased production and hence also emissions.

Figure 2 shows the predicted percentage changes in New Zealand's GHG emissions for all scenarios, as well as in the producer returns for each scenario. Scenarios 5 and 6 are particularly important for New Zealand. Producer returns increase above the base scenario; however, unlike under scenario 2, GHG emissions decline at the same time.

Discussion and Conclusions

The results presented in the previous section can be divided into the two categories of production

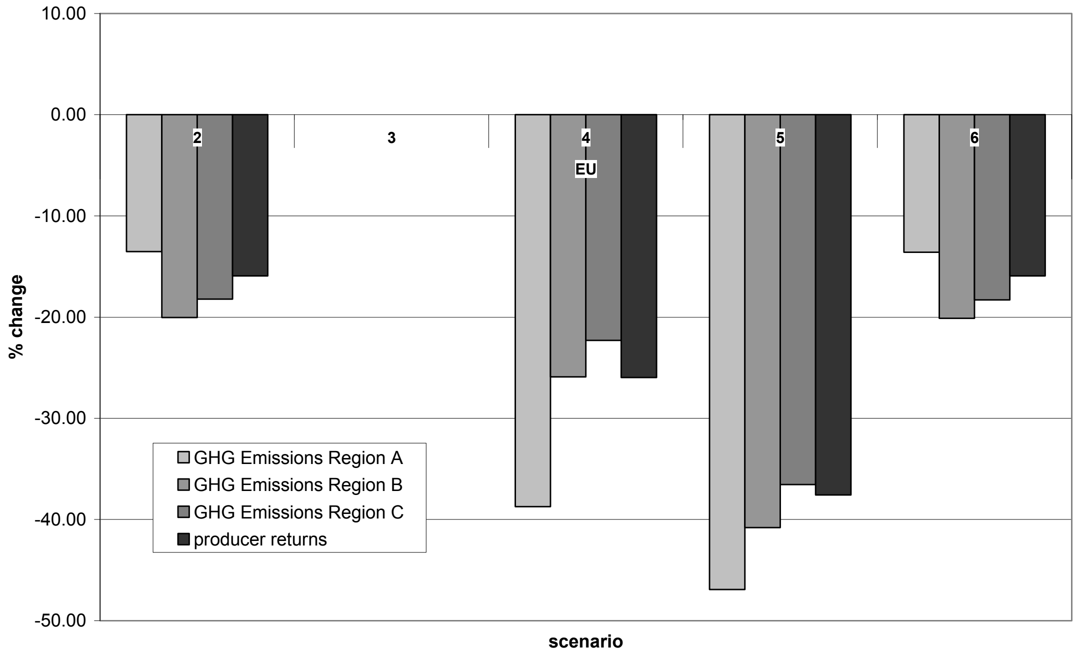

Figure 1. European Union Changes in GHG Emissions and Producer Returns in 2010 (by scenario)

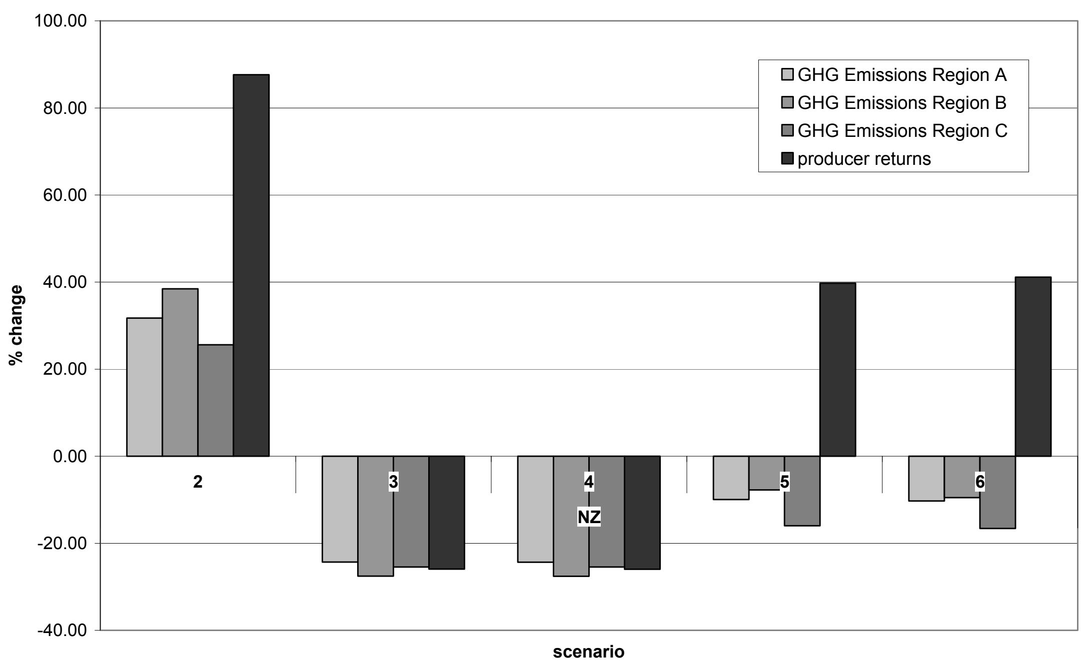

Figure 2. New Zealand Changes in GHG Emissions and Producer Returns in 2010 (by scenario)

and trade estimates, and environmental estimates. The first group represents standard outputs from a trade model, and may be compared with other studies of agricultural trade liberalization. These results correspond broadly with expectations from trade theory. If the EU and the OECD countries remove their border policies, their prices and production fall, while they rise for countries such as New Zealand. New Zealand could potentially gain significantly due to its comparative advantage in dairy production.

The second group of results shows one possible environmental effect resulting from trade liberalization—GHG emissions from agriculture. These results are particularly important for New Zealand agriculture. As discussed previously, agriculture accounts for 55 percent of the country's GHG emissions, and has already been identified as a potential area for a reduction in emissions. The current New Zealand government has ratified the Kyoto Protocol, and even at current emission levels this would mean some form of policy designed to reduce GHGs. Any change in the predicted emission levels, such as simulated here under OECD liberalization, would increase the burden faced by the agricultural sector to reduce emissions. Under current EU and other significant trading partners' 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 export greater amounts, but as a consequence would possibly face some form of financial penalty for their increased GHG emissions. Options that reduce GHG emissions and at the same time increase producer returns are clearly the most desirable for New Zealand. It would not be sufficient to simply reduce emissions to the base level, as this would still not reach the Kyoto target—a decrease beyond that would be necessary to make progress towards meeting the New Zealand commitment. Scenarios 3 and 4, which involve a mitigation strategy against a background of no trade liberalization, are clearly damaging to producer returns—while, although scenario 2 may be attractive to producers in terms of increased returns, the increase in GHG emissions would be a threat to achieving Kyoto targets.

Conversely, the EU, as an example of a highly protected agricultural market, and as 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. While the EU faces reasonably serious reductions in producer returns following liberalization, it will at least be able to go some way towards meeting its commitments under the Kyoto Protocol, with the resultant decline in GHG emissions.

While the complete liberalization of the international markets as simulated here may not be realistic, some reduction of international agricultural support policies is inevitable, and it is vital that New Zealand has mechanisms in place to cope with the anticipated production increases. The trade-off for achieving some level of GHG emissions reduction is clearly a lower increase in producer returns than without the mitigation strategy; however, this may be in the best overall interest for New Zealand. The point may also be made that without trade liberalization, a production-based GHG mitigation strategy would be very harmful to New Zealand producer returns—although the goal of GHG reduction would possibly be met, the cost to the economy would likely make the policy undesirable.

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Appendix

Table A1. Countries and Commodities in the Lincoln Trade and Environment Model (LTEM)

ID	Country	Region	ID	Commodity
AR	Argentina	--	WH	Wheat
AU	Australia	Region A—Victoria	CG	Coarse grains
		Region B—New South Wales (NSW)	SU	Sugar (refined)
		Region C—Other	OS	Oilseeds
CN	Canada	--	OM	Oilseed meals
CZ	Czech Republic	--	OL	Oils
EU	European Union (15)	Region A—West (UK, Ireland, Netherlands, Denmark)	BV	Beef, veal
			BT	Butter
		Region B—East (Germany, France)	CH	Cheese
		Region C—Other	PG	Pig meat
HU	Hungary	--	SH	Sheep meat
JP	Japan	--	WL	Wool
MX	Mexico	--	PY	Poultry meat
NI	New Independent States	--	EG	Eggs
NO	Norway	--	MK	Raw milk
NZ	New Zealand	Region A—South Auckland, Waikato	ML	Milk (liquid, other products)
		Region B—South Island	MW	Whole milk powder
		Region C—Other	MS	Skim milk powder
PO	Poland	--		
SL	Slovakia	--		
SW	Switzerland	--		
TU	Turkey	--		
US	United States of America	Region A—California		
		Region B—Wisconsin, Michigan, Minnesota, Pennsylvania, New York		
		Region C—Other		
RW	Rest of World	--		