

# **Agricultural trade reform and nitrogen pollution in OECD countries**

**Allan Rae and Anna Strutt**

**Director  
Centre for Applied Economics and Policy Studies  
Massey University  
Palmerston North  
New Zealand  
Tel: 64-6-350 5346  
Fax: 64-6-350 5660  
e-mail: [A.N.Rae@massey.ac.nz](mailto:A.N.Rae@massey.ac.nz)**

**and**

**Department of Economics  
Waikato Management School  
Private Bag 3105**

*Hamilton*

**New Zealand**

*Tel: 64 7 838 4958*

**Fax: 64 7 838 4331**

**e-mail: [astrutt@waikato.ac.nz](mailto:astrutt@waikato.ac.nz)**



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Massey University, Palmerston North  
NEW ZEALAND**

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## **Foreword**

This paper aims to contribute to improved understanding of some environmental impacts that could result from agricultural reforms in the current WTO Round. We use a global general equilibrium model to simulate anticipated changes in output and land use resulting from trade reform. These are used to estimate changes in inputs and uptake of nitrogen to determine the impact on regional nitrogen balances for OECD countries. The WTO trade reforms simulated appear likely to lead to slightly improved nitrogen balances at the aggregate OECD level, with more ambitious trade reform tending to lead to a larger aggregate improvement. There will however be redistributions of nitrogen surplus across regions within the OECD. Our findings suggest that some regions are expected to experience an increase in their national nitrogen surplus and the associated environmental impacts. However, most regions with a high initial per hectare nitrogen surplus are anticipated to experience some improvement in this environmental indicator at the national level.

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**Allan N Rae**  
**Director**

## 1. Introduction

Reform of agricultural trade and associated policies has the potential to be both beneficial and harmful to the natural environment and it is by no means clear how future reform of farm and trade policies will influence environmental damage caused by agricultural activities. In the current paper we focus on regional nitrogen balances in the OECD to examine some of the potential environmental impacts of the ongoing trade negotiations of the Doha Development Agenda (the Doha Round).

Nitrogen is a vital input to animal and plant production processes, in animal feedstuffs and in fertilisers applied to crops and pastures or as nitrogen fixation by certain pasture plants such as clovers. Nitrogen is also a component of the marketable outputs of the system, such as crops, live animals, milk and meat. But excess nitrogen may move into surface and ground waters and also cause concerns about the release of ammonia and nitrous oxide to the air. The adverse impact on natural systems can cause substantial human health and economic costs. For example: excessive nutrients in waterways may cause algae growth which kills aquatic life; high levels of nitrates in drinking water can cause methemoglobinemia, which can be fatal to infants; the release of ammonia into the atmosphere may contribute to acid rain and therefore to acidification of soils and water, along with damage to crops and forests; and nitrous oxide is a greenhouse gas that can contribute to global warming.

While much methodological progress has been made in modelling the global economic consequences of agricultural trade policy reform (see, for example, OECD 2001a, 2002; Rae and Strutt, 2003; Conforti and Salvatici, 2004; Ingco and Winters, 2004; Anania *et al.* 2004), much remains to be done in modelling the consequences of such policy reforms on the natural environment (Leuck *et al.*, 1995; Anderson and Strutt 1996; OECD, 2000; Rae and Strutt, 2001; Tsigas *et al.*, 2002; Cooper *et al.*, 2003; Vasavada and Nimon, 2003). 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 of the welfare effects resulting from trade reform, it is important that progress be made on modelling environmental effects (Strutt and Anderson 2000). Given the potentially ambiguous effect of reform on the environment, careful modelling is required to improve understanding of the likely overall impact.

The first objective of this paper is to model the effect of global agricultural trade liberalisation on the level and location of farm production. The second, and major, objective is to estimate the effects of these modelled trade reforms on regional nitrogen balances. WTO trade negotiations currently include discussions of the linkages between trade and environmental policies, and the issue is likely to become increasingly important. Studies such as the current one can further our understanding of the environmental impacts that may result from removal of trade restrictions and distortions. Potential problems can be highlighted, as well as the extent to which trade

liberalisation and environmental protection may be mutually reinforcing. We begin by outlining the nature of environmental degradation from agricultural nitrogen emissions, the environmental indicators we will use, and the agricultural and environmental issues that have arisen in the course of the current WTO negotiations. We then describe the trade model used and how it is linked to the environmental model. The liberalisation scenarios are explained and followed by a discussion of the trade and environmental results of our modelling. We end with some tentative conclusions.

## **2. Nitrogen balances as environmental indicators**

The way in which nitrogen losses from farming activities affect the natural environment and impact on people and economies is complex and not fully understood. However, environmental indicators can be used to draw attention to possible pressure points between agricultural activity and the environment. Nutrient balances measure the surplus of nutrients not taken up by crops and assumed to finish up in air, water or soil. In this sense they are an indicator of environmental impacts, since the precise relationship between such surpluses and actual environmental impacts remains unclear (Vanongeval and Bomans, 1997).

Two nutrient balance models currently in use are the soil surface and farm gate measures. The former measures the difference between nutrient levels entering the soil (e.g. from fertilisers, animal manures, crop residues and biological nitrogen fixation) and nutrient uptake by crops (marketed crops and as well as those used for livestock feed). In the latter method, nutrient measures are taken at the farm gate, and the balance reflects nutrients entering or leaving the farm system. Nutrient inputs could include those in purchased fertiliser, feedstuffs and livestock as well as nitrogen fixation. The nutrient content of marketed crops, livestock production and manure disposal off-farm would be counted as outputs. The farm gate measure forms the basis of the mineral balance sheets that are a necessary component of environmental policy in some countries (Breembroek *et al.*, 1996; De Clercq *et al.*, 2001). Although both approaches ought to provide similar results, the farm gate method may be superior for grazing situations since it requires meat and milk output to be recorded, rather than the estimation of consistent data on the feed-animal-manure balance that the soil balance approach requires (van Eerd and Fong, 1998).

In this study we require national nitrogen balance indicators and our choice of data reflects the best current availability. We use the OECD nitrogen balance database (OECD, 2001b) which employs the soil-surface method and is a very comprehensive source of national nitrogen balance data for 28 member countries. There may exist localities within countries where environmental impacts may be much greater than is indicated by national balances, suggesting limitations of environmental analysis at a very aggregate level. Nevertheless, pollution from agricultural activities is sometimes viewed by policymakers and the public as a 'national problem' and relevant information can be gained from the use of national balances. Environmental policies can be formulated at the national or super-national level (such as the EU Directive regarding nitrate pollution of water due to agricultural activities). In such cases policymakers may wish to monitor trends in environmental impacts for their own country, or across countries. Slak *et al.* (1998) propose that national nitrogen balances could be developed and used for these purposes. National balances were used by van

Eerdt and Fong (1998) to monitor nitrogen surpluses from agriculture in the Netherlands, concluding that over a ten-year period little progress had been made in reducing nitrogen surpluses. Van der Hoek (1998) even supports the aggregation of national data to the global level to study nitrogen efficiency in crop and animal production and to establish the sustainable balance between human food and animal feed production.

An advantage of national-level research is that it can highlight simulated directions and magnitudes of environmental damage at a country or regional level. The trade model that we use to simulate policy reforms provides impact data that can be interpreted as showing responses over a medium-term time horizon. When combined with the national nitrogen balance data, we interpret the indicators as trends in national environmental conditions over a similar time period. In some cases this will reassure policy makers that a reform is unlikely to have adverse impacts at the aggregate level; in other cases, the analysis will highlight regions or countries of particular concern, where further research is called for and where domestic policies may need to be improved to mitigate adverse environmental outcomes. Thus this type of aggregate research will complement, and be complemented, by studies at the local or farm level.

### **2.1. Linkages between nitrogen balances and nutrient losses**

The nitrogen surplus calculated by either the soil surface or farm gate method does not indicate the importance of the various processes of nitrogen loss or the direct impacts on groundwater or atmospheric quality. If such balance measures are to be used as indicators for nutrient losses, then a strong correlation between nitrogen balance indicators and nitrogen losses would be helpful.

In the soil, organic nitrogen compounds are transformed in the presence of microorganisms into nitrates or nitrites (De Clercq *et al.*, 2001; Vanongeval and Bomans, 1997). Denitrification is the process that converts nitrates and/or nitrites to gaseous nitrogen components, and takes place more easily on poorly aerated soils. Most denitrification takes place in the upper layer of the soil and the gases produced are released to the atmosphere. Ammonium in the soil solution (e.g. from applied urea fertiliser or animal manures) that is close to the surface can volatilise as ammonia and impact on air quality, depending on microbial activity, soil properties and climatic conditions. Volatilisation can also occur from stored manures and animal housing. Leaching of nitrogen occurs when nitrate is transported beyond the root zone by drainage water; it depends on soil characteristics, rainfall volumes and patterns and the depth of the groundwater table. Leaching can cause substantial increases in the nitrate content of the soil water, but denitrification may result in not all leached nitrate reaching the groundwater table. Runoff due to excess precipitation can also transport nutrients away from farm fields into surface water systems.

The linkage between the balance measure and actual nitrogen losses is explored by Ledgard *et al.* (1998; 1999) in the case of dairy farms in New Zealand (where nitrogen fixation by white clover is the major source of this nutrient). Nitrogen surpluses were measured using the farm-gate method, as indicators of potential nutrient losses to the environment. Actual losses of nitrogen due to the various processes described above were then measured over a three-year period. In all cases studied, the sum of the nitrogen outputs and the measured nitrogen losses were similar to the sum of the nitrogen inputs. This work also indicated the relative importance of

denitrification, volatilisation and leaching and concluded that the main potential for environmental impact on such farm systems was from nitrate leaching to groundwater, which accounted for approximately 40% of the total nitrogen surplus. A marked increase in leaching also occurred with increasing use of nitrogen (urea) fertiliser on pastures.

Vanongeval and Bomans (1997) provide examples of correlations between nitrogen balance (soil-surface) indicators and nitrogen losses for farm regions in Belgium. In this case, nutrient losses were computed by modelling, rather than by field measurements. They concluded that for catchment areas with a nitrogen surplus above 100 kg N/ha, a clear and positive relationship existed between nitrogen surplus and nitrogen loss. For sites where the surplus was below 100 kg N/ha, the link between surplus and loss appeared weaker, perhaps indicating that at such levels of surplus, the role of factors such as soil type, soil use and slope are as important as the surplus.

Bechmann *et al.* (1998) examine the correlation between nitrogen surface balances and nitrogen leaching in four agricultural catchments in Norway. Across these catchments and the years 1992-96, nitrogen balances varied between 30 and 85 kgN/ha, well below the 100kg/ha threshold suggested by Vanongeval and Bomans. Perhaps not surprisingly then, they found a low correlation between surface balances and leaching when all catchment and annual data were pooled. A much higher correlation was found between nitrogen leaching in autumn and the surface balance, when only catchments with similar soil properties and years with similar weather conditions were included. This appears to support the Vanongeval and Bomans conclusion regarding the importance of other factors such as soil type when surface balances are relatively low.

### **3. The WTO Doha Development Agenda, agriculture and the environment**

While the WTO Uruguay Round Agreement on Agriculture (URAA) made some progress in liberalising trade in food and agricultural products (OECD, 2001a), major policy-induced distortions remain in agricultural markets. The Doha Ministerial Mandate (WTO, 2001) 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. The negotiations have proved to be protracted and the original completion date of 1 January 2005 was missed. The so-called ‘July framework’ (WTO, 2004a) agreed on 1 August 2004, sets the framework for future agricultural negotiations. It provides little specificity in terms of reduction formulae, but does commit members to eliminating agricultural export subsidies, as well as “substantial trade expansion” and “substantial reductions in trade-distorting domestic support”.

Linkages between agricultural production and the environment have been recognised for some time in the WTO and multilateral trade negotiations. For example the URAA permits countries to make unlimited expenditures on certain farm environmental programmes (within the so-called Green Box exemptions). Environmental issues are

also included in the mandate of the current Round. The Doha Mandate itself does not explicitly link the work of the Committee on Agriculture (agricultural negotiations) and the Committee on Trade and Environment (CTE). However, that Mandate does require the CTE and the Committee on Trade and Development<sup>1</sup> to identify and debate developmental and environmental aspects of the negotiations, to assist with achieving the objective of having sustainable development appropriately reflected.

The work programme of the CTE suggests ample scope for the possibility of closer linkages to agricultural negotiations in future. For example, the programme includes: work on trade rules and environmental agreements; 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”.<sup>2</sup> To assist the CTE’s discussions, the WTO secretariat prepared background papers that include information on environmental impacts of protection and trade-distorting support in agriculture.<sup>3</sup> The Chair recently invited delegations to reflect on the next steps to be taken by the CTE (WTO, 2004b) and reported discussions on an EU proposal to invite briefings from relevant international organizations involved in sustainable development issues and indicated that updates of earlier reports on environmental aspects of the negotiations would be useful at a later stage (WTO, 2004c).

Within the agricultural negotiations, members have discussed environmental issues as non-trade concerns, and some have tabled proposals on the subject. One group of members sees trade liberalisation and environmental protection as mutually reinforcing, 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 (WTO, 2003a). Proposals that call for limits on Green Box spending could affect spending under environmental programmes. Some proposals suggest changes, for example to ensure that support provided under environmental programmes is not related to the volume of production. Another is to add a new category of Green Box exempt payments to compensate for the costs accruing from higher production standards, which presumably could cover environmental standards (WTO, 2003b).

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<sup>1</sup> The CTD has a mandate to review all special and differential treatment provisions for developing and least-developed countries.

<sup>2</sup> [http://www.wto.org/english/tratop\\_e/envir\\_e/cte05\\_e.htm](http://www.wto.org/english/tratop_e/envir_e/cte05_e.htm)

<sup>3</sup> WTO (1997) examines various sectors including agriculture, and WTO (2003b) covers specifically the environmental issues raised in the agricultural negotiations.

## 4. The trade and environmental models

In this study, we use the OECD nitrogen balance database (OECD, 2001b) to build an environmental module that works in tandem with the Global Trade Analysis Project (GTAP) global computable general equilibrium model.<sup>4</sup> The GTAP model is used to simulate the economic impacts of some liberalisation scenarios, with results providing a starting point to which we add the environmental side module. This facilitates analysis of the implications of reform for changes in the nitrogen balance of each region.

### 4.1. The global trade model

We simulate the impact of trade liberalisation scenarios using a modified version of the GTAP applied general equilibrium model (Hertel, 1997), solved using GEMPACK (Harrison and Pearson, 1996). We modify the standard model in two ways. First, we explicitly model milk production quotas in EU15, EFTA and Canada, since dairy farming makes a substantial contribution to nitrogen emissions in several countries. Where such quotas exist and are binding, reductions in domestic prices that might result from trade liberalisation would reduce rents but need not result in a reduction in milk or manure output. Modifications to include the production quotas in the model are based on Lips and Rieder (2005), with the associated data discussed in Appendix A. The second modification made to the GTAP model is to include substitution among feedstuffs in livestock production (in place of the standard Leontief formulation). This is a potentially important relationship, given the high protection given to livestock and feedcrop production in some regions, and the contribution that livestock make to environmental pollution. We use a value of 0.9 for the CES substitution elasticity, being a share-weighted average derived from the elasticities of substitution estimated by Surry (1990).

The modified trade model is coupled with the GTAP Version 6 beta-release database<sup>5</sup> benchmarked to the year 2001. The full database covers 87 regions, which we aggregate to 16 OECD and three non-OECD regions. Five of the EU15 countries are individually specified, with the remaining aggregated into three groups reflecting their agricultural N-balances 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 EU15 countries are grouped into the Rest of EU.<sup>6</sup> Of the other OECD countries, N-balances were highest in South 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

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<sup>4</sup> See [www.gtap.org](http://www.gtap.org) for a detailed description of the GTAP model and database.

<sup>5</sup> This database contains a number of improvements compared with earlier versions. In particular we note that trade-weighted agricultural tariffs have been sourced from the MAcMap Database, including tariff preferences and *ad valorem* equivalents of specific tariffs. The new database upgrades estimates of trade elasticities, which are amongst the most critical parameters of global trade models and tend to be particularly important in determining the terms of trade effects associated with export expansion. This latest database uses estimates based on the methodology of Hummels (1999) that used trade, tariff and transport cost data from various countries to estimate a differentiated products model of import demand. The elasticities are sector-specific and for the majority of farm sectors are larger than the values in the previous database (Hertel *et al.* 2003).

<sup>6</sup> Excluding new members admitted on 1 May 2004.

these groupings. At the sectoral level, we aggregate the full 57 sectors up to 14, with 11 of these aggregated sectors representing farm and food production. We focus particularly on the seven sectors for which nitrogen balances are computed: rice; wheat; cereal grains; other crops; milk; cattle and sheep;<sup>7</sup> and other livestock.<sup>8</sup> All other sectors are included in either the natural resources, manufacturing or services aggregates.

#### 4.2. The nitrogen model and its linkage to GTAP

The OECD nitrogen database contains very detailed data by country, particularly in the case of nitrogen coefficients for crops and livestock. Much of the basic data such as livestock numbers, crop production and fertiliser use are taken from official agricultural census data. Nitrogen coefficient estimates from agricultural research institutes and published literature are used to convert these data into nitrogen equivalents (OECD, 2001c). Nitrogen coefficients can differ between countries for many different reasons, for example: different agro-ecological conditions; variation in livestock weights and yields; and variation in methods used to estimate coefficients (OECD, 2001c). Nitrogen coefficients are multiplied by the relevant quantity of crop production or livestock numbers, with the overall balance obtained by summing all inputs and outputs. The database covers the nitrogen inputs and outputs noted in Table 1.

**Table 1. Summary of nitrogen inputs and uptake**

<b>Nitrogen inputs</b>	<b>Nitrogen uptake</b>
Inorganic or chemical nitrogen fertilisers	Harvested crop production
Net livestock manure nitrogen production <sup>a</sup>	Grass consumption 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

a. 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).

We use the following mathematical representation of the OECD's nitrogen balance database: equation (1) gives the balance as the difference between nitrogen input and output, equation (2) identifies nitrogen output as the sum of crop and fodder outputs and pasture grass consumption, and equation (3) indicates the various components that together comprise total nitrogen inputs.

<sup>7</sup> Also includes goats and horses.

<sup>8</sup> Also includes pigs and poultry.

*Soil surface nitrogen balance (SSNB), country i:*

$$(1) \text{ SSNB}_i = \text{NI}_i - \text{NO}_i$$

*Nitrogen output (NO):*

$$(2) \text{ NO}_i = \sum n_{ki} Q_{ki} + \sum n_{ki} \text{HF}_{ki}$$

*Nitrogen input (NI):*

$$(3) \text{ NI}_i = F_i + \text{LM}_i + \text{MW}_i + \text{BNF}_i + \text{AD}_i + \text{SPM}_i$$

$$(3.1) F_i = \sum f n_{ki} F_{ki}$$

$$(3.2) \text{ LM}_i = \sum l m_{ji} L_{ji}$$

$$(3.3) \text{ BNF}_i = \sum n f_{ki} A_{ki} + n f x_i \text{LD}_i$$

$$(3.4) \text{ AD}_i = l d n_i \text{LD}_i$$

$$(3.5) \text{ SPM}_i = \sum n s_{ki} Q S_{ki}$$

where:  $n_{ki}$  = nitrogen uptake to produce a tonne of the  $k$ th harvested crop or forage crop, or grass consumption from pasture;  $Q_{ki}$  = quantity of the  $k$ th harvested crop;  $\text{HF}_{ki}$  = quantity of the  $k$ th harvested forage crop or total pasture consumption;  $F_i$  = total quantity of N from fertiliser;  $f n_{ki}$  = quantity of N per unit of  $k$ th fertiliser;  $F_{ki}$  = quantity of  $k$ th fertiliser;  $\text{LM}_i$  = livestock manure N production;  $l m_{ji}$  = N manure per head per annum of  $j$ th livestock type;  $L_{ji}$  = total inventory of  $j$ th type of livestock;  $\text{MW}_i$  = total manure withdrawals from agriculture;  $\text{BNF}_i$  = biological N fixation;  $n f_{ki}$  = N fixation per hectare of  $k$ th legume crop or pasture;  $A_{ki}$  = planted area of  $k$ th legume crop or pasture;  $n f x_i$  = N fixation per hectare by free living soil organisms;  $\text{LD}_i$  = total area of agricultural land;  $\text{AD}_i$  = atmospheric deposition of N;  $l d n_i$  = atmospheric deposition of N per hectare;  $\text{SPM}_i$  = N contained in seeds & planting materials;  $n s_{ki}$  = N content of seeds & planting materials for  $k$ th crop and  $Q S_{ki}$  = total quantity of seeds & planting materials for  $k$ th crop.

We use the most recent OECD data available, with the very detailed data aggregated into a form compatible with our GTAP modelling results.<sup>9</sup> A summary of the total nitrogen balance by region for the base year is provided in Table 2.<sup>10</sup>

The nitrogen balance model is linked to the GTAP model by assuming that all coefficients of the nitrogen balance model are invariant to changes in trade policy and, by implication, to changes in the levels of agricultural inputs and outputs. We then

<sup>9</sup> The base year is 1997, reflecting the most recently available OECD data. We note that our very detailed reworking of the OECD database exposed a number of discrepancies within the database. These have been adjusted where appropriate, leading to some calculations of regional nitrogen balances differing from those presented in the original OECD dataset.

<sup>10</sup> Mexico and Turkey are excluded since these countries are aggregated with non-OECD countries in our regional aggregation.

draw on our GTAP solution variables to compute changes to the nitrogen model variables.

Output of nitrogen is comprised of output from the crop sectors and from pasture (Table 1). 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 the level of nitrogen uptake will change by the same proportion as the level of output in each crop sector.<sup>11</sup> For uptake of nitrogen by forage produced and pasture consumed, we assume that any change from the base level is proportional to the change in livestock units computed over dairy cows, other cattle, sheep and goats. Livestock units are computed using the coefficients of Sere and Steinfeld (1995). Data on livestock numbers for the trade model base year of 2001 are sourced from FAOSTAT and these are assumed to change in proportion to changes in the relevant GTAP output variables.

**Table 2. 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 fertilisers. We model changes in nitrogen from livestock manure as changing by the proportional change in output of each type of livestock. Withdrawals of nitrogen due to changes in manure stocks and manure imports are assumed to maintain the same ratio to livestock manure as in the initial benchmark database. For fertiliser, changes in the nitrogen input level are due to changes in fertiliser used on both cropland and pasture. In the absence of crop-specific fertiliser rates, these change by the average change in output for the crop sectors using these fertilisers, weighted by initial output values. Fertiliser use on pasture is assumed

<sup>11</sup> Consistent with assumptions used in the OECD nitrogen output calculations.

to change in proportion to the weighted average change in output in pasture-using livestock sectors.

The other particularly important nitrogen input is biological nitrogen fixation, which can be separated 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, as appropriate given our aggregation of the GTAP database. For New Zealand, however, our treatment of nitrogen fixation by leguminous plants differs, reflecting a difference in the OECD database. In particular, we model the contribution of pulses to N-fixation as changing in proportion to land use in the other crops sector, while the contribution of clover changes by land use in pasture-using sectors, reflecting the importance of clover in New Zealand pastures.

Other sources of nitrogen inputs include atmospheric deposition of nitrogen, nitrogen from recycled organic matter and nitrogen contained in seeds and planting material. In the absence of better information, these are assumed constant with changes in trade policies.

## **5. Liberalisation scenarios and results**

### **5.1. Liberalisation scenarios**

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 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. For example, some proposals suggest reductions (such as in tariff rates) be made from bound levels, while others suggest reductions from levels that actually applied in a given base period. The data used here include the applied levels of tariffs and support, rather than the bound rates.<sup>12</sup> Any agreed liberalisation will be phased in over a number of years and as the trade model used here is comparative static, the adjustment path to the targeted reductions in support is not revealed and any dynamic gains from trade are not captured.

The two scenarios modelled are summarised in Table 3. The first scenario reflects a modest reform scenario which has some elements in common with earlier proposals and, in terms of the average tariff reductions, has some similarities to the URAA. The second scenario is much closer to a full liberalisation by developed countries. Export

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<sup>12</sup> 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 liberalisations could overstate the extent of tariff reductions in such cases, if any Agreement based tariff reductions on the bound rates. A further limitation is that we do not explicitly model TRQs. The large number of tariff rate quotas (TRQs) that exist for food and agricultural products provides a major aggregation problem and the possibility of aggregation bias, since the database we employ aggregates many such products into single commodities.

subsidies are eliminated and all agricultural tariffs levied by these countries are reduced to zero. Special and differential treatment is reflected by retaining the first scenario's liberalisation as far as developing countries are concerned. Domestic support reforms are limited to output and input subsidies which map rather closely to the trade-distorting policies of the amber box, but we do not reduce other domestic subsidies (i.e. those classified in either blue or green boxes).<sup>13</sup> No changes are made to policies in the manufacturing and services sectors.

Given the lack of consensus over the size of milk quota rents, two versions of each simulation are conducted reflecting different EU estimates. The first set (scenarios #1a and #2a) use the quota rent estimates of INRA-Wageningen (2002) prepared for the European Commission. The second set (scenarios #1b and #2b) use the quota rent estimates of Jensen and Nielson (2004). We will refer to the first as the EC and the second as the Jensen quota rent estimates. We also conduct a sensitivity analysis to examine the significance of the feedstuffs substitution elasticity. Results are not reported, since output changes were very insensitive to these parameter choices, even when we use the value of 0.15 (i.e. the lowest positive substitution parameter reported by Surry 1990).

**Table 3. Trade liberalisation scenarios**

<b>Item</b>	<b>Scenario #1</b>	<b>Scenario #2</b>
Change in Tariffs <sup>a</sup>		
Developed regions	-36%	-100%
Developing regions	-24%	-24%
Change in Export subsidy spending		
Developed regions	-45%	-100%
Developing regions	-45%	-45%
Change in Trade-distorting support spending <sup>b</sup>		
Developed regions	-55%	-100%
Developing regions	No change	No change

a. Agricultural and food tariffs only

b. Output and input subsidies, but excluding all other payments such as those based on crop areas or livestock numbers.

## 5.2. Changes in the location and level of farm production

The first scenario simulates outcomes from our more modest liberalisation. As shown in Appendix Table B1, farm production of most commodities tends to decline in EU countries and regions, and also in the EFTA countries and Japan. The exceptions were some relatively small increases of wheat in Den\_Blg, cereal grains in EFTA, other

<sup>13</sup> The GTAP database follows the OECD's PSE classification rather than breaking down domestic support policies according to the URAA classifications.

crops (which includes horticulture) in Germany and the Netherlands, and the quota rents lead to no change in milk output for EU countries. For Central Europe, small increases are simulated for all farm sectors. Output of most farm sectors, with the exception of wheat and other crops are simulated to increase in Australia. For New Zealand, all crop sectors and the milk sector experience increases in output, while for cattle and sheep and other livestock, some declines in production are simulated. All crop sectors are simulated to expand in Canada, while livestock, with the exception of milk, is simulated to decline. The US, on the other hand, is simulated to experience declines in all crop sectors and milk, but increases in cattle and other livestock. Livestock farming and output of wheat also exhibited some expansion in South Korea.

Results for the same simulation with the Jensen quota rents (i.e. scenario #1b) are shown in Table B2. For the main part, the direction and magnitude of simulated changes is very similar to the previous simulation using the EC rents. However, for the EU-LowN, Den\_Blg, the UK and the rest of the EU regions, milk production falls a little rather than remaining constant, as is the case when we use the larger EC quota rent estimates. The other sector in which results vary notably appears to be the other crops sector. Although the direction of change simulated is the same in most cases, results differ for many regions. For Germany and Central Europe, increases in output in scenario #1a become small reductions in output in scenario #1b, and for the Den\_Blg region, the decline in output in the other crops sector is much more significant when the EC quota rent estimates are used. Indeed for the Den\_Blg region, results across most farming sectors differ quite significantly when alternative estimates of quota rents are used.

In the second scenario, modelled trade reforms become more liberal, with deeper cuts to tariffs, as well as to export and domestic subsidies in OECD countries. The output results from these second simulation scenarios are provided in Appendix Tables B3 and B4. By and large, the patterns of changes to regional farm production remain similar to those described above, but are of greater magnitude. For example, milk production in Australia and New Zealand expanded by 5% and 12% in scenario #1, but by almost 9% to well over 40% in the second scenario. The output of most crops and all livestock sectors in the EU, with the exception of milk, continues to decline in the second scenario. Reduced milk prices drive output below quota levels only in EFTA in scenario #2a, whereas for scenario #2b milk production declines by between 4% and 18% in all of the regions with quotas, with the exception of Canada and the Netherlands.

### **5.3. Environmental impacts of agricultural market reform**

The simulated changes in agricultural output will have implications for the nitrogen balance in each region. Given the above scenarios and the assumptions outlined in section 4.2, we find that trade liberalisation may lead to a small reduction in the aggregate nitrogen balance for OECD countries. In the base year, the total nitrogen balance for OECD countries included in our modelling is estimated to be 27.3 million tonnes. As shown in the final row of Table 4, when using the EC quota rent estimates, the total nitrogen balance for the OECD is simulated to fall by 129 thousand tonnes in the first liberalisation scenario. In the second, more ambitious reform scenario, results presented in Table 5 indicate that the overall nitrogen balance is simulated to fall by 394 thousand tonnes. When the alternative Jensen quota rent estimates are used,

overall reductions in the nitrogen balance are slightly less for the first scenario and a little deeper for the second scenario (final row of Tables 4 and 5).

**Table 4. Changes in nitrogen balance and components, scenario #1a and #1b (000 tonnes)**

	Quota rents	Harvested crops	Pasture & forage	Total nitrogen uptake	Net livestock manure	Fertiliser	Other nitrogen inputs <sup>a</sup>	Total nitrogen inputs	<b>Nitrogen balance</b>
Australia	EC	7	197	203	91	38	-4	125	<b>-78</b>
	Jensen	6	198	204	91	38	-4	126	<b>-78</b>
NZ	EC	1	-7	-6	1	7	28	36	<b>42</b>
	Jensen	1	-5	-4	2	7	32	40	<b>45</b>
Japan	EC	-15	-16	-31	-35	-15	1	-50	<b>-18</b>
	Jensen	-15	-16	-31	-35	-15	1	-50	<b>-18</b>
Korea	EC	-5	0	-5	4	-7	0	-3	<b>2</b>
	Jensen	-5	0	-5	4	-7	0	-3	<b>2</b>
Canada	EC	31	-5	26	-13	13	0	0	<b>-26</b>
	Jensen	30	-5	25	-12	11	0	-1	<b>-26</b>
USA	EC	-185	50	-134	60	-102	-39	-81	<b>53</b>
	Jensen	-189	51	-138	61	-104	-39	-83	<b>55</b>
Den_Blg	EC	-18	-14	-32	-13	-86	-3	-101	<b>-69</b>
	Jensen	-8	-18	-26	-21	-11	0	-31	<b>-5</b>
Netherlands	EC	-5	-11	-15	-15	-2	0	-17	<b>-2</b>
	Jensen	-5	-10	-15	-15	-4	0	-18	<b>-3</b>
Rest of EU	EC	-124	-206	-329	-183	-174	0	-357	<b>-27</b>
	Jensen	-127	-211	-339	-187	-199	-2	-387	<b>-49</b>
EFTA	EC	-4	-9	-13	-8	-7	0	-15	<b>-2</b>
	Jensen	-4	-9	-13	-8	-7	0	-15	<b>-2</b>
C. Europe	EC	6	5	11	3	4	0	7	<b>-4</b>
	Jensen	6	5	11	3	4	0	6	<b>-5</b>
Total	EC	-310	-15	-325	-108	-331	-16	-454	<b>-129</b>
OECD	Jensen	-310	-22	-332	-117	-286	-12	-415	<b>-83</b>

<sup>a</sup> Biological nitrogen fixation by leguminous plants.

**Table 5. Changes in nitrogen balance and components, scenario #2a and #2b (000 tonnes)**

	Quota rents	Harvested crops	Pasture & forage	Total nitrogen uptake	Net livestock manure	Fertiliser	Other nitrogen inputs <sup>a</sup>	Total nitrogen inputs	Nitrogen balance
Australia	EC	132	292	424	132	60	-16	175	<b>-249</b>
	Jensen	129	305	434	139	68	-17	190	<b>-244</b>
NZ	EC	1	-63	-62	-10	21	93	104	<b>166</b>
	Jensen	1	-66	-65	-10	25	108	123	<b>188</b>
Japan	EC	-184	-48	-232	-99	-143	6	-236	<b>-4</b>
	Jensen	-184	-48	-232	-99	-143	6	-236	<b>-4</b>
Korea	EC	-4	0	-4	5	-4	0	1	<b>4</b>
	Jensen	-4	0	-4	5	-4	0	1	<b>5</b>
Canada	EC	90	1	91	-10	39	-1	28	<b>-63</b>
	Jensen	91	2	93	-9	40	-2	30	<b>-64</b>
USA	EC	-307	250	-57	283	-112	-167	4	<b>61</b>
	Jensen	-304	259	-44	291	-100	-173	18	<b>62</b>
Den_Blg	EC	-21	-49	-70	-57	-50	0	-106	<b>-36</b>
	Jensen	-20	-67	-87	-79	-57	0	-135	<b>-49</b>
Netherlands	EC	-10	-37	-47	-55	-18	1	-72	<b>-25</b>
	Jensen	-10	-37	-47	-54	-18	1	-72	<b>-25</b>
Rest of EU	EC	-247	-834	-1081	-747	-549	-10	-1306	<b>-225</b>
	Jensen	-241	-965	-1206	-848	-674	-8	-1529	<b>-323</b>
EFTA	EC	-14	-26	-39	-31	-22	2	-51	<b>-12</b>
	Jensen	-14	-23	-37	-29	-21	2	-48	<b>-11</b>
C. Europe	EC	22	16	38	12	16	-1	27	<b>-11</b>
	Jensen	23	18	41	13	17	-1	29	<b>-12</b>
Total	EC	-542	-498	-1040	-577	-762	-95	-1433	<b>-394</b>
OECD	Jensen	-533	-620	-1153	-679	-866	-84	-1629	<b>-476</b>

<sup>a</sup> Biological nitrogen fixation by leguminous plants.

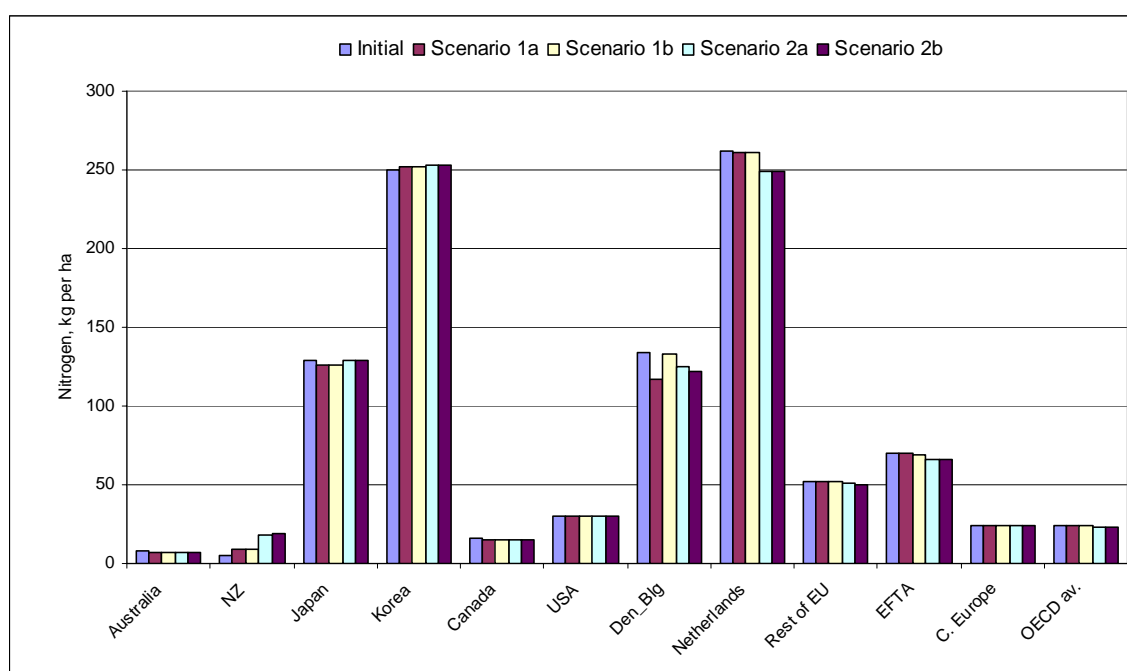
Our simulation results imply that the total nitrogen balance for the OECD decreases from its initial level by between 0.3 and 0.5 percent in the first scenario and by between 1.4 and 1.7 percent in the second scenario, depending on the choice of milk quota rents used. To the extent that nitrogen balances 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.

Changes in the aggregate OECD nitrogen balance can be decomposed into changes in uptake and inputs of nitrogen, as shown in the final two rows of Tables 4 and 5. Since

the pattern of results for both estimates of quota rents are very similar, we focus our analysis on the simulations using the EC quota rent estimates. Relative to the initial levels, total nitrogen uptake for OECD countries reduces by 0.7 percent of the initial value in the first scenario and by 2.3 percent in the more ambitious second scenario. There is reduced uptake of nitrogen by forage and pasture as well as by the crop sectors (particularly the large other crops sector). Although the total uptake of nitrogen is simulated to fall in the liberalisation scenarios modelled, total inputs of nitrogen are simulated to fall even further, leading to the overall reduction in the nitrogen balance with liberalisation. Total nitrogen inputs for OECD countries reduce by 0.6 percent of the initial value in the first scenario and by 2 percent in the second scenario. The main drivers of the reduced nitrogen inputs are lower overall fertiliser use and reduced manure from the cattle and sheep sector. The other livestock sector is also simulated to slightly reduce its total nitrogen inputs, as is biological nitrogen fixation by leguminous crops. These reductions in nitrogen inputs are sufficient to far outweigh the small increases in nitrogen inputs simulated with liberalization for other components such as dairy manure. The overall reduction in nitrogen inputs turns out to be more significant than the reduced overall uptake of nitrogen. This results in a lower simulated aggregate nitrogen balance for the OECD region, following trade reform.

The overall slight decrease in the aggregate OECD nitrogen surplus does however mask some quite significant redistributions across regions, to which we now turn. When the aggregate changes in nitrogen balance results are decomposed by region, many countries and regions are simulated to experience reductions in their nitrogen balance. For this section of the discussion, we aggregate the EU results (which were somewhat similar) into one region, with the exception of the particularly high nitrogen surplus regions of Den\_Blg and the Netherlands. Of the aggregate regions shown in Figure 1, all sets of simulations show nitrogen balances to reduce from their initial levels for eight of the eleven regions.

**Figure 1. Nitrogen balances by OECD region (kg/ha)**



Changes in the regional nitrogen balances are driven by changes in sectoral outputs, livestock units and land use in each region. The nitrogen balance results are decomposed by region in Tables 4 and 5 for each of the two liberalisation scenarios under the two different quota rent estimates. While the general pattern of results for scenarios #1 and #2 is similar, the magnitude of change is generally greater in the second more ambitious liberalisation scenario. Results for the two scenarios using the different milk quota rent estimates tend to be very similar in direction and magnitude. Not surprisingly, the biggest differences are evident in the EU countries where the quotas tend to be less binding under the Jensen estimates. This is particularly the case for Den\_Blg, for the reasons noted in section 5.2. We concentrate our analysis first on results using the EC quota rent estimates, later discussing some key areas where nitrogen balance results diverge when the Jensen estimates are used.

The three OECD regions simulated to experience an increase in their nitrogen balances are New Zealand, the USA and Korea, as detailed in Tables 4 and 5. Under the EC quota estimates, the largest nitrogen balance increases are 53 thousand tonnes for the USA in the first scenario and 166 thousand tonnes for New Zealand in the second scenario. The increase for Korea in each scenario is less than 5 thousand tonnes.

In the first scenario, we simulate an increase in the nitrogen balance of 42 thousand tonnes for New Zealand, increasing to 166 thousand tonnes in the more ambitious second scenario. These are significant increases over the initial balance of 74 thousand tonnes reported in Table 2. From Tables 4 and 5, we can see that the primary cause is the increase in nitrogen inputs in both scenarios. The simulated increase in other nitrogen inputs is due largely to higher levels of biological nitrogen fixation by leguminous plants which, for New Zealand, contributes over 55% of nitrogen inputs in the initial database. Therefore any increase in this component is likely to heavily influence results. Recall that our assumption for biological nitrogen fixation by leguminous plants for New Zealand differs to the assumption made for other regions (reflecting a difference in the OECD database). In particular, the relatively small contribution of pulses to N-fixation changes in proportion to land use in the other crops sector, while the much larger contribution of clover changes in proportion to land use in pasture-using sectors. The change in land use in the other crops sector is simulated to be -1.6% in scenario #1a and -2% in scenario #2a, while the corresponding change in land use by pasture-using sectors is 1.5% and 4.9% for the two scenarios. The results for New Zealand turn out to be very sensitive to our assumption on the sources (i.e. crops or pasture) of N-fixation. We have opted to report the most pessimistic result here, noting that a small change in this assumption could lead to a significant reduction in the nitrogen balance.<sup>14</sup>

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<sup>14</sup> For instance, if we followed the standard assumption used for other countries of biological nitrogen fixation changing in proportion to land use in the other crops sector, the results for New Zealand in scenario #2a would display an almost 10% reduction in biological nitrogen fixation, leading to an overall improvement, rather than a worsening of the nitrogen balance for New Zealand. The sensitivity of the change in New Zealand's nitrogen balance to this assumption is unique among the OECD countries that we study here: it is primarily due to the relatively small initial nitrogen surplus for New Zealand, combined with the significance of clover-based pasture land in New Zealand.

The net nitrogen input from fertiliser and manure is also simulated to increase a little for New Zealand, while uptake by pasture and forage is simulated to reduce. Table B1 indicates that output of milk in New Zealand increases by 12% in scenario #1a, while output of the larger manure-producing cattle and sheep sector decreases by almost 4%, and the other livestock sector declines by almost 2%. These changes result in a small net increase in manure output in the first scenario, while implying an overall reduction in cattle and sheep livestock units of 0.2%. Given our assumption that changes in N-uptake by pasture are driven by changes in livestock units, this contributes to a reduced uptake of nitrogen. For the second scenario, the effects are much larger. Table B3 shows that output of milk is simulated to increase by 42%, while output in the cattle and sheep sector is simulated to reduce by 14%, leading to an overall 1.9% reduction in livestock units and consequent reduction in the uptake of nitrogen by pasture. However in this case, net manure output also falls and contributes to a decline in N-inputs.

What drives the relatively large increase in the nitrogen balance for the US in the first scenario? In scenario #1, nitrogen inputs are simulated to reduce by just over 80 thousand tonnes. With the increases in output simulated for the cattle and sheep and other livestock sectors, net livestock manure is shown to increase. However, the impact on nitrogen inputs of the 60 thousand tonne increase from net livestock manure is swamped by the 100 thousand tonne reduction in nitrogen inputs from fertiliser, given the reduced output simulated for all US crop sectors. There is also some reduction in other nitrogen inputs. While the total level of nitrogen inputs reduces, uptake of nitrogen is simulated to reduce even further for the US, leading to the overall increase in the nitrogen balance. Increased output in the cattle and sheep and other animal sectors, dampened a little by the reduction in the milk sector, leads to the increase in livestock units and consequent 50 thousand tonne increase in nitrogen uptake by pasture and forage. However, the impact of this is overturned by the much more significant 185 thousand tonne reduction in nitrogen uptake by crops. This reduced crop uptake is not surprising, given the reduction in output simulated for all crop sectors indicated in Table B1. In particular, there is a 1% reduction in output of the cereal grains sector and the 2.5% reduction in output of the other crops sector – both of which are large sectors in the US and significant contributors to nitrogen uptake. The reduced uptake of nitrogen by crops is the major cause of the overall increase in the US nitrogen balance by 53 thousand tonnes (0.4% of the initial level) in the first scenario. For the second scenario, the patterns of change in nitrogen inputs and uptake are very similar for the US, though greater in magnitude.

The other country to experience an increase in its nitrogen balance is South Korea. However, the increase is only 2.4 thousand tonnes in the first scenario and, even in the second scenario, the increase is only estimated to be 4.4 thousand tonnes (less than 1% of the initial value). Total uptake of nitrogen reduces by 5 thousand tonnes in the first scenario and by 3.9 thousand tonnes in the second. This is due to reduced uptake by harvested crops, given the contractions in output simulated for all crop sectors with the exception of wheat. Fertiliser use reduces, given the reduced crop output, however manure increases with the increases in output from all livestock sectors. The reduced nitrogen input from fertiliser tends to dominate in the first scenario, leading to a reduction in total nitrogen inputs of 2.7 thousand tonnes. However, in the second scenario, the input effect that dominates is the increased manure, leading to an

increase in total nitrogen inputs of 0.6 thousand tonnes. The reduced uptake of nitrogen combines with smaller changes in inputs of nitrogen in both scenarios to lead to the slightly increased overall nitrogen balances reported for each scenario for South Korea.

While the increases in nitrogen balances may pose some environmental problems, our simulation results suggest these are not likely to be large problems at the aggregate level for several reasons. First, the US has a relatively low initial nitrogen balance of slightly under 30 kg per hectare (see Table 2), and this will increase very little, to just over 30 kg per hectare with reform. For New Zealand, even with the most ambitious trade reform and our harshest of assumptions for biological nitrogen fixation, the per hectare nitrogen balance increases to less than 18 kg per hectare – still the third lowest out of the OECD countries/regions we model. In the case of South Korea, the initial nitrogen balance is high, at 250 kg per hectare; however the simulated increases are of little significance.

Apart from the three regions discussed above, other OECD regions are simulated to experience some reduction in their per hectare nitrogen balances with the trade reforms simulated, as indicated in Tables 4 and 5. The largest absolute reduction in nitrogen balance is found for Australia in the first scenario and for the rest of the EU region in the second scenario.

For Australia, the nitrogen balance reduces by 78 thousand tonnes in the first scenario and by 249 thousand tonnes in the second scenario. The latter represents a reduction of almost 7 percent from the initial level of nitrogen surplus for Australia. While Australia is simulated to experience increased nitrogen inputs in both scenarios, the increases in nitrogen uptake by pasture, particularly in the second scenario, are the driving force behind the anticipated improvement in the overall nitrogen balance. The increases in pasture and the associated nitrogen uptake arise with the strong increases in output from the cattle and sheep sector and, to a lesser extent, dairy cattle. As indicated in Table B3, the large cattle and sheep sector increases by 6.5% in scenario #2a, causing much of the 6.6% increase in nitrogen uptake by pasture. Increased output in the livestock sectors leads to increased net manure in all scenarios; however this effect dampens, rather than overturns, the overall improvement in the nitrogen balance for Australia.

The relatively large reduction in the nitrogen balance for the rest of the EU region in scenario #2 (over 3% of the base level) is caused by nitrogen inputs declining more significantly than does nitrogen uptake. The reduced inputs are driven by less manure and less fertiliser. This outcome is not surprising when we examine Table B3 and find that all farm sectors contract for these countries, with the exception of the relatively small rice sector in EU\_lowN countries and the dairy cattle sector which, in many EU regions, is prevented from declining by the quota rents. There will be reduced uptake of nitrogen by the crop sectors and also by pasture and forage, however this reduced uptake is estimated to total only 1,081 thousand tonnes, compared with the 1,306 thousand tonne increase in nitrogen inputs.

Nitrogen balances in scenario #2a reduce by over 5% of initial levels for Australia, Canada,<sup>15</sup> Den\_Blg, the Netherlands and EFTA. Den\_Blg, and the Netherlands have particularly high nitrogen surpluses and for both regions, the decline in nitrogen surplus is due to nitrogen inputs falling more than nitrogen uptake is anticipated to decline. Reduced nitrogen manure is an important contributor in both regions, as expected, given the falls in livestock output simulated in Table B3.

As can be seen throughout the results, those using the EC quota estimates are generally very similar to those generated using the Jensen quota estimates, with a few notable exceptions. Comparing results for scenario #1a and #1b from Table 4: for the first scenario, Table B1 indicates that all quotas are binding using the EC estimates. Under the Jensen estimates, however, quotas for Den\_Blg, the Rest of EU, EU\_lowN and the UK are no longer binding. The largest fall below quota levels is for Den\_Blg and this lies behind the significant differences in the EC and Jensen results for this region shown in Table 4. Under the EC quota rent estimates, the Den\_Blg region is estimated to have an almost 69 thousand tonne reduction in its nitrogen surplus, diminishing to just over five thousand tonnes under the Jensen quota estimates. From Table B1, we can see that in scenario #1a, the quota is binding and there is no reduction in milk output. For scenario #1b, however, Table B2 indicates a 3% reduction in milk output is simulated for the region. The key to the differing results turns out to be the larger reduction in fertiliser use in scenario #1a. This is primarily because the large other crops sector is simulated to decline in output by 26% under the EC quota rent assumption, but only by 1% under the Jensen quota rents. Because the crop sector declines significantly more under the first assumption, there is a consequent much larger reduction in fertiliser input required for the crop sector. We also note some significant differences in results for the rest of the EU region in both scenarios. Again this is because the Jensen quota rents are much smaller and declines in the dairy cow sector are anticipated for a number of EU regions, whereas the larger EC quotas rent estimates would have left the quotas binding.

## 6. Conclusions

Whether reforms to trade policies will enhance or degrade the natural environment is an empirical matter that will depend in part on how the altered economic incentives affect outputs of pollution-intensive relative to pollution-extensive industries and sectors. Dairy and meat production are amongst the world's most highly protected agricultural activities, through high tariffs and (especially in the EU) export subsidy payments. Consequently, our agricultural trade liberalisation simulations suggest 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 relatively high-income, densely populated countries of Northeast Asia and Western Europe, lowered farm protection could lead to less nitrogen input from livestock manure and less fertiliser used in cropping. Given the relatively high population densities in these regions, this may give rise to significant welfare gains. Some of the farm production is likely to shift to other regions of the world, where human population densities are much lower and farm

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<sup>15</sup> We note Canada's initial environmental assessment of the WTO trade negotiations, submitted in January 2003. A conclusion was that further agricultural liberalisation is not likely to cause significant environmental damage since Canada's agriculture is of relatively low intensity (WTO, 2003c).

production systems are more extensive. Thus the additional costs of environmental damage in the latter countries could be much less than the reduction in environmental damage costs in the densely populated regions (Anderson and Strutt, 1996).

While our findings suggest that the aggregate OECD nitrogen balance is likely to decline slightly with trade reform (particularly with the more ambitious reform), we find some significant redistributions in nitrogen balances. Even in the absence of specific environment-enhancing policies and activities, we find that the trade liberalisations modelled here are likely to reduce the nitrogen balances for most OECD countries. While trade liberalisation may increase nitrogen surpluses at the national level in countries such as New Zealand and the US, these regions tend to have low base nitrogen balances per hectare, and the level of environmental damage may be relatively small at the aggregate level.

We did not model changes in environmental policy,<sup>16</sup> but improved policy ought to be considered if the simulated environmental damage remaining after trade policy reforms is to be reduced or avoided. For example, New Zealand is already developing environmental policies to limit the impact of environmental pollution from the dairy sector due to global demand growth and trade reform (OECD, 2004). 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 study. 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, where the environmental impacts may be many times more severe than is indicated by national indicators. In defence of our approach, we recall Vanongeval and Boman's finding of a strong positive relationship between nitrogen balances and nitrogen losses when the soil-surface surplus exceeded 100kg N/ha. Given that our base national nitrogen balances (Table 2) are above this threshold for the Netherlands, Korea, Denmark/Belgium and Japan, and at least 80kg in the UK and Ireland, it follows that some localities in these countries must have balances well in excess of 100kg/ha. Any improved environmental conditions due to trade reform that we indicate at the national level are also likely to be observed in such high-pollution farming localities. 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 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 the current study.

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

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<sup>16</sup> For some recent work on interventions to reduce farm pollution, see Cassells and Meister (2001), Komen and Peerlings (1998), Reinhard *et al.* (1998) and Brouwer *et al.* (1999).

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 grazing livestock. However, changes in the intensity of livestock production in response to trade liberalisation might involve changes in stocking rates, changes in fertiliser use on pasture, in grass consumption and in excretion volumes of nitrogen per hectare of pasture. In addition, we note that agricultural pollution is multi-dimensional but we have focused only on one environmental indicator.<sup>17</sup>

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 tend to be positive for nitrogen balances in the OECD. We say nothing about nitrogen balances in non-OECD countries in this study due to lack of data. We also make no attempt in this paper to project the global economy forward from the benchmark 2001 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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<sup>17</sup> As data for other indicators become available, this shortcoming can of course be rectified.

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### Appendix A. Milk quotas

Estimation of the size of milk quota rents is controversial. Jensen and Nielsen (2004) provide a review of some approaches to the problem in the EU. We use two sets of EU estimates. One is from a study for the European Commission (INRA-Wageningen, 2002) based on national accounts data, and the other by Jensen and Frandsen (2003) that estimate rents indirectly from observed quota (rent or lease) prices. Quota rents are presented for each EU15 country, and production-weighted averages of them are used here for the EU sub-regions. Since both sets of estimates are quite different, we employ both in sensitivity analyses.

Quotas were binding in all EU countries in 2001. Let PS be the market price of milk and PQ the marginal cost of milk supply at the quota volume, so that PS-PQ is the rent per unit of quota. The INRA-Wageningen (2002) PQ/PS ratio estimates ranged from 0.51 for Ireland to 0.85 in the case of Sweden. The estimates of Jensen and Frandsen (2003) are larger (implying smaller per unit rents), ranging from 0.86 for the Netherlands to 0.98 in Finland. Lips and Rieder (2005) estimate 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). Details of the ratios are in Table A1.

**Table A1. Milk quota PQ/PS ratios for modelled countries and regions**

Region	PQ/PS ratio	
	INRA-Wageningen	Jensen and Fransen
Australia	1	1
Den_Blg	0.62	0.93
Rest of EU	0.72	0.96
EU_lowN	0.61	0.95
Ireland	0.51	0.93
France	0.64	0.91
Germany	0.55	0.89
UK	0.57	0.92
Netherlands	0.64	0.86
NZ	1	1
Canada	0.6	0.6
USA	1	1
Rest of ASIA	1	1
Japan	1	1
Korea	1	1
Cen. and Sth. America	1	1
EFTA	0.74	0.74
Central Europe	1	1
Rest of the World	1	1

Sources: INRA-Wageningen (2002); Jensen and Nielson (2004).

## Appendix B. Changes in sectoral output by region resulting from trade reform

**Table B1. Changes in farm sector outputs (%): Scenario #1a**

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep livestock	Other livestock
Australia	34.6	-4.1	8.7	-1.7	5.4	4.4	0.5
NZ	..	1.3	2.5	2.1	12.1	-3.7	-1.8
Japan	-3.8	-41.3	-8.9	-0.6	-2.5	-10.4	-7.8
Korea	-1.8	3.7	-10.5	-1.9	0.4	1.0	1.9
Canada	..	3.0	0.2	1.2	0.0	-0.8	-2.1
USA	-27.9	-1.0	-1.0	-2.5	-0.7	0.8	0.9
EU_lowN	-9.0	-1.5	-1.4	-2.8	0.0	-4.5	-0.9
Den_Blg	..	1.0	-3.8	-25.8	0.0	-9.5	1.2
France	..	-1.3	-3.3	-0.7	0.0	-3.0	-1.1
Germany	..	-0.4	-3.7	0.5	0.0	-8.4	-1.8
UK	..	-0.6	-3.1	-2.7	0.0	-2.7	-2.1
Ireland	..	-17.4	-7.9	-3.3	0.0	-15.6	-3.7
Netherlands	..	-26.3	-16.3	3.8	0.0	-14.4	-4.4
Rest of EU	..	-3.2	-4.3	-3.8	0.0	-5.3	-1.1
EFTA	..	-21.1	0.8	-3.8	0.0	-7.2	-5.8
C. Europe	..	1.1	0.3	0.1	0.3	0.8	0.0

**TableB2. Changes in farm sector outputs (%): Scenario #1b**

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep livestock	Other livestock
Australia	34.4	-4.2	8.7	-1.8	5.6	4.4	0.5
NZ	..	1.3	2.6	1.6	12.6	-3.7	-1.8
Japan	-3.8	-41.4	-8.9	-0.6	-2.5	-10.4	-7.8
Korea	-1.8	3.7	-10.5	-1.9	0.5	1.1	2.0
Canada	..	3.0	0.2	1.0	0.0	-0.7	-2.0
USA	-27.9	-1.0	-1.0	-2.6	-0.7	0.8	0.9
EU_lowN	-9.3	-1.4	-1.5	-3.1	-0.7	-4.6	-0.8
Den_Blg	..	-2.2	-5.6	-1.1	-3.0	-10.7	-0.3
France	..	-1.2	-3.2	-1.1	0.0	-3.0	-1.0
Germany	..	-0.3	-3.6	-0.1	0.0	-8.4	-1.7
UK	..	-0.6	-3.1	-3.1	-0.2	-2.7	-2.1
Ireland	..	-17.3	-7.8	-3.8	0.0	-15.7	-3.7
Netherlands	..	-26.0	-16.1	2.9	0.0	-14.2	-4.1
Rest of EU	..	-3.1	-4.3	-4.4	-1.3	-5.4	-1.1
EFTA	..	-21.0	0.9	-4.2	0.0	-7.2	-5.8
C. Europe	..	1.1	0.3	0.0	0.3	0.8	0.0

**Table B3. Changes in farm sector outputs (%): Scenario #2a**

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep livestock	Other livestock
Australia	607.8	-17.3	16.4	-4.1	8.8	6.5	-4.6
NZ	..	2.8	5.2	0.1	42.0	-14.2	-8.7
Japan	-81.7	-86.8	-23.6	-0.9	-9.6	-29.1	-21.3
Korea	-1.6	5.1	-9.3	-1.2	1.3	1.3	2.1
Canada	..	8.4	1.9	2.2	0.0	0.1	-2.8
USA	37.0	0.3	-1.9	-5.5	-1.6	3.6	4.0
EU_lowN	244.5	-6.5	-5.9	-7.3	0.0	-22.9	-3.5
Den_Blg	..	-2.7	-13.4	-10.6	0.0	-34.6	-1.7
France	..	-3.2	-10.2	-2.5	0.0	-12.6	-3.4
Germany	..	-1.3	-9.9	-0.3	0.0	-30.9	-6.6
UK	..	-1.7	-9.3	-5.7	0.0	-12.5	-9.6
Ireland	..	-38.5	-20.9	-9.6	0.0	-49.3	-8.9
Netherlands	..	-54.3	-32.7	6.6	0.0	-51.0	-16.3
Rest of EU	..	-6.3	-11.6	-8.7	0.0	-26.7	-3.0
EFTA	..	-60.1	-10.1	-9.8	-4.7	-16.9	-32.7
C. Europe	..	2.8	1.6	0.6	1.3	2.3	1.1

**Table B4. Changes in farm sector outputs (%): Scenario #2b**

	Rice	Wheat	Cereal grains	Other crops	Milk	Cattle & sheep livestock	Other livestock
Australia	604.6	-17.6	16.2	-4.2	12.1	6.6	-4.7
NZ	..	2.2	5.6	-1.9	48.2	-16.1	-10.2
Japan	-81.8	-86.8	-23.6	-0.9	-9.4	-29.0	-21.3
Korea	-1.6	5.2	-9.2	-1.2	1.6	1.4	2.1
Canada	..	8.4	2.0	2.2	0.0	0.3	-2.9
USA	37.3	0.3	-1.8	-5.5	-1.4	3.7	4.0
EU_lowN	248.2	-6.5	-6.4	-7.3	-5.8	-23.5	-3.4
Den_Blg	..	-2.0	-13.5	-10.0	-18.5	-35.0	-1.2
France	..	-2.9	-10.0	-2.4	-5.9	-14.0	-4.0
Germany	..	-1.1	-9.8	-0.1	-3.7	-31.4	-6.7
UK	..	-1.7	-9.3	-5.6	-4.1	-12.5	-9.6
Ireland	..	-38.5	-21.1	-9.2	-17.4	-50.2	-10.8
Netherlands	..	-54.6	-32.9	6.6	0.0	-50.4	-16.1
Rest of EU	..	-6.2	-11.7	-8.6	-5.9	-27.0	-3.2
EFTA	..	-60.5	-10.2	-10.3	-1.8	-16.8	-32.7
C. Europe	..	2.8	1.6	0.6	1.7	2.5	1.1