AGRICULTURAL TRADE REFORM AND ENVIRONMENTAL POLLUTION FROM LIVESTOCK IN OECD COUNTRIES

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ABSTRACT

The Doha Development Agenda negotiations have the potential to lower agricultural protection and improve livestock production incentives for many farmers worldwide. Global trade barriers are particularly high in the case of products derived from livestock, especially dairy products and beef. While liberalisation is a source of economic benefits, it may also impose environmental costs such as through water and atmospheric pollution from livestock wastes. Agricultural trade liberalisation is a particularly contentious negotiating issue, and potential obstacles to reform include concern that it will lead to adverse environmental outcomes, and that national environmental policy interventions may not be compatible with WTO trade rules. In this paper we aim to contribute to an improved understanding of some environmental impacts of agricultural reform that may be agreed in the current WTO Round. We model the anticipated changes in livestock and crop production and compute the impact on regional nitrogen balances, using the OECD Nitrogen Balance Database. We estimate changes in inputs and uptake of nitrogen to determine the impact on the nitrogen balance for each region. Our findings suggest that for most OECD countries, WTO trade reform is likely to lead to improved nitrogen balances and lower nitrogen pollution. The more ambitious the trade reform, the better the environmental outcomes appear to be.

1. INTRODUCTION

Food consumption patterns in many developing countries are switching from an emphasis on traditional foods (cereals and root crops) to non-traditional cereals (eg wheat-based foods) along with processed and high-protein foods such as animal products. In Asia for example, cereals still provide the bulk of calorie intakes but rapid economic development is encouraging shifts from these foods to higher-value and higher-protein foods such as those derived from livestock. In response, livestock production has been increasing at a rapid pace in many developing regions but also in some OECD countries, sometimes with a consequent increase in the associated environmental problems. There is concern in many countries that these environmental problems will continue to worsen over time. There is also a belief by some that international trade may further exacerbate the problems.

For a variety of reasons, some OECD and other countries have a comparative disadvantage in livestock production. Government assistance, including trade barriers, has been used to encourage domestic livestock production to help meet the growing domestic and export demands. Such assistance has in some cases led to more intensive livestock farming systems. The expansion in production, and the development of intensive livestock systems, has caused concerns over waste disposal. Environmental degradation such as water and atmospheric pollution from increased livestock production is increasing the private and social marginal costs of livestock production.

While much progress has been made in modeling the global consequences of agricultural trade policy reform, less has been done in modeling the consequences of such policy reforms on the natural environment (Leuck *et al*. 1995, OECD 2000, Anderson and Strutt 1996, Rae and Strutt 2001, Saunders *et al*. 2004). This is understandable given the complex interactions between farm production and the environment and the dearth of available data on those relationships. However, if we are interested in as full a picture as possible about the welfare effects of trade reform, it is important that progress be made on modelling environmental effects. The effects on global environmental damage of trade reform-induced increases in growth and the location of farm production are ambiguous and remain an empirical question (Anderson and Strutt 1996). Improved information on anticipated environmental impacts can help to explicitly address environmental concerns and reduce the potential for trade negotiations to be derailed or stalled on environmental grounds.

The first objective of this paper is to determine the impact of some possible approaches to agricultural trade liberalisation on the level and location of farm production, with a particular focus on livestock activities. The second and major objective is to estimate the effects of these modeled trade reforms on regional nitrogen balances, for which we employ the OECD Nitrogen Balance Database. WTO trade negotiations currently include discussions of the linkages between trade and environmental policies, and the topic is likely to become increasingly important. Studies such as this can further our understanding of the environmental impacts that result from removal of trade restrictions and distortions, including the extent to which trade liberalization and environmental protection can be mutually reinforcing. We begin by outlining the nature of environmental degradation from livestock, the environmental data we will use, and the agricultural environmental issues that have arisen in the course of the current WTO negotiations. We then describe the trade model and liberalization scenarios, followed by discussion of the trade and environmental results of our modeling. We end with some tentative conclusions.

2. ENVIRONMENTAL DEGRADATION FROM LIVESTOCK

Pollution from livestock farming can affect air quality, surface water and groundwater. Livestock produce around 13 billion tonnes of waste annually and, while a large part of this is recycled, such waste can pose enormous environmental problems. Animal manure can be an environmental hazard due to its high concentration of nitrate, phosphate, potassium and ammonia. For example the global pig and poultry industries produce 6.9 million tons of nitrogen per year, equivalent to 7% of total inorganic nitrogen fertiliser produced in the world (Delgado *et al*. 1999). Animal feeds can contain heavy metals such as copper and zinc as growth stimulants. Their addition to the soil can pose human and animal health risks. Decomposition of manure can release these elements directly into surface waters or they can be leached through soil to ground water sources. This threatens the quality of drinking water and damage to aquatic and wetland ecosystems.

Livestock farming also results in emissions of ammonia and (in the case of ruminant animals) methane gases into the air. Livestock and manure management contribute about 16% to global annual production of methane (Delgado *et al*. 1999). Methane is a potent greenhouse gas, and in some countries is a major contributor to the greenhouse effect. Land application and the storage of manure are also important sources of ammonia emissions. The release of ammonia into the atmosphere contributes to acid rain and therefore to the acidification of soils and water and damage to crops and forests. Livestock's contribution to global climate change has been estimated at between 5% and 10% (de Haan *et al*. 1997, Steinfeld *et al*. 1997).

The current study focuses on nitrate pollution from agriculture, and particularly that from livestock sources. Nitrogen is important in the often highly subsidized, high-income countries that dominate global livestock production with their intensive livestock systems. Nitrogen is an input to the animal production process, primarily in animal feedstuffs, but also in fertilisers applied to pastures or as nitrogen fixed by certain pasture plants such as clovers. Nitrogen is also a component of the marketable outputs of the system, such as live animals, milk and meat. Manure, whether gathered from animal enclosures and spread on fields or deposited naturally by grazing animals, supplies nitrogen for plant growth. But nitrogen can also move into surface and ground waters, and ammonia gas can escape from manure on fields and from animal enclosures.

2.1 The Crop and Livestock Nitrogen Balance Model

Mineral balance sheets can record the inputs and outputs of a particular mineral in a production system, with the difference being the mineral surplus. Their construction and use has been refined in the Netherlands, for example, where they are a necessary component of environmental policy (Breembroek *et al.* 1996). Estimation of a nitrogen balance sheet requires estimation of the nitrogen inputs entering and outputs leaving the farm. Inputs would include the purchase of fertilisers, organic manure, feed and (young) animals. It would also include nitrogen supplied from the environment, such as N-fixation. Outputs would include the nitrogen content of products sold or otherwise disposed of by the farm, such as animals and animal products, crop products and manure. The difference between nitrogen input and output is the surplus of nitrogen remaining on the farm during the production process. It is this surplus that may cause environmental damage through emissions to the soil, water and air.[1]

In this paper, we use the OECD nitrogen balance database (OECD 2001a) to build a side module that works in tandem with the Global Trade Analysis Project (GTAP) global computable general equilibrium model.[2] The GTAP model is used to project the standard economic impacts of some WTO liberalization scenarios. These results provide a starting point, to which we add the environmental side module enabling analysis of the implications for environmental degradation (following Strutt and Anderson 2000 and Rae and Strutt 2001).

The nitrogen balance database is used to assess the soil surface nitrogen balance. This is calculated as the annual difference between the total nitrogen inputs and the total nitrogen outputs for soil in OECD countries (OECD 2001a). The inputs of nitrogen that are available to an agricultural system are primarily from livestock manure and chemical fertilisers, while uptake of nitrogen is mainly by crops and forage. The OECD database is a very comprehensive source of nitrogen balance data. Much of the basic data such as livestock numbers, crop production and fertiliser use, are taken from official agricultural census data. The nitrogen coefficients used to convert these data into nitrogen equivalents are estimates from agricultural research institutes and published literature (OECD 2001b). Nitrogen coefficients can differ between countries for many different reasons; for example, agro-

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[1] While persistent surpluses of nitrogen can cause environmental pollution, a persistent deficit may cause agricultural sustainability problems (OECD 001b)

[2] See www.gtap.org for details of the GTAP model.

ecological conditions, livestock weights and yields, and furthermore, the methods used to estimate these coefficients may vary (OCED 2001b). Nitrogen coefficients are multiplied by the relevant quantity of crop production or livestock numbers and an overall balance obtained by summing all inputs and outputs.

Table 1 Summary of nitrogen inputs and outputs

Nitrogen Inputs	Nitrogen Outputs
Inorganic or chemical nitrogen fertilisers	Harvested crop production
Net livestock manure nitrogen production[3]	Grass and fodder production
Biological nitrogen fixation	
Atmospheric deposition of nitrogen	
Nitrogen from recycled organic matter	
Nitrogen contained in seeds and planting materials	

Source: OECD Nitrogen Balance Database

3. THE WTO, AGRICULTURE AND THE ENVIRONMENT

Linkages between agricultural production and the environment have been recognised for some time in the WTO and multilateral trade negotiations. For example the Uruguay Round Agreement on Agriculture (URAA) permits countries to make unlimited expenditures on certain farm environmental programmes, provided those programmes meet the criteria laid down in Annex 2 of the URAA (the so-called Green Box exemptions). These include direct payments to farmers under environmental programmes, so long as they are part of a clearly-defined government programme and are limited to the extra compliance costs or loss of income involved (paragraph 12 of Annex 2).

The Doha Ministerial Mandate draws attention, with respect to agriculture, to the aims of “substantial improvements in market access; reductions of, with a view to phasing out, all forms of export subsidies; and substantial reductions in trade-distorting domestic support”. Special and differential treatment for developing countries is to be an integral part of all elements of the agricultural negotiations and non-trade concerns, including the need to protect the environment, are to be taken into account in the agricultural negotiations.

Thus environmental issues are included in the mandate of the current Round. The agricultural negotiations are being pursued in the Committee on Agriculture, and the negotiations on trade and the environment are taking place in the Committee on Trade and Environment (CTE). The Doha Mandate itself does not explicitly link the work of the Agricultural, and Trade and Environment Committees. However, that Mandate does (paragraph 51) require the Committees on Trade and Environment, and Trade and Development (which has a mandate to review all special and differential treatment provisions for developing and least-developed countries), to identify and debate developmental and environmental aspects of the negotiations, to assist achievement of the objective of having sustainable development

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[3] These data should be net of the nitrogen loss through the volatilisation of ammonia to the atmosphere from livestock housing and stored manure; however livestock manure in the OECD database excludes these nitrogen losses (OECD 2001b).

appropriately reflected. This could include, presumably, those environmental aspects of the agricultural negotiations that may impinge on developing countries.

The work programme of the CTE suggests ample scope for the possibility of closer linkages to agricultural negotiations in future. For example, that programme includes work on trade rules and environmental agreements (bear in mind the contribution of livestock to greenhouse gases), environmental measures with significant trade effects, the relationship between the provisions of the multilateral trading system and charges and taxes for environmental purposes, the effect of environmental measures on market access, and the environmental benefits of removing trade restrictions and distortions. The CTE itself sees the latter two as "holding the key to the way sound trade policy-making and sound environmental policy-making can support each other". To assist the CTE's discussions, the WTO secretariat has prepared background papers[4] that include information on environmental impacts of protection and trade-distorting support in agriculture.

Within the agricultural negotiations, members have discussed environmental issues as non-trade concerns, and some have tabled proposals on the subject. The debate has not focused on whether protection of the environment is a legitimate policy goal, but on identifying the appropriate instruments with which to achieve such an objective. One group of members sees trade liberalisation and environmental protection as mutually enforcing, since protection and trade-distorting domestic support can encourage environmentally-harmful agricultural practices. Such distortions, it is argued, are also linked to poverty in developing countries – a major cause of environmental degradation. Another group of member countries focuses on agriculture's positive environmental effects including land conservation, water management and landscape maintenance. Their view is that a certain level of (assisted) farm production is necessary to ensure provision of such externalities[5]. While many countries oppose establishing limits on Green Box spending, other members have proposed such limits, either for all countries or restricted to developed countries. These could therefore affect spending under environmental programmes. Some proposals suggest changes to paragraph 12 of Annex 2, for example to ensure that support provided under environmental programmes is not related to the volume of production, or to allow landscape and animal welfare payments, or payments to compensate for the provision of environmental benefits. Yet another proposal is to add a new category of Green Box exempt payments, those to compensate for the costs accruing from higher production standards, which presumably could cover environmental standards (Wolter 2003).

4. AGRICULTURAL TRADE LIBERALISATION: THE DOHA DEVELOPMENT AGENDA

The WTO Uruguay Round Agreement on Agriculture made some progress in liberalising trade in food and agricultural products, through reductions in tariffs and expansion of market access, and reductions in export subsidies and some types of domestic support payments

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[4] WT/CTE/W/67 examines various sectors including agriculture, and WT/CTE/GEN/8 covers specifically the environmental issues raised in the agricultural negotiations.

[5] WT/CTE/8.

(OECD 2001). Clearly, however, major policy-induced distortions remain in agricultural markets (see, for example, Gibson *et al*. (2001) for details of current agricultural and food tariffs). A new WTO Round of agricultural trade negotiations began in March, 2000. These talks have since been incorporated into the broader negotiating agenda set at the 2001 Ministerial Conference in Doha, Qatar. This current Round of multilateral trade negotiations (the Doha Development Agenda) is examining prospects for further liberalisation of many of these policy interventions.

Many WTO members have put forward proposals for reform. An overview of these was provided by the Chair of the Agriculture Committee in December 2002. The Chair also released in February 2003 a first draft of modalities for achieving the objectives of the agricultural negotiations. After receiving mixed reaction from Members, a revised first draft was released in March 2003. The target of reaching agreement on agricultural reform modalities by 31 March 2003 was not met. The EU and USA released a joint paper in August 2003 in an effort to maintain negotiating momentum, to which a group of developing countries signalled their dissatisfaction by releasing their own reform plans later that month. This was soon followed by a new draft text issued by the Chair of the WTO General Council that received strong criticism from many groups. A further revised text was released in September 2003 to assist the WTO Ministerial meeting in Cancun in November of that year, but that meeting collapsed without any agreement reached and the agricultural negotiations continue. The deadline for completion of the Round was set as January 2005, although this appears increasingly unlikely to be achieved.

4.1 The trade model

We simulate the impact of three trade liberalisation scenarios using a modified version of the Global Trade Analysis Project (GTAP) applied general equilibrium model (Hertel 1997). This is a multi-region model with detailed inter-industry linkages for each of the economies represented. Although GTAP is among the most sophisticated applied general equilibrium models currently available, it necessarily involves some simplifications and abstractions from the real world. While resources are heterogeneous, the GTAP production system distinguishes sectors by their intensities in just four primary production factors: land (agricultural sectors only), natural resources (extractive sectors only), capital, and labour. Some differentiation is introduced by dividing the labour resource into two classes – skilled and unskilled. While the standard GTAP model allows substitution amongst the employment of these resources in any sector in response to price changes, Leontief functions imply that intermediate inputs are used in fixed proportions . This assumption has been modified in this application to the extent that substitution among feedstuffs in livestock production is permitted. While all units of output from any sector in each country are assumed identical, at least in trade products are differentiated by country of origin, allowing bilateral trade to be modelled. The model is solved using GEMPACK (Harrison & Pearson 1996).

The GTAP Version 5 database covers 66 regions and 57 commodity sectors (including 20 in agriculture and food). Such a detailed disaggregation is unnecessary in this study and we aggregate the regions to 16 OECD and three non-OECD regions. Five of the EU countries are individually specified, with the remaining aggregated into three groups, reflecting their agricultural N-balances[6] per hectare. Denmark and Belgium are grouped together under Den_Blg as they (along with the Netherlands) exhibited the highest per hectare N-balances. Austria, Italy and Greece exhibited the lowest N-balance values and are grouped under EU_lowN. Remaining EU countries are grouped into Rest of EU.[7] Of the other OECD countries, N-balances were highest in Korea and also relatively high in Japan, both of which are modelled separately. Three regional groupings of Central and South America, the Rest of Asia and the Rest of the World are used to model non-OECD countries, but nitrogen balances are not available for these groupings. At the sectoral level, 11 of the 14 modelled sectors represented farm and food production, including separate sectors for milk production, cattle and sheep farming and non-ruminant livestock production. We focus particularly on the seven sectors for which nitrogen balances are computed: rice; wheat; cereal grains; other crops; raw milk; cattle and sheep;[8] and other livestock.

In this work, we explicitly model milk production quotas. Where such quotas exist and are binding (i.e. they effectively constrain production), then reductions in domestic prices that might result from trade liberalisation need not result in a reduction in milk output. Figure 1 depicts the demand curve (D) and supply curve (S) for milk. In the absence of a quota on production, QM will be produced at price PM. Should a quota be used to restrict milk output below the equilibrium level QM, PS is the equilibrium price and reductions in this price (such as may result from a decrease in demand for milk) may not discourage output. In Figure 1, the producer price would have to fall to PQ before any further price reductions would result in reduced milk output. The difference between PS and PQ is the rent per unit of quota. Thus knowledge of the ratio of PQ to PS is essential to a detailed modelling of production quotas.

A recent study for the European Commission (INRA-Wageningen 2002) contained estimates of PS and PQ for all EU member countries for the year 1998. The ratio PQ/PS was less than one in each country, indicating binding quotas in all cases, and ranged from 0.51 for Ireland to 0.85 in the case of Sweden. Where EU countries were aggregated into larger groups, a weighted average ratio was computed using milk production data as weights. Lips and Rieder (2002) estimated a PQ/PS ratio for Switzerland of 0.74, which is assumed here to apply to the entire EFTA region. Milk quotas are also binding in Canada, and a PQ/PS value of 0.6 is used (Meilke *et al*. 1998; Karl Meilke, personal communication 2003). Thus quota countries or regions to be recognised in the model are all of the EU countries or groups, Canada and the EFTA region, and all quotas are binding in the base data. The GTAP model modifications to include these production quotas were based on Lips and Rieder (2002), and details of the ratios used are in Table 2.

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[6] Defined as nitrogen inputs less nitrogen outputs. Positive values hence imply net additions of nitrogen to the environment.

[7] Remainder of the EU15 (excluding new members admitted on 1 May 2004).

[8] This sector also includes goats and horses.

Figure 1 Modelling output quotas

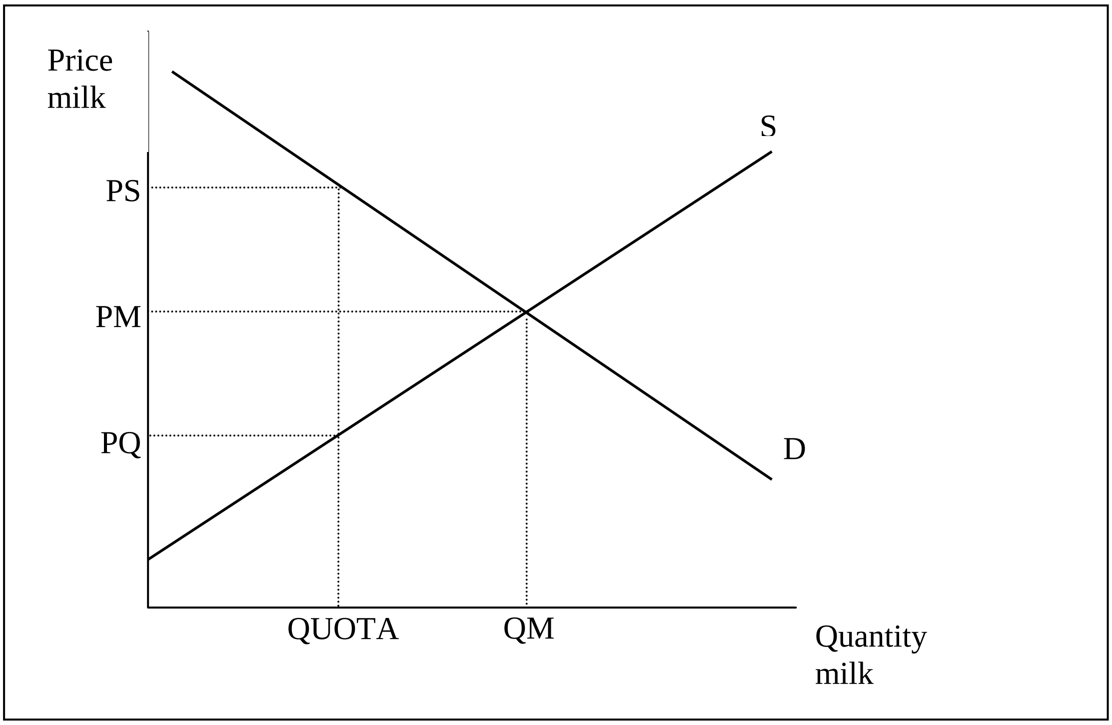

Table 2 PQ/PS ratios for regions in our aggregation

Region	PQ/PS ratio	Region	PQ/PS ratio
Australia	1	Canada	0.6
Den_Blg	0.62	USA	1
Rest of EU	0.72	Rest of ASIA	1
EU_lowN	0.61	Japan	1
Ireland	0.51	Korea	1
France	0.64	Cen. and Sth. America	1
Germany	0.55	EFTA	0.74
UK	0.57	Central Europe	1
Netherlands	0.64	Rest of the World	1
NZ	1		

4.2 Liberalisation scenarios modelled

The scenarios we model reflect certain elements of some of the agricultural proposals made during the current WTO Round. They incorporate changes within each of the major negotiation pillars – market access, export competition and domestic support. It is not possible, however, to model all details of many of the proposals, such as those related to special safeguards, food aid, state trading enterprises, export credits, and the non-trade concerns. In addition, other simplifications and omissions are made, given the data and trade model to be used here. For example, some proposals suggest reductions (such as in tariff rates) be made from bound levels, others from levels that actually applied in a given base period. The data to be used here (see below) include the applied levels of tariffs and support, rather than the bound rates.[9] The large number of tariff rate quotas (TRQs) that exist for food

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[9] In OECD countries, the applied tariff rates are often similar to the bound rates. However in many developing countries, applied rates are considerably below the bound rates, so the modelled

and agricultural products provides a major aggregation problem and the possibility of aggregation bias, since the database we employ (see below) aggregates many such products into single commodities. Thus we do not model TRQs. Any agreed liberalisation will be phased in over a number of years. As the trade model used here is comparative static in nature, the adjustment path to the targeted reductions in support is not revealed and the dynamic gains from trade are not captured.

The scenarios are described in Table 3. The first scenario has some elements in common with the EU's proposal of December 2002 and in some respects has similarities to the URAA outcome. The second scenario draws on some elements (such as the tariff reduction formulas) of the February 2003 draft modalities document prepared by the Chair of the WTO Agricultural Committee, referred to above. The third, and most ambitious scenario for reform, is modelled on some elements of the proposals from the Cairns Group (September 2002) and the USA (July 2002). No changes are made to policies in the manufacturing and services sectors.

5. RESULTS

5.1 Agricultural trade liberalisation and the location and level of farm production

The first scenario simulates outcomes from a liberalisation which had some features in common with the URAA outcome. As shown in Table 4, farm production of most commodities (with the exception of milk in the EU) declined in all EU countries and sub-regions, and also in the EFTA countries and Japan. In percentage terms, the declines in crop outputs were generally of a higher magnitude than for livestock production. Output from all farm sectors expanded in Central and South America, as did output in several farm sectors in Australasia and North America. Livestock farming and output from some cropping sectors also exhibited some expansion in South Korea.

Results for the second and third simulation scenarios are shown in Tables 5 and 6. In the third scenario, modelled trade reforms become more liberal, with deeper cuts to tariffs, as well as export and domestic subsidies. By and large, the patterns of changes to regional farm production remained similar to those described above, but were of greater magnitude. For example, as indicated in Table 6, raw milk and cattle and sheep production in Australia and New Zealand expanded by between 5% and 10% in scenario #1, but by 9% to over 26% in the third scenario. While outputs of most crops and all livestock sectors with the exception of milk continued to decline in EU countries, the relatively lightly-assisted 'other crops' sector (which includes fruits and vegetables) showed expansion in several EU countries under the second and third scenarios. Note that across all scenarios, reduced milk prices drove output below quota levels only in EFTA.

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liberalisations could overstate the extent of tariff reductions in such cases, provided that any Agreement based tariff reductions on the bound rates.

Table 3 Trade Liberalisation Scenarios

Item	Scenario #1	Scenario #2	Scenario #3
Change in tariffs[a]			
Developed regions	-36%	$If\quad t_o \geq 90\%,\quad t_1 = t_o * 0.4$ $If\quad 15\% \leq t_o < 90\%,\quad t_1 = t_o * 0.5$ $If\quad t_o < 15\%,\quad t_1 = t_o * 0.6$	Swiss formula (a=25)
Developing regions	-24%	$If\quad t_o \geq 120\%,\quad t_1 = t_o * 0.6$ $If\quad 20\% \leq t_o < 120\%,\quad t_1 = t_o * 0.67$ $If\quad t_o < 20\%,\quad t_1 = t_o * 0.73$	$If\quad t_o \geq 250\%,\quad t_1 = 125\%$ $If\quad 50\% \leq t_o < 250\%,\quad t_1 = t_o * 0.5$ $If\quad t_o < 50\%, Swiss\ formula\ (a = 50)$
Change in Export subsidy spending			
Developed regions	-45%	-100%	-100%
Developing regions	-45%	-50%	-100%
Change in Trade-distorting support spending[b]			
Developed regions	-55%	-60%	-100%
Developing regions	No change	-20%	-50%

a. None of the scenarios incorporates changes in non-agricultural tariffs.

b. Defined for modelling purposes as output and input subsidies, and excluding all other payments such as those based on crop areas or livestock numbers

Table 4 Changes in Farm Sector Outputs: scenario #1

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep	Other livestock
Australia	7.0	0.1	7.8	-0.6	5.1	4.9	-0.6
Den_Blg	..	-4.7	-5.1	-1.6	0.0	-9.1	-0.7
Rest of EU	..	-4.6	-5.8	-1.1	0.0	-2.0	-0.3
EU_lowN	-4.4	-4.4	-3.4	-0.3	0.0	-1.9	-0.7
Ireland	..	-7.3	-7.0	0.5	0.0	-8.6	-0.2
France	..	-7.0	-9.2	0.0	0.0	-1.5	0.1
Germany	..	-4.1	-4.3	-0.4	0.0	-4.2	-1.0
UK	..	-4.0	-5.3	-0.4	0.0	-1.9	-1.3
Netherlands	..	-8.5	-21.8	-0.4	0.0	-10.9	-1.4
NZ	..	5.2	5.2	-0.7	9.8	5.5	-9.6
Canada	..	13.0	1.3	1.4	0.0	-0.3	-4.2
USA	2.6	-0.6	-1.2	0.4	-0.7	0.2	0.1
Rest of ASIA	0.4	0.2	-0.1	-0.1	0.1	0.2	0.2
Japan	-2.2	-35.1	-6.8	-3.6	-5.0	-6.8	-2.1
Korea	1.7	5.5	-18.8	-1.6	-0.2	0.7	1.4
Cen. and Sth. America	0.9	2.0	1.1	0.7	0.2	1.2	0.5
EFTA	..	-9.0	-8.6	-7.5	-0.4	-2.2	-1.0
Central Europe	..	0.2	1.4	-0.9	0.5	2.4	0.5
Rest of the World	0.0	-1.2	0.2	0.1	-0.5	-0.8	-0.6

Source: Authors' model results

Table 5 Changes in Farm Sector Outputs: scenario #2

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep	Other livestock
Australia	14.0	0.5	11.0	-1.1	10.6	6.7	-1.2
Den_Blg	..	-6.2	-9.9	-1.5	0.0	-15.0	-1.0
Rest of EU	..	-6.8	-9.2	-0.8	0.0	-3.1	-0.3
EU_lowN	-6.4	-6.5	-4.6	-0.3	0.0	-3.0	-0.8
Ireland	..	-9.5	-8.7	1.1	0.0	-15.1	1.4
France	..	-10.4	-13.0	0.1	0.0	-2.1	0.6
Germany	..	-6.5	-7.5	0.1	0.0	-6.6	-1.1
UK	..	-5.6	-8.6	0.0	0.0	-2.7	-1.8
Netherlands	..	-12.1	-32.7	-0.3	0.0	-17.2	-2.4
NZ	..	7.6	7.6	-2.3	17.2	8.0	-16.4
Canada	..	19.2	2.5	2.1	0.0	-0.5	-5.6
USA	4.9	0.8	-0.8	0.6	-0.9	0.7	0.3
Rest of ASIA	0.6	0.1	-0.1	0.0	0.1	0.4	0.2
Japan	-3.6	-56.6	-9.1	-5.1	-8.6	-10.4	-2.5
Korea	3.1	7.7	-33.3	-2.4	0.2	1.2	2.3
Cen. and Sth. America	1.5	3.0	1.6	0.8	0.6	1.8	0.8
EFTA	..	-18.6	-12.3	-8.7	-10.7	-4.5	-2.2
Central Europe	..	0.3	2.5	-1.3	1.2	3.4	0.4
Rest of the World	0.4	-1.8	0.6	0.1	-0.2	-0.9	-1.0

Source: Authors' model results

Table 6 Changes in Farm Sector Outputs: scenario #3

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep	Other livestock
Australia	46.7	-1.2	19.5	-2.2	18.6	9	-3.1
Den_Blg	..	-4.5	-11.3	-0.1	0	-24.2	-1.4
Rest of EU	..	-8.7	-11.7	-0.1	0	-4.9	-0.4
EU_lowN	-8.8	-9.8	-6.4	0.5	0	-5.1	-0.6
Ireland	..	-13.8	-12.6	4	0	-19.6	1.1
France	..	-15.2	-18	1.3	0	-4.5	1.2
Germany	..	-8.9	-8.7	0.9	0	-11.7	-1.3
UK	..	-7.4	-10.2	0.7	0	-3.9	-3.1
Netherlands	..	-17.2	-47.1	0.8	0	-27.2	-2.1
NZ	..	13.4	13.3	-6.6	26.2	14.3	-27.8
Canada	..	29.2	3.5	4.5	0	-1.3	-10.3
USA	14.3	-0.2	-2.2	1.4	-1	0.9	0
Rest of ASIA	0.8	0.3	-0.3	-0.1	0.1	0.8	0.4
Japan	-6.7	-81	-8	-6.9	-16.8	-14.4	-2.3
Korea	4.7	14	-50.2	-3.9	-0.1	2.7	4.4
Cen. and Sth. America	1.3	5.1	2.5	0.4	1	3.7	1.3
EFTA	..	-47.1	-25.2	-11.2	-22.3	-12.8	-5.3
Central Europe	..	-0.4	2.2	-1.6	1.8	4.1	-0.4
Rest of the World	0.1	-2.9	0.8	-0.4	-0.8	-1.7	-1.5

Source: Authors' model results

5.2 Agricultural trade liberalisation and environmental impacts

The simulated changes in agricultural output will have implications for the nitrogen balance in each region. The nitrogen balance module captures the nitrogen inputs and outputs noted in Table 1, for all OECD economies.[10] We use the OECD data for 1997, corresponding to the base year of version 5 of the GTAP model used. The OECD database contains very detailed data by country, particularly on nitrogen coefficients for crops and livestock. This very detailed information is aggregated into a form compatible with the GTAP database used. A summary of the total nitrogen balance by region is provided in Table 7.

Output of nitrogen is comprised of output from the crop sectors and from pasture (OECD 2001a). Nitrogen coefficients for crops range from 1.5 kg per tonne to nearly 70 kg per tonne of output, with much variation by crop type and region. We assume that these coefficients remain constant when trade is reformed, and that the level of nitrogen uptake will change by the same proportion as the level of output in each crop sector (consistent with the assumptions used in the OECD calculations of nitrogen output). For uptake of nitrogen by pasture, we assume that any change from the base level is proportional to the average change in land use for the pasture-using livestock sectors (cattle, dairy cows and sheep), weighted by the initial land use by these sectors.

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[10] With the exception of Mexico and Turkey since these countries are aggregated with non-OECD countries in our current aggregation.

Table 7 Initial Nitrogen Balances, 1997

	Nitrogen Balances, 000 tonnes	Nitrogen Balances, kg/ha
Australia	3,566	7.6
NZ	74	5.5
Japan	641	129.5
Korea	498	250.4
Canada	1,159	15.5
USA	12,524	29.9
EU_lowN	719	29.5
Den_Blg	554	134.0
France	1,517	50.6
Germany	976	56.4
UK	1,477	86.7
Ireland	401	80.0
Netherlands	511	262.1
Rest of EU	1,826	47.4
EFTA	184	70.3
C. Europe	699	24.2

Source: Authors' calculations from the OECD Nitrogen Balance Database

For inputs of nitrogen, the OECD database contains very detailed data on nitrogen coefficients by country and livestock category, with the largest sources of nitrogen inputs being livestock manure and inorganic fertilizers. Changes in nitrogen from livestock manure are modeled as changing in proportion to the change in output of each type of livestock in each region as shown in our GTAP results (Tables 4-6). Withdrawals of nitrogen due to changes in manure stocks and manure imports are modeled by assuming that the proportion of withdrawals to livestock manure will remain constant. For fertilizer, changes in the nitrogen input are due to changes in fertilizer use on cropland or pasture.[11] Nitrogen input on cropland is assumed to change in proportion to the weighted average percentage change in output for the crop sectors using these fertilizers (in the absence of crop-specific fertilizer rates). Fertilizer use on pasture is assumed to change in proportion to changes in output in pasture using sectors. The OECD database separates biological nitrogen fixation into that by free living soil organisms on agricultural land and that by leguminous crops or pasture. Since the total agricultural land area does not change in our simulations, we assume that nitrogen fixation by free living organisms remains constant. However, nitrogen fixation by leguminous plants is assumed to change in proportion to changes in land use for the 'other crops' sector.[12] Other sources of nitrogen inputs include atmospheric deposition of nitrogen, nitrogen from recycled organic matter and nitrogen contained in seeds and planting material (OECD 2001a).; in the absence of better information, these are assumed constant when trade policies are changed.

Given the scenarios and assumptions outlined above, we find that trade liberalization tends to lead to an overall reduction in the total nitrogen balance for OECD countries. In the base year

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[11] We assume that fertiliser use changes in proportion to the relative land use in crops and pasture.

[12] For New Zealand, the treatment is different, reflecting a difference in the OECD database. The contribution of pulses to N-fixation changes in proportion to land use in 'other crops' while the contribution of clover changes by land use in pasture-using sectors, reflecting the importance of clover in New Zealand pastures.

of 1997, the total nitrogen balance for OECD countries included in our modelling is estimated to be 27.33 million tonnes. In the first liberalization scenario, this is projected to fall to 27.21 million tonnes. It is projected to fall further to 27.12 and 27.04 million tonnes for the second and third reform scenarios (see Table 8). Thus it appears that with more ambitious reform, the overall OECD nitrogen balance falls more. For the third scenario, simulation results suggest that the total nitrogen balance for the OECD falls from its initial level by just over 1 percent. To the extent that nitrogen balances are reduced, it might be expected that environmental outcomes improve, with a reduction in the surplus nitrogen that can cause damage to soil, air and water.

Table 8 Total Nitrogen Balance for OECD Countries, 000 tonnes

		Initial 1997	Scenario 1	Scenario 2	Scenario 3
Uptake					
	Rice	487	484	484	492
	Wheat	5,156	5,128	5,139	5,119
	Cereal grains	7,152	7,017	6,986	6,900
	Other crops	12,128	12,126	12,146	12,230
	Pasture	20,153	20,466	20,622	20,825
	Total uptake	45,076	45,221	45,378	45,567
Inputs					
	Cattle and sheep	13,811	13,851	13,864	13,853
	Other livestock	7,333	7,297	7,289	7,246
	Milk	4,524	4,552	4,573	4,596
	Fertilizer	26,216	26,104	26,112	26,116
	Withdrawals	-4,398	-4,392	-4,392	-4,380
	Seeds	462	462	462	462
	BioNFx	13,580	13,687	13,721	13,843
	Atmospheric	10,873	10,873	10,873	10,873
	Total inputs	72,402	72,434	72,503	72,610
Total Nitrogen Balance		**27,326**	**27,213**	**27,125**	**27,043**

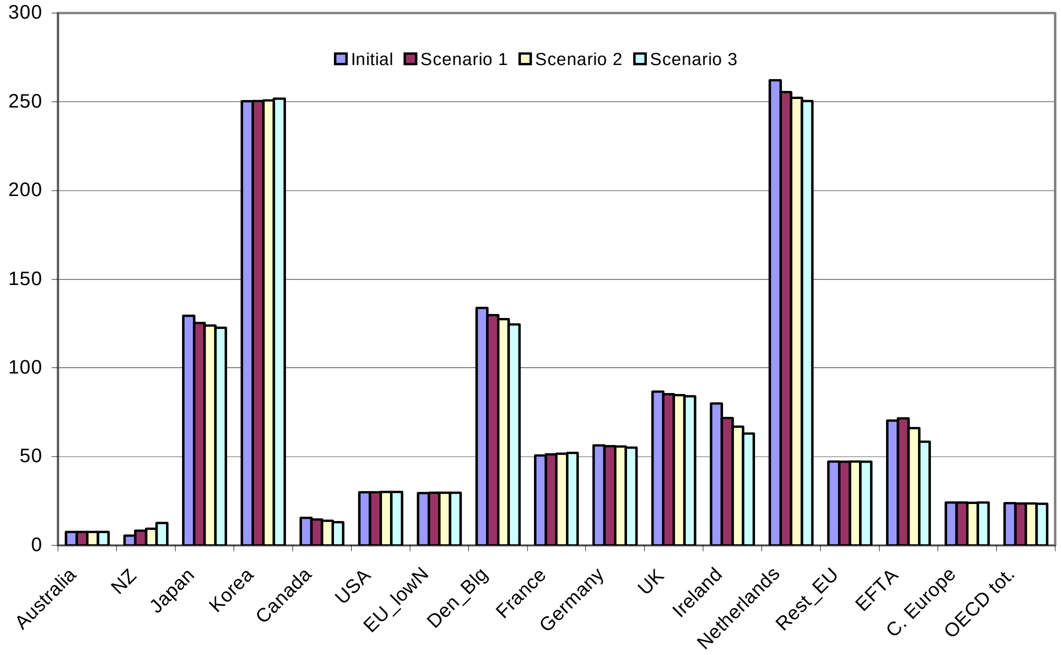
Source: Authors' model results

Further insights can be gained by decomposing overall the nitrogen balance into uptake and inputs as shown in Table 8. Total nitrogen uptake for OECD countries increases by 0.3 percent in scenario one and by 0.7 percent in the second scenario. In the most ambitious third trade simulation we model, total nitrogen outputs increase by 1.1 percent for OECD countries. The largest contributor to increased nitrogen uptake is pasture, which increases uptake of nitrogen by 3.3 percent. The other crops sector also increases nitrogen uptake by 0.8 percent. The rice sector makes a small contribution to the total increase in nitrogen uptake, increasing uptake by 1 percent. Cereal grains, and to a lesser extent wheat, reduce uptake of nitrogen a little in the aggregate OECD region.

Nitrogen inputs increase a little with trade reform, slightly dampening the reduction in the nitrogen balance for the OECD. Total nitrogen inputs for OECD countries increase by only 0.29 percent, even in the most ambitious scenario modelled. The main increase in nitrogen input is the 1.9 percent increase in biological nitrogen fixation. Most other inputs of nitrogen either remain constant or increase only a little, the largest increase being 1.6 percent for the milk sector in scenario 3. The main reduction in inputs comes from fertilizers, which are projected to reduce their nitrogen inputs by around 0.4 percent in each scenario. The other livestock sector reduces nitrogen inputs by 1.2 percent. The overall small increase in nitrogen inputs combine with the increased overall uptake of nitrogen to result in lower nitrogen balances for the OECD region with trade reform, reflecting a shift from nitrogen-intensive to nitrogen-extensive farming systems.

When these nitrogen balance results are decomposed by region, many countries are projected to experience reductions in their nitrogen balance. As shown in Figure 2, reduced nitrogen balances are simulated for 10 of the 16 regions in the first scenario, increasing to 11 of the 16 regions in the third simulation. Changes in the nitrogen balance are driven by the changes in sectoral output in each region projected using the GTAP model. We will focus our analysis here on results for the most ambitious third reform scenario, though similar insights tend to apply (with lesser magnitude) in the first two scenarios.

Figure 2: Nitrogen Balance by OECD Region (kg/ha)



Source: Author’s model results

The five countries projected to experience an increase in their nitrogen balance in the third simulation are New Zealand, the US, EN_lowN, Korea and France. Of these, the largest increase is 96 thousand tonnes projected for New Zealand, an almost 130 percent increase from the initial level. While this increase may pose some environmental problems for New Zealand, the initial nitrogen balance per hectare is the lowest of any OECD region (Table 7), and even this magnitude of increase would place it only higher than one country (Australia). For New Zealand, inputs of nitrogen are projected to increase by 11 percent while uptake of nitrogen increases by 8.5 percent from initial levels. In Table 9, changes in nitrogen inputs and uptake by region are decomposed into key components. Increased nitrogen inputs for New Zealand are primarily due to increases in the pasture using sectors of milk and cattle and sheep. The projected increases in output of 14 and 26 percent for the cattle and sheep and the milk sector lead to increased livestock manure, which contribute almost 60 percent of the increased nitrogen inputs. Much of the remainder is contributed by increased biological nitrogen fixation by leguminous plants, due to the increase in land use in pasture using sectors and the assumptions on biological nitrogen fixation for New Zealand outlined above. There is also an increase in fertilizer on pasture, contributing eight percent to the increase in nitrogen inputs. Other nitrogen inputs reduce a little, particularly other livestock manure, given the reduction in output for this sector and the effect of increased nitrogen withdrawals. On the nitrogen uptake side, almost all of the increase is due to increased land use in pasture using sectors and the consequent increased nitrogen uptake by pasture. However, this higher uptake is not sufficient to offset the increased input of nitrogen, hence the increase in New Zealand's overall nitrogen balance.

Table 9 Changes in nitrogen balance components, scenario 3 (000 tonnes)

	Harvested crops	Pasture	**Total nitrogen uptake**	Net livestock manure	Inorganic Fertilizer	Other nitrogen inputs[a]	**Total nitrogen inputs**	**Nitrogen balance**
Australia	40.1	290.7	**331**	231.0	100.0	-43.7	**287**	**-44**
NZ	1.8	283.0	**285**	220.6	30.4	129.6	**381**	**96**
Japan	-36.5	-16.7	**-53**	-58.0	-49.1	20.6	**-86**	**-33**
Korea	-1.8	0.3	**-2**	11.1	-7.9	-2.0	**1**	**3**
Canada	284.3	-45.2	**239**	-55.1	112.2	2.3	**59**	**-180**
USA	31.4	30.0	**61**	33.8	40.2	71.8	**146**	**84**
EU_lowN	-50.3	9.4	**-41**	-33.9	-23.2	18.6	**-39**	**2**
Den_Blg	-14.9	-1.9	**-17**	-47.6	-16.3	8.4	**-55**	**-39**
France	-213.6	65.1	**-149**	-40.6	-89.8	27.0	**-103**	**45**
Germany	-83.3	13.6	**-70**	-58.2	-56.1	21.7	**-93**	**-23**
UK	-28.7	25.9	**-3**	-26.8	-26.5	6.2	**-47**	**-44**
Ireland	-4.5	-2.7	**-7**	-71.7	-30.8	10.3	**-92**	**-85**
Netherlands	-6.9	-2.3	**-9**	-24.0	-14.2	6.2	**-32**	**-23**
Rest of EU	-68.0	9.8	**-58**	-37.8	-34.7	6.0	**-66**	**-8**
EFTA	-31.3	-1.7	**-33**	-33.5	-32.7	2.5	**-64**	**-31**
C. Europe	0.4	14.9	**15**	16.4	-1.6	-3.1	**12**	**-4**

[a] Withdrawals and biological nitrogen fixation by leguminous plants.

The US nitrogen balance is projected to increase by 84 thousand tonnes in the most ambitious scenario, a 0.67 percent increase from the initial level. Uptake of nitrogen increases by 61 thousand tonnes, but the increase in nitrogen inputs is estimated to be 146 thousand tonnes. The cattle and sheep sector is projected to increase output by 0.9 percent and this leads to a 47 thousand tonne increase in nitrogen inputs from manure, dampened somewhat by reductions in manure from other livestock and milk. Increased fertilizer is required for the pasture land, and given that fertilizer use also increases when crop production increases, there is a 40 thousand tonne total increase projected for nitrogen inputs from fertilizer. These increases in the cattle and sheep sector and fertilizer cause the increase in the nitrogen inputs for the US. Increased output of 1.4 percent in the other crops sector leads to a 102 thousand tonne increase in uptake of nitrogen. Increased uptake of nitrogen by pasture is also significant, at 30 thousand tonnes and there is an 8 thousand tonne increase in uptake by the rice sector. Reduced output of 2.2 percent in cereal grains leads to a 76 thousand tonne reduction in nitrogen uptake by this sector, and the small reduction in wheat output leads to a 2.5 thousand tonne reduction. The net increase in nitrogen uptake is 61 thousand tonnes, however, this is not significant enough to outweigh the increased nitrogen inputs, hence the increased nitrogen balance.

The nitrogen balance for France is projected to increase by 45 thousand tonnes in scenario 3, a 3 percent increase from initial levels. While total nitrogen inputs reduce by 103 thousand tonnes, uptake of nitrogen reduces by almost 150 thousand tonnes, leading to the overall increased nitrogen balance. Harvested crops dominate the reduced nitrogen uptake; in particular, wheat and cereal grains are projected to reduce in output by more than 15 percent. As the land shifts out of these sectors, pasture land use is projected to increase, dampening the level of reduction in nitrogen uptake by 65 thousand tonnes. The reduction in nitrogen inputs is primarily due to less fertilizer now needed on crops, with the output reductions projected for wheat and cereal grains. The reduction in overall fertilizer use leads to 90 thousand tonnes less nitrogen input than in the initial scenario. Nitrogen input from livestock manure also reduces by over 40 thousand tonnes for France, primarily due to the 4.5 percent reduction in cattle and sheep sector output. These effects are dampened a little by relatively small increases in other nitrogen inputs, particularly biological nitrogen fixation by leguminous plants.

As indicated earlier, most OECD regions are projected to see some reduction in their per hectare nitrogen balances with the trade reforms simulated. The largest absolute reduction in nitrogen balance is projected to be for Canada, with the total nitrogen balance reducing by 76 thousand tonnes in the first scenario, 114 thousand tonnes in the second and 180 thousand tonnes in the third scenario. Table 9 indicates that total nitrogen inputs increase by 59 thousand tonnes in the third scenario, but this is swamped by the 239 thousand tonne increase in nitrogen uptake. Increased nitrogen uptake in Canada is dominated by uptake from harvested crops, particularly wheat. Wheat is projected to increase in output by almost 30 percent in scenario three and this contributes 232 thousand tonnes of increased nitrogen uptake. More fertilizer is required to support this increase in crop production, hence the increased input of nitrogen from fertilizer. However, this increased input is dampened by reduced nitrogen from manure, particularly as Canada is projected to reduce other livestock production by over 10 percent.

The absolute reduction in nitrogen balance for Ireland is 85 thousand tonnes in scenario three, giving it the largest percentage reduction in the per hectare nitrogen balance, at over 21 percent. The reasons are rather different to Canada. For Ireland, uptake of nitrogen reduces by 7 thousand tonnes, but inputs of nitrogen reduce by 92 thousand tonnes. The reduction in inputs is primarily due to a more than 70 thousand tonne reduction in livestock manure as indicated in Table 9. This is entirely due to the almost 20 percent projected reduction in output for the cattle and sheep sector. Interestingly, for the EFTA region, we project a 1.7 percent increase in the nitrogen balance for the first scenario, but this changes to a 6 percent reduction in the second scenario and an almost 17 percent reduction for the most ambitious third scenario. Why does the change in the nitrogen balance move from a small increase in the first scenario to a significant reduction in the third scenario? In the third scenario, the results are dominated by the more than 30 thousand tonne reductions in nitrogen inputs by both livestock manure and fertilizer. Further decomposition of these results indicates that two thirds of the lower livestock manure projection is driven by the 22 percent reduction in output in the milk sector. It is the milk sector that explains much of the difference between the overall nitrogen balance results for the first and third scenario. In the first scenario, the milk sector is only projected to reduce output by 0.4 percent (Table 4), but this becomes a projected reduction of more than 22 percent in the more ambitious third scenario (Table 6).

6. TENTATIVE CONCLUSIONS

Whether reforms to trade policies will enhance or degrade the natural environment is an empirical matter, and will depend partly on how the altered economic incentives affect outputs of pollution-intensive relative to pollution-extensive industries and sectors. Dairy production is one of the world's most highly protected agricultural activities, through high tariffs and (especially in the EU) substantial export subsidy payments. Consequently, our simulation of possible WTO round agreements suggests a contraction of the dairy sectors for parts of Europe, and Northeast Asia, but expansion in Australasia. The beef sector also contracts in the EU, EFTA and Japan. To the extent that farm protection is highest in the high-income, densely populated countries of Northeast Asia and Western Europe, lowered farm protection could see less manure output from livestock and less fertilizer used in cropping, with relatively high gains to society due to high population densities in these regions. Some of the farm production is likely to shift to other regions of the world, where human population densities are much lower and farm production systems are more extensive. Thus the additional environmental damage in the latter countries could be much less than the reduction in environmental damage in the densely populated regions (Anderson and Strutt 1996).

Even in the absence of specific environment-enhancing policies and activities, we suggest the WTO trade liberalizations modelled are likely to reduce the nitrogen balances for most OECD countries, particularly the most ambitious reform. Trade liberalization may increase environmental problems from livestock manure and fertilizer in countries such as New Zealand but there may be greater nitrogen uptake through pasture land. Although we projected a large percentage increase in the nitrogen balance for New Zealand in scenario three,[13] the level of per hectare nitrogen pollution is still projected to remain one of the lowest in the OECD. Also, due to relatively low population densities, the human consequences of such damage may be relatively low. The other regions for which we project increases in the nitrogen balances tend to have relatively low nitrogen balances per hectare, with the exception of Korea, for which we projected a less than 0.2 percent increase in the first and second scenarios and only a 0.5 percent increase in the most ambitious third scenario. On the other hand, trade liberalization leads to reduced livestock production in the densely populated regions of the EU and Northeast Asia, and therefore offers the potential of overall gains in environmental quality, even without taking increased uptake of nitrogen into account (see Rae and Strutt 2001).

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[13] And we note that results for New Zealand are particularly sensitive to our assumption of weighting pasture land for changes in biological nitrogen fixation. We have opted to report the most negative scenario here and a small change in this assumption would lead to a significant percentage reduction in the nitrogen balance. The sensitivity of the percentage change in New Zealand's nitrogen balance to this assumption is unique and is primarily is due to the relatively small nitrogen numbers for New Zealand, combined with the significance of pasture land.

While we did not model changes in environmental policy,[14] improved policy ought to be considered if the projected environmental damage remaining after trade policy reforms is to be reduced or avoided. For example, Rae and Strutt (2001) suggest that New Zealand may also need to further consider appropriate environmental policies to limit the impact of livestock pollution due to growth and trade reform. However this comment should be tempered with mention of the low population density in New Zealand, which may limit the damage to human health.

There are of course a number of important tradeoffs and limitations with this type of work. We raise two issues, in particular. Firstly, with our focus on global trade reforms, we had to work at an aggregate level of analysis that required us to treat nitrogen pollution as a 'national' problem. In reality, there often exist 'hot spots' of pollution, for example in intensive pig production regions, the environmental impacts may be many times more severe than is indicated by national indicators. Also there is a range of suggested reference levels against which to assess changes in nitrogen surpluses, and the appropriate reference level may vary widely, depending on many factors including soil and climatic conditions (OECD 2001b). For example, guidelines for nutrient loadings in New Zealand range vary from 30 kg N/ha on sandy soils to 300 kg N/ha on clayey soils (Cameron and Trenouth, 1999 as cited in OECD 2001b). Local level studies will therefore complement (and be complemented by) this work. In addition, we only focus on one environmental indicator, when agricultural pollution is multi-dimensional.[15] Secondly, scope exists for the nitrogen balance model to be enhanced to increase its suitability for analysing trade and environment interactions. Two examples are briefly mentioned here. Obtaining fertiliser input coefficients on a crop and pasture basis would improve the current work, where we assumed constant application rates across all crops. It may also be possible to improve the way in which livestock-pasture interactions are modelled. At present, the nitrogen model contains fixed rates per animal for manure deposition on pasture and N uptake from pasture by livestock. Yet an increase in stocking rate (or substitution of livestock capital for land, as occurs in some of our solutions), for example, could be accompanied by greater use of fertiliser on pasture, an increase in grass consumption and increased excretion of manure per hectare of pasture.

Changes in other (non-agricultural) sectors will also impact on the *net* national and international level of environmental damage. However, given the model and data available, our analysis suggests that the aggregate environmental implications of trade policy reform appear to be positive for nitrogen balances in the OECD. We say nothing about nitrogen balances in non-OECD countries in this study.[16] We also make no attempt in this paper to project the global economy from the benchmark 1997 year. Other work, including Strutt and Anderson (2000) and Rae and Strutt (2001), suggests that when we project economies a decade or more into the future, the aggregate environmental impact of structural change, rather than trade reform, is likely to be of much greater consequence to those concerned about environmental damage.

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[14] For some recent work on interventions to reduce livestock pollution, see Cassells and Meister (2001), Komen and Peerlings (1998), Reinhard *et al.* (1998) and Brouwer *et al.* (1999).

[15] As data for other indicators become available, this shortcoming can of course be rectified.

[16] See Rae and Strutt (2001) for a discussion of changes in livestock manure in other regions.

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