THE POTENTIAL DIRECT IMPACTS OF THE EGE ON AUSTRALIAN AGRICULTURE: A GENERAL EQUILIBRIUM APPROACH

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1. Introduction

During recent years, the greenhouse debate has centred on issues such as the abatement cost of regulating carbon emissions, relevant taxation control methods, and the burden of responsibility for controlling greenhouse gas levels. The focus of most cost-benefit analysis has been on the cost of reducing carbon emissions, and has tended to ignore the potential economic impacts of the EGE on agriculture. This paper aims to examine these impacts, in order to give some insight into the consequences of the expected climate change on the Australian agricultural sector, and the economy as a whole.

Godden and Adams (1990) recommended a general equilibrium approach for examining the potential impacts of the EGE on Australian agriculture. The present study uses the FH-ORANI model of the Australian economy to analyse the economic impact of the direct production effects associated with the EGE. The production effects have been derived from Pittock and Nix's (1986) use of the Miami Model. As the Miami Model does not account for direct CO_2 effects, data on the expected CO_2 fertiliser effect was added to the temperature and rainfall impacts generated by the Miami Model in an additional Simulation. Section 2 of this paper looks at the direct climate change effects to be modelled within the ORANI structure, and Section 3 is concerned with how these relevant effects have been translated, using the Miami Model, into a form suitable for ORANI analysis. Section 4 explains the methodology behind the estimation of the production changes and their effects, and in Section 5, the results of the ORANI simulations are presented, with conclusions drawn from them in section 6.

2. Potential direct agricultural effects of the EGE.

Godden and Armitstead (1992) identified four direct impacts of the EGE on agriculture that could be economically modelled:

- CO_2 availability
- Increased temperature
- Changes in rainfall patterns
- Scourges

Currently, only the first three of these can be satisfactorily modelled, due to the lack of suitable estimates concerning the production effects of scourges such as pests and diseases, across industries and regions.

2.1 CO_2 availability.

Not all plant species are affected by CO_2 concentrations in the same way. Temperate species, with C3 photosynthetic pathways, combine mixtures of CO_2 and O_2 more efficiently than tropical species with a C4 photosynthetic pathway. This phenomenon, known commonly as the "CO_2 fertiliser effect", may result in increased production in many crops, and a substitution away from C4 type crops. Increases in water use efficiency have also been attributed to increased CO_2 concentrations. As most of Australia's commercial plants can be classified as C3, Godden and

Armitstead (1992) concluded "Other factors remaining constant, increased concentration of CO_2 would have a positive effect on overall production".

2.2 Increased temperature.

Increased average temperature is likely to have a varied effect across agricultural regions. As temperature increases, plants tend to reach maturity quicker, and nutrient uptake and organic matter breakdown are accelerated with higher soil temperatures. A moderate rise in temperature (2-4^{o}C) is likely have little effect on cereal production, especially given a higher CO_2 concentration (Wang and Hennesy, 1991). There is likely to be a greater effect on the pome and stone fruit industry, due to the winter chilling requirements of the crops. This is likely to cause an inter-regional substitution effect, with colder areas such as Tasmania, which have an excess of winter chilling units, benefiting over warmer areas such as the Goulburn Valley (Godden and Armitstead, 1992). The total effect on the pome and stone fruit industry is however likely to be negative, resulting in reduced output from these crops. The effects on livestock are also likely to be varied, reducing cold stress in some cases, and increasing heat stress in others, again leading to possible inter-regional substitution, changes in production management, and breed or variety preference.

2.3 Changes in Rainfall Patterns

Rainfall patterns are likely to change in quantity, seasonality, variability and intensity, all having an impact on agricultural production. Increased nutrient leaching from soils due to heavier rainfall, the need for changes in crop rotations, and possible effects on the use of heavy machinery, may all lead to changes in production techniques. However, most rural regions in Australia are likely to benefit from increased summer rainfall. This observation ignores the possible effects of increased rainfall variability (e.g. on the ability to harvest winter cereal crops), and the frequency of "extreme" events.

3 Modelling the Direct Effects

In order to examine changes in a general equilibrium model, it is necessary for those changes to be evaluated in a uniform manner, consistent across industries and regions. There is a wide range of literature on the effects of CO_2, temperature and rainfall on agricultural production. However, most of these studies are partial, in that they examine the effects on individual crops or animals. This situation provides a plethora of disaggregated studies, yielding non uniform data, which can not be included in general equilibrium modelling.

3.1 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 built from data obtained from 52 datum points throughout the world, centred mainly in Europe. Productivity measured in 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 $^{\circ}C$, 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) remarked 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, as previously mentioned, the CO_2 fertiliser effect is ignored.

3.2 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 $1^{\circ}C$, 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 $0.1^{\circ}C$ 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. It is relevant to note at this point that 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.

4. Methodology.

There are three distinct steps in the estimation procedure:

1. Translating the Miami Model estimates into ORANI terms.
2. Incorporating Miami model production effects into the FH-ORANI model.

3. Including commodity specific estimates for the expected CO_2 production effects, and re-estimating the results.

Following the implementation of this procedure, two simulations were carried out. In the first, only the temperature and rainfall effects of the Miami Model as reported by Pittock and Nix (1986) were examined. In the second simulation, the CO_2 fertiliser effect, and the temperature effect on the stone and pome fruit industries were added to the Miami Model results.

4.1 Calibrating the Miami Model estimates to ORANI.

In order to calculate the regional effects of the Miami Model, the percentage change map presented in Pittock and Nix (1986) was scanned into a computer, and an outline created (Figure 1). The ORANI zones, as illustrated in a map by Higgs (1986), were then scanned in (Figure 2), and superimposed over the Miami map. The resulting map (Figure 3), indicated the productivity percentage change bands within each of the ORANI zones. The area of each band was then estimated to derive the area of each ORANI industry in each of the bands of productivity change estimated by Pittock and Nix (Table 1). The weighted average of productivity change by proportion of industry was then estimated (Table 2). Dry weight productivity increases as per Pittock and Nix (1986) were estimated to result in a 50% increase in output for crops, and a 30% increase in output for livestock.

4.2 Incorporating the Miami Model estimates into FH-ORANI.

The net primary productivity change estimates for each industry were then incorporated in the FH-ORANI model as a negative shock to the variable *alland*, for each industry. The *alland* variable is the land-augmenting technical change variable and, when negative, means an increase in the productivity of each unit of land (i.e. less land is needed to produce the same level of output).

The following is a list of shocks app ied in this first simulation:

Variable: *alland*

#	Industry	Shock
1	Pastoral	-5.76
2	Wheat/Sheep	-5.91
3	H. Rainfall	-2.62
4	N. Beef	-9.75

4.3 Including the CO_2 fertiliser effect.

The second simulation contained the same productivity estimates as the first, with commodity specific estimates for the effects of CO_2 also added. These CO_2 estimates .ere taken from Godden and Armitstead (1992), who summarised data on the production effects of CO_2 on the

The second simulation contained the same productivity estimates as the first, with commodity specific estimates for the effects of CO_2 also added. These CO_2 estimates were taken from Godden and Armitstead (1992), who summarised data on the production effects of CO_2 on the main ORANI commodities. The effect of CO_2 on each commodity was then weighted according to that commodity's importance in each industry, taken from the production weights found in the listing of the 1986-87 ORANI database. The CO_2 effect was then estimated for each of the four industries from these weighted estimates. These estimates are presented in Table 3. These figures were then added to the Miami Model estimates used in the first simulation (Table 4). This procedure resulted in a total shock, covering the temperature, rainfall and CO_2 effects on production for each zone. As in the first simulation, the shocks were represented as a negative change to the *alland* variable, to indicate the increase in productivity.

One further change was made to the Miami Model estimates to account for the reduction in chilling days for pome and stone fruit crops. This problem was represented in the "Other Farming1 Zone", industry 6 in the ORANI model. This zone accounts for sugarcane, fruit and nuts, and experiences a decrease in productivity. This decrease is accounted for by the increase in sugarcane and nut production being overshadowed by the decrease in fruit productivity due to reduced chilling days. These estimates were again taken from Godden and Armitstead (1992), and are represented in the model as a positive change to the "Other Farming1" variable.

The following is a list of shocks applied in the second simulation:

Variable: *alland*

#	Industry	Shock
1	Pastoral	-15.39
2	Wheat/Sheep	-31.34
3	H. Rainfall	-9.89
4	N. Beef	-14.75
6	Other Farming	+6.38

Before running the second simulation, it was noted that these percentage changes were quite high, and were actually above *a priori* expectations.

5. Results.

The results of each ORANI simulation are examined separately for their macro economic and micro economic effects. The first simulation indicates the change in economic factors, from the current situation, if the MIAMI model explains the climatic effects on production under the EGE. The second simulation does the same, with the CO_2 effect and the temperature effect on the pome and stone fruit industry also included. Both simulations look at the changes resulting from the shocks applied to them, against a situation of no change. Any absolute figures quoted for production and exports are estimates based on 1991 statistics from the 1992 Commodity Statistical Bulletin. The variables held exogenous in the ORANI closure are listed in Appendix 1.

nominal exchange rate, which has affected both the balance of trade, and the current account deficit. The current account deficit has reduced slightly (-\$1.8m), due to the exchange rate effect on interest repayments, and the balance of trade has worsened (-\$8.9m), as non-agricultural exports fall also due to the marginal appreciation of the Australian dollar. Higher priced imports have increased the CPI, and GDP has risen slightly, due to the increased activity in the agricultural sector.

As a result of the assumed EGE, there is a noticeable redistribution of resources used in agricultural production, towards the industries benefiting most from increased productivity (Table 6). Production in the Northern Beef industry increases by 5.1%, and the Wheat-Sheep industry by 3.8%. These large production increases correspond to the relatively larger productivity increases in those zones. These changes are at the expense of industries with lower productivity increases, such as the High Rainfall zone, whose production declines by 1% despite an increase in productivity of 2.6%. Production in the rest of the agricultural sector is not significantly affected, with the exception of the Poultry industry. The Poultry industry experiences a 1.1% increase in production, due to lower domestic grain prices (Table 7). The decrease in wheat, barley and other cereals prices represents a significant reduction in production costs for the Poultry industry. Services to agriculture rise from the overall increase in agricultural production. Labour demand and land prices respond as expected to the shift in activities, with the greatest increases in the industries with the greatest production increases.

The most significant commodity change occurs in meat cattle exports, increasing by 25.1% (approximately 187kt). Wheat, barley and other cereals all show small percentage increases in exports and domestic supply. Wheat exports rise by 5.1% (604kt) and barley exports by 4.2% (120kt). The rise in wool exports of almost 1.4% is offset by a fall in export price of around the same amount. Wool is the only commodity in which there is a significant price effect, due to Australia being a "price taker" in most other world markets. The fall in exports from the milk cattle and pigs industry (3.2%) does not represent a major reduction in export dollars due to its comparatively small share of the export sector. Domestic supply increases for all commodities, except for those in the Other Farming2 category which are vegetables, oilseeds, cotton and tobacco. Domestic prices move in inverse proportion to supply, except in those commodities which total production is reduced and import prices have forced the domestic price up. This effect is most significant in the milk cattle and pigs commodities, where imports have increased by almost 2.3%.

5.2 Simulation 2: The MIAMI Model plus CO_2 Shocks

The macro economic effects in the second simulation are similar to, but larger than those of the first simulation (Table 8). The greater appreciation in the Australian dollar has reduced interest repayments on the current account deficit by more, and non-agricultural exports have also fallen by more. There is also a more significant GDP and CPI effect, brought about by increased agricultural sector activity and more expensive imports respectively. In comparison, the balance of trade in the second simulation has worsened by \$16m and the current account deficit reduced by \$18m.

The most significant difference between the two simulations is the CO_2 effect on the C3 type crops, which has led to production in the Wheat-Sheep zone increasing by 27.9%, compared to

3.8% in the first simulation (Table 9). This substantially greater change has shifted production away from the Pastoral and High Rainfall zones, where production has fallen by 10.4% and 6.1% respectively, and represents a turn around in production in the Pastoral zone from a small percentage increase in the first simulation. The Other Farming1 industry (sugar cane, fruit and nuts), experiences a decline in production of 1.8% as a result of the adverse temperature effects on the pome and stone fruits. The Northern Beef zone experiences a 3% smaller increase in the second simulation, and the Milk Cattle and Pigs industry decreases by slightly more.

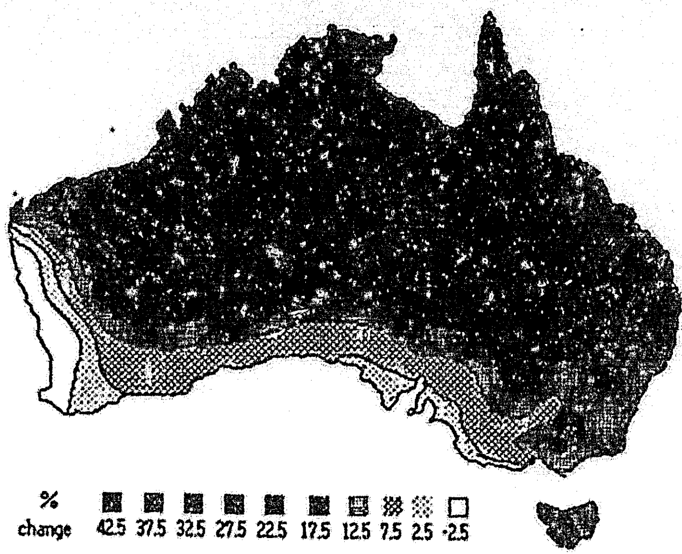
Wheat exports rise by 35.2% (4040kt) in the second simulation, compared to an increase of 604kt in the first simulation. Barley and other cereal exports also rise also, by 29.4% and 52.6% respectively, both up significantly from the first simulation (Table 10). Beef exports also rise dramatically by 75.1% (560kt), due to increased production in the Wheat-Sheep zone. Higher sheep numbers in the Wheat-Sheep zone have also increased wool and sheep exports by 8.7% and 21.9% respectively, representing significantly larger increases than in the first simulation. Domestic supply of wool, sheep, wheat, barley and other cereals all experience considerable increases in the second simulation, with corresponding reductions in price. These changes have resulted in cheaper grain feed for the cattle and poultry industries, and correspondingly increased production in these industries.

6. Conclusions

The results presented in this paper indicate a positive production effect on parts of the Australian agricultural sector resulting from the potential effects of the EGE. Many of these results are small in magnitude, however they do indicate significant relative changes relating to the potential EGE. The industries to benefit most from the EGE would appear to be the Wheat-Sheep, and Northern Beef zones. Within these zones, beef, wheat, barley and other cereals experience the greatest increases in production. There is a significant shift in resources however, away from zones such as the High Rainfall zone and, when CO_2 is included, the Pastoral zone. The size of these increases depends on the amount to which the Miami Model represents the physical effects of the EGE, and the extent of the CO_2 effects. Taking the results from applying the Miami Model productivity changes to the ORANI model, increased productivity occurs in all Australia's major agricultural export commodities. These increases are stimulated further by the inclusion of the CO_2 effects. The agricultural sector as a whole grows, despite a redistribution of resources away from milk cattle, pigs, and crops such as fruit, sugar cane, vegetables and cotton.

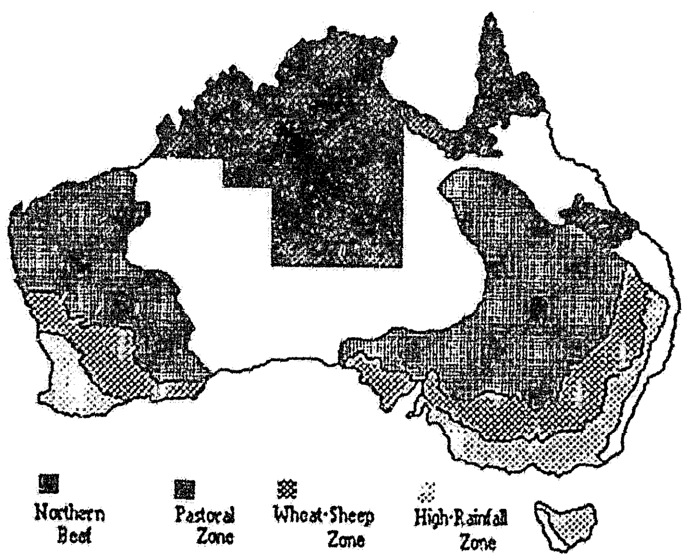
However, these results do not indicate the effects of rainfall characteristics other than annual means, nor scourges. These effects could not be simulated, and may have a large impact on the production of some commodities. Modern genetic engineering and disease controls may overcome some of the possible scourges that result from the EGE, possibly at the expense of higher production costs. Rainfall variability and seasonality may also have considerable effect on production, a situation which is much harder to control. Another factor not considered here is the effects of the EGE on overseas agricultural production which may either increase or decrease the demand for Australia's agricultural exports this aspect is the subject of continuing research by the authors. Even so, these results do indicate significant possible benefits to some parts of the agricultural sector as a result of the EGE. There needs to be further research into the possible effects not modelled here, and refining of estimates for the effects of CO_2, rainfall and temperature.

Figure 1: The Miami Model Productivity Zones



Source: rescaled from Pittock and Nix (1986)

Figure 2: The ORANI Zones



Source: rescaled from Higgs (1986)

Figure 3: Combined Miami Model & ORANI Zones

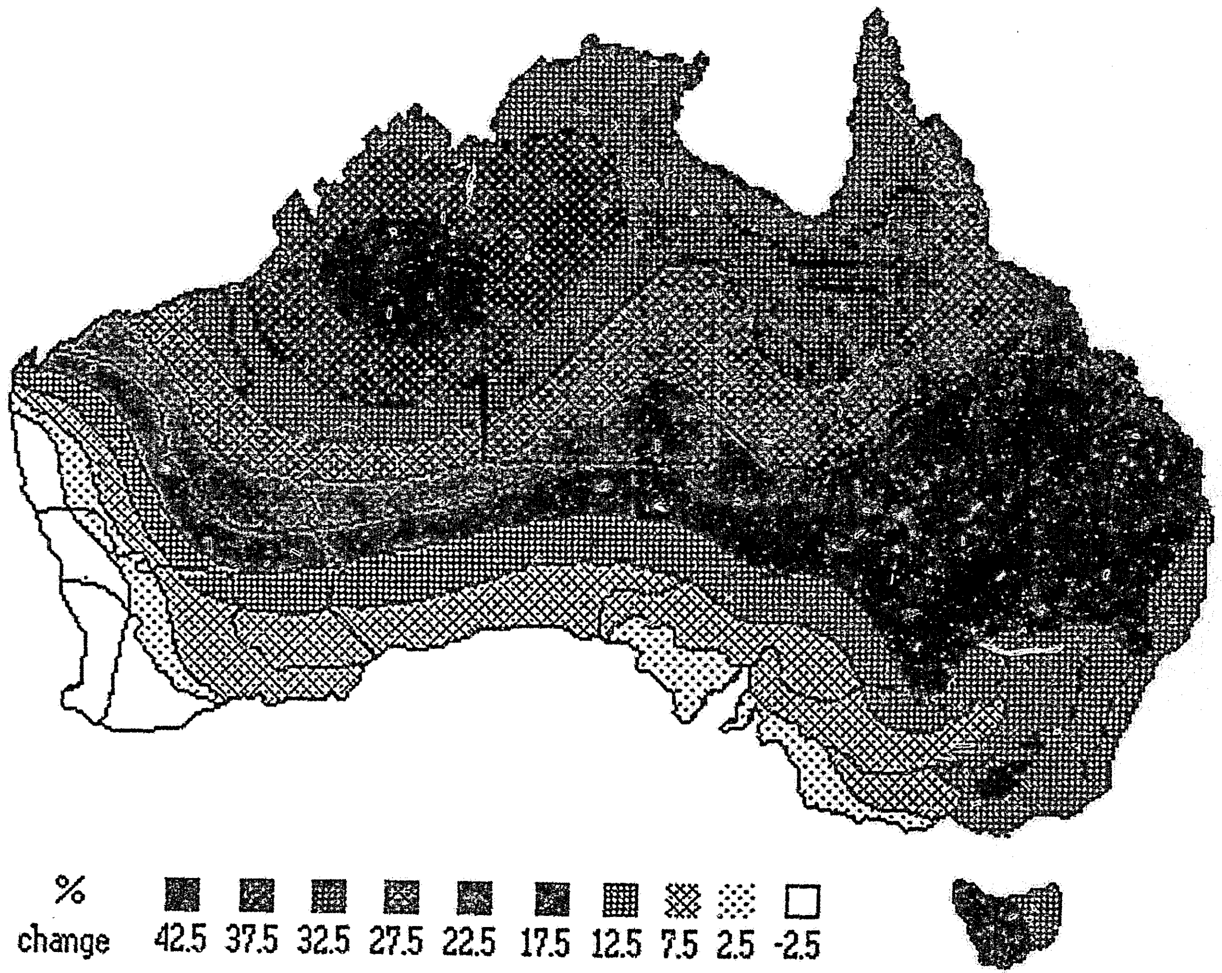


Table 1: % Area of each ORANI Industry Within each Miami Model % Change Band

% Change Band	ORANI Industry			
	Pastoral	Wheat-Sheep	H.Rainfall	N. Beef
-2.50	2.58	0.00	11.18	0.00
2.50	2.23	4.66	27.94	0.00
7.50	13.46	14.38	10.88	0.00
12.50	13.74	32.46	33.82	0.00
17.50	27.68	34.01	16.18	0.00
22.50	24.27	14.19	0.00	13.35
27.50	9.27	0.29	0.00	12.72
32.50	6.76	0.00	0.00	42.53
37.50	0.00	0.00	0.00	23.45
42.50	0.00	0.00	0.00	7.95
Total	100.00	100.00	100.00	100.00

Source: Calculated from Figure 3

Table 2: % Productivity Change / Industry

% Change Band	ORANI Industry			
	Pastoral	Wheat-Sheep	H.Rainfall	N. Beef
-2.50	-0.06	0.00	-0.28	0.00
2.50	0.06	0.12	0.70	0.00
7.50	1.01	1.08	0.82	0.00
12.50	1.72	4.06	4.23	0.00
17.50	4.84	5.95	2.83	0.00
22.50	5.46	3.19	0.00	3.00
27.50	2.55	0.08	0.00	3.50
32.50	2.20	0.00	0.00	13.82
37.50	0.00	0.00	0.00	8.79
42.50	0.00	0.00	0.00	3.38
Wtd.Avg	17.77	14.48	8.29	32.50

Source: Calculated from Table 1

Table 3: CO2 Effects/Commodity

ORANI Commodity	ORANI Industry				
	Pastoral	Wheat-Sheep	H.Rainfall	N. Beef	Total
wool	5.00	5.00	5.00		5.00
sheep	5.00	5.00	5.00		5.00
wheat	47.00	47.00	47.00		47.00
barley	36.00	36.00	36.00		36.00
cereals	23.00	23.00	23.00		23.00
meat cattle	5.00	5.00	-5.00	5.00	5.00
Fruit/Sugar	*	*	*	*	-6.38

Source: Godden and Armitstead (1992)

Table 4: Commodity Productivity Increase / ORANI Industry

ORANI Commodity	ORANI Industry				
	Pastoral	Wheat-Sheep	H.Rainfall	N. Beef	Fruit/Sugar
wool	2.84	1.25	2.04	0.00	0.00
sheep	0.34	0.37	0.59	0.00	0.00
wheat	4.44	19.15	0.97	0.00	0.00
barley	0.52	2.58	0.76	0.00	0.00
cereals	0.26	1.41	0.95	0.00	0.00
meat cattle	1.21	0.69	1.95	5.00	0.00
Fruit/Sugar	*	*	*	*	-6.38
Total	9.62	25.44	7.27	5.00	-6.38

Source: Calculated from Table 3 and ORANI Database

Simulation 1

Miami Model Temperature & Rainfall Effects

Table 5: Macroeconomic effects

Balance of Trade	($m)	-8.80
Change in real CAD	($m)	-1.80
Real GDP (market expenditure)	(% Change)	0.11
Nominal exchange rate ($A/unit)	(% Change)	-0.01
CPI	(% Change)	0.03

Table 6: Industry effects (% change)

Industry	Production	Labour	Land Price
Pastoral zone	0.2	-1.8	0.1
Wheat-Sheep	3.8	2.3	3.2
High Rainfall	-1.1	-3.1	-1.7
Northern Beef	5.1	2.4	4.2
Milk Cattle & Pigs	-0.1	-0.2	-0.1
Other Farming1	-0.1	-0.1	-0.1
Other Farming2	-0.1	-0.2	-0.1
Poultry	1.1	1.1	0.9
Services to Ag.	0.5	0.5	0.5

Table 7: Commodity effects (% change)

Commodity	Exports	Export Price	Domestic Supply	Domestic Price
Wool	1.4	-1.1	1.3	-1.3
Sheep	1.7	-0.1	1.7	-0.2
Wheat	5.1	-0.4	3.8	-0.5
Barley	4.2	-0.2	3.4	-0.3
Other Cereals	7.5	-0.4	3.2	-0.5
Meat Cattle	25.1	1.1	2.1	-1.4
Milk Cattle & Pigs	-3.2	0.2	0.2	0.2
Other Farming1	-1.3	0.1	-0.1	0
Other Farming2	-1.2	0.1	0.1	0
Poultry	-0.4	0	1.1	0

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

Simulation 2
Miami Model Plus CO2 Effects

Table 8: Macroeconomic effects

Balance of Trade	($m)	-15.98
Change in real CAD	($m)	-18.31
Real GDP (market expenditure)	(% Change)	0.22
Nominal exchange rate ($A/unit)	(% Change)	-0.19
CPI	(% Change)	0.06

Table 9: Industry effects (% change)

Industry	Production	Labour	Land Price
Pastoral zone	-10.4	-19.1	-11.8
Wheat-Sheep	27.9	18.8	24.1
High Rainfall	-6.1	-14.4	-9.1
Northern Beef	2.1	-4.9	-0.2
Milk Cattle & Pigs	-1.7	-2.5	-1.7
Other Farming1	-1.8	-0.6	-1.5
Other Farming2	-0.7	-0.9	-0.4
Poultry	2.9	2.8	2.4
Services to Ag.	3.1	2.9	2.6

Table 10: Commodity effects (% change

Commodity	Exports	Export Price	Domestic Supply	Domestic Price
Wool	8.7	-6.2	8.1	-7.7
Sheep	21.9	-1.3	11.8	-1.8
Wheat	35.2	-2.4	26.1	-3.2
Barley	29.4	-1.3	24.1	-1.8
Other Cereals	52.6	-2.1	21.8	-2.8
Meat Cattle	75.1	-2.8	5.2	-3.7
Milk Cattle & Pigs	-5.3	0.3	0.5	0.1
Other Farming1	-17.3	0.9	-1.7	0.9
Other Farming2	-5.7	0.3	0.3	0.1
Poultry	-3.3	0.2	2.9	-0.1

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

Appendix A

Exogenous Variables

Macro economic:

ai	Share of govt. investment in total investment expenditure
bmr	Real means-tested transfers per recipient
bnr	Real non-means-tested transfers per recipient
bur	Real unemployment benefit per unemployed person
delgbr	Absolute change in real govt. borrowing requirement ($m)
f5gen	Overall shift in govt. demands
fc	Shift in fiscal consumption function
fgo	Shift in other nominal govt. expenditure
fk	Shift in average rate of (direct) tax on non-labour incomes
fl	Shift in average rate of (direct) tax on labour income
fro	Shift in nominal govt. revenue from other sources
lu	Number of persons unemployed
omega	Economy-wide expected rate of return on fixed capital
rf	Rentals received by Australians from investments overseas
q	Number of households
taxrate1	Uniform % change in ad vel. tax on sales to industry for intermediate use
taxrate2	Uniform % change in ad vel. tax on sales to industry for fixed capital
taxrate3	Uniform % change in ad vel. tax on sales to households
taxrate5	Uniform % change in ad vel. tax on sales to govt.

Micro economic:

$a1_{(j)}$	Hicks-neutral input-augmenting technical change in industry j
$a1cap_{(j)}$	Fixed capital-augmenting technical change in industry j
$a1lab_{(j)}$	Labour-augmenting technical change in industry j
$a1land_{(j)}$	Land-augmenting technical change in industry j
$a1prim_{(j)}$	Primary factor-augmenting technical change in industry j
$alpha_{(j)}$	Rate of investment allowance in industry j
$delta_{(j)}$	Rate of depreciation allowance in industry j
$f2_{(j)}$	Shift in investment in industry j
fyk(j)	Shift in (direct) tax rate on non-labour income in industry j
$fw_{(j)}$	Shift in price of working capital in industry j
$fwagei_{(j)}$	Shift in average wages in industry j
$n_{(j)}$	Use of land in industry j
$r0_{(j)}$	Current rate of return after tax on fixed capital in industry j
ti(j)	Scaling factor, indirect non-commodity taxes (net) in indusrty j
tpkcap	Property tax rate on fixed capital in industry j
tpkland	Property tax rate on agricultural land in industry j
fe(i)	Shift in export demand for commodity i
pm(i)	Forgein currency fob price of commodity i
$powtax4_{(i)}$	Power of tax on exports of commodity i
$powtaxm_{(i)}$	Power tariff on commodity i
$f5_{(i,s)}$	Shift in govt. demand for commodity i, from source s
$fwageoi_{(j,m)}$	Shift in wages received by labour in occupation m, industry j
$fyl_{(j,m)}$	Shift in tax rate on labour income in occupation m, industry j
tploi(j,m)	Payroll tax rate on occupation m, industry j

REFERENCES

ABARE, (1992), *Commodity Statistical Bulletin,* Australian Government Printing Service, Canberra.

Dixon, P. Parmenter, B. Sutton, J. Vincent, D. (1982), *ORANI: A Multisectoral Model of the Australian Economy,* North-Holland, Amsterdam.

Godden, D. and Adams, P. (1992), "The Enhanced Greenhouse Effect and Australian Agriculture". Chapter 17 in J.M. Reilly and M. Anderson (eds), *Economic issues in Global Climate Change: agriculture, forestry, and natural resources,* Westview press, Boulder.

Godden, D. and Adams, P. (1991), "Economics, Agriculture, and the Enhanced Greenhouse Effect". Veterinarians and the Environment, Pan Pacific Conference, Darling Harbour, Sydney 12-17 May.

Godden, D.and Armitstead, P. (1992), "Modelling the Direct Effects of a Potential Enhanced Greenhouse Effect on Australian Agriculture". 36th Annual Conference Australian Agricultural Economics Scociety, Australian National University, Canberra 10-12 February.

Higgs, P. (1986), *Adaption and Survival in Australian Agriculture,* Oxford University Press, Melbourne.

Lieth, H. (1975), "Modeling the Primary Productivity of the World", in Lieth, H. and Whittaker, R.H. (eds.), *Primary Productivity of the Biosphere*, Springer-Verlag New York, pp. 237-263.

Pittock, A.B. and Nix, H.A. (1986). "The Effect of Changing Climate on Australian Biomass Production - A Preliminary Study". *Climatic Change* 8, pp. 243-255.