# AGRICULTURAL TRADE REFORM AND ENVIRONMENTAL POLLUTION FROM LIVESTOCK IN OECD COUNTRIES

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**ABSTRACT**

*Global trade barriers are particularly severe in the case of products derived from livestock, and especially for dairy products and beef. The Doha Development Agenda negotiations have the potential to lower agricultural protection and improve livestock production incentives for many farmers worldwide. While such 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 impacts on regional nitrogen balances, using the OECD Nitrogen Balance Database. We estimate the changes in inputs and outputs 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, and there are concerns 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, have 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*. 2003). This is understandable given the complex interactions between farm production and the environment and the dearth of available data on those relationships. Yet it is important that progress be made if we are interested in as full a picture as possible about the welfare effects of trade reform. Increased growth and changes in the global location of farm production that result from trade reform may have an ambiguous effect on global environmental damage (Anderson and Strutt 1996). But the concerns of some environmentalists have the potential to derail or stall trade negotiations. Improved information on anticipated environmental impacts will help us to address such concerns, while still facilitating the benefits of trade liberalisation.

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 impacts 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 add to our understanding of the environmental impacts that result from removal of trade restrictions and distortions, and the determination of the extent to which trade liberalization and environmental protection can be mutually reinforcing We begin by outlining the nature of environmental degradation from livestock and 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).

This 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] This approach follows the work of Strutt and Anderson (2000) and Rae and Strutt (2001). The GTAP model is used to project the standard economic impacts of the various WTO liberalization scenarios that we consider. These results provide a starting point, to which we add environmental side modules which are used to analyse the implications of these economic changes for environmental degradation.

The nitrogen balance database we use measures the soil surface nitrogen balance. This is calculated as the difference between the total nitrogen inputs and the total nitrogen outputs for soil over one year for OECD countries (OECD 2001a). The inputs of nitrogen available to an agricultural system are primarily from livestock manure and chemical fertilisers, while the uptake of outputs 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-ecological conditions, livestock weights and yields, and the methods used to estimate these coefficients may all vary (OCED 2001b). The nitrogen coefficients are multiplied by the

[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.

relevant quantity such as crop production or livestock numbers then all inputs and outputs can be summed and an overall balance obtained. Table 1 shows a summary of the inputs and outputs of nitrogen available in the OECD database.

**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 also to be an integral part of all elements of the agricultural negotiations and non-trade concerns, which include 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 appropriately reflected. This could include, presumably, those environmental aspects of the agricultural negotiations that may impinge on developing countries.

[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).

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 included 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 been whether protection of the environment is a legitimate policy goal, but about 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. 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. 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] WT/CTE/W/67 examines various sectors including agriculture, and WT/CTE/GEN/8 covers specifically the environmental issues raised in the agricultural negotiations.

# 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 (OECD 2001). Clearly, however, major policy-induced distortions remain in agricultural markets (see, for example, Gibson *et al*. for details of current agricultural and food tariffs). A new WTO Round of agricultural trade negotiations began in March, 2000. These talks have now 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 the 'modalities' for achieving the objectives of the negotiations, and a revised draft the following month. Completion of this 'modalities' phase was set for the end of March 2003 (but was not met), with the countries' comprehensive draft commitments to be ready for the 5$^{th}$ Ministerial Conference in September 2003. The deadline for the completion of the Round is January 2005.

The draft modalities document received mixed reactions. The US and the Cairns Group of agricultural exporting countries had earlier proposed mechanisms for deep tariff cuts, and believed that the draft document was not sufficiently ambitious in this regard. The EU, on the other hand, had proposed use of the same tariff reduction modalities as in the URAA, and considered the Chair's draft as biased towards the interests of exporting countries. Some developing countries welcomed the draft, noting it would provide the flexibility necessary for their development needs to be addressed. The Cairns Group and US had proposed elimination of export subsidies, as did the Chair's draft document. However, the EU's proposal was for a 45% cut in these subsidies, so providing another point of difference. The draft proposed 60% cuts in the trade-distorting domestic support of developed countries, which compares with the EU's proposed 55% reduction, although the Cairns Group and the US had proposed much deeper cuts. There were also differences of opinion between member countries with regard to the draft proposals for the treatment of other categories of domestic support and the 'non-trade' concerns.

## 4.1 The liberalisation scenarios modelled

These scenarios reflect some of the elements of the various agricultural proposals currently before the WTO. 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 the 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 some given base period. The data to be used here (see below) include the applied levels of tariffs and support, rather than the bound rates.[5] 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 (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 not dynamic, but static in nature, the adjustment path to the targeted reductions in support cannot be revealed.

The scenarios are described in Table 2. The first scenario has some elements in common with the EU's proposal 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 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 and the USA. 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 impacts of the three trade liberalisation scenarios were simulated with the GTAP applied general equilibrium model (see Annex 1 for a short description of the model and our data aggregation). Only changes in farm production will be discussed here (see Tables A1 to A3).

The first scenario simulates outcomes from a liberalisation which had some features in common with the URAA outcome. Farm production of most commodities (with the exception of 'other crops') 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.

Moving from the first through to the third scenario, modelled trade reforms became more liberal, with deeper cuts to tariffs, and 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, cattle and sheep production, and that of milk, in Australia and New Zealand expanded by between 5% and 14% in scenario #1, but by 9% to over 35% in the third scenario. While outputs of most crops and all livestock sectors 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.

[5] 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 would overstate the extent of tariff reductions in such cases, provided that any Agreement based tariff reductions on the bound rates.

| Table 2 Trade Liberalisation Scenarios | | | |
|---|---|---|---|
| Item | Scenario #1 | Scenario #2 | Scenario #3 |
| **Change in Tariffs** [a] | | | |
| Developed regions | -36% | $If \quad t_o \geq 90\%, \quad t_1 = t_o * 0.4$<br>$If \quad 15\% \leq t_o < 90\%, \quad t_1 = t_o * 0.5$<br>$If \quad t_o < 15\%, \quad t_1 = t_o * 0.6$ | Swiss formula (a=25) |
| Developing regions | -24% | $If \quad t_o \geq 120\%, \quad t_1 = t_o * 0.6$<br>$If \quad 20\% \leq t_o < 120\%, \quad t_1 = t_o * 0.67$<br>$If \quad t_o < 20\%, \quad t_1 = t_o * 0.73$ | $If \quad t_o \geq 250\%, \quad t_1 = 125\%$<br>$If \quad 50\% \leq t_o < 250\%, \quad t_1 = t_o * 0.5$<br>$If \quad t_o < 50\%, Swiss\ formula\ (a = 50)$ |
| **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

### 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 that we run in tandem with the GTAP model fully exploits the OECD Nitrogen Balance Database. In particular we model the nitrogen inputs and outputs noted in Table 1 for all OECD economies.[6] We use the OECD data for 1997, corresponding to the base year of version 5 of the GTAP model used. The OEDC database contains very detailed data by country, particularly on nitrogen coefficients for crops and livestock. We aggregate this very detailed information into a form compatible with our GTAP database aggregation.[7] A summary of the total nitrogen balance by country is provided in Table 3.

Outputs of nitrogen are comprised of outputs from the crop sectors and from pasture (OECD 2001). Nitrogen coefficients for crops range from 1.5 kg per tonne to nearly 70 kg per tonne of output, with a great deal of variation by crop type and region. We assume that the 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. (This is 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 nitrogen output is proportional to the average percentage change in land use for the pasture-using livestock sectors (cattle, dairy cows and sheep), weighted by the initial land use by these sectors.

**Table 3 Initial Nitrogen Balances, 1997**

| | Nitrogen Balances, 000 tonnes | Nitrogen Balances, kg/ha |
|---|---|---|
| **AU** | 3,566 | 7.6 |
| **NZ** | 74 | 5.5 |
| **JAP** | 641 | 129.5 |
| **KOR** | 498 | 250.4 |
| **CAN** | 1,159 | 15.5 |
| **USA** | 12,524 | 29.9 |
| **EU_lowN** | 719 | 29.5 |
| **Den_Blg** | 554 | 134.0 |
| **France** | 1,517 | 50.6 |
| **Germ** | 976 | 56.4 |
| **UK** | 1,477 | 86.7 |
| **Ire** | 401 | 80.0 |
| **Neth** | 511 | 262.1 |
| **Rest_EU** | 1,826 | 47.4 |
| **EFTA** | 183.99 | 70.3 |
| **C_Eur** | 699.29 | 24.2 |

Source: Authors' calculations from the OECD Nitrogen Balance Database

For inputs of nitrogen, the OCED database contains very detailed data on nitrogen coefficients by country and livestock category, with the largest sources of nitrogen inputs

[6] With the exception of Mexico and Turkey since these countries are aggregated with non-OEDC countries in our current aggregation. Mexico and Turkey are excluded from all of our subsequent analysis of OECD countries.

[7] Painstaking research assistance by Sandra Barns of the University of Waikato is gratefully acknowledged.

being livestock manure and inorganic fertilizers. Changes in nitrogen from livestock manure are modeled as changing in proportion to changes in the output of each type of livestock in each region as shown in our GTAP results (Tables A3 – A5). 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 be constant. In particular, we first calculate the initial nitrogen withdrawals as a proportion of the initial nitrogen manure; we then apply this percentage to the post-simulation estimate of nitrogen input from manure. For inorganic fertilizers, the nitrogen input is assumed to change in proportion to the weighted average percentage change in output for the crop sectors that are using these fertilizers (in the absence of crop-specific fertilizer rates). Other sources of nitrogen inputs include biological nitrogen fixation, atmospheric deposition of nitrogen, nitrogen from recycled organic matter and nitrogen contained in seeds and planting material (OEDC 2001). In the absence of better information, we assume these to be constant when trade policies are changed.[8]

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 of 1997, we estimate the total nitrogen balance for OECD countries included in our modelling to be 27.3 million tonnes. In the first liberalization scenario, this is projected to fall to 27.0 million tonnes. It is projected to fall to 26.7 and 26.0 million tonnes for the second and third reform scenarios (see Table 4). In short, total OECD nitrogen balances are expected to fall more, the more ambitious the reform modelled. For the most ambitious third scenario, our results suggest that the total nitrogen balance for the OECD falls from its initial level by 4.7 percent. This reduction in the overall nitrogen balance is likely to lead to improved environmental outcomes, with a reduction in the surplus nitrogen that can cause damage to soil, air and water.

Further insights can be gained by decomposing the nitrogen balances into inputs and outputs as shown in Table 4. Total nitrogen uptake for OECD countries increases by almost 0.4 percent in scenario one and by just over 1 percent in the second scenario. In the most extreme third trade simulation we model, total nitrogen outputs increase by almost 2.5 percent for OECD countries. The largest contributor to increased nitrogen uptake is pasture, which increases its nitrogen uptake by just 6.5 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 5.2 percent. Coarse grains, and to a lesser extent wheat, reduce their uptake of nitrogen a little, reflecting a small reduction in the aggregate OECD regional output in these sectors. While the uptake of nitrogen increases, nitrogen inputs reduce with trade reform, thus further reducing the nitrogen balance for the OECD. Total nitrogen inputs for OECD countries reduce by around 0.25 percent in each scenario modelled. The main reduction in inputs comes from non-organic fertilizers, which are projected to reduce their nitrogen inputs by around 0.6 percent.  The ‘O_lvstk’ sector reduces nitrogen inputs by between 0.5 and 1.2 percent. All other inputs of nitrogen either remain constant or increase only a little, the largest increase being 0.7 percent for the milk sector in scenario three. The overall reductions in nitrogen inputs combine with the increased overall uptake of nitrogen to result in the lower nitrogen balances for the OECD region with trade reform, reflecting a shift from nitrogen-intensive to nitrogen-extensive farming systems.

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[8] It is possible that this assumption could be improved for biological nitrogen fixation and for seeds and planting material. These coefficients are available by crop sector and (with significant additional effort) it is possible that the change in output by sector could be applied to these coefficients. However this is unlikely to significantly affect our results.

**Table 4 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 | 5,124 | 5,133 | 5,113 |
| | Cgrains | 7,152 | 7,015 | 6,983 | 6,894 |
| | O_crops | 12,128 | 12,125 | 12,143 | 12,223 |
| | Pasture | 20,153 | 20,496 | 20,792 | 21,465 |
| | **Total uptake** | 45,076 | 45,244 | 45,535 | 46,187 |
| **Inputs** | | | | | |
| | Cattle | 13,811 | 13,836 | 13,838 | 13,820 |
| | O_livstk | 7,333 | 7,296 | 7,288 | 7,245 |
| | Dairy | 4,524 | 4,531 | 4,535 | 4,555 |
| | Fertilizer | 26,216 | 26,044 | 26,046 | 26,074 |
| | Withdrawals | -4,398 | -4,384 | -4,384 | -4,384 |
| | Seeds | 462 | 462 | 462 | 462 |
| | Bio Nit Fx | 13,580 | 13,580 | 13,580 | 13,580 |
| | Atmospheric | 10,873 | 10,873 | 10,873 | 10,873 |
| | **Total inputs** | 72,402 | 72,238 | 72,238 | 72,225 |
| **Total Nitrogen Balance** | | **27,326** | **26,994** | **26,703** | **26,037** |

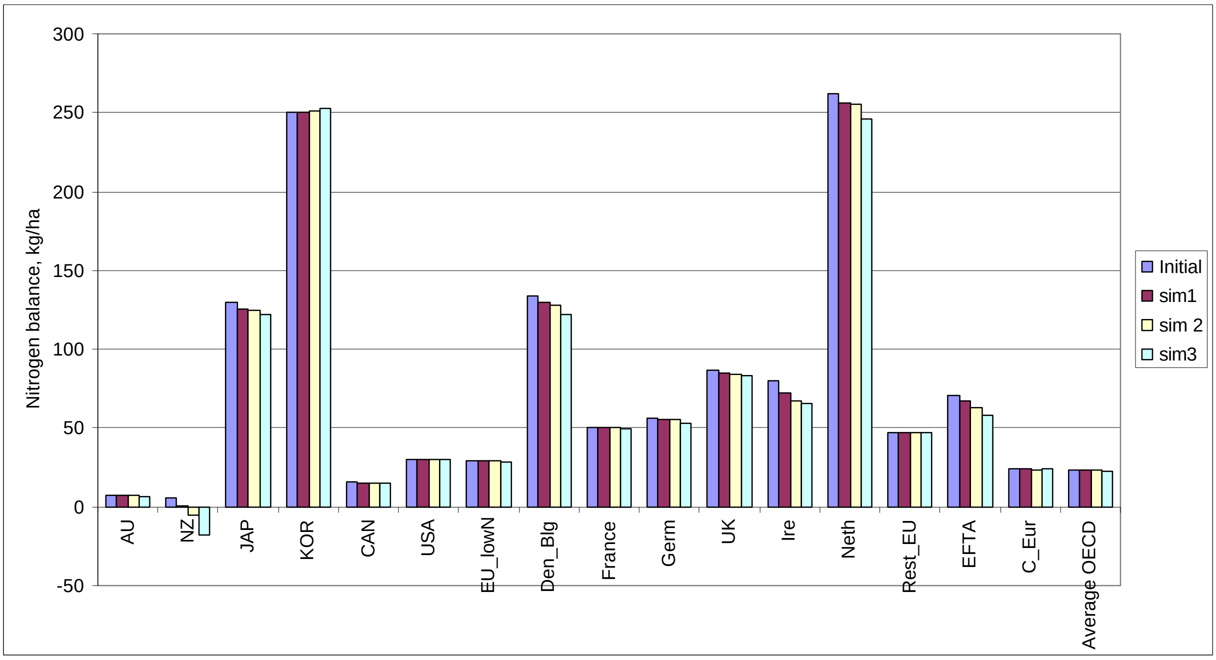
Source: Authors' model results

When these nitrogen balance results are decomposed by country most countries are projected to experience a reduction in its nitrogen balance. Only two countries are projected to experience an increase in their nitrogen balance with trade reform – the US and Korea. The nitrogen balance for the US is projected to increase by just over 53 thousand tonnes in the most ambitious scenario, a 0.4 percent increase from the initial level. Increased output in some crops sectors, particularly the 'O_crops' sector by 1.4 percent and the rice sector by 14.4 percent (see Table A5) leads to greater nitrogen uptake for the US. However, these increases in uptake are not significant enough to outweigh the increased nitrogen inputs in the US. The cattle sector is projected to increase output by 1 percent and this leads to a 52.4 thousand tonne increase in nitrogen inputs and, given that fertilizer use is assumed to increase when crop production increases, there is a 42.1 thousand tonne increase in nitrogen inputs from fertilizer. These increases in the cattle sector and fertilizer use, combine with the small increase in O_lvstk projected, to cause the overall increase in the nitrogen balance for the US.

For Korea, the increase in the nitrogen balance for scenario three is projected to be just over 4 thousand tonnes, a 0.85 percent increase from the initial 1997 base level. The increased nitrogen balance for Korea is driven by both a reduction in nitrogen uptake and an increase in nitrogen inputs. The reduced uptake is due to reduced output in the coarse grains and other crops sectors. The reduced need for crop fertiliser does reduce inputs of nitrogen, but not by enough to counter the large increase in the other animal product (O_lvstk) sector, where nitrogen inputs are projected to increase by almost 9 thousand tonnes, reflecting the 4.5 percent increase in this sector. The increase in output from the cattle sector also increases nitrogen inputs in Korea, as does the increased output from the milk sector, though to a lesser extent.

As shown in Figure 1, all OECD regions, with the exception of the US and Korea, are projected to see some reduction in their per hectare nitrogen balances with the trade reforms simulated. The largest reduction in nitrogen balance is projected to be for Australia, with the total nitrogen balance reducing by 48.5 thousand tonnes in the first scenario, 205.5 thousand tonnes in the second scenario, and over 544 thousand tonnes in the third scenario. Although we project some increase in output from the cattle and milk sectors for Australia in scenario three (see table 5), the increased nitrogen inputs caused by this are much more than offset by an increase in nitrogen uptake. The main component of the increased uptake is pasture, accompanying the expansion of the cattle and milk sectors. Uptake of nitrogen by coarse grains and rice also contribute to a reduced nitrogen balance for Australia. The country expected to see the next most significant absolute reduction in its nitrogen balance is New Zealand, with the total nitrogen balance reducing by 62.7 thousand tonnes in scenario one, 158.6 thousand tonnes in scenario two and over 320 thousand tonnes in scenario three. As shown in Table A5, the cattle and dairy sectors in New Zealand are projected to increase by almost 14 and 37 percent respectively under the most ambitious scenario modelled. This leads to inputs of nitrogen increasing by 6.7 percent, however the increased inputs are much more than offset by a more than 16.4 percent increase in nitrogen uptake. The increase nitrogen output is almost entirely due to the increased pasture use accompanying higher livestock output[9]. While the absolute reduction in the total nitrogen balance for other regions is small by comparison to Australia and New Zealand, the percentage reduction is significant for some regions. For example, our results for both Ireland and the EFTA region project a reduction in nitrogen balances for these regions of 18 percent from the initial level.

**Figure 1: Nitrogen Balance by OECD Region (kg/ha)**




Source: Author's model results

## 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 Europe, Northeast Asia and Canada, but expansion in most other OECD countries. The beef

[9] Although recall that we have not allowed N inputs from biological nitrogen fixation to increase with increased pasture production.

sector also contracts in most of the above regions. 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. Furthermore, 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, Rae and Strutt 2001). Extensive livestock production systems also tend to utilize less grain-feeding than intensive systems, with increased reliance on nitrogen-fixing pasture plants, both suggestive of net environmental gains from the relocation to extensive systems. Our quantitative analysis confirms these effects.

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 almost every OECD country, with a small increase for the US. Trade liberalization may increase livestock environmental problems in countries such as New Zealand but there may be greater nitrogen uptake through pasture land and, due to relatively low population densities, the human consequences of such damage may be relatively low. On the other hand, trade liberalization leads to reduced livestock production in the densely populated countries 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).

While we did not model changes in environmental policy,[10] 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 and with consideration of the increased potential for nitrogen uptake by pasture.

There are of course a number of important tradeoffs and limitations with this type of work. In particular, 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. Local level studies will therefore complement (and be complemented by) this work. In addition, we only consider environmental damage from one sector.[11] Changes in other sectors will also impact on the *net* national and international level of environmental damage. However, given the model and data we use, 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.[12] We also make no attempt in this paper to project the global economy from the benchmark 1997 year. Strutt and Anderson (2000) and Rae and Strutt (2001) suggest 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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[10] 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).

[11] And we focused on just one environmental indicator, when agricultural pollution is multi-dimensional. As other indicators become available, this shortcoming can of course be rectified.

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

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## ANNEX 1

### The trade model

A slightly modified version of the GTAP applied general equilibrium model (Hertel 1997) is used. This is a relatively standard, multi-region model built on a complete set of economic accounts and 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 GTAP allows substitution amongst the employment of these resources in any sector in response to price changes, intermediate inputs are used in fixed proportions in producing the various outputs. 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).

### Regional and commodity aggregation

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. At the regional level, the 15 EU countries were aggregated into eight subgroups, reflecting their agricultural N-balances[13] per hectare (Annex Table 1). Austria, Italy and Greece exhibited the lowest N-balance values, while Denmark, Belgium and the Netherlands exhibited the highest values. Of the other OECD countries, N-balances were highest in Korea and also relatively high in Japan. 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. Details of these aggregations are found in Annex Tables A1 and A2.

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

**Annex Table A1  Regional Aggregation**

| Acronym | Description |
|---|---|
| AU | Australia |
| Den_Blg | Denmark, Belgium |
| Rest_EU | Finland, Luxembourg, Portugal, Spain, Sweden |
| EU-lowN | Austria, Greece, Italy |
| Ire | Ireland |
| France | France |
| Germ | Germany |
| UK | United Kingdom |
| Neth | Netherlands |
| NZ | New Zealand |
| CAN | Canada |
| USA | United States |
| Rest_ASIA | All Asia except Japan and Republic of Korea |
| JAP | Japan |
| KOR | Republic of Korea |
| C_S_Amer | All Central & South America incl. Mexico |
| EFTA | Switzerland & rest of EFTA |
| C_Eur | Hungary, Poland, Czech Republic, Slovak Republic & rest of Central Europe |
| ROW | Former Soviet Republic, Middle East, Africa, rest of world |

**Annex Table A2   Sectoral Aggregation**

| Acronym | Description |
|---|---|
| RICE | Paddy rice |
| WHEAT | Wheat |
| CGRAINS | Cereal grains nec |
| O_crops | Oil crops, horticulture & all other crops |
| Milk | Raw milk production |
| cattle | Cattle, sheep, goats, horses |
| O_lvstk | Pigs, poultry & other livestock products nec |
| Rum_meat | Ruminant meats |
| Oth_meat | Non-ruminant meats |
| DAIRY | Dairy products |
| O_ProcFood | All other processed foods & beverages |
| ResProds | Wool, forestry, fishing, coal, oil, gas |
| MANUF | Manufactures |
| SVCS | Services |

**Simulated changes in farm sector outputs**

**Table A3 Changes in Farm Sector Outputs: scenario #1**

| | RICE | WHEAT | CGRAINS | O_crops | Milk | Cattle | O_lvstk |
|---|---|---|---|---|---|---|---|
| AU | 6.9 | -0.2 | 7.7 | -0.7 | 7.2 | 5 | -0.6 |
| Den_Blg | .. | -4.8 | -5.2 | -1.6 | -2.3 | -9 | -0.6 |
| Rest_EU | .. | -4.7 | -6.1 | -1.1 | -0.9 | -2.1 | -0.5 |
| EU_lowN | -4.4 | -4.4 | -3.6 | -0.3 | -0.7 | -2.2 | -0.7 |
| Ire | .. | -8 | -7.9 | 1 | -4.3 | -9.1 | -1.9 |
| France | .. | -7.2 | -9.5 | -0.1 | -1 | -2.9 | -0.4 |
| Germ | .. | -4.3 | -4.5 | -0.3 | -1.4 | -4.9 | -1 |
| UK | .. | -4.3 | -5.6 | -0.6 | -1.2 | -2 | -1.4 |
| Neth | .. | -8.8 | -21.8 | -0.1 | -3.1 | -10.7 | -1.4 |
| NZ | .. | 5.2 | 5.2 | -1.9 | 13.8 | 5.5 | -11.6 |
| CAN | .. | 13 | 1.2 | 1.2 | -1.7 | 0 | -4.1 |
| USA | 2.6 | -0.6 | -1.1 | 0.4 | -0.4 | 0.2 | 0.2 |
| Rest_ASIA | 0.4 | 0.2 | -0.1 | -0.1 | 0.1 | 0.3 | 0.2 |
| JAP | -2.2 | -35.1 | -6.8 | -3.6 | -4.7 | -6.8 | -2.1 |
| KOR | 1.7 | 5.5 | -18.8 | -1.6 | 0.1 | 0.7 | 1.4 |
| C_S_Amer | 0.9 | 2 | 1.2 | 0.7 | 0.4 | 1.3 | 0.6 |
| EFTA | .. | -8.4 | -7.9 | -5.8 | -7 | -4.5 | -0.9 |
| C_Eur | .. | 0.2 | 1.4 | -1 | 1.2 | 3.1 | 0.5 |
| ROW | 0.1 | -1.2 | 0.2 | 0.1 | 0 | -0.7 | -0.5 |

Source: Authors' model results

**Table A4 Changes in Farm Sector Outputs: scenario #2**

| | RICE | WHEAT | CGRAINS | O_crops | Milk | Cattle | O_lvstk |
|---|---|---|---|---|---|---|---|
| AU | 13.8 | 0.1 | 10.9 | -1.2 | 14.8 | 6.8 | -1.2 |
| Den_Blg | .. | -6.4 | -10 | -1.5 | -4.9 | -14.9 | -0.8 |
| Rest_EU | .. | -7 | -9.6 | -0.8 | -1.7 | -3.3 | -0.7 |
| EU_lowN | -6.5 | -6.6 | -4.7 | -0.3 | -0.9 | -3.5 | -0.7 |
| Ire | .. | -10.8 | -10.2 | 2 | -8.7 | -15.9 | -1.4 |
| France | .. | -10.8 | -13.5 | 0.1 | -1.9 | -4.5 | -0.3 |
| Germ | .. | -6.7 | -7.8 | 0.2 | -2.6 | -7.9 | -1.2 |
| UK | .. | -6 | -9 | -0.3 | -2.1 | -2.9 | -1.9 |
| Neth | .. | -12.6 | -32.7 | 0.5 | -7 | -17.1 | -2.2 |
| NZ | .. | 7.3 | 7.3 | -4.5 | 24.5 | 7.8 | -19.9 |
| CAN | .. | 19.4 | 2.3 | 1.9 | -3.5 | -0.1 | -5.5 |
| USA | 4.9 | 0.8 | -0.7 | 0.6 | -0.3 | 0.8 | 0.4 |
| Rest_ASIA | 0.7 | 0.1 | -0.1 | 0 | 0.2 | 0.5 | 0.3 |
| JAP | -3.6 | -56.6 | -9 | -5.1 | -8.1 | -10.3 | -2.4 |
| KOR | 3.1 | 7.8 | -33.3 | -2.4 | 0.8 | 1.2 | 2.3 |
| C_S_Amer | 1.5 | 3 | 1.6 | 0.7 | 0.9 | 2 | 0.8 |
| EFTA | .. | -18.3 | -12 | -7.5 | -16.2 | -7.1 | -2.2 |
| C_Eur | .. | 0.3 | 2.6 | -1.3 | 2.7 | 4.6 | 0.4 |
| ROW | 0.5 | -1.8 | 0.7 | 0 | 0.7 | -0.7 | -0.9 |

Source: Authors' model results

**Table A5  Changes in Farm Sector Outputs: scenario #3**

| | RICE | WHEAT | CGRAINS | O_crops | Milk | Cattle | O_lvstk |
|---|---|---|---|---|---|---|---|
| AU | 46.1 | -2 | 19.3 | -2.4 | 25.5 | 9.1 | -3.3 |
| Den_Blg | .. | -4.8 | -11.4 | -0.1 | -5 | -24 | -1.1 |
| Rest_EU | .. | -8.9 | -12.2 | -0.1 | -2.6 | -5.2 | -0.9 |
| EU_lowN | -8.8 | -9.9 | -6.7 | 0.5 | -1.2 | -5.7 | -0.5 |
| Ire | .. | -15.6 | -14.6 | 5.4 | -12.3 | -20.6 | -2.4 |
| France | .. | -15.6 | -18.6 | 1.3 | -2.4 | -7.3 | 0.2 |
| Germ | .. | -9.1 | -9.1 | 1 | -4.5 | -13.4 | -1.4 |
| UK | .. | -7.9 | -10.7 | 0.4 | -3.3 | -4.2 | -3.2 |
| Neth | .. | -17.9 | -47.2 | 1.6 | -8 | -27 | -1.7 |
| NZ | .. | 12.6 | 12.6 | -10 | 36.9 | 13.7 | -32.7 |
| CAN | .. | 29.9 | 2.8 | 4 | -10.8 | -0.3 | -10 |
| USA | 14.4 | -0.2 | -1.9 | 1.4 | 0 | 1 | 0 |
| Rest_ASIA | 0.9 | 0.4 | -0.3 | -0.1 | 0.2 | 0.9 | 0.4 |
| JAP | -6.7 | -81 | -7.8 | -6.8 | -16 | -14.3 | -2.2 |
| KOR | 4.7 | 14.1 | -50.1 | -3.9 | 0.7 | 2.7 | 4.5 |
| C_S_Amer | 1.3 | 5.1 | 2.5 | 0.3 | 1.5 | 3.9 | 1.3 |
| EFTA | .. | -47.1 | -25.2 | -10.6 | -25.5 | -15.1 | -5.3 |
| C_Eur | .. | -0.5 | 2.3 | -1.7 | 4.4 | 5.6 | -0.5 |
| ROW | 0.1 | -2.8 | 1 | -0.5 | 0.6 | -1.4 | -1.4 |

Source: Authors' model results