LIVESTOCK PRODUCTION AND THE ENVIRONMENT

An initial assessment of some impacts of trade liberalisation

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SUMMARY

In many regions of the world, consumption patterns are changing from traditional foods to value-added and high-protein foods including livestock products. Economic incentives, sometimes enhanced by policy inducements, have been both increasing the output and intensity of livestock production in many regions. One result has been increased pressures on natural environments and water and atmospheric pollution from increased livestock production. Such environmental problems are projected to worsen in future in the absence of new environmental policies as demands for livestock products continue to grow. However, liberalization of international trade policies as in the Uruguay round Agreement are shown to have the effect of reducing livestock production in some densely-populate regions and hence improving environmental quality.

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1. INTRODUCTION

The way in which dietary patterns are changing in many parts of the world as economic growth and development proceeds is now well documented. Due to factors such as income growth, urbanisation and the modernisation of marketing infrastructures, consumption patterns are switching from an emphasis on traditional foods (such as some cereals and root crops) to non-traditional cereals (eg wheat-based foods) and value-added processed and high-protein foods such as those derived from animal products (Huang and Bouis 1996, Huang and David 1993, Rae 1997 and 1998). 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. This typically involves a switch in the domestic utilisation of grains from human consumption to feeding of livestock.

The need to feed growing populations, together with the desire to increase income levels, employment and foreign exchange earning, have placed heavy pressure on global supplies of land and natural resources. For a variety of reasons, some countries including several in Asia 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 demands. Such assistance has in some cases led to more intensive livestock farming systems, to a shift from backyard to commercial production units and to self-sufficiency in the production of some meats and milk. Even so, the sustainability of such self-sufficiency into the future must be questioned. The development of intensive livestock systems has caused concerns over waste disposal – animal densities per hectare of cropland are much higher in Asian countries than for the USA, for example (Taha 1992). Environmental degradation such as water and atmospheric pollution from increased livestock production, as well as increasing pressures on land and labour resources, are all increasing the private and social marginal costs of livestock production in these and other regions.

The above demand and supply factors have contributed to a rapid increase in world trade in coarse grains. In response to demand changes, many countries have assisted and expanded domestic livestock production and found their demand for animal feeds exceeded their ability to supply from domestic sources. But in more recent times, the rate of growth of global trade in coarse grains has slowed considerably, while that of global trade in meats has continued to increase. Also, the share of value-added agricultural products (including processed livestock products) has over recent times been increasing relative to total global agricultural trade. As a consequence, much recent debate has centered on the impacts of such consumption and production changes on world food markets, especially those for grains. Also of interest, however, is the manner in which such changes in the location of livestock production and in patterns of international trade in livestock products impact on the levels and location of resulting environmental damage.

The first objective of this paper is to determine the likely impact of some of the above global demand and supply developments on the location of livestock production and hence changes in the regional severity of environmental damage from livestock pollution. This is attempted through modeling a projection of the world economy over a 10-year period. This analysis allows for no changes in policies, including no recognition of policies that may target reductions in livestock environmental damage over that 10-year period. In this sense, it is a worst-case scenario. The paper's second objective is to determine what effects the reform and liberalization of agricultural trade, in particular that of the Uruguay Round, might have on environmental pollution due to livestock production. This is considered to be of interest since a new Round of trade negotiations is about to begin, and because the belief is held by some that agricultural trade liberalisation is a cause of increased environmental pollution. The next section reviews the nature and extent of environmental degradation due to livestock production, makes the case for the study's focus on nitrogen pollution, and presents some data. The following section presents two studies of policy reforms and environmental damage from livestock production. The first looks at New Zealand's domestic reforms since the mid-1980s, while the second is an analysis of the impacts of the Uruguay Round on livestock production and environmental impacts.

2. ENVIRONMENTAL DEGRADATION FROM LIVESTOCK PRODUCTION

2.1.1 The nature of environmental degradation from livestock

Livestock can offer both positive and negative impacts on the physical environment. In extensive grazing systems, problems tend to be the degradation of soils and deforestation. As livestock production systems intensify towards industrial and feedlot systems, water pollution and manure disposal issues become more serious.

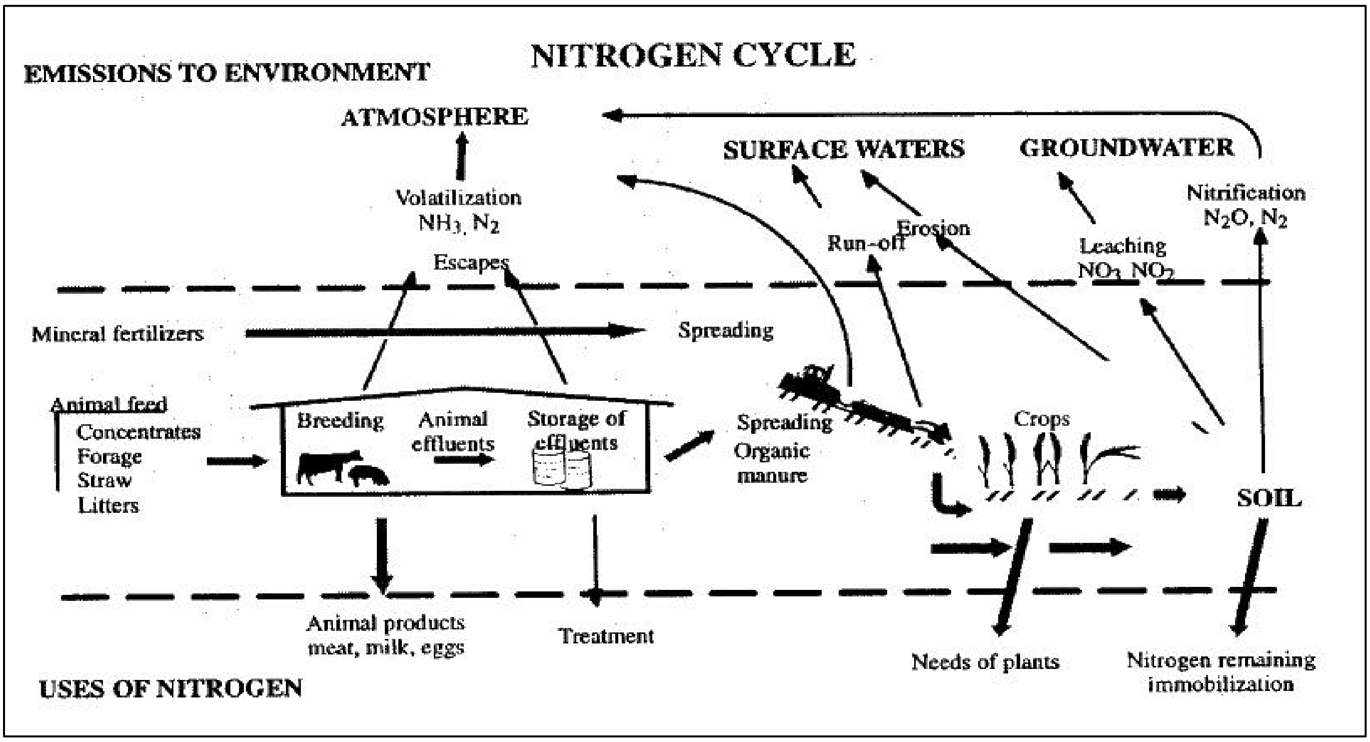
Pollution from livestock farming can affect the atmosphere, surface water and groundwater. Livestock produce around 13 billion tonnes of waste annually – while a large part of this is recycled, such waste can pose enormous environmental problems. Animal manure is an environmental hazard due to its high concentration of nitrate, phosphate, potassium and ammonia. For example 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 as growth stimulants, such as copper and zinc. Their addition to the soil can also 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 leads to eutrophication of fresh and coastal water and contamination of groundwater, and threatens the quality of drinking water and damage to aquatic and wetland ecosystems. In surface water, nutrients may cause excessive growth of algae and fish kills. High levels of nitrates in drinking water can cause methemoglobinemia which can be fatal to infants.

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% of 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 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% (Steinfeld et al 1997)

About 26% of the world's land area is used to graze livestock. Grazing animals can improve the soil cover through controlling unwanted vegetation and through manure. But other environmental damage caused by livestock farming includes soil degradation, compaction and erosion due to overgrazing. More commonly observed in the low-intensity livestock systems of the developing world, such damage occurs when expansion of livestock farming pushes these systems beyond the capacity for which they evolved. Overgrazing can cause soil compaction and erosion (especially on hilly land and where common rangeland is grazed) and soil fertility, organic matter content and water infiltration can suffer. The clearing of forests to allow development of new grazing lands is another way in which livestock production can cause environmental damage. Some estimate that the majority of the world's arid rangelands are moderately or severly desertified. In some semi-arid zones, land degradation through grazing livestock is even more serious. This problem has been linked to the growing human population in such regions, and crop encroachment, fuelwood collection and overgrazing. Water pollution, due to livestock production, has also been observed in some such regions (Steinfeld et al 1997).

This study focuses on nitrate pollution from livestock sources, because of its importance in intensive livestock systems in the developed world, and because of the prevalence of the latter in global livestock production. The availability of some data on the extent of such pollution was also a consideration. Figure 1 describes the nitrogen cycle with respect to livestock farming. 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 such as stables.

Figure 1: The nitrogen cycle



2.2 The evidence

Ideally, data would have been assembled on nitrogen balances for various livestock production systems in the countries of interest. This information is not generally available, so gross nitrogen production from animal manure was used as a proxy. From reviews of the scientific literature, data was assembled on N-manure production from dairy, beef, sheep, pig and poultry production in Europe, the USA, and New Zealand.

Data for the USA was obtained from Babcock (1998) and CARD(1997). Estimates were given of the weight of total waste generated as if a single animal lived on the farm for an entire year. They therefore estimate annual waste production per "animal space". Data was available for finishing hogs and breeding sows, for milk cows as well as for a further five categories of cattle, and for layers and broilers. Average data were obtained for pigs and cattle by using animal inventories for the various livestock categories as weights.

N-manure data per animal-year for the European Union have been well-researched and documented relative to other regions (Baltussen et al. 1990, Brouwer and Hellegers 1997, Jongbloed and Lenis 1993, Taha 1992, Verstegen et al. 1993, Brouwer et al. 1995, Leuck et al. 1995). Much of this research refers to the Netherlands, where the environmental problems are among the most severe. Estimates of N-production per animal year for dairy cows, sheep and poultry were taken directly from Brouwer et al. (1994), for the Netherlands, Denmark, and the rest of the EU. The same source was used for cattle and pigs, except that the data was averaged over the various cattle and pig classifications. These data are not inconsistent with estimates of N-manure outputs from the other sources.

Some New Zealand data are available. Lambert et al (1982) gathered data from three sheepfarming systems in the Wairarapa (unimproved pasture, and both low and high fertilizer systems. Annual N-manure production per stock unit was 6.2 kg, 8.1kg and 12.7kg respectively for the three systems. Quin (1982) gives data for irrigated sheep-grazing systems in Canterbury, that implies N-manure production per stock unit of between 11 and 12kg per year. Guided by average stocking densities in New Zealand sheep farming, we chose for this study a level of 8kg of N-manure production per animal-year. Ledgard et al. (1997) compared nitrogen surpluses for dairy farming in New Zealand, England and the Netherlands. While the production of N-manure was not reported, the N-surplus per cow for the New Zealand system (54kg/year) was around only 25% of that in the Netherlands. N-manure production from dairy farming in New Zealand was then assumed to be about one-quarter of the Netherland's level. The above data for New Zealand are also discussed in Goh and Williams (1999). Other sources of New Zealand data are the farm contaminant budgets given in Robertson Ryder and Associates (1993 and 1995) and Williams (1993). Based on the farm contaminant budgets for intensive sheep and beef farms, it appeared that on assuming the same N-manure production for beef cattle as for dairy cows, along with the N-manure output for sheep (see above), total N-manure output per stock unit[1] was similar to that published in the farm contaminant budgets. No specific New Zealand N-manure or N-surplus data could be found for pigs and poultry production. Therefore it was assumed that N-manure levels for pig and poultry production in the USA would also apply in New Zealand.

The above data are summarized in Table 1. They were also applied to the other regions considered in this study, in the absence of further region-specific evidence. Estimates for the EU (excluding Netherlands and Denmark) were applied to Japan and Korea, perhaps not unreasonably due to the intensive nature of livestock production in Northeast Asia. The New Zealand data were applied to Australia and all other regions, on the assumption that their livestock systems were more nearly similar to the extensive systems of New Zealand rather than the more intensive systems of livestock production found in the EU of the USA. The data for the USA was assumed to apply in Canada.

Table 1: Livestock N-manure coefficients (kg N /animal/year)

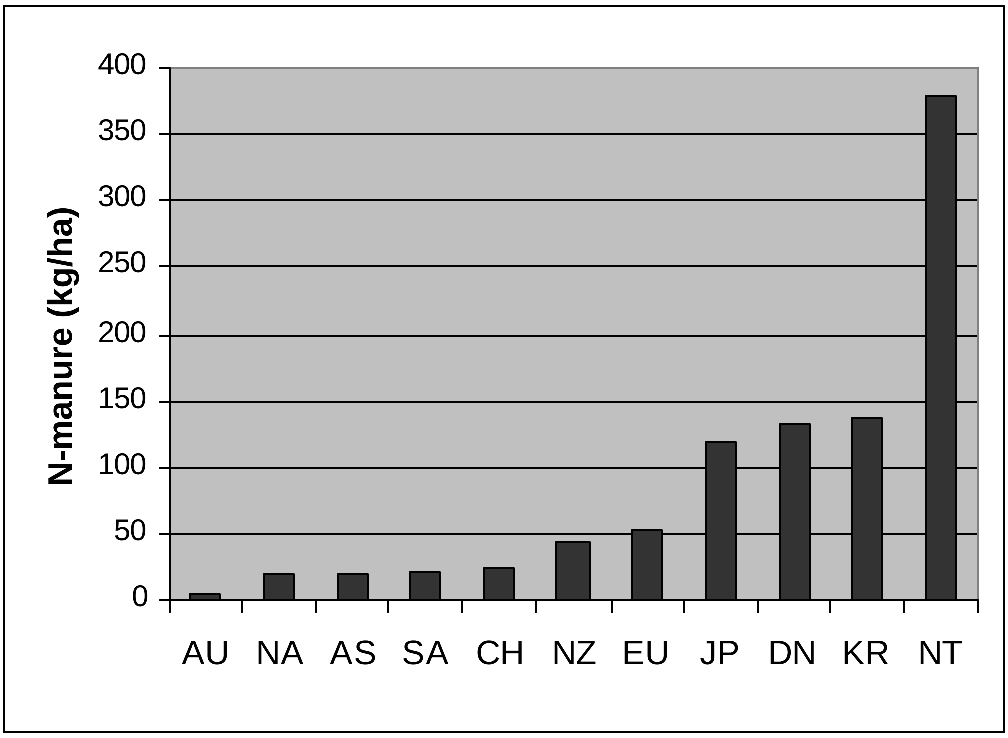
	Cattle	Dairy cows	Sheep	Pigs	Chickens
North America	60	108	8	13.7	0.30
Denmark	50	126	15	16.6	0.66
Netherlands	65	144	22	16.5	0.58
Rest of EU	50	85	8	13.8	0.55
New Zealand	40	40	8	13.7	0.30

The above coefficients, combined with information on total 1995 animal inventories, allowed estimates of total N-manure production to be assembled. Total N production from ruminant and non-ruminant farm animal manure was measured relative to the area of agricultural land (cropland plus permanent pasture). This ratio was highest for the Netherlands, with over 350 kg

[1] This calculation was assisted with estimates of total N-manure production not published in Robertson Ryder and Associates (Dr Prue Williams, personal communication).

of nitrogen produced from manure per hectare of agricultural land. This was almost three times the output level for Denmark, Japan and Korea, where livestock pollution problems are also recognized as serious. The level of N-manure output relative to the agricultural land area for the remainder of the EU is not much higher than that produced in New Zealand. This measure of livestock pollution was lowest for China, North and South America, Southeast Asia and Australia. However, it is recognized that average N-manure output at the national level hides localized high-pollution pockets, such as in parts of the USA, France and the UK.

Figure 2: Country comparisons of N production per hectare farmland from animal waste



Notes: AU=Australia, DN=Denmark, NA=Canada and USA, NT=Netherlands, AS=Indonesia, SA = Malaysia, Philippines and Thailand, EU=rest of European Union, SA=South America, JP=Japan, CH=China, KR=Korea NZ=New Zealand

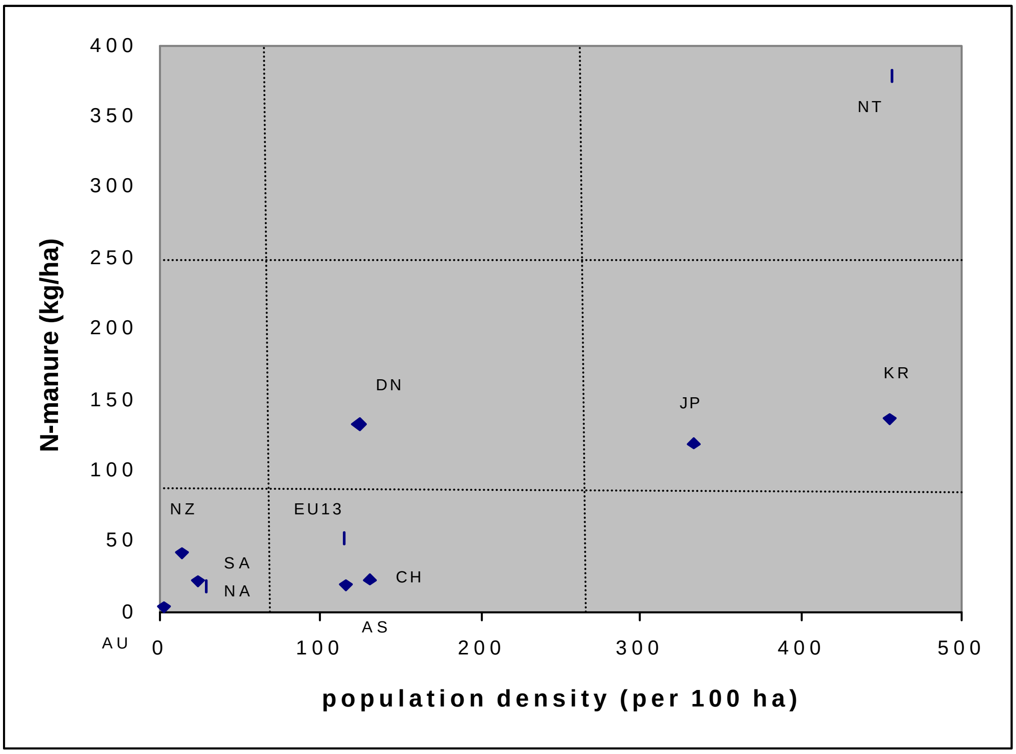
While the total output per hectare of nitrogen from animal waste need not be an indicator of the extent of societies' losses due to such pollution, the costs of such pollution from a given level of N-manure output are likely to be higher the higher the human population density. Thus in Figure 3, the N-manure per hectare data are graphed against each country's human population relative to its total land area. Generally, countries with the highest levels of N-manure per hectare are also those with the highest human population densities. This is especially true in the case of the Netherlands. Japan and Korea have somewhat similar population densities to the Netherlands, but lower N-manure output levels. The costs of this type of environmental damage could be greater in Denmark than in the rest of the EU, China or Southeast Asia, since while population densities are rather similar N-manure output levels are considerably higher in Denmark. The remaining regions (North and South America and Australasia) have the lowest population densities and among the lowest N-manure levels per hectare.

2.3 National policy reactions

Increasing environmental degradation due to expanded livestock production has persuaded a number of economies to react in a variety of ways (European Commission 1997; Hacker and Du 1993; Meister and Rae 1997; Parris and Melanie 1993; Rae and Meister 1993; Taha 1992, 1994).

In East Asia, pig farming has been banned in Singapore, and regulatory restrictions on pig farming and the treatment of manure have been attempted in Japan, Malaysia, Taiwan, Hong Kong and South Korea. For example the intensification of livestock production in Japan has brought with it increasing environmental problems such as water pollution, bad smells and insect problems. The large production units, in particular, are claimed to be a major cause of such problems. Recent serious problems have included water pollution disputes between livestock farmers and fishers in the dairy farming area of Hokkaido. While the amount of nitrogen (N) produced annually from livestock manure is about equal to the crop sector's total demand for N fertiliser, the location of livestock production in remote areas means an N-balance cannot easily be achieved, and farmers face the problem of manure disposal (Sakurada et al 1997). Small producers are leaving the livestock sector, and larger producers wrestle with non-profitability of investments required to manage manure disposal according to environmental regulations (Taha 1992).

Figure 3: Relationship between N-manure levels and human population density



In New Zealand, local governments have responsibilities under the Resource Management Act. Concern is primarily with dairy farm effluent, which has been discharged either into water or (increasingly) onto land. This Act provides some flexibility to regional councils in terms of their enforcement of the Act, and the conditions under which consents may be granted vary across regions. Discharges to water may be prevented unless specifically allowed for under regional plans. Effluent discharges to land may also be controlled under regional plan provisions. In the country's main dairy region, economic incentives are used to encourage discharge onto land due to poor surface and ground water quality.

In the USA, regulations governing manure disposal include those of the Federal Clean Water Act (Lovell and Kuch 1999). The discharge of livestock wastes into the water of the nation is forbidden without a permit. Such run-off waste must be applied to agricultural land in agronomically-acceptable ways, although existing regulations do not provide much explicit guidance on land application and do not clearly specify requirements. They may be specified in permits, and such requirements could vary across States and permits. However the Clean Water Act does not legislate for other livestock-related problems such as odours and methane emissions. Land applications from animal feeding operations of less than 1,000 animal units are not subject to regulation. Current proposals for new state and federal regulations include specific controls on land-application of manures.

The European Union has a number of regulations and payments schemes aimed at reducing environmental damage due to livestock farming (European Commission 1997, Meister 1995, OECD). These include schemes to prevent over-grazing and to encourage extensification of livestock farming, the maintenance of grassland areas for livestock farming and the reduction of stocking rates. Some member states have stringent controls over animal waste management, for example in response to the Nitrate Directive. This Directive aims to reduce water pollution caused by nitrates from agricultural sources. Member States have adopted procedures for the land application of livestock manure so as to keep nutrient losses to water to an acceptable level. For example manure quotas were established in the Netherlands, along with manure bookkeeping and nutrients accounting at the farm level. Fines can be levied on N and P losses exceeding the standards. In 1998, the Netherlands government approved measures to reduce the size of the national pig herd to help meet environmental targets. In Denmark and Germany also, some farming systems are required to keep manure and fertilizer balance sheets.

Environmental policy instruments and regulations to avoid or minimise the environmental impacts of livestock production may increase production costs and decrease farmers' net returns. These measures may take the form of regulations that aim to constrain or modify the ways in which livestock farming is permitted to operate. Such modifications may bring about major changes to agricultural production systems, which in turn may lead to new directions in domestic production and international trade. Because of the severity of livestock environmental problems in parts of Western Europe, that region has been the focus of research during the 1990s into alternative regulatory approaches. For example, Baltussen and Hoste (1993), Giesen et al. (1993) and Wijnands (1993) evaluated new production practices to reduce ammonia emissions, Baltussen (1993) examined the effect of nitrogen levies in reducing N-content in feedstuffs, Fontein et al. (1994) evaluated the link between nitrogen levies and livestock nitrogen surpluses, Komen and Peerlings (1998) modeled the reduction in livestock production as a means of meeting environmental targets along with trade impacts, Reinhard et al. (1998) analysed the 'nitrogen surplus efficiency' of Dutch dairy farms and computed 'nitogen surplus' shadow prices that could be used to set nitrogen levies, and Brouwer et al. (1999) examined linkages between agricultural and environmental policies, along with nutritional management in terms of compliance with the Nitrates Directive.

3. REFORMS & NITROGEN POLLUTION

3.1 Introduction

While much progress has been made over the last decade in modelling the global consequences of agricultural trade policy reform, less has been done in modelling the consequences of such policy reforms on the natural environment (Anderson and Strutt 1996; Whalley 1996; van Beers and van den Bergh 1996; OECD 1994, 1998; Anderson and Blackhurst 1992; Bredahl et al. 1996; Shane and von Witzke 1993). 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, since there would appear to be a general belief among some environmentalists that trade policy reform is bad for the environment.

Why might environmentalists hold such beliefs? Trade liberalization will lead to increases in real incomes, and to changes in the mix and international location of production. Freer agricultural trade, by raising incomes, could therefore accelerate the rate at which livestock products are replacing traditional foods in national diets. This could exacerbate environmental problems should livestock production be more damaging to the environment than the production of the traditional foods that it replaces.

Changes in the global location of farm production, including livestock farming, may or may not increase global environmental damage. To the extent that farm subsidies are highest in the high-income, densely-populated countries of Western Europe and Northeast Asia, then 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. Further, that lost farm production could be regained elsewhere in the world, where human population densities are much lower, and farm production systems are much more extensive. Thus the additional environmental damage in the latter countries could be less than the reductions in environmental damage in the densely-populated regions. Also, extensive livestock production systems 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. Only quantitative analyses, however, will indicate whether such outcomes are likely to materialise.

3.2 The New Zealand case

This case may be considered as one of unilateral reform of trade policies. The predominant instrument of farm support up to the early 1980s was the supplementary minimum price programme which raised received export prices up to the support level. The price programme can therefore be considered a type of export subsidy. For those countries where reliable measure of producer subsidies are available, only in New Zealand did those given to livestock producers fall substantially over the past decade (with the exception of poultry production – see Table 2). Did a reduction in livestock-induced environmental damage result? Because sheep production was more heavily subsidised than other livestock farming in New Zealand (total support to sheep farmers was equivalent to 65% of their gross revenue in 1985), removal of subsidies led to a switch away from sheep farming to beef and dairy production. Total N production from livestock manure was estimated from the nitrogen coefficients of Table 1 and the relevant livestock numbers in 1985 and 1995. Total N production from livestock manure decreased, since the increased production from cattle was less than the reduction due to contraction of the sheep flock (Table 2). But since available evidence suggested that sheep systems in New Zealand are closer to

N-balance than is dairy farming[2], coupled with the fact that dairy farming (relative to sheep farming) is usually an intensive land use located nearer to human population centres, then removal of livestock subsidies could also have been accompanied by increased environmental problems in certain regions of New Zealand.

Table 2 : New Zealand's policy reforms and N-manure outputs from livestock

	Producer subsidy equivalent (%)		N output from manure (000 MT)		Change in N output (000 MT)
	1985	1995	1985	1995	
Cattle	14	2	317	349	+32
Sheep	65	2	679	471	-208
Pigs	13	1	6	6	0
Poultry	21	56	2	4	+2
Dairy cows	13	1	102	122	+22
Totals	20	3	1,106	953	-153

Source: OECD for producer subsidy equivalents; author s calculation for other data.

The above results ignore the regional distribution of the changes in livestock populations as a result of New Zealand's policy reforms. In particular, the expansion of dairy farming that was encouraged not only by the removal of supplementary minimum prices (which had primarily been paid on sheepmeat and wool) but also by the Uruguay Round reforms that promised higher dairy returns, did not occur evenly over the entire country.

Table 3 compares data from 1996 with that from 1984 when the agricultural reforms were initiated. Over that period, dairy and beef cattle numbers increased in most regions, while sheep numbers declined in all regions with the exception of Taranaki. Pig numbers fell in all regions except Canterbury. Between 1984 and 1996, dairy cow numbers in the South Auckland-Bay of Plenty region (which includes Waikato) increased by 280,000. However the largest relative expansions in dairy numbers occurred in the South Island – by around 175% in Canterbury and Otago, and by 350% in Southland. Beef cattle numbers expanded the most, in both absolute and relative terms, in Taranaki and Canterbury.

Using the N-manure coefficients from Table 1, and assuming the same coefficients applied in both 1984 and 1996, the change in regional N-manure outputs over the 1984-96 period were calculated, and also shown in Table 3. In all regions except Taranaki, total nitrogen output from livestock manure declined as a result of the changes in livestock numbers encouraged by the removal of farming subsidies. But this reduction in manure outputs should be considered relative to changes in farmland areas before concluding that the economic reforms may have contributed to reduced livestock pollution. Livestock farming may have become more intensive, and the smaller manure outputs may be spread on even smaller land areas. Not unexpectedly, the total area of farmland fell between 1984 and 1996, and in all regions with the exception of Taranaki. Thus the output of N-manure per hectare of farmland actually increased in several regions between 1984 and 1996. While this change was greatest in Westland, the low human population density in that region suggests relatively low social costs of the increased N-manure pollution. Nelson/Marlborough, Southland and South Auckland-Bay of Plenty also showed substantial increases in N-manure output per hectare. Of these regions, the human population is largest in the latter. Thus while we used an imperfect measure of livestock pollution, the changes that have taken place in the livestock sector as a result of the policy reforms, coupled with the continuation

[2] Goh and Williams (1999) provide nitrogen budgets that indicate surpluses of N inputs over N outputs of 101 to 227 kg N/ha/year for New Zeand dairy farms, compared with 0 to 117 kg for New Zealand sheepfarms.

of the decline in the area of farmland, suggest an increase in environmental damage from livestock in certain regions of New Zealand, particularly in South Auckland/Waikato and some parts of the South Island.

Table 3: Changes in livestock numbers, N-manure output: 1984-96

Region	Change in livestock numbers (000)				Change in total N-manure (000 MT)	Change in farm land (000 ha)	Change in N kg /ha
	Beef cattle	Dairy cattle	Sheep	Pigs			
Northland	-45.8	38.5	-1522.6	-5.3	-12.	-226.5	-1.2
C Auckland	23.7	-14.2	-441.9	-56.0	-3.	-11.6	-7.7
Sth Auck - BOP	-218.4	281.3	-5974.0	-54.0	-46.	-1052.6	4.1
East Coast	10.6	5.5	-974.4	0.0	-7.	-3.1	-9.5
Hawkes Bay	19.5	-21.1	-3388.6	-6.0	-27.	-313.1	-7.1
Taranaki	152.4	87.0	717.6	-34.1	14.	277.9	-4.7
Wellington	92.3	152.6	-3348.4	-27.1	-17.	-287.6	0.6
Nelson/Marl	21.9	32.5	-1141.4	-28.9	-7.	-1282.0	8.9
Westland	-11.3	22.4	-220.6	-0.9	-1.	-825.8	11.3
Canterbury	159.0	145.8	-2976.3	101.8	-10.	-438.4	1.4
Otago	34.5	62.0	-1760.2	-3.3	-10.	-388.2	0.1
Southland	38.1	102.2	-1569.5	-11.5	-7.	-319.7	7.6

Source: Agricultural Statistics, Statistics New Zealand (various issues) for livestock and farmland data

4. GLOBAL TRADE REFORM: THE URUGUAY ROUND

4.1 Methodology and experimental design

We use the GTAP applied general equilibrium model (Hertel 1997) to project national and regional production, consumption and trade flows in Asia. 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. The GTAP production system distinguishes sectors by their intensities in five primary production factors: land (agricultural sectors only), natural resources (extractive sectors only), capital, and skilled and unskilled labour. Producers choose inputs that minimize production costs subject to separable, constant returns to scale technologies. Constant elasticity of substitution (CES) functions describe substitution possibilities between primary factors. Market clearing conditions equate supply with demand for each factor of production. For intermediate inputs, the assumption of a Leontief function implies no substitution between different intermediates or between them and a composite primary factor. In trade, products are differentiated by country of origin, allowing bilateral trade to be modeled, and bilateral international transport margins are incorporated and supplied by a global transport sector. The model is solved using GEMPACK (Harrison and Pearson 1996).

Because of our interest in livestock production and implications for international trade in grains as well as in livestock products, we have modified the standard GTAP model to allow for substitution between the various feedstuffs in livestock and milk production. Also, we utilize the newly developed, version 4 GTAP data base, which is benchmarked to 1995 and which offers an important disaggregation of livestock production into ruminants and non-ruminants. We aggregate this data base up to the level of 10 regions and 14 commodities (see Appendix Tables 1 and 2). We combine Canada and the USA into a single North America region, while Southeast Asia is an aggregation of Indonesia, Malaysia, the Philippines and Thailand. The 50 commodities in the version 4 GTAP database have been aggregated up to 14, of which 6 commodities (rice, wheat, other grains, oil crops, other crops and processed food) compete for use in the feedstuffs composite. Livestock farming is represented by three aggregates: beef cattle (i.e. ruminant livestock), other livestock (i.e. non-ruminants)[3] and raw milk production. These farming sectors provide inputs to the beef processing (ruminant meat), other meat (non-ruminant meat) and dairy products industries in each region. All remaining production sectors are aggregated into manufactures and services, or other natural resource-based commodities.

4.2 The base projection scenario

Following other recent work using the GTAP model for projections, a small number of exogenous macroeconomic variables are shocked to simulate the effects of growth in the global economy over time. These exogenous shocks drive projections of intersectoral and international economic impacts. We make a number of modifications to the standard version of GTAP for simulating the projections presented in this chapter. Many of these modifications draw on existing work in this area (for example, Gehlhar et al. 1994, Arndt et al. 1997, Bach 1996; Dimaranan 1996; Hertel et al. 1995). Previous work uses Version 3 of the GTAP database and, with the recent release of Version 4 (V4), a number of the important modifications are already included in the database. In particular, V4 of the GTAP database includes sector-specific natural resources as well as a split between skilled and unskilled labour. The inclusion of sector-specific natural resources is important to tie down the response of natural resource sectors and thereby avoid

[3] While we refer to these aggregates as ruminant and non-ruminant livestock, it should be remembered that the former also includes sheep, goats and horses, while the latter comprises eggs, honey, hides and skins in addition to pigs, poultry and live animals not otherwise covered.

large exogenous capital shocks leading to inappropriately large output responses in these sectors. In the case of natural resource sectors, some capital is not reproducible and it may not be appropriate to effectively allow unrestrained expansion of these sectors. V4 includes such a specific factor in the natural resource intensive industries.

Gehlhar (1997) shows that breaking labour into two components produced significantly better results in a backcasting exercise for the decade 1992-1982. Therefore, separating the single factor labour into skilled and unskilled labour is considered to be particularly important for projections work. V4 of the GTAP database includes a split between skilled and unskilled labour. We create a composite capital nest for human and physical capital following Arndt et al. (1997).

The GTAP model assumes an Armington structure for imports. They are distinguished by origin and aggregated at the border, where the composite import is distinguished from the domestically produced commodity and the optimal mix is determined. Increasing the Armington elasticities was shown to lead to more accurate simulation results in a backcasting exercise with GTAP (Gehlhar, 1997). With this in mind, and following previous work on projecting with GTAP, the Armington elasticities are doubled. Since rigidities in trade flows are expected to diminish over time, this will better facilitate the large exogenous growth shocks involved with projecting long into the future (Arndt et al. 1997).

To project future changes in the global economy, we make assumptions about economic and factor growth rates. The GTAP V4 benchmark database is for 1995. Our growth rates for 1995-2005 are given in Appendix Table 3. The model can be closed with either gross domestic product (GDP) or total factor productivity as exogenous targets for each region. We endogenise GDP, but compare our projections of that variable with forecasted vales in the final columns of Appendix Table 3. We assume an average rate of non-farm productivity growth[4] in the OECD economies (except Korea) of 0.75% per year. For non-OECD economies and Korea, we assume a somewhat higher rate of productivity growth of 1.25% per year, except for China where we assume an annual productivity growth rate of 1.75%. Therefore China's, Southeast Asia's and Korea's productivity growth rates are expected to remain quite high, but somewhat lower than implied by the period prior to the Asian crisis. Empirical evidence suggests that agriculture has a higher total factor productivity growth rate than other sectors (see Martin and Mitra 1996). The assumption made here is that agricultural productivity increases at a rate of 0.6 percent per annum above the rate of growth of productivity in the non-farm sector – this being the difference used by Martin and Mitra.

Forecasts for population, investment (capital stock), and labour force are based on the latest forecasts from the World Bank as of early 1999. Projected changes in skilled labour are based on expected increases in the stock of tertiary educated labour and are taken from Ahuja and Filmer (1995) for developing countries. Projections for the OECD countries are based on inputs developed for the World Bank's Global Economic Prospects (1998). The stock of farmland in each region is simply held constant.

As a check on the plausibility of these assumptions, we compare our baseline cumulative GDP growth (second to last column) to that forecast by the World Bank, in the last column of Appendix Table 3. Together with projected growth rates in capital, skilled and unskilled labour, this yields overall GDP growth rates for these countries (Appendix Table 3) which are in the main rather similar to those forecast by the World Bank (World Bank, 1998). We capture the continuing rapid growth in China, and a return to positive but still low growth in Japan. Otherwise our projected growth rates are a little below those of the World Bank for China, Korea and the EU, and a little above in the case of Southeast Asia.

[4] Throughout this paper when we refer to productivity growth we will be referring to productivity of value-added.

In the solution projected for 2005, differences in the relative rates of factor accumulation interact with the various sectoral factor intensities and the income elasticities to drive changes in the sectoral composition of output over time. For example sectors making intensive use of land and natural resources may show little supply response since supplies of these factors were held constant over the projection period.

In New Zealand, the largest increases in output and contribution to GDP occurred in the natural resource-based sector (which includes forestry, fishing and wool), dairy and the manufacturing and services aggregate. Much smaller increases are projected in the grains sectors and other livestock (eg non-ruminant production). Globally, the largest output expansions in livestock production are projected for China, of the order of 50-60%. Substantial expansion is also projected in Southeast Asia, of between 29-38%. The smallest projected expansion of livestock production occurred in Japan (8-9%) and in the EU where beef and non-ruminant output expanded by around 10% whereas milk output was constrained by the current quota arrangements.

To translate these changes in livestock and milk sector outputs to estimates of changes in N-manure production, it was necessary to form estimates of animal numbers. Changes in the latter will differ from sectoral output changes due to our assumed productivity growth. Our approach was to subtract from the percentage changes in livestock outputs, the cumulative (10-year) percentage changes in livestock productivity (from Appendix Table 3). Results are given in the first three data columns of Table 4. Cattle numbers are projected to expand substantially in New Zealand, even in the absence of Uruguay Round policy reforms, especially dairy cattle. The largest increases in livestock numbers are projected in China. But to put these increases in China in some context, increases over the 1985-95 period were 36% (pigs), 122% (chickens), 58% (beef cattle) and 135% (dairy cattle). Note that for the EU, milk output was held constant in the projections due to the milk quota but dairy cow numbers decrease by 14% - this is the effect of the increased productivity in this sector.

4.3 The Uruguay Round scenario

The Uruguay Round (UR) trade liberalization is simulated from the updated 2005 database. That is, the 1995-2005 projection was performed first, the projected 2005 database was then saved, and the Uruguay Round scenario was applied to the latter data.

Ideally, this simulation would include the appropriate cuts to import tariffs, export subsidy quantities and expenditures, quantitative market access targets, and elimination of the Multifibre Arrangement (MFA) quotas. Unfortunately, these data are not completely available for the GTAP version 4 database. (A special data set had been prepared by the World Bank for evaluation of the Uruguay Round for the GTAP version 3 database which used a 1992 base year). However, it was possible to obtain a set of non-agricultural UR tariff reductions estimated from the 1995 base year[5], along with the MFA reforms. These reductions were applied to the tariff equivalents in the "other natres", "procfood" and "man_srvc" sectors.

Reforms stipulated in the UR Agricultural Agreement can be grouped under domestic support, export subsidies and market access. Considerable problems exist in modeling this Agreement. It would not be appropriate to reduce the output subsidies in the GTAP database by the agreed 20%, since many domestic subsidies were excluded from the UR reduction commitment, and the reduction applies to the total agricultural subsidy outlay rather than those at the individual commodity level. For tariffs, it was agreed in the UR that they be reduced by an average of 36%.

[5] Thanks are due to Dr Joe Francois and Dr Anna Strutt for making this data available.

Thus governments have considerable leeway in reducing tariffs, and may reduce tariffs on less-sensitive commodities by more than 36% so allowing those on politically-sensitive commodities to be reduced by less. Further, the agreed rates refer to bound tariffs whereas the tariffs in the GTAP database are applied rates. Because tariffs were often bound at levels above the applied rates, the agreed tariff reductions may have little impact on the rates actually applied. The agreed reductions in export subsidies (a 36% reduction in subsidy expenditures and a 21% reduction in subsididsed export volumes) have been considered to be the most effective part of the Agricultural Agreement in terms of its trade liberalization impacts. But certain countries have also taken actions in efforts to weaken these commitments, and these have led to formal disputes within the WTO. As a compromise and as an approximation to the degree of reform that might be achieved, our UR scenario of this study incorporates 20% reductions in all tariffs and export subsidies relating to the agricultural commodities, but no reductions in output subsidies (domestic support).

Table 4: Estimated changes in livestock numbers (%)

	Projection 1995-2005: no policy reform			Due to the Uruguay Round: 2005		
	Beef cattle	Other livestock	Milk	Beef cattle	Other livestock	Milk
Australia	-0.9	-0.9	-1.4	1.4	-0.4	2.2
New Zealand	6.5	-0.5	23.0	4.7	-34.6	20.7
Japan	-6.2	-5.9	-4.9	-3.6	-1.4	-2.3
Korea	0.9	1.2	1.7	-3.9	1.0	-0.2
China	30.4	31.6	36.5	0.7	0.5	0.4
SE Asia	8.8	9.1	17.8	-3.1	-1.5	-6.7
N America	6.5	10.2	8.4	1.3	0.6	0.5
S America	1.0	1.9	1.7	2.8	0.3	1.4
European U	-3.5	-4.8	-14.4	-10.5	0.1	-2.8

Source: Author s calculation

Application of the UR scenario caused beef cattle sector output to fall in Japan, Korea, Southeast Asia by up to 4%, and a larger 10% reduction in the EU. Beef cattle output expanded 1%-5% in all other regions. Production of other (non-ruminant) livestock declined in Japan, Southeast Asia and Australasia, but in the latter region milk output expanded substantially. Milk production declined in Northeast and Southeast Asia and the EU. There was also a substantial shift out of cereals production in Japan, Korea and Southeast Asia, and by less in the EU. The UR reforms encouraged expansion of the manufacturing and services sector in the EU, Japan, Korea and China. The final three columns of Table 4 are our estimates of the changes in livestock numbers in the year 2005 resulting from the policy reforms of the Uruguay Round.

4.4 Changes in N-manure outputs due to economic growth and trade liberalization

By applying the N-manure coefficients discussed earlier to the simulated changes in livestock numbers, we obtain an estimate of the separate impacts of economic growth and the UR reforms on the level of N-manure outputs from livestock production. These are reported in Table 5. The largest increase in N-manure output was estimated for China – not surprising given the size of that country, its projected rapid growth rate and its likely comparative advantage in at least some forms of livestock production. But nearly all of that increase, and the subsequent environmental problems, can be traced to the effects of economic development; very little additional livestock-induced environmental problems result from the UR trade liberalization. Livestock environmental problems from increased N-manure production were also estimated in both North and South America. In the former region, like China, the majority of the emerging problem is due to livestock expansion as part of economic growth, rather than trade liberalization *per se*. This is not the case in South America, however, where the UR trade reforms encourage expansion of the beef and dairy sectors. In New Zealand, livestock N-manure output might increase by almost 20% over the 1995-2005 period, with about half this increase resulting from livestock sector expansion encouraged by the UR liberalizations. Livestock environmental problems may also become more severe in Southeast Asia, but we estimate this to be entirely due to the effects of economic development: the UR reforms actually reduce this problem somewhat since livestock production in this region could contract.

We estimate a more than 10% reduction in livestock N-manure outputs in the EU over the 1995-2005 period. This reduction is driven almost equally by the downsizing of the livestock sector that results from future economic development within the region, and the additional downsizing enforced by the reforms of the Uruguay Round. Similar remarks can be made in the case of Japan.

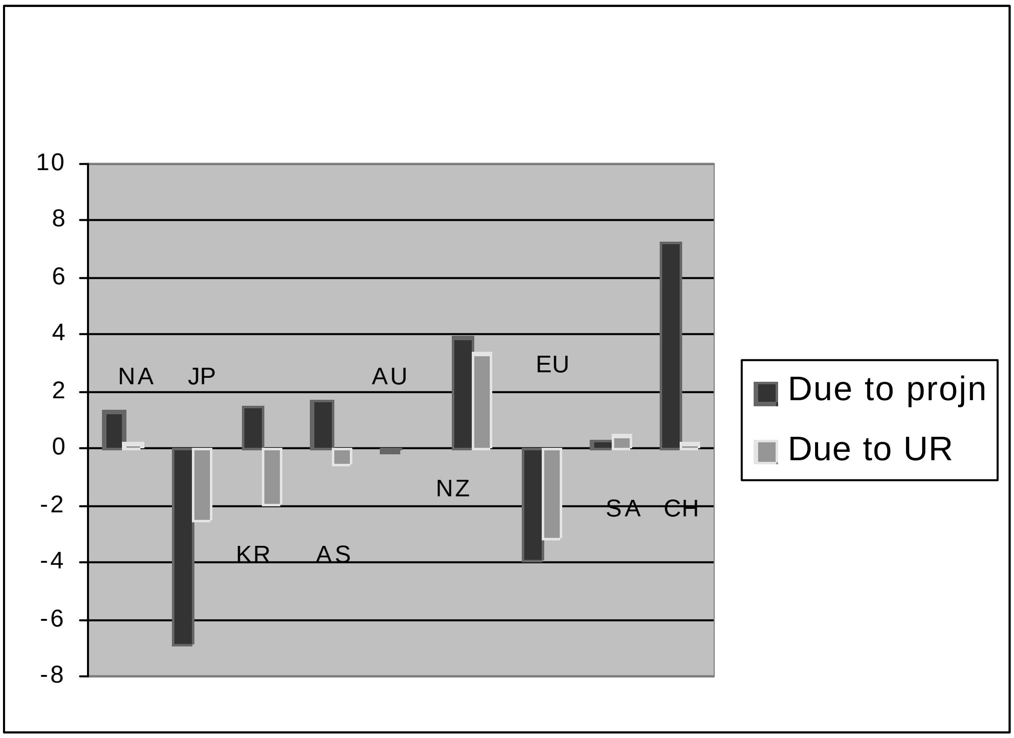
Table 5: Change in N-manure outputs ('000 MT)

	Total N-manure output		Projected 1995-2005 change under:		Total projected change
	1995	2005	No policy reform	Uruguay Round	
Australia	2069	2078	-18	27	9
New Zealand	736	862	67	59	126
Japan	608	560	-36	-12	-48
Korea	293	292	3	-4	-1
China	11631	15342	3624	87	3711
SE Asia	1571	1670	142	-43	99
N America	9094	9871	673	104	777
S America	14408	14931	170	353	523
European U	8229	7237	-546	-446	-992

Source: Author s calculation

The extent of environmental damage from increased N-manure outputs is likely to be more closely related to changes in manure outputs per hectare of agricultural land, rather than to the total output levels. For this reason, Figure 4 gives these measures, decomposed into the effects due to economic growth and those due to the trade reforms. The largest increase in N-manure output per hectare due to economic growth occurs in China, and the largest such reduction in Japan followed by the EU. But as far as the impacts of trade liberalisation are concerned, the largest impact on increased N-manure output per hectare occurs in New Zealand. By comparison, this increase is much smaller in North and South America and Australia.

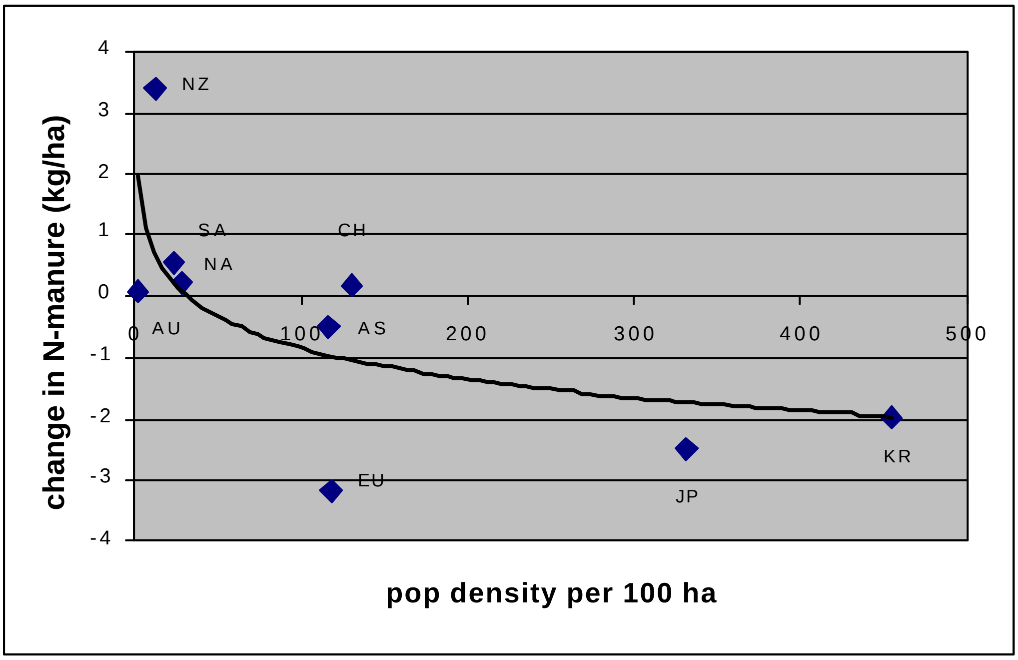
Figure 2: Changes in N-manure output (kg/ha) under two scenarios



Source: Author s calculation

High levels of N-manure output per unit of agricultural land tend to pose the greatest environmental problems in regions with high human population densities (such as in the Netherlands). Figure 5 indicates a relationship between changes in N-manure outputs per hectare and human population density. This figure focuses on the changes in N-manure output that may result from the UR trade liberalization alone. As can be seen, trade liberalization appears to encourage increased livestock environmental problems in countries with relatively low population densities, such as New Zealand and North and South America, where the human consequences of such damage may be relatively low. On the other hand, trade liberalization leads to *reduced* potential livestock environmental problems in the *densely*-populated countries of the EU and Northeast and Southeast Asia.

Figure 3: The relationship between the change in N-manure output per ha due to trade liberalisation and population density



Source: Author s calculation

5. CONCLUSIONS

Growth in incomes, population and urbanization are fuelling a massive increase in demand for animal products, particularly in developing countries. This is encouraging the expansion of livestock numbers, the intensification of livestock production, the concentration of livestock populations in urban areas and over-grazing of agricultural land.

Continuation of these forces will, in the absence of appropriate intervention, further exacerbate the negative environmental impacts of livestock production in many regions of the world. However in the highly industrialised economies of Japan and the EU, their future economic development may feature a decline in the size of the livestock sector relative to some others, especially manufacturing, services and some natural-resource-based sectors.

Whether or not reforms to trade policies will enhance or degrade the natural environment is an empirical matter, and will depend on how the altered economic incentives will affect outputs of pollution-intensive relative to pollution-extensive industries and sectors. In the case of New Zealand's unilateral policy reforms, removal of support led to a switch of resources from sheep to dairy and beef production. Since sheep farm systems in this country appear to be nearer N-balance than dairy systems, and dairy farming is a more intensive land use located nearer to urban centres, the policy reforms appear to have caused increased environmental problems from livestock farming in certain areas of the country.

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 the Uruguay Round Agricultural Agreement indicated contraction of dairy sectors in the EU and parts of East Asia and their expansion elsewhere. The beef sector also contracted in the above regions, as did non-ruminant livestock production in East Asia. Thus, even in the absence of specific environment-enhancing activities, the UR trade liberalization would reduce the level of N-manure output from livestock farming in parts of Europe and Asia. Trade liberalization may increase livestock environmental problems in countries such as New Zealand and North and South America but due to their 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 and Southeast Asia, and therefore offers the potential of overall gains in environmental quality.

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APPENDIX A: REGIONAL AGGREGATION

Appendix Table 1 Regional aggregation

b) Regional Aggregation	*GTAP Aggregation*
NZ	New Zealand
Aus	Australia
Japan	Japan
Korea	Korea
China	China
SE Asia	Indonesia Thailand Malaysia Philippines
Nth America	United States Canada
Sth America	Mexico Central America and the Caribbean Venezuela Colombia Rest of the Andean Pact Argentina Brazil Chile Uruguay Rest of South America
EU	United Kingdom Germany Denmark Sweden Finland Rest of European Union
ROW	Singapore Vietnam Hong Kong Taiwan India Sri Lanka Rest of South Asia (Bangladesh, Bhutan, Maldives, Nepal, Pakistan) EFTA (Iceland, Norway, Switzerland) Central European Associates (Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) Former Soviet Union Turkey Rest of Middle East Morocco Rest of North Africa South African Customs Union Rest of Southern Africa Rest of Sub-Saharan Africa Rest of World

APPENDIX B: COMMODITY AGGREGATION

Appendix Table 2: Commodity aggregation

Abbreviation	*GTAP Commodity*
Rice	Paddy rice
Wheat	Wheat
Other grains	Cereal grains nec
Oils	Oil seeds
Beef cattle	Bovine cattle, sheep and goat, horses
Other livestock	Animal products nec
Milk	Raw milk
Beef	Bovine cattle, sheep and goat, horse meat prods
Other meat	Meat products nec
Dairy products	Dairy products
Other natres	Wool, silk-worm cocoons
	Forestry
	Fishing
	Coal
	Oil
	Gas
	Minerals nec
	Vegetable oils and fats
Procfood	Processed rice
	Sugar
	Food products nec
Other crops	Vegetables, fruit, nuts
	Sugar cane, sugar beet
	Plant-based fibers
	Crops nec
Man_srvc	Beverages and tobacco products
	Textiles, Wearing apparel and leather products
	Wood products
	Paper products, publishing
	Petroleum, coal products
	Chemical, rubber, plastic products
	Mineral products nec
	Ferrous metals, metals nec and metal products
	Motor vehicles and parts
	Transport equipment nec
	Electronic equipment
	Machinery and equipment nec
	Manufactures nec
	Electricity, gs manufacture, distribution
	Water
	Construction, trade and transport
	Financial, business, recreational services
	Public admin and defence, education, health
	Dwellings

APPENDIX C: PROJECTION ASSUMPTIONS

Appendix Table 3 Assumptions made in the projections: annual percentage changes in AVA and factor endowments for the period 1995 to 2005 – These shocks apply in all scenarios

	"ava" All farm[a]	"ava" All Non-farm[b]	Physical capital	Unskilled labour	Skilled labour	Population	Forecast GDP	World Bank forecast
Aus	1.35	0.75	1.6	1.0	4.7	0.91	2.5	2.9
NZ	1.35	0.75	2.3	0.7	4.7	0.73	2.6	2.3
Japan	1.35	0.75	0.3	-0.3	2.6	0.18	1.1	0.9
Korea	1.85	1.25	1.5	0.6	4.7	0.74	2.6	3.4
China	2.35	1.75	8.2	1.1	3.3	0.75	5.4	6.9
SE Asia	1.85	1.25	2.3	1.9	6.3	1.36	3.3	2.6
Nth Amer	1.35	0.75	3.0	0.9	3.0	0.78	2.9	2.5
Sth Amer	1.85	1.25	1.0	1.9	5.5	1.37	2.7	3.0
EU	1.35	0.75	0.8	0.02	3.0	0.09	1.6	2.3
ROW	1.85	1.25	2.5	1.9	5.4	1.38	3.6	3.2

Notes: (1) All farm = {rice, wheat, other grain, oils, other crops, beef_ctl, oth_lvstck, milk}. (2) All non-farm = {beef, other meat, dairy products, other natres, procfood, man_srvc}
ava = percent change in productivity of value-added in the relevant sector.

Source: Author s calculation