Australian Agricultural Production and Trade under a potential Enhanced Greenhouse Effect

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1. Introduction

A framework for examining the potential impacts of an Enhanced Greenhouse Effect (EGE) on Australian agriculture has previously been outlined (Schofield and Godden 1993). The preliminary findings showed significant increases in agricultural productivity in some areas of Australia, due to the potential climate change effects of an EGE scenario. The previous work has been refined, and extended to include detail on the "scourge effect", and international trade effect. This paper is part of continuing research by the authors into the potential impacts of the EGE on Australian agriculture.

As background to the present paper, it is necessary to review some aspects of the previous paper. The two main models used in the current study are reviewed in section 2 of this paper, and the earlier work is reviewed in section 3. The methods used in the current work are outlined in section 4 and the results presented in section 5.

2. The MIAMI and ORANI Models

The Miami Model was chosen for its ability to evaluate the climate change effects in a uniform manner, consistent across industries and regions. With some transformation, the Miami Model estimates are compatible with the ORANI input requirements, adding to the model's suitability for the study. The ORANI model was a natural choice for determining the possible impacts of the climate change, due to the model's flexibility, and detail it provides of the Australian economy as a whole.

2.1 The Miami Model

As described in Lieth (1975), the Miami model analyses the net primary production effects of annual temperature and rainfall. The model was constructed using data obtained from 52 datum points throughout the world, but centred mainly in Europe. Annual productivity, measured in dry weight g/m^2, was examined separately with mean annual temperature, and mean annual rainfall. These data sets were then analysed using the least squares method, to derive the following productivity formulas.

$$Y = 3000/(1 + e^{1.315-0.119\,t})$$

and

$$Y = 3000(1 - e^{-0.000664\,p})$$

Where Y is the productivity level measured in dry weight g/m^2/year, t is mean annual temperature measured in °C, and p is mean precipitation per year.

One advantage of the Miami Model is that it applies a uniform procedure for estimating climate effects across all regions and is not crop, industry, or region specific. Pittock and Nix (1986) noted that the Miami model has an advantage over site-specific models, in that it can account for a range of climates far outside that of regional historical data sets. There are drawbacks, however, in that no data collection points were in the close vicinity of Australia and the CO_2 fertiliser effect is ignored.

2.2 The Miami Model in Australia

Pittock and Nix (1986), applied the Miami model to Australian data, using 980 observation stations with long term climatic means (>30 years). Pittock and Nix then used the model to estimate the productivity of Australian agriculture given a doubling of CO_2 concentrations. Pittock and Nix recognised the general consensus amongst climate modellers that, with a doubling of CO_2, average temperature are estimated to rise by 1°C at the equator, and by even more at higher latitudes. These estimates are however relatively site specific, and Pittock and Nix used the same input data as Lieth (1975) of a 0.1°C average temperature increase for every degree of latitude. Similarly for rainfall data, Lieth's estimates of a 20% increase in winter rainfall and a 40% increase in summer rainfall were adopted by Pittock and Nix. The Miami Model only accounts for annual rainfall, and does not allow for changes in variability, seasonality and intensity.

Pittock and Nix mapped the expected productivity changes in Australia, in a manner compatible with the ORANI system of percentage change equations. The percentage change map is shown in Figure 1. The largest increases in productivity occur in the summer rainfall areas of northern and north-western Australia, where the main effect is due to precipitation and not temperature. Over half of Australia experiences an increase in productivity of around 20%, mainly due to summer rainfall patterns. The exceptions are Tasmania, which seems to benefit from the temperature increase, and south-western Australia, where a decrease in productivity is found due to the lack of summer rainfall.

2.3 The ORANI Model

The ORANI model is a large scale computable general equilibrium model (CGE) of the Australian economy. It is based on traditional micro economic theory, where consumers maximise utility subject to a budget constraint, and producers minimise costs subject to production constraints. "The foundation of the ORANI data base is input-output information which, amongst other things, captures the sales and purchase patterns of industry sectors within the economy" (IAC 1987). ORANI is a multi sectoral model in that it embodies the interrelationships amoung industries, households, and the goods and services they trade. ORANI, however, is capable of examining general, economy wide trends, as well as industry, or commodity specific questions. The model draws on a large body of data, to provide a framework for analysing "What if...." questions, in the sense that it sets up an initial, base situation, and examines the consequences of changes within the system. ORANI is a comparative static model, examining the movement from one equilibrium to another, as a result of some economic stimuli.

Rather than being a forecasting tool, ORANI is a causation type model, examining relationships amongst economic variables, and not just trends in historical data. This means that ORANI can model external economic shocks, and their expected outcomes, without a bias occurring in the result. Details on the supply and demand for 113 industries and 115 commodities, along with information on imports, and 'margins' *etc*. come from the Australian Bureau of Statistics (ABS) data banks, and is updated accordingly. ORANI models the agricultural sector as multi-product industries, and multi-industry products, breaking some industries into regions or zones. The agricultural component of the ORANI model is split into approximately 8 industries (of which 3 are multi-product), and 10 commodities. This allows modelling and analysis of commodity specific, industry specific, and regional specific effects, as well as economy wide results, helping to create a more detailed picture of the possible impacts of the climate change effects under an EGE scenario. The FH-ORANI version was used for the present modelling.

3. Review of Earlier Work

Schofield and Godden (1993) ran two ORANI simulations, one with just the Miami Model estimates, and the second including estimated commodity specific CO_2 effects. The Miami Model estimates were translated graphically into the ORANI model, to give a consistent, uniform approach to the estimation of the rainfall and temperature effects across the country. The percentage change map presented in Pittock and Nix (1986), was combined with a map by Higgs (1986), of the ORANI zones. The ORANI zones map was superimposed over the Miami Model map, with the resulting map (Figure 1) indicating the productivity percentage change bands within each of the ORANI zones. The estimates for the CO_2 effects were taken from Godden and Armitstead (1992), and translated from commodity specific figures into ORANI industry effects. The resulting production changes estimated from these two techniques were as follows.

Table 1: Productivity Increase Estimates (% change)

ORANI Industry	Miami Model Effect	Including CO_2 Effect
Pastoral Zone	5.76	15.39
Wheat/Sheep Zone	5.91	31.34
High Rainfall Zone	2.62	9.89
Northern Beef Zone	9.75	14.75
Other Farming1 Zone*	--------	- 6.38

* The "Other Farming1 Zone", accounts for sugarcane, fruit and nuts

Production effects were estimated to be greater than *a priori* expectations, especially when the CO_2 effect was included. These increases were modelled using ORANI, and a summary of the production results is presented below.

Table 2: Production Increase Results (% change)

ORANI Industry	Miami Model Effect	Including CO_2 Effect
Pastoral Zone	0.2	-10.4
Wheat/Sheep Zone	3.8	27.9
High Rainfall Zone	-1.1	-6.1
Northern Beef Zone	5.1	2.1
Other Farming 1 Zone	-0.1	-1.8
Poultry	1.1	2.9

Schofield and Godden (1993) concluded that the results indicated "...significant possible benefits to some parts of the agricultural sector as a result of the EGE". These benefits were combined with a shift in resources away from those zones adversely affected, or less beneficially affected, by the EGE climate change.

4. Method

The current study involves three major changes from the previous paper. The first is in the way Net Primary Productivity (NPP) is translated into live weight gain in animals and economic yield in crops. The second is the inclusion of a pest and disease, or "scourge", factor. The third major change is that there is a preliminary examination of the impact of a change in overseas demand for agricultural commodity exports as a result of EGE-induced changes elsewhere in the world.

4.1 Miami Model NPP increases and Economic Output

The net dry weight productivity increases represent total plant growth, grain, leaf, and stem. For the present study, it was necessary to look solely at the increase in grain production in crops, as it is the grain from which income is obtained. Taking into account temperature increases, and changes in rainfall patterns, the net economic productivity change was estimated as 20% of the total dry weight gain (Schofield 1993). The increased temperature reduced the grain yields, but by less than the increased rainfall benefits. Similar factors were examined for pasture growth, carrying capacity, and pasture digestibility in livestock. Increased temperature tends to decrease the digestibility of pasture, hampering weight gain. Increased rainfall however increases the carrying capacity of pasture, and allows improved stocking rates. When these factors were taken into account, a 12% increase in economic productivity for dry weight productivity increases in southern and Eastern areas was estimated (Schofield 1993). The effect in the Northern Beef Zone was even more dramatic, with a reduction in productivity of around 10% compared to the previous analysis. The resulting increase in economic productivity for the Northern Beef zone was 5%.

4.2 Allowing for the "Scourge" Effect

As no data was available on the effect of the EGE on pest and disease levels in a form currently suitable for ORANI modelling, it was necessary to undertake a parametric analysis of the scourge question. This was done by increasing the demand for the "services to agriculture augmenting technical change" parameter in ORANI (*a1ci*), for each of the agricultural industries, until the EGE scenario production benefits were reduced to zero. "Services to agriculture" include activities such as sheep shearing, wool classing, aerial seeding, and crop dusting (Higgs 1986). Although this variable comprises a wide range of agricultural activities, if all non-scourge related activities are assumed to be unchanged, then the total increase in the variable represents the increase in demand for services to combat the EGE enhanced scourges. The result was an indicator of how the resources required to counter these scourges, without having a negative production effect. The same shocks were applied to the *a1land* variable as in the first simulation, and only the values of the *a1ci* variable were changed.

4.3 International Demand Effects

As a large proportion of Australian agricultural produce is exported, any shift in world demand for commodities is likely to have a significant effect on the Australian agricultural sector. If the EGE benefits, or inhibits production to a lesser extent, overseas then the demand for Australian commodities will fall, possibly negating or reversing any benefits experienced from the climate change. If however the EGE detrimentally affects Australia's major rural competitors, Australia may gain a climate change comparative advantage, and any beneficial production effects may be multiplied. To examine the possible effects or changes in the demand for Australian agricultural exports, a sensitivity type analysis was undertaken. Two scenarios were tested, and compared to the original simulation results (not including the scourge factor). A 5% increase and a 5% decrease in the demand for agricultural exports were simulated in the FH-ORANI model. These increases ignore any marginal effects on individual commodities, but provide a guide as to the direction and magnitude of any impacts of a change in export demand. The sensitivity of production to changes in export demand was tested by adjusting the "shift in export demand for commodity i" (fe) variable for each of the commodities examined, by +5% the first time, and by -5% the second.

5. Results

Due to the assumptions used in each of the models, and the speculative nature of the estimates, the results of both simulations should be taken as guides, providing suggestions about the direction and coarse magnitude of possible change, rather than the precise magnitude of that change. Although many of the results are small in absolute terms, their importance is in the way the EGE may impact on Australian agriculture, and the possible areas of the economy where this impact may ripple through. The focus of the results should be on the relative changes within the economy, revealing possible production shifts.

5.1 EGE Production Effects

a) Industry effects

With the EGE shock, production rises in the industries where productivity has increased most (Table 4). The most significant effect has been a substantial shift in resources towards the wheat-sheep zone, at a cost mainly to the pastoral zone. Estimated production in the wheat-sheep zone has risen by 6.6%, whilst production has declined by 2.5% in the pastoral zone. The results suggest the impacts are very small in most industries, with the main changes being in the pastoral and wheat-sheep zones.

b) Commodity effects

The estimated production changes outlined above have had significant effects on the export of agricultural commodities (Table 5). Wheat exports are estimated to have risen by 8.6% (or 1000kt), and barley by 7.3% (200kt). The "other cereals" exports have also increased (13.82%), but involve a much smaller quantity of grain in absolute terms. Increased carrying capacity in the wheat-sheep and high rainfall zones also resulted in greater stocking rates in sheep and cattle and led to a rise of 2.6% in wool exports, and 6.2% in sheep exports. The same trend is shown in meat cattle exports, with an increase of 20.6% (or 180kt).

5.2 Scourge Analysis

The same shocks were applied to the *alland* variable as in the first simulation, and only the values of the *alci* variable were changed. After several sensitivity test simulations were run, the following shocks were found to offset the positive production effects estimated in the first simulation.

Table 3: "Services to Agriculture"-augmenting technical change which offset EGE effects in ORANI

Industry/Zone	(Variable: *a1ci*) Shock
Pastoral	60
Wheat/Sheep	140
High Rainfall	50
Northern Beef	40

From the impact of the shocks applied to the *a1ci* parameter, it can be seen that only a small change in the demand for scourge control is possible before any production benefits of an EGE climate change are negated. This result is conditional on the production in the other agricultural industries being held constant due to scourge control. If the actual demand for services to agriculture in any of the other industries is below the shocks applied, which prevented any production increase, then the effect of scourges in the Northern Beef, Milk Cattle and Pigs, and the Sugarcane, Fruit and Nuts industries will be quite significant. If the effect of these scourges exactly offsets the EGE-production benefits, then it would take an increase of 140% in the demand for services to agriculture in the Wheat-Sheep zone to offset the positive EGE induced production effect derived in the first simulation. Likewise it would take increases in the demand for services of 60% and 50% respectively in the Pastoral and High Rainfall zones to offset their initial EGE effects. Considering the relatively small proportion of total farm expenditure on these services, the effect of pests and diseases under the EGE scenario set out in this study, could have a potentially dramatic effect on agricultural production.

In the first simulation, farmers in the Wheat-Sheep and High Rainfall zones were advantaged by the assumed EGE climate change. In the second simulation, this benefit has been shifted away from farmers and into other areas of the economy, namely the services to agriculture industry which has increased production and labour demand by around 30%. Paradoxically, the economy as a whole may benefit from the need to combat the increased level of pests and diseases, if the level of control does not lead to a reduction in agricultural production.

5.3 Shift in Export Demand Effects

The 5% positive shift in export demand for agricultural commodities has the overall expected effect of increasing production and export volume. The decrease in production experienced in the Pastoral, Other Farming1, Other Farming2, and Poultry Zone, under the EGE effect, is reversed as a result of the positive shift in export demand (Table 6). Production in all these zones increases, most significantly in the Pastoral Zone, where production has increased from -2.5% to +1.4%. In contrast, the Milk Cattle and Pigs Zone, whose export contribution to total production is low, remains lower due to the EGE despite the shift in export demand. The other exception is the Northern Beef Zone, where production is reduced by 3.6% when export demand shifts, as opposed to a slight increase under the EGE scenario. This is due to a reallocation of resources away from the Northern Beef Zone, into the Pastoral, Wheat/Sheep and High Rainfall Zones.

The negative shift, as expected, has the reverse effect on production and export quantity. The Meat Cattle, Milk Cattle and Pigs, and Poultry commodity exports seem particularly elastic to the shifts in export demand (Table 7). Domestic demand for Meat Cattle falls by around 2.5%, due to a price increase of almost 4.5%. This has produced the shift away from the domestic market, and hence the large export effect. The reverse occurs when export demand contracts. It should also be noted that those commodities experiencing very large export demand shifts have a lower export percentage of total product than commodities such as wool and wheat.

6. Conclusions

The results of this study indicate that based on our current knowledge of the effects of dry matter production, and ignoring other effects, the EGE may not have a dramatic effect on Australian agriculture. The benefits of an EGE climate change are not clear, however some parts of the agricultural sector may experience an increase in productivity due to the change in climate. As expected, the results of this study indicate a smaller production effect on Australian agriculture than the previous one. The only region to show significant gains is the Wheat-Sheep Zone but, as with the results for all agricultural production, these gains are far less then in the preliminary study. This highlights the importance of accurate data on the effects of CO_2, temperature, and rainfall on plant production. The revised estimates used in this paper have had a marked effect on the production changes resulting from the EGE when compared to the preliminary investigation.

When the effect of pests and diseases is taken into account, the situation may be very different. It can be seen that the potential effects of scourges in the Northern Beef, Milk Cattle and Pigs, and Sugarcane, Fruit and Nuts industries could be substantial. There is also only a limited tolerance to an increase in scourge controls in the Pastoral and Wheat-Sheep zones before any production benefits from the EGE are offset. There are significant production and export effects exhibited as a result of a shift in export demand for agricultural commodities. It would appear that the effect of the EGE on overseas agricultural production, and the extent of the CO_2 fertiliser effect, could be the deciding factors on the degree of impact the EGE has on Australian agriculture. The most important factor coming from the current research is that the degree of impact that a potential EGE may have on Australian agriculture may well be smaller than initially thought. The likely effect of scourges on Australian agricultural production with an EGE, and the international trade effects are being further investigated by the authors.

Figure 1: Combined Miami Model & ORANI Zones

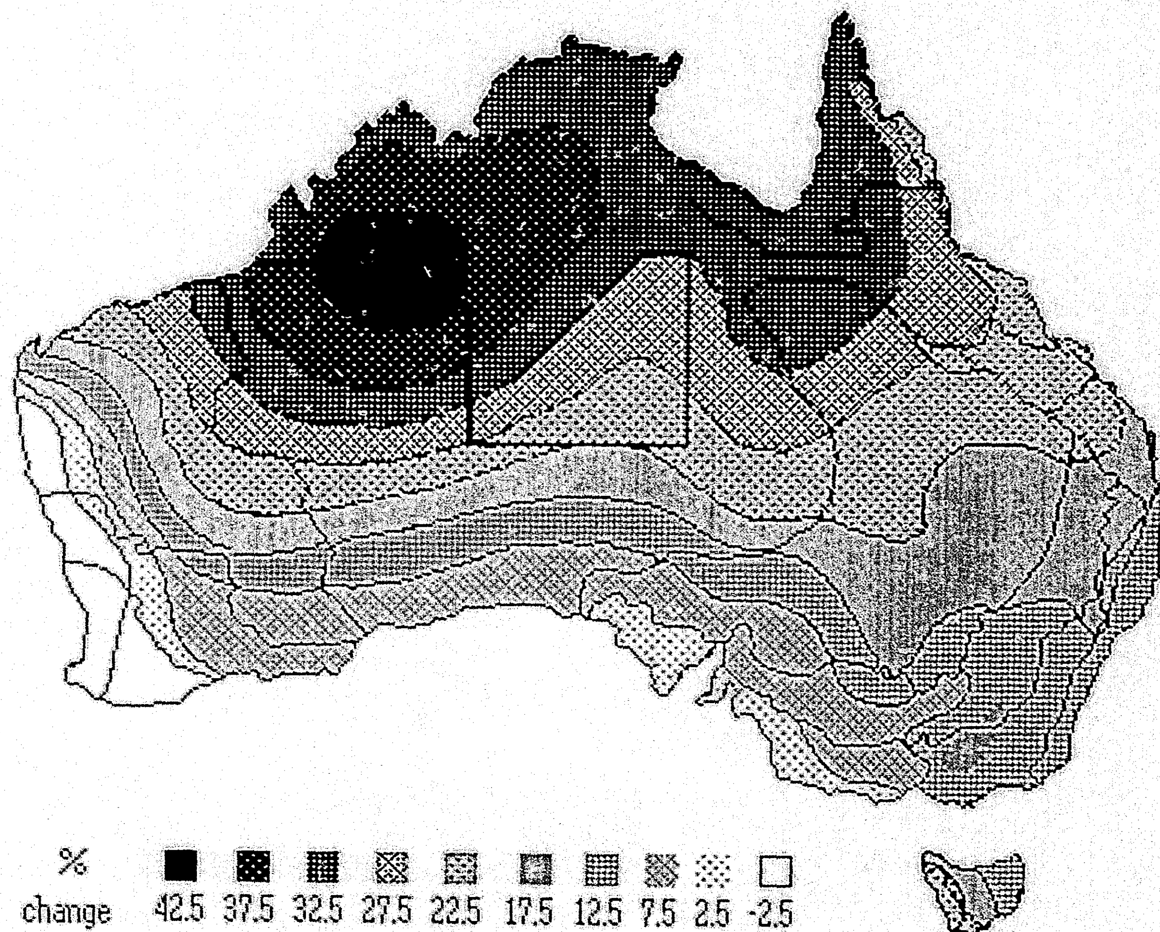
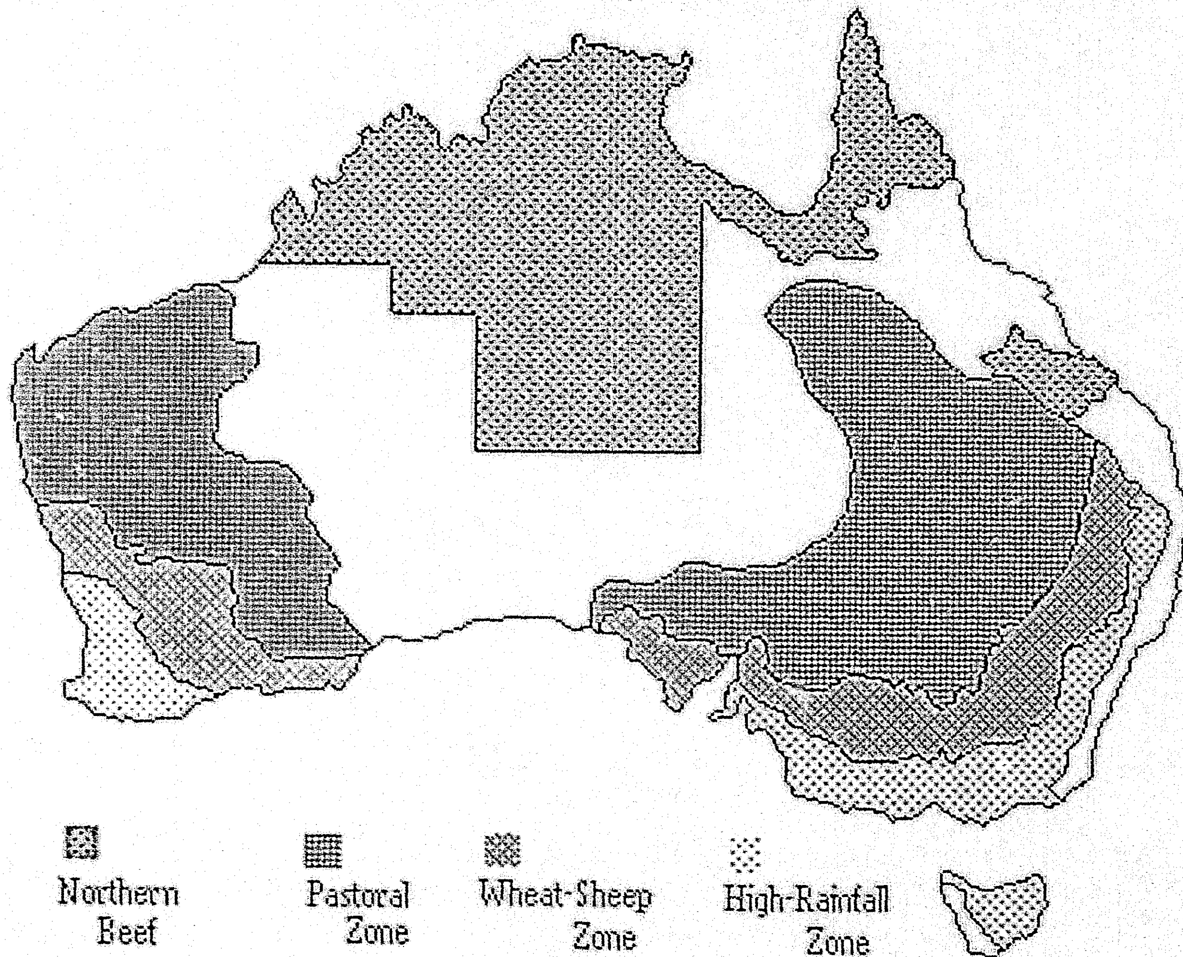


Figure 2: ORANI Agricultural Zones



Climate Change Effects

Table 4: Industry effects (% change)

ORANI Industry	Production
Pastoral Zone	-2.51
Wheat-Sheep Zone	6.62
High Rainfall Zone	0.34
Northern Beef Zone	0.52
Milk Cattle & Pigs	-0.41
Other Farming1*	-1.52
Other Farming2*	-0.26
Poultry	0.94
Services to Ag.	

Table 5: Commodity effects (% change)

ORANI Commodity	Exports
Wool	2.64
Sheep	6.23
Wheat	8.61
Barley	7.33
Other Cereals	13.82
Meat Cattle	20.61
Milk Cattle & Pigs	-2.07
Other Farming1	-13.69
Other Farming2	-1.35
Poultry	-1.29

*Other Farming1 consists of: sugar cane, fruit and nuts.
*Other Farming2 consists of vegetables, cotton, oilseeds, and tobacco

Export Demand Shift Effects

Table 6: Industry effects (% change)

	'+5%	'-5%
ORANI Industry	Production	Production
Pastoral Zone	1.44	-6.38
Wheat-Sheep Zone	14.34	-1.14
High Rainfall Zone	2.86	-2.16
Northern Beef Zone	-3.63	5.16
Milk Cattle & Pigs	-1.81	0.91
Other Farming1	3.32	-4.44
Other Farming2	6.86	-4.98
Poultry	0.95	0.93
Services to Ag.	3.06	-1.13

Table 7: Export Volume effects (% change)

	'+5%	'-5%
ORANI Commodity	Exports	Exports
Wool	8.70	-3.00
Sheep	21.90	-8.09
Wheat	35.20	-5.21
Barley	29.40	-3.15
Other Cereals	52.60	-5.81
Meat Cattle	75.10	-73.67
Milk Cattle & Pigs	-5.30	-74.79
Other Farming1	-17.30	-76.27
Other Farming2	-5.70	-69.12
Poultry	-3.30	-71.53

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