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The WTO, Agricultural Trade Reform and the Environment: Nitrogen and Agro-chemical Indicators for the OECD*

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The WTO Ministerial Statement of November 2001 mandates work on those situations where reduction of trade restrictions would benefit both trade and the environment. To contribute to such research, we use a modified version of the Global Trade Analysis Project (GTAP) model to estimate for OECD countries' changes in two environmental indicators resulting from simulated trade reforms: the impact on regional nitrogen balances, and associated changes in intensity of agro-chemical use. The trade reforms simulated lead to slightly improved nitrogen balances at the aggregate OECD level, with more ambitious trade reform resulting in a larger aggregate improvement. Most regions with a high initial per hectare nitrogen surplus are expected to experience some improvement in this environmental indicator at the national level. Cropping becomes less intensive in agro-chemical use in Western Europe and Northeast Asia, but more intensive in other OECD countries.

Keywords: agriculture, agro-chemicals, nitrogen balance, general equilibrium modelling, trade liberalisation

Introduction

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). Such initiatives include direct payments to farmers under environmental programmes, so long as these payments 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).

Environmental issues are included in the mandate of the current round of negotiations. They are set out in paragraphs 31 to 33 of the Ministerial Mandate (WTO, 2001). To enhance the mutual supportiveness of trade and environmental protection, paragraph 31 legitimises negotiations on the relationship between existing WTO rules and those of multilateral environmental agreements (MEAs). Amongst other things, paragraph 32 instructs the Committee on Trade and Environment (CTE) to give particular attention to situations in which the elimination or reduction of trade distortions would benefit trade, the environment and development (the so-called "win-win-win" situation[1]). In recognising the importance of capacity building in the field of trade and environment, paragraph 33 encourages the sharing of expertise and experiences with members wishing to perform environmental reviews.

After briefly reviewing some of the progress in the trade and environment negotiations, we introduce the environmental indicators that are to be used in this study. Then we describe how we modified the standard Global Trade Analysis Project (GTAP) applied general equilibrium model to incorporate these indicators. Following a description of our trade reform scenarios, we discuss our results in relation to changes in agricultural production and associated changes to our environmental indicators.

The WTO Doha Development Agenda, Agriculture and the Environment

The agricultural negotiations are being pursued in the Committee on Agriculture, and the negotiations on trade and the environment are taking place in the CTE. The Doha Mandate itself does not explicitly link the work of these two committees. However, that mandate does require (paragraph 51) both the CTE and the Committee on Trade and Development (or CTD, 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.[2] This could include, presumably, addressing those environmental aspects of the agricultural negotiations that may impinge on developing countries.

The work programme of the CTE suggests ample scope for the possibility of closer linkages to agricultural negotiations. 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".[3] To assist the CTE's discussions, the WTO Secretariat has prepared background papers[4] that include information on environmental impacts of protection and trade-distorting support in agriculture.

Within the agricultural negotiations, members have discussed environmental issues as non-trade concerns, and some have tabled proposals on the subject. The debate has not focused on whether protection of the environment is a legitimate policy goal, but on identifying the appropriate instruments with which to achieve such an objective. One group of members sees trade liberalisation and environmental protection as mutually enforcing, since protection and trade-distorting domestic support can encourage environmentally harmful agricultural practices. Such distortions, it is argued, are also linked to poverty in developing countries – a major cause of environmental degradation. Another group of member countries focuses on agriculture's positive environmental effects, including land conservation, water management and landscape maintenance. Their view is that a certain level of (assisted) farm production is necessary to ensure provision of such externalities.[5]

While many countries oppose establishing limits on green-box spending, other members have proposed such limits, either for all countries or restricted to developed countries. These limits 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 exempt green-box payments, designed to compensate for the costs accruing from higher production standards, which presumably could cover environmental standards (WTO, 2003a). Under paragraph 33 of the Doha Mandate (regarding national environmental reviews), Canada introduced in January 2003 its initial environmental assessment of the WTO trade negotiations, one conclusion of which was that further agricultural liberalisation is not likely to cause significant environmental damage since Canada's agriculture is of relatively low intensity.[6] The EU's programme on sustainability impact assessment contributed a paper (George and Kirkpatrick, 2003) to the CTE, on which discussion was recorded in WTO 2005a.

The Ministerial Declaration at the WTO 6th Ministerial in Hong Kong (WTO, 2005b) welcomed the significant work undertaken in the CTE under paragraph 31 of the Doha Mandate, and made specific reference to work under paragraph 31(i) on relationships between WTO rules and obligations under MEAs, work under 31(ii) on procedures for regular information exchange, and more recent work under paragraph 31(iii) on reducing trade barriers to environmental goods and services. Members were instructed to intensify their negotiations on all parts of paragraph 31. No mention was made of progress relating to paragraphs 32 and 33, nor were further instructions given in this regard.

This paper is motivated by paragraph 32(i) of the Doha Mandate and its reference to situations where trade reforms may be beneficial to the environment. Our focus is specifically on the agricultural negotiations. Reform of agricultural trade and associated policies could be both beneficial and harmful to the natural environment, and it is unclear how reform will influence environmental damage caused by farming. Given the potentially ambiguous effect of reform on the environment, careful modelling of the trade-environment interface and the complex interactions between farm production and the environment is required to improve understanding of the likely overall impact.

Several studies have examined linkages between agricultural trade reform and the environment (for example Leuck et al., 1995; Anderson and Strutt, 1996; OECD, 2000, 2003, 2004, 2005; Rae and Strutt, 2001; Tsigas, Gray and Hertel, 2002; Cooper, Johansson and Peters, 2003). Tsigas, Gray and Hertel are concerned with methodology and a U.S. application; Leuck et al. (the CAP) and Cooper, Johansson and Peters (the United States) focus on national policies; Rae and Strutt's paper is restricted to pollution from the livestock sector; and the OECD's programme on trade and the environment has produced several sector-specific studies (OECD 2003 examines the pig sector, OECD 2004 the dairy sector, and OECD 2005 the arable sector). We believe our research adds to this literature not only by taking an OECD-wide view, but also through addressing comprehensive trade reforms and selected specific environmental indicators in both the cropping and livestock sectors simultaneously.

Selected Environmental Indicators

There are several ways in which agricultural production can produce harmful environmental outcomes. These include impacts on soil structure, salinity and erosion, deforestation, loss of biodiversity, greenhouse gas emissions and loss of water quality due to chemical use and livestock production. Rather than measure environmental outcomes directly, an accepted approach is to utilise variables that can be shown to be linked to, or are indicative of, certain environmental outcomes. In a choice largely determined by data availability, we use two environmental indicators in this study: changes in nitrogen balances, and agro-chemical use.

Our indicators are measured at the national level. There may be localities within countries where environmental impacts are greater than indicated by national indicators, suggesting limitations of environmental analysis at a very aggregate level. Nevertheless, pollution from farming is sometimes viewed by policy-makers and the public as a 'national problem' and relevant information can be gained from national indicators. Environmental policies can be formulated at the national or super-national level (for example, the EU Nitrate Directive). In such cases policy-makers may wish to monitor trends in environmental impacts for their own country, or across countries. Slak, Commagnac and Lucas (1998) propose that national nitrogen pollution indicators could be developed and used for these purposes. National indicators were used by van Eerdt and Fong (1998) to monitor nitrogen surpluses from agriculture in the Netherlands; they concluded that over a ten-year period little progress had been made in reducing nitrogen surpluses.

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. We interpret changes in the national-level environmental indicators as trends in national environmental conditions over a similar time period. In some cases the analysis will reassure policy-makers that a reform is unlikely to have adverse impacts at the aggregate level; in other cases it will highlight 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 the national-level research will complement, and be complemented by, studies at the local or farm level.

Nitrogen balances as environmental indicators

Nitrogen is a vital input to agricultural production processes, in animal feedstuffs and in fertilisers or as nitrogen fixation by plants. Nitrogen is also a found in marketable outputs such as crops, live animals, milk and meat. But excess nitrogen may move into surface water and groundwater or be released as ammonia and nitrous oxide to the air. The adverse impact on natural systems can cause substantial human-health and economic costs.

Two nutrient balance models in use are the soil-surface and farm-gate indicators. The former measures the difference between nutrient levels entering the soil and nutrient uptake by crops. In the latter, nutrients are measured at the farm gate, and the balance reflects nutrients entering or leaving the farm system. In this current study we require national nitrogen balance indicators, and our choice of data reflects the best currently available, which is the OECD nitrogen balance database (OECD, 2001a). This database uses the soil-surface method and is a comprehensive source of national nitrogen data for 28 countries.

The nitrogen balance does not indicate the importance of the various processes of nitrogen loss or the direct impacts on groundwater or atmospheric quality. If such balances are to be used as indicators for nutrient losses, then a strong correlation between nitrogen balance indicators and actual nitrogen losses and environmental damage would be helpful. Three scientific studies that establish such a correlation are summarised in the technical annex.

Agro-chemical inputs in farm production

Agro-chemicals such as inorganic fertilisers, pesticides, fungicides and herbicides have been important in increasing crop and pasture yields. They can also result in chemical residues on food products, which may give rise to concern about food safety, can be directly harmful to human health and can result in leaching of chemicals and nutrients (such as phosphates in addition to nitrates) into surface water and groundwater, resulting in damage to soil organisms, water quality and freshwater ecosystems.

To indicate the impact of trade liberalisation on such environmental outcomes, we monitor changes in agro-chemical use relative to changes in cropland area. In this way we capture changes in chemical input intensity at the national level. This approach requires modifications to the standard GTAP trade model, which we explain below.

Greenhouse gas emissions

Agricultural production can be a major contributor to greenhouse gas emissions in some countries. Both crop and livestock production can emit nitrous oxide, ammonia, carbon dioxide and methane to the atmosphere. In this research we do not use specific measures of changes in such gas emissions resulting from trade reforms. Rather, we note Yli-Viikari and Lemola's (2004) finding that there is a clear positive correlation between nitrogen surpluses and agricultural greenhouse gas emissions. This result was observed from data on the nitrogen balance (kg/ha) and greenhouse gas emissions (equivalents/ha) for 24 OECD countries in 1995-97. Therefore, a change in the nitrogen balance indicator could also indicate a change in the same direction in greenhouse gas emissions.

The Trade and Environmental Models

The OECD nitrogen balance database and the GTAP global computable general equilibrium model are the points of departure for building an environmental module that works in tandem with a global trade model. We use a modified version of the latter to simulate the economic impacts of liberalisation scenarios and changes in agro-chemical intensity, with results directed to the nitrogen environmental side-module.

The global trade model

The standard GTAP model[7] (Hertel, 1997) is modified in two important ways. First, we allow additional input substitution possibilities, since trade liberalisation may encourage changes in production intensity such as changes to agro-chemical use per hectare and hence more or less potential environmental damage. We also allow for substitution between land and purchased feedstuffs in livestock production, since intensive use of these feedstuffs may result in emissions to surface and ground water of nitrogen and other nutrients and heavy metals (such as copper and zinc) that are contained in feeds as growth stimulants. Details of these modifications are found in the technical annex.

We explicitly model milk production quotas in EU15, the European Free Trade Association (EFTA) and Canada, since dairy farming makes a substantial contribution to nitrogen emissions in several countries. We also model sugar quotas in the EU15, where sugar beet is a relatively high user of nitrogen fertilisers (FAO, 2002). Where such quotas exist and are binding, reductions in domestic prices that might result from policy reforms would reduce rents but need not result in reduction in milk or sugar output. Our modifications are based on Lips and Rieder (2005); details are also found in the technical annex.

Aggregation of the GTAP database

The GTAP Version 6 database (benchmarked to 2001) is aggregated to 16 OECD and 3 non-OECD regions. Five of the EU15 countries are individually specified, with those remaining aggregated into three groups reflecting their agricultural N-balances per hectare. Denmark and Belgium are grouped together, as they (along with the Netherlands) exhibited the highest per hectare N-balances. Austria, Italy and Greece exhibited the lowest N-balances and are grouped as EU_lowN. Remaining EU15 countries are grouped into the Rest of EU.[8] Of other OECD countries, N-balances were highest in South Korea and also relatively high in Japan, and both are modelled separately. Three regional groupings are used to model non-OECD countries, but nitrogen balances are not available for these. Production sectors are aggregated up to 17, with 13 of these representing farm and processed food production. We focus on the 8 sectors for which nitrogen balances are computed: rice; wheat; coarse grains; sugar crops; other crops; milk; cattle and sheep; and other livestock.[9] The processed sugar sector is modelled separately to better capture the linkage between changes to sugar tariffs and the derived demand for sugar crops. Agro-chemicals are included in

GTAP's chemicals sector. All other sectors are included in either the natural resources, manufacturing or services aggregates.

The nitrogen model and its linkage to GTAP

The OECD nitrogen database[10] contains very detailed data by country, particularly in the case of nitrogen coefficients for crops and livestock. Much of the basic data, such as for livestock numbers, crop production and fertiliser use, are taken from official sources. Nitrogen coefficient estimates from agricultural research institutes and published literature are used to convert these data into nitrogen equivalents (OECD, 2001b). Nitrogen coefficients differ between countries for many reasons, for example, different agro-ecological conditions, variation in livestock weights and yields and variation in methods used to estimate coefficients (OECD, 2001b). 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. A detailed description of this model is found in the technical annex.

Table 1 Summary of Nitrogen Inputs and Uptake Mechanisms

Nitrogen Inputs	**Nitrogen Uptake**
Inorganic or chemical nitrogen fertilisers	Harvested crop production
Net livestock manure nitrogen production[a]	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).

This model, with its very detailed data, was aggregated to be compatible with our GTAP data aggregations.[11] A summary of the total nitrogen balance by region is provided in table 2. The nitrogen model is linked to GTAP by assuming all coefficients of the nitrogen model are invariant to changes in trade policy and, by implication, to changes in the levels of agricultural inputs and outputs. The GTAP solution variables are used to compute changes to the nitrogen model variables.

Table 2 Initial Nitrogen Balances

	Nitrogen balances (000 tonnes)	Nitrogen balances (kg/ha)
Australia	3,566	7.6
NZ	370	27.4
Japan	641	129.5
Korea	498	250.4
Canada	1,159	15.5
USA	12,524	29.9
EU_lowN	719	29.5
Denmark/Belgium	554	134
France	1,517	50.6
Germany	976	56.4
UK	1,477	86.7
Ireland	401	80
Netherlands	511	262.1
Rest of EU	1,826	47.4
EFTA	184	70.3
C. Europe	699	24.2

Source: Authors' calculations based on the adjusted OECD Nitrogen Balance Database. Positive values imply nitrogen inputs exceed uptake.

Nitrogen uptake 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 uptake will change by the same proportion as the level of output in each crop sector.[12] Uptake of nitrogen by forage and pasture consumed (which is already aggregated over animal types in the OECD database), is assumed to change from the base level in proportion to the change in livestock units summed over dairy cows, other cattle, sheep and goats. Livestock units are computed using the coefficients of Sere and Steinfeld (1995). Data on livestock numbers are taken from the OECD nitrogen database, and these are assumed to change in proportion to changes in the relevant GTAP output variables.

The largest sources of nitrogen inputs in most countries are livestock manure and fertilisers. Changes in nitrogen from livestock manure are assumed to occur in proportion to output of each livestock type. Nitrogen withdrawals due to changes in manure stocks and imports are assumed to maintain the same ratio to livestock manure as in the benchmark database. The OECD database does not provide fertiliser use by crop, only the total nitrogen input from fertilisers (F_i – see technical annex). We obtained the additional country- and crop-specific N-fertiliser consumption data from FAO (2002).[13] For each country, these consumption data were aggregated up to our farm sector aggregation. These values were then (if necessary) scaled to sum to the F_i values in the OECD database. N-fertiliser inputs to modelled crops and pasture then change in proportion to the modelled change in use of agro-chemicals in each farm sector.

The other important nitrogen input is biological nitrogen fixation by free-living soil organisms on agricultural land and 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 changes in proportion to changes in land use for the 'other crops' sector, appropriate given our aggregation of the GTAP cropping sectors.[14]

Liberalisation Scenarios and Results

Liberalisation scenarios

The scenarios we model reflect certain elements of some of the agricultural proposals made during the current WTO round. The two scenarios modelled (table 3) draw on the Doha Draft Ministerial Text prepared for the Hong Kong Ministerial Conference (WTO, 2005b), which text reflects the range of proposals and offers made at that stage in the negotiations. For tariff cuts, four bands are specified, based on those presented in WTO 2005b. In each case, a range of tariff cuts was given that portrayed the extent of existing divergences in the proposals. The minimum tariff cuts are included in scenario #1 and the maximum cuts in scenario #2. Export subsidies are eliminated in all developed countries, but not in developing countries in recognition of their minor use of export subsidies and the commitment to special and differential treatment.

It is debatable whether reductions in trade-distorting domestic support will have a significant impact on production, for at least two reasons. First, while the Hong Kong draft indicates the possibility of non-green domestic support being cut substantially, recent actual spending in several countries has been below bound levels. Therefore those proposed cuts would result in lower cuts in actual spending and by our calculations no change at all in some cases. Second, some governments have been increasing their green-box spending in 'compensation' for cuts in trade-distorting support. For these reasons, we chose not to model reforms to domestic subsidy spending.

Table 3 Trade Liberalisation Scenarios

Item	Scenario #1	Scenario #2
Change in tariffs[a]		
Developed regions		
Tariffs in range 0%-25%	-20%	-65%
25%-50%	-30%	-75%
50%-75%	-35%	-85%
Over 75%	-42%	-90%
Developing regions		
Tariffs in range 0%-35%	-15%	-25%
35%-70%	-20%	-30%
70%-100%	-25%	-35%
Over 100%	-30%	-40%
Change in export subsidy spending		
Developed regions	-100%	-100%
Developing regions	nil	nil

[a] Agricultural and food tariffs only

Changes in the location and level of farm production

To save space, only results for the first, more modest reform scenario will be presented.[15] Output of most farm sectors (table 4) with the exception of wheat and other crops are simulated to increase in Australia. For New Zealand, all crop sectors with the exception of other crops expand somewhat. The largest expansion is for milk, while for the cattle and sheep and other livestock sectors, some declines in production are simulated. Production of most commodities tends to decline in EU regions, and also in the EFTA countries and Japan. The exceptions are some relatively small increases in other crops (which includes horticulture) in many EU regions and coarse grains in EFTA. Of the commodities constrained by quotas, sugar rents decline, but not output, in France and Germany; however, output of sugar beets falls below quota in other EU regions, most noticeably in the Netherlands and Ireland. Milk output falls below quota in all EU regions except for the Netherlands and Germany. The milk quotas remain binding in Canada and the EFTA region. All crop sectors except other crops expand in Canada, as do cattle and non-ruminant livestock production. The United States is simulated to experience increases in all sectors, apart from a marginal decline in sugar crops. Livestock farming and wheat production also exhibit some expansion in South Korea.

Table 4 Changes in Farm Sector Outputs (%): Scenario #1

	Rice	Wheat	Coarse grains	Sugar crops	Other crops	Milk	Cattle & sheep	Pigs & poultry
Australia	19.8	-0.6	11	3	-2.8	9.3	3.3	0.1
NZ		0.6	2.7		-3.3	18.1	-7.2	-3.7
Japan	-4.7	-45.8	-6.3	-4.8	0	-1.1	-7.1	-5.6
Korea	-2.4	5.9	-12.9	0.4	-1.6	1.8	3.5	4
Canada		4.2	3.7	-7.1	-1	0	0.6	1.2
USA	11.8	0.8	0.9	-0.7	0.1	0.1	1.2	1.5
EU_lowN	-9.8	-2	-3.3	-3.7	-0.1	-3.2	-5	-0.8
Denmark/Belgium		-1.5	-9.1	-5.3	0.2	-12.8	-15.3	-2.8
France		-6.6	-5.6	0	0.7	-1.9	-2.8	-0.7
Germany		-4.5	-7.4	0	1.6	0	-11.2	-1.2
UK		-0.5	-3.7	-10.3	-0.1	-0.6	-3.1	-2.1
Ireland		-5.5	-6.6	-15.5	2.6	-6.9	-14.9	0.7
Netherlands		-4	-6.5	-14.4	0.2	0	-17.2	-5.7
Rest_EU		-0.8	-7.7	-6.9	0.6	-3.2	-6.2	-0.9
EFTA		-19.6	7.3	-0.7	-3.7	0	-5.6	-6.7
C. Europe		0.9	0.6	-0.1	-0.3	0.5	0.7	0.1

Some Environmental Impacts of Trade Reform

Impacts of agricultural trade reform on nitrogen balances

We find that trade liberalisation may lead to a small reduction in the aggregate nitrogen balance for OECD countries from the base-year level. The initial 27.6 million tonne nitrogen balance for the whole OECD region is simulated to fall by 171 thousand tonnes (0.62 percent) in the first scenario (final row of table 5). In the second scenario, the overall nitrogen balance is simulated to fall by 560 thousand tonnes (2.03 percent). To the extent that nitrogen balances are reduced and there is a lower level of surplus nitrogen that can cause damage to soil, air and water, it might be expected that environmental outcomes improve.

Changes in the nitrogen balance can be separated into changes in uptake and inputs of nitrogen. Relative to the initial levels, total nitrogen uptake for OECD countries reduces by 0.4 percent of the initial value in the first scenario (final row of table 5) and by 1.1 percent in the 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). However, 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 0.5 percent of the initial value in the first scenario and by 1.5 percent in the second. The main drivers of the reduced nitrogen inputs are lower overall fertiliser use and reduced manure from the cattle and sheep sector. These reductions in nitrogen inputs are sufficient to outweigh the increases in nitrogen inputs simulated for other components such as dairy manure. The other livestock sector is also simulated to slightly increase its total nitrogen inputs, as is biological nitrogen fixation by leguminous crops.

Table 5 Changes in Nitrogen Balance and Components (000 tonnes): Scenario #1

	Harvested crops	Forage and pasture	***Total nitrogen uptake***	Net livestock manure	Fertiliser	Other nitrogen inputs [a]	***Total nitrogen inputs***	**Nitrogen balance**
Australia	21	164.9	***185.9***	76.6	23	-5.3	***94.3***	**-91.5**
NZ	0.1	-1.2	***-1.1***	-14.4	9	-17.9	***-23.3***	**-22.2**
Japan	-17.1	-10.7	***-27.8***	-24	-20.3	0.5	***-43.8***	**-16**
Korea	-5.9	0.4	***-5.5***	10	-13.4	-0.1	***-3.5***	**1.9**
Canada	54.3	4	***58.3***	8.2	37.6	-3.2	***42.7***	**-15.7**
USA	53.5	88.5	***142.1***	104.4	101.1	-15.6	***189.9***	**47.8**
Denmark/Belgium	-10.2	-33.6	***-43.8***	-44	-28.9	0.5	***-72.4***	**-28.6**
Netherlands	-3	-11.3	***-14.3***	-18.8	-19	0.1	***-37.7***	**-23.5**
Rest of EU	-205.7	-267.7	***-473.5***	-220.4	-275	15.2	***-480.2***	**-6.7**
EFTA	-1.7	-6.9	***-8.6***	-7.2	-13.3	-0.5	***-21***	**-12.4**
C. Europe	6.4	5.3	***11.6***	3.1	4.5	-0.5	***7.1***	**-4.5**
Total OECD	-108.4	-68.1	***-176.5***	-126.4	-194.7	-26.8	***-347.9***	**-171.3**

[a] Biological nitrogen fixation by leguminous plants.

The decrease in the OECD nitrogen surplus is also found to occur in most of the OECD countries or regions. Changes in the regional nitrogen balances are driven by changes in sectoral outputs, livestock units, fertiliser and land use. For this section of the discussion, with the exception of the particularly high nitrogen surplus regions of Denmark/Belgium and the Netherlands, we aggregate the EU results into a single region (Rest of EU). Both simulations show nitrogen balances reducing from their initial levels for nine of the eleven regions in figure 1. Korea is the only OECD country simulated to experience an increase in its nitrogen balances under both scenarios. The largest absolute reduction in nitrogen balance is found for Australia in both scenarios, although the largest percentage reductions are for EFTA, New Zealand, Denmark/Belgium and the Netherlands.[16] We also mention in passing that the findings of Yli-Viikari and Lemola (2004) would suggest that greenhouse gas emissions from agriculture in these countries or regions are also likely to decline with trade liberalisation.

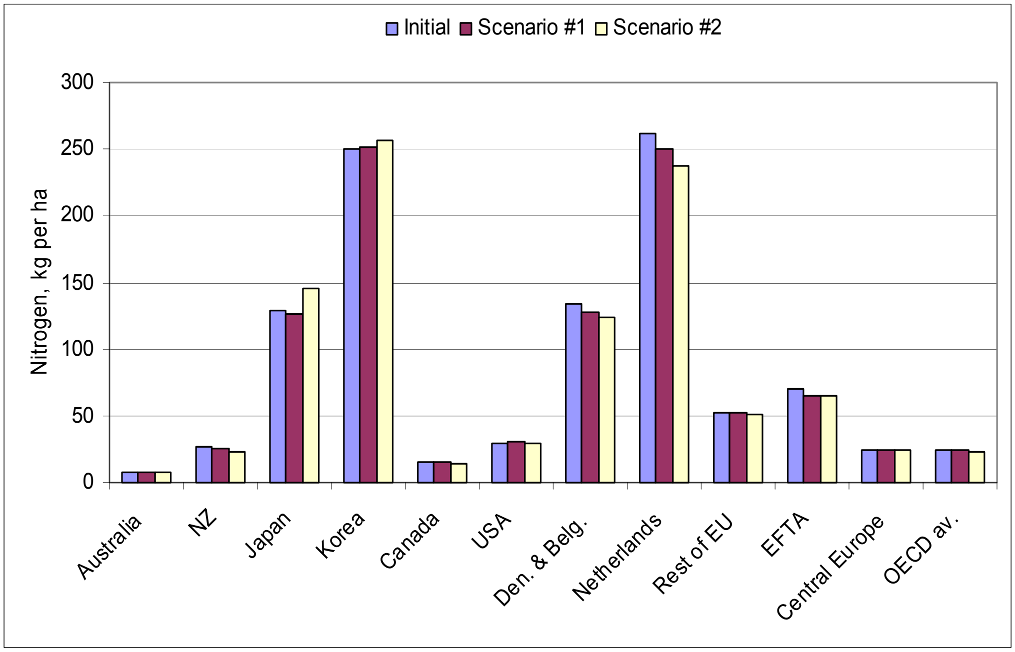

Figure 1 Nitrogen balances by OECD region (kg/ha).

Australia's nitrogen balance reduces by 92 thousand tonnes in the first scenario, or by 2.6 percent from the initial level of nitrogen surplus. While we simulate an increased level of nitrogen inputs, increases in nitrogen uptake are much larger in magnitude. The increased uptake by pasture is the key driving force behind the anticipated improvement in the overall nitrogen balance. This arises with the strong increases in output from the dairy sector and the cattle and sheep sector. The large beef cattle and sheep sector increases by 3.3 percent in scenario #1 (table 4), leading to much of the 3.7 percent increase in nitrogen uptake by pasture. Increased output in the livestock sectors leads to increased manure output; however this effect dampens, rather than overturns, the overall improvement in the nitrogen balance for Australia.

For New Zealand, in the first scenario we simulate a reduction in the nitrogen balance of 22 thousand tonnes, or of 6 percent from the initial balance reported in table 2. From table 5, we see that the cause is primarily the reduction in nitrogen inputs. This is due largely to lower levels of biological nitrogen fixation, which, for New Zealand, contributes around a quarter of nitrogen inputs in the base data. Therefore any change in this component is likely to heavily influence results. The nitrogen input from manure is also simulated to reduce a little for New Zealand, and input from fertiliser is simulated to increase somewhat, while uptake of nitrogen by pasture is simulated to reduce. Table 4 indicates that output of milk in New Zealand increases by 18 percent in scenario #1, while output of the larger manure-producing cattle and sheep sector decreases by over 7 percent, and the other livestock sector declines by almost 4 percent. These changes result in a small net reduction in manure, while implying an overall reduction in cattle and sheep livestock units of 0.07 percent, contributing to a slightly reduced uptake of nitrogen from pasture.

The relatively large reductions in nitrogen balances for the Netherlands and Denmark and Belgium are due to nitrogen inputs declining more significantly than nitrogen uptake. In each of these regions, the reduced inputs are due to decreases in manure and fertiliser inputs. This outcome is not surprising, as all farm sectors contract for these countries, with the exception of the other crops sector and the milk sector in the Netherlands. There is reduced uptake of nitrogen by the crop sectors and also by pasture and forage; however this reduced uptake is not sufficient to outweigh the reductions in nitrogen inputs. A somewhat similar situation is obtained for the EFTA region and Japan.

While increases in nitrogen balances are projected for two OECD countries, the increases are rather small, particularly in terms of the initial nitrogen balance in each case. The increase in the nitrogen surplus for the United States in the first simulation is less than 0.4 percent of the initial level, and for South Korea the nitrogen surplus is projected to increase in both scenarios, but only by 2.7 percent even in the relatively ambitious second scenario.

The increases in nitrogen surplus may pose some environmental problems for the affected countries; however, these are not generally anticipated to be large problems at the aggregate level for several reasons. The United States has a relatively low initial nitrogen balance of 30 kg per hectare (table 2), and the small increase in scenario #1 would only raise the balance to slightly over 30 kg per hectare. In the case of South Korea, the initial nitrogen balance is relatively high, at 250 kg per hectare, but would increase under trade reform only to 251 kg.

Impacts of agricultural trade reform on agro-chemical use

Substitution between agro-chemical use and land may also play a role, driven primarily by simulated changes in land prices. Table 6 indicates, for some farm sectors, the direction of change in sectoral demands for agro-chemicals and land in the OECD regions. Regions that exhibit increasing (decreasing) land use and decreasing (increasing) agro-chemical use are becoming less (more) intensive, which may provide environmental benefits (costs). Where demands for both inputs are moving in the same direction, it is not immediately clear whether production is intensifying or not. Answers are found in table 7, which shows the difference between the change in demand for agro-chemicals and that for land; where this change is positive (negative), crop production is becoming more (less) intensive with trade liberalisation. We find that cropping generally becomes less chemical-intensive following liberalisation in the

EU, EFTA, Japan and Korea (all relatively high N-balance regions). Arable crop sectors in these regions generally contract, and chemical use decreases by more than does the demand for land (in a few cases, land use actually increases). The other crops sector expands with liberalisation in some EU regions, but in all cases production becomes less chemical-intensive. Generally, for other OECD countries crop production becomes more intensive following liberalisation.

For the land-feedstuffs substitution in ruminant livestock production, we find that where liberalisation results in an expansion of output (usually relatively low N-surplus regions), production becomes more intensive in purchased feedstuffs relative to land, the one exception being Korea. In other regions where production is simulated to decline (EU, EFTA and Japan), production becomes less intensive in feedstuffs relative to land.

Table 6 Country Groupings in Terms of Changes in Intensity of Agro-chemicals and Feedstuffs Usage: Scenario #1

	Wheat		Coarse grains		Other crops		Milk		Cattle & sheep	
	Agro-chems.+	Agro-chems.–	Agro-chems.+	Agro-chems.–	Agro-chems.+	Agro-chems.–	Feeds+	Feeds–	Feeds+	Feeds–
Land+	Canada USA Korea C.Eur	Den/Blg Rest_EU UK	Australia NZ Canada USA EFTA C.Eur		Rest_EU Ireland France Germany Neth	EU_LowN UK Japan Den/Blg	Australia NZ Korea C.Eur	All other EU EFTA Japan	Australia Korea C.Eur	Rest_EU France UK
Land–	NZ	Australia All other EU Japan EFTA		All of EU Japan Korea	USA	NZ Canada Korea EFTA C.Eur	Canada USA	Den/Blg	Canada USA	Den/Blg EU_LowN Ireland Germany Neth NZ Japan EFTA

Note: Land+, Feeds+ and Agro-chems.+ imply increased sectoral demands; Land–, Feeds– and Agro-chems.– imply the reverse.

Table 7 Change in Agro-chemical or Purchased Feed Use Relative to Land: Scenario #1[a]

	Rice	Wheat	Coarse grains	Sugar crops	Other crops	Milk	Cattle & sheep
Australia	2.5	0.4	1.6	0.7	0.2	4.3	2.4
Den/Blg	..	-3.3	-3.8	-3.6	-3.2	-13.1	-13.1
Rest_EU	..	-2.2	-2.7	-2.6	-2.1	-7.5	-8.1
EU_lowN	-2	-1.4	-1.5	-1.6	-1.3	-4.7	-4.8
Ireland	..	-4	-4	-4.5	-3.5	-12.4	-14
France	..	-3	-3	-2.6	-2.6	-8.5	-7.9
Germany	..	-2.9	-3.1	-2.6	-2.5	-7.6	-9.2
UK	..	-1	-1.3	-1.8	-1	-2.8	-3.7
Neth.	..	-1.6	-1.8	-2.4	-1.3	-4.2	-8.3
NZ	..	1.7	2	..	1.3	12.1	2.5
Canada	..	1.1	1.1	0.1	0.6	2.5	2.4
USA	1.7	0.6	0.6	0.5	0.5	1.6	1.9
Japan	-2.3	-4.2	-2.4	-2.3	-2	-5.6	-6.6
Korea	-2.1	-1.5	-2.8	-1.9	-2.1	-2.8	-2
EFTA	..	-3.7	-2	-2.6	-2.8	-6.3	-5.8
C. Europe	..	0.1	0.1	0	0	0.3	0.3

[a] Data are percent change in demand for agro-chemicals (in crops) or purchased feedstuffs (livestock), less percent change in land demands.

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, in terms of high tariffs and 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 use of nitrogen inputs and less agro-chemical use relative to land in cropping. 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 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).

Even in the absence of specific environment-enhancing policies and activities, we find that the trade liberalisations modelled are likely to reduce the nitrogen balances for most OECD countries, and lead to less intensive use of agro-chemicals in the more highly protected agriculture of Western Europe and Northeast Asia. While we did not model changes in environmental policy, improved policy ought to be considered if the simulated environmental damage remaining after trade policy reforms is to be reduced or avoided.

There are of course a number of important trade-offs and limitations with this type of study. With our focus on global trade reforms, we had to work at an aggregate level of analysis that required us to treat nitrogen and agro-chemical pollution as 'national' problems. 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 in regard to nitrogen pollution, we recall Vanongeval and Bomans' (1997) 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, 2001a). Local-level studies, such as OECD 2005, which used U.S. and Canadian regional models, will therefore complement the current study.

Changes in other (non-agricultural) sectors and in non-OECD countries will also affect the international level of environmental damage, but the data were not available to include these in our analysis. Furthermore, we note that agricultural pollution is multi-dimensional although we have focused on only two environmental indicators.[17] Finally, we made no attempt 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 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.

References

Anderson, K. and Strutt, A. (1996). On measuring the environmental impact of agricultural trade liberalization. In Bredahl, M.E., Ballenger, N., Dunmore, J.C. and Roe, T.L. (eds), *Agriculture, Trade and the Environment: Discovering and Measuring the Critical Linkages*. Boulder, Colorado: Westview Press, 151-72.

Bechmann, M., Eggestad, H.O and Vagstad, N. (1998). Nitrogen balances and leaching in four agricultural catchments in southeastern Norway. *Environmental Pollution* 102 (S1): 493-499.

Cooper, J., Johansson, R. and Peters, M. (2003). Some domestic environmental effects of U.S. agricultural adjustments under liberalised trade: A preliminary analysis. Presented to the International Conference on Agricultural Policy Reform and the WTO, International Agricultural Trade Research Consortium, 23-26 June, Capri, Italy.

De Clercq, P., Gertis, A.C., Hofman, G., Jarvis, S.C., Neeteson, J.J. and Sinabell, F. (2001). *Nutrient Management Legislation in European Countries.* The Netherlands: Wageningen Pers.

FAO (2002). *Fertiliser Use by Crop* (5th edition). Food and Agricultural Organisation, United Nations, Rome.

Frandsen, S.E., Jensen, H.G., Yu, W. and Walter-Jorgensen, A. (2003). Reform of EU sugar policy: price cuts versus quota reductions. *European Review of Agricultural Economics* 30(1): 1-26.

George, C. and Kirkpatrick, C. (2003). Sustainability Impact Assessment of Proposed WTO Negotiations: Preliminary Overview of Potential Impacts of the Doha Agenda. Final Report. Institute of Development Policy and Management, University of Manchester, June.

Harrison, W.J. and Pearson, K.R. (1996). Computing solutions for large general equilibrium models using GEMPACK. *Computational Economics* 9: 83-127.

Hertel, T.W. (ed.) (1997). *Global Trade Analysis: Modelling and Applications.* Cambridge and New York: Cambridge University Press.

Jensen, H.G. and Frandsen, S.E. (2003). Impacts of the Eastern Enlargement Accession and the 2003 Reform of the CAP: Consequences for Individual Member Countries. Working Paper No. 11. Copenhagen: Danish Research Institute of Food Economics.

Ledgard, S.F., Crush, J.R. and Penno, J.W. (1998). Environmental impacts of different nitrogen inputs on dairy farms and implications for the Resource Management Act of New Zealand. *Environmental Pollution* 102 (S1): 515-519.

Ledgard, S.F., Penno, J.W. and Sprosen, M.S. (1999). Nitrogen inputs and losses from clover/grass pastures grazed by dairy cows, as affected by nitrogen fertiliser application. *Journal of Agricultural Science* 132: 215-225.

Leuck, D., Haley, S., Liapis, P. and McDonald, B. (1995). The EU Nitrate Directive and CAP Reform: Effects on Agricultural Production, Trade, and Residual Soil Nitrogen. Foreign Agriculture Economic Report No. 255. Economic Research Service, U.S. Department of Agriculture (USDA). Washington DC: USDA.

Lips, M. and Rieder, P. (2005). Abolition of raw milk quota in the European Union: A CGE analysis at the member country level. *Journal of Agricultural Economics* 56: 1-17.

Meilke, K., Sarker, R. and Le Roy, D. (1998). The potential for increased trade in milk and dairy products between Canada and the United States under trade liberalisation. *Canadian Journal of Agricultural Economics* 46: 149-169.

OECD. (2000). *Assessing the Environmental Effects of Trade Liberalization Agreements: Methodologies.* Paris: OECD.

OECD. (2001a). *OECD National Soil Surface Nitrogen Balances: Explanatory Notes.* Paris: OECD.

OECD. (2001b). *Environmental Indicators for Agriculture: Volume 3 Methods and Results*. Paris: OECD.

OECD. (2003). *Agriculture, Trade and the Environment: The Pig Sector*. Paris: OECD.

OECD. (2004). *Agriculture, Trade and the Environment: The Dairy Sector*. Paris: OECD.

OECD. (2005). *Agriculture, Trade and the Environment: The Arable Crop Sector*. Paris: OECD.

Parfitt, R.L., Schipper, L.A., Baisden, W.T. and Elliott, A.H. (2006). Nitrogen inputs and outputs for New Zealand in 2001 at national and regional scales. *Biogeochemistry* 80:71-88.

Rae, A.N. and Strutt, A. (2001). Livestock production and the environment: Some impacts of growth and trade liberalisation. *New Zealand Economic Papers* 35:176-194.

Sere, C. and Steinfeld, H. (1995). World Livestock Production Systems: Current Status, Issues and Trends. FAO Animal Production and Health Paper 127. Food and Agricultural Organisation of the United Nations. Rome: FAO.

Slak, M-F., Commagnac, L. and Lucas, S. (1998). Feasibility of national nitrogen balances. *Environmental Pollution* 102 (S1): 235-240.

Strutt, A. and Anderson, K. (2000). Will trade liberalization harm the environment? The case of Indonesia to 2020. *Environmental and Resource Economics* 17: 203-232.

Surry, Y. (1990). Econometric modelling of the European compound feed sector: An application to France. *Journal of Agricultural Economics* 41: 404-421.

Tsigas, M.E., Gray, D. and Hertel, T.W. (2002). How to Assess the Environmental Impacts of Trade Liberalisation. Fifth Annual Conference on Global Economic Analysis, 5-7- June, Taipei, Taiwan.

Van Eerdt, M.M. and Fong, P.K.N. (1998). The monitoring of nitrogen surpluses from agriculture. *Environmental Pollution* 102 (S1): 227-233.

Vanongeval, L. and Bomans, E. (1997). Surplus Calculations as a Potential Indicator for Nutrient Losses from Agriculture to the Aquatic Environment. Study on behalf of the Land Department of Animal, Ministry of the Flemish Community. Environment, Nature and Water Management Administration: Brussels.

WTO. (1997). Environmental Benefits of Removing Trade Restrictions and Distortions, Committee on Trade and Environment, WT/CTE/W/67. 7 November. Geneva: WTO.

WTO. (2001). Ministerial Conference – Fourth Session – Doha, 9-14 November 2001 – Draft Ministerial Declaration, WT/MIN(01)/DEC/W/1. 14 November. Geneva: WTO.

WTO. (2003a). Environmental Issues Raised in the Agricultural Negotiations – Statement by Mr Frank Wolter at the Regular Session, WT/CTE/GEN/8. 18 February. Geneva: WTO.

WTO. (2003b). Report to the 5th Session of the WTO Ministerial Conference in Cancun, Committee on Trade and Environment, WT/CTE/8. 11 July. Geneva: WTO.

WTO. (2003c). Initial Environmental Assessment: Trade Negotiations in the World Trade Organisation – Submission by Canada. WT/CTE/W/221. 24 January. Geneva: WTO.

WTO. (2005a). Committee on Trade and Environment: Report of the Meeting Held on 11 October 2005. WT/CTE/M/41. 30 November. Geneva: WTO.

WTO. (2005b). Doha Work Programme Preparations for the Sixth Session of the Ministerial Conference Draft Ministerial Text, JOB(05)/298/Rev.1. 1 December. Geneva: WTO.

Yli-Viikari, A. and Lemola, R. (2004). Usability of management indicators – considerations from a Finnish perspective. OECD Expert Meeting on Farm Management Indicators and the Environment. Palmerston North, New Zealand. Accessed at http://webdomino1.oecd.org/comnet/agr/farmind.nsf/viewHtml/index/$FILE/Viitkari.PDF, 10 October 2006.

Endnotes

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1. http://www.wto.org/english/tratop_e/envir_e/envir_backgrnd_e/c4s1_e.htm
2. The CTD has a mandate to review all special and differential treatment provisions for developing and least-developed countries.
3. http://www.wto.org/english/tratop_e/envir_e/cte05_e.htm
4. WT/CTE/W/67 (7 November 1997) examines various sectors including agriculture, and WT/CTE/GEN/8 (18 February 2003) covers specifically the environmental issues raised in the agricultural negotiations.
5. WT/CTE/8, 11 July 2003.
6. WT/CTE/W/221, 24 January 2003.

7. See www.gtap.org for a detailed description of the GTAP model and database. We solve GTAP using GEMPACK (Harrison and Pearson, 1996).
8. Excluding new members admitted on 1 May 2004.
9. Mainly pigs and poultry.
10. The database is accessible at http://www.oecd.org.
11. The base year is 1997, reflecting the most recently available OECD data. Mexico and Turkey are excluded since these countries are aggregated with non-OECD countries in our GTAP data aggregation. 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. We also make significant changes to the nitrogen data for New Zealand, reflecting improved and updated information and the unique nature of New Zealand's mainly pastoral farming systems (Parfitt et al., 2006). Further details can be obtained from the authors.
12. Consistent with assumptions used in the OECD nitrogen balance calculations.
13. These fertiliser data were from 1998 (Japan and the United States), 1996 (Korea), 1999/2000 for EU15 countries and Switzerland and 2000 for other OECD countries.
14. 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.
15. Results from the more liberal second scenario are not discussed in detail here since the patterns of changes to regional farm production and the environmental indicators remain largely similar to those described above, although of greater magnitude. For example, milk production is now simulated to fall below quota in all EU regions with the exception of the Netherlands, and sugar beet output falls below quota in all regions of the EU. Other notable changes include a substantially larger increase in rice production in Australia and the United States, a larger decline in rice and wheat production in Japan and greater dairy expansion in New Zealand. Further details are of course available from the authors.
16. The latter two regions have particularly high initial nitrogen balances, as indicated in table 2.
17. As data for other regions and other indicators become available, these shortcomings can of course be rectified.

The technical annex to this paper, pages 32-36 is available as a separate document.