The International Effects of Climate Change on Agricultural Commodity Prices, and the Wider Effects on New Zealand

Adolf Stroombergen*

Motu Working Paper 10-14
Motu Economic and Public Policy Research

December 2010

* Adolf Stroombergen is an Affiliate of Motu, and is Chief Economist and Director of Infometrics Limited.

Author contact details
Adolf Stroombergen
Infometrics
astro@infometrics.co.nz

Acknowledgements
This report has been prepared by Dr Adolf Stroombergen. Comments on a first draft by Dr Suzi Kerr and Niven Winchester are gratefully acknowledged. Funding for this report was from the Foundation for Research Science and Technology through the Integrated Economics of Climate Change programme, led by Motu.

Motu Economic and Public Policy Research
PO Box 24390
Wellington
New Zealand

Email info@motu.org.nz
Telephone +64 4 9394250
Website www.motu.org.nz

 ISSN 1176-2667 (Print), ISSN 1177-9047 (Online).

Abstract
This research takes a closer look at the effects of climate change on New Zealand agriculture and on the wider economy, including indirect international effects such as changes in the prices of goods exported from and imported to New Zealand, as well as carbon prices and policies. Economic loss from short term catastrophic events such floods and landslides is not investigated. Infometrics (2007) presented an initial quantitative analysis of some of the above issues. In this paper they update the part of that report that looked at the effect of climate change on agricultural commodity prices, by considering some new scenarios based on international research since 2007, and expand the time-period from 2025 to 2070.

JEL codes
F18, Q1, Q54

Keywords
agricultural commodity prices, GE modelling

Contents

1. Introduction

Research by EcoClimate (2007) looked at the direct effects of climate change on New Zealand agriculture and on the wider economy. It summarised the findings of other researchers, coming to the provisional conclusion that a change of one standard deviation in the number of days of soil moisture deficit (DSMD, a measure of climate change effects on agriculture), reduces agricultural gross output by less than 5% in most cases. The flow-on effect on New Zealand's GDP of such a change is around 0.1%. However, the effects are not linear. A change of three standard deviations in DSMD reduces national GDP by around 1%.

These estimates do not include economic loss from short term catastrophic events such floods and landslides.

Another, possibly more important dimension of the impact of climate change on New Zealand agriculture is via indirect international effects. In broad terms this has two components:

1. How the impacts of climate change on other countries, and other countries' reactions to those impacts (such as via trading arrangements and production subsidies), affect the prices of the sorts of goods New Zealand exports and imports.

2. How other countries deal with the task of reducing emissions, such as via carbon prices and protective policies against 'free-riders'.

Infometrics (2007) presented an initial quantitative analysis of some of the above issues. Here we update the part of that report that looked at the effect of climate change on agricultural commodity prices, by considering some new scenarios based on international research since 2007. We also extend the focus of the analysis from 2025 to 2070, a more sensible time horizon for looking at the effects of global warming, and take advantage of the new version of the 'Energy Substitution Social Accounting Matrix' (ESSAM) model, which is based on an estimated input-output table for 2005/06.[1]

The results generally show that New Zealand benefits from the sorts of changes in agricultural commodity prices that are expected to occur under global warming, especially if there is no carbon fertilization effect. This is perhaps counter-intuitive. It

[1] See Stroombergen (2008).

arises because other countries also benefit from carbon fertilization, eroding the higher international prices that would occur without carbon fertilization – from which New Zealand would benefit substantially.

Floods and other extreme events aside, it seems that the effects on New Zealand from changes in agricultural commodity prices caused by global warming could easily outweigh the direct effects of global warming on New Zealand agricultural output.

2. Previous Research

Infometrics (2007) looked at the economic effects on New Zealand in 2025 of changes in world agricultural commodity prices that could accompany climate change. Estimates of the effects of climate change on agricultural prices came from international studies. At the time such studies were scarce, and the situation has not changed much.

The dearth is not in terms of the effects of climate change on agricultural production, although there is still much uncertainty in this regard, as will be discussed below. The scarcity of research is in the link between changes in production and changes in prices, especially in relation to commodities that are important to new Zealand such as dairy and meat. A change in the climate may shift agricultural supply curves, but the new price-quantity equilibria will include price changes as well as quantity changes. Estimating these links requires the use of models that incorporate both demand curves and supply curves, and allow for international trade.

Earlier studies such as Fischer et al (2005) and Parry et al (2004) used an integrated ecological-economic modelling framework to assess food production and security under climate change. Cereal production is taken as a proxy for agricultural production as wheat, rice, maize and soybeans, account for two thirds of average calorific intake and provide most human protein either directly or indirectly via livestock feed.

In contrast to Parry et al, Darwin (2004) distinguishes between crop and livestock production and prices. Some livestock uses feed crops such as corn, so suggesting a positive relationship between crops and livestock production. However, crops and livestock could also be substitutes with regard to land use.

The analyses by Fischer et al proposes that climate change will increase the prices of agricultural commodities on world markets, but probably by less than 10%, allowing for CO_2 fertilisation. Darwin's analysis also projects higher prices if CO_2 fertilisation is excluded, but including it leads to a fall in prices. Darwin's methodology is somewhat more appealing as it allows for land use change and provides confidence intervals. Nevertheless all authors urge caution as there is substantial uncertainty around CO_2 fertilisation such that it is difficult to be confident about even the direction of price changes under climate change, let alone their magnitude.

Accordingly Infometrics (2007) looked at two scenarios:

- **Scenario 1:** A 10% increase in world agricultural prices relative to a no climate change scenario, reflecting a drier and hotter climate.

- **Scenario 2:** A 10% fall in world agricultural prices due to better growing conditions throughout the world, which leads to a fall in demand for but New Zealand's agricultural exports. However, in recognition that this would likely be driven by CO_2 fertilisation, agricultural productivity in New Zealand is raised by 2% in crop production and 1% in livestock production. (This is all broadly consistent with Darwin's estimates).

The main results are shown in Table 1.

Table 1: Effects of Climate Change in 2025
(% change on BAU without climate change)

	Scenario 1	Scenario 2
RGNDI	1.9	-2.7
CO_2e emissions	1.9	-3.5

The increase in RGNDI[2] in Scenario 1 is caused by the lift in the terms of trade delivered by higher agricultural prices. However, greenhouse gas (GHG) emissions, notably emissions of methane and nitrous oxide rise above BAU. To the extent that New Zealand is part of an international agreement to reduce global emissions, this increase in emissions might affect how many emission units New Zealand would have to purchase on the world market. This was not explored.

Scenario 2 presents the opposite picture, further exacerbated by the decline in demand for New Zealand products. The international effects (lower prices and lower demand) easily outweigh the local productivity effect of CO_2 fertilisation.

In the following section some new international research is considered, which is then used as input in general equilibrium modelling in Section 4.

[2] RGNDI is Real Gross National Disposable Income. It is a better measure of economic welfare than GDP as it allows for net factor payments to foreigners and for changes in the terms of trade.

3. New Estimates of Changes in World Prices

As was the case previously, mention of dairy, meat and wool in studies of the effects of climate change on agriculture is extremely rare. Thus we are forced into inferring what we can from studies that focus on changes in the prices of grains – following Fischer et al.

Msangi and Rosegrant

Msangi and Rosegrant (2007) look at the effects of climate change on agriculture by linking the IMPACT-WATER model to models of stream flow and run-off that can downscale GCM results to 69 river basin areas.[3] The IMPACT model does include meats and milk, but unfortunately these commodities are not included in the WATER module. The analysis concentrates on rice, wheat and maize which, following Fischer at al, we can assume is a general proxy for human calorific intake.

The modelling produces the price projections shown in Table 2.

Table 2: Projections to 2000-2025 relative to BAU (%)

	Price Changes				Quantity Changes			
	Rice	Wheat	Maize	Average	Rice	Wheat	Maize	Total
2020:A1	-17	-13	-44	-27	2.0	-1.4	14.1	5.6
2080:A1	-17	-14	-50	-23	2.0	-2.9	16.7	6.1
2020:B2	-15	-12	-36	-30	2.0	0.0	11.9	5.2
2080:B2	-17	-13	-40	-26	3.1	0.7	13.5	6.4

The labels A1 and B2 refer to scenarios produced in the Special Report on Emission Scenarios (SRES) report by the International Panel on Climate Change (IPCC) Briefly:

Scenario A1: Rapid economic growth, low population growth, rapid introduction of new and more efficient technology. Economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. The pursuit of personal wealth dominates the

[3] GCM denotes Global Climate Models or General Circulation Models.

pursuit of environmental quality. Global temperature change by 2010 is estimated at 2.8-3.8°C above 1990 (from the Hadley and Max Planck models).

Scenario B2: Less world integration with local solutions to economic, social, and environmental sustainability. Less rapid, and more diverse technological change, with emphasis on community initiatives and social innovation. Global temperature change by 2100 estimated at 2.5-3.5°C above 1990 (from the Hadley and Max Planck models).

All results are expressed relative to a Business as Usual (BAU) scenario without climate change. Note also that the 2020 scenarios from the GCMs relate to the 30 year period centred on the 2020s. Similarly for the 2080 scenarios; their application to the 2000-2025 period is (presumably) to provide sensitivity testing.

Msangi and Rosegrant also look at production and price variability, not just averages, by changing the frequency of ENSO events.[4] For the same mean change in water availability the models project lower total food production as a lack of water from more droughts reduces production, but more water from flooding cannot be utilised to lift production.

Halving the number of ENSO events in tandem with the A1 and B2 scenarios reduces world food commodity prices by 2-3%, while doubling the number of events raises them by around 15%. However, the effects of more ENSO are nonlinear. Against the background of the current climate the change in prices for halved ENSO is still -2%, but for the doubled ENSO it is about 23%. Thus the CO_2 fertilization effect reduces the severity of an increase in the number of future ENSO events.

The modelling results also show that rain fed agriculture is more affected by climate change than irrigated agriculture, due to the absence of means to supplement water deficits with more irrigation in many countries. However, from an economics perspective this could be simplistic as irrigation is unlikely to have a vertical supply curve. Perhaps a better way to interpret the results is as indicating that adaptive measures such as irrigation and the development of more drought resistant crop varieties are worth pursuing, so that the outcomes projected by the model are ameliorated. Of course other

[4] El Nino Southern Oscillation – a measure of pressure difference between Tahiti and Darwin, and of the amount of warming or cooling of surface waters of the tropical eastern Pacific Ocean.

actions such as changing cultivation practices and developing new cultivars might be cheaper.

Cline

Cline (2007) uses six climate models to analyse the effect of climate change on agricultural production by two different methods:

- Reduced-form, process-based crop models that include adaptation responses such as fertilizer, irrigation, crop varieties, planting dates, and so on.

- Riccardian, regional cross-section models based on econometric analysis of the effects of temperature and precipitation on output. Implicitly these models include some types of adaptation responses, but cannot by definition, allow for the effects of carbon fertilization.

The focus of the analysis is on the 2080s, with the GCM results relating to SRES Scenario A2. Global warming by the 2080s is 3°C. Both types of models are applied country by country or at an even finer level.[5]

The results from the various models are weighted up according to author's assessment of their reliability, leading to a 'preferred estimate' of a 16% reduction in world agricultural output in 2080 without any carbon fertilization effect and a reduction of 3% with carbon fertilization – relative to a scenario without climate change. Interestingly, for New Zealand the estimates are for increases of 2.2% and 17.5% respectively. (It may be worthwhile obtaining some other opinions on the reasonableness of these numbers.) Cline notes that variability across the agricultural-economic models is more important than variability across the climate models.

It is unfortunate that the useful metric of Days of Soil Moisture Deficit used in Ecoclimate (2007) for measuring the direct impact of climate change, is not used in the studies cited above. This would have made it possible to reconcile these studies with the earlier work.

[5] Some of the models were also those used in Parry et al (2004), whose research contributed to the modelling in Infometrics (2007).

Estimate price changes

While the focus on 2080 is welcome, essentially all we have is some information about the shift in the supply curve. Prices are completely absent and there is no allowance for international trade. This seemingly makes the information of little value to our intended GE modelling.

In Table 2 (from Msangi and Rosegrant) the average price change is about -26% for a 6% increase in quantity, implying a demand elasticity of 0.23. As noted, Cline's estimates of changes in production relate to shifts of the supply curve, not to a change in the quantity consumed. However, from standard theoretical results on the incidence of a tax, we can write:

$$\frac{\partial P}{P} \approx \frac{-1}{\eta_S - \eta_D} * \frac{\partial Q}{Q}$$

where $\partial Q/Q$ is the horizontal shift of the supply curve, not the change in the quantity at equilibrium.

Intuitively, if the supply curve is vertical (η_S=0), the effect on price is determined only by the elasticity of demand. If the supply curve is horizontal ($\eta_S=\infty$), price does not change.

Using the estimate η_D = -0.23 and assuming this holds in 2080, Table 3 shows the implied change in the market price for a range of plausible values of η_S.

Martin (1991) in a survey of many studies estimates a long run price elasticity of supply of 0.3 to 0.9; covering a range of 0.6 to 0.9 in relatively advanced and land-abundant countries and 0.2-0.5 in developing countries. In the long run supply responses depend more on technologies than on opportunities for land use change.[6]

Table 3: Changes in Global Food Prices in 2080

Supply curve shift η_S	0.30	0.50	0.70	0.90
$\partial Q/Q$=-3%, C fert.	5.7%	4.1%	3.2%	2.7%
$\partial Q/Q$=-16%, no C fert	30.2%	21.9%	17.2%	14.2%

[6] There is much uncertainty in estimates of the price elasticity of supply for agriculture. A good discussion is given in Diebold and Lamb (1996).

Without carbon fertilization the price changes are significant. Note that these price changes are after any movement along the supply curve. For example, for η_S=0.5 and a shift in the supply curve of -16%, the change in the actual quantity supplied to the market is only -5.0%.

As a further illustration of the effects of uncertainty, Tebaldi and Lobell (2008) present a probabilistic assessment of the effects of climate change on crop yields using regression models. Excluding adaptation responses (and price effects), they estimate ranges of yield uncertainty for barley, maize and wheat, as shown in Figures 1-3. With climate and crop uncertainty combined, the interquartile range spans about ten percentage points, but the estimates are firmly negative. Adding the carbon fertilization effect still gives a strong negative result for maize, but a weak negative result for barley and a weak positive result for wheat.

The maize result is at odds with that obtained by Msangi and Rosegrant, shown in Table 2 above. The difference is more than can be attributed to the difference in time horizons. However, Tebaldi and Lobell point out that their ranges are intended more to quantify the degree of uncertainty around any given point estimates, rather than portraying the actual uncertainty around whatever might be the best point estimates. This would also need to include other sources of uncertainty such as around the choice of model and data quality.

Figure 1: Changes in Barley Yield to 2030

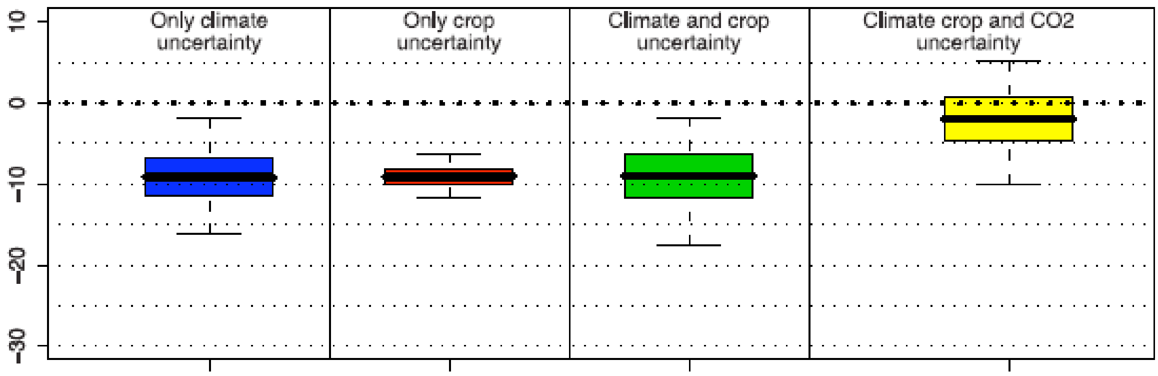


Figure 2: Changes in Maize Yield to 2030

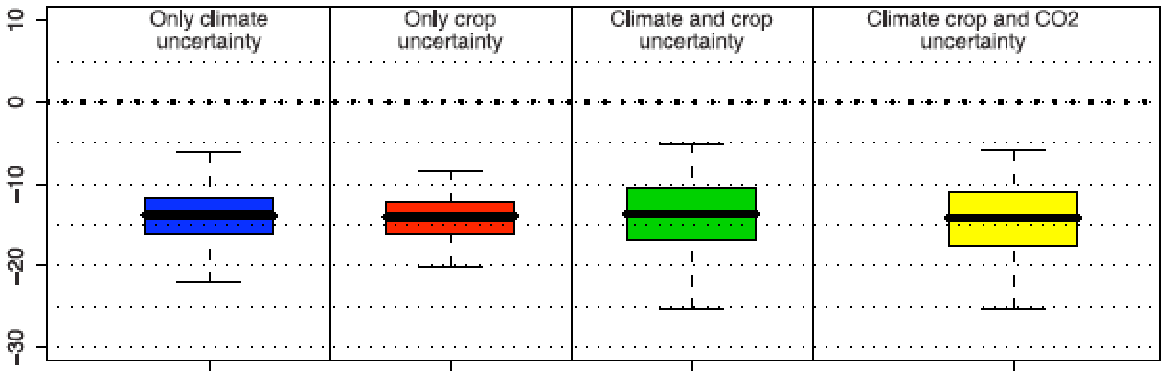
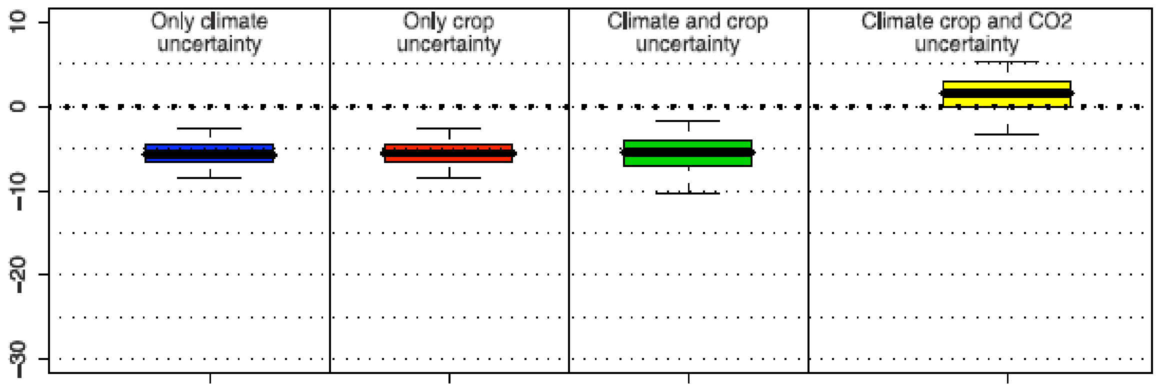


Figure 3: Changes in Wheat Yield to 2030



Source: Tebaldi and Lobell (2008)

<u>Summary</u>

From the implied price changes in Table 3 it seems that a reduction in global food prices of around 5% under carbon fertilization is plausible. According to Cline new Zealand's agricultural output would increase by 17.5%, but for modelling purposes (in the following section) we scale this back to 15%.

Without carbon fertilization the price changes in Table 3 cover a large range, from around 15% to 30%. Hence we look at both of these values in the following section.

4. General Equilibrium Modelling

Scenario specification

Infometrics (2009) looks at alternative emissions scenarios for New Zealand in 2070. So as to preserve the opportunity to integrate that research with our current focus on the effects of climate change on New Zealand via its effect on global food prices, we use the same 2070/71 Business as Usual (BAU) scenario as a reference case against which to compare different food price scenarios.

The BAU is not intended as a forecast of the economy. Rather it is intended as a plausible projection of the economy in the absence of major external events and major policy changes, although a carbon price is included. Details of its construction are given in Appendix A.

To the BAU the following 'shocks' are applied to simulate the indirect effects of climate change on the demand for New Zealand's agricultural exports. These draw on the results discussed in Section 3.

- **Scenario 1:** A price increase of 5% for exports and imports of dairy, meat and horticultural products, coupled with an improvement in agricultural productivity of 15% to simulate the effects of carbon fertilization.

- **Scenario 2:** A price increase of 15% for exports and imports of dairy, meat and horticultural products, with no change in productivity.

- **Scenario 3:** A price increase of 30% for exports and imports of dairy, meat and horticultural products, with no change in productivity. Scenario 3a is a sensitivity test with all price elasticities of demand for New Zealand exports arbitrarily halved.

- **Scenario 4:** As in Scenario 3 but in the context of New Zealand being part of an international agreement to reduce emissions. Higher agricultural prices can be expected to increase New Zealand's GHG emissions, implying the need for either more domestic abatement or the purchase of emissions permits on the international market at the prevailing carbon price.

Scenarios 1-3 and the BAU, while including a carbon price, do not contain any assumption about an international emissions obligation in 2070. Thus if emissions rise New Zealand is not forced to purchase more emission permits on the world market. In Scenario 4, any rise in emissions must be offset by the purchase of permits.

In these scenarios the following are held constant at BAU levels:

- Total employment, wage rates endogenous.
- Total capital stock, user costs of capital endogenous.
- Balance of payments as in world prices, real exchange rate endogenous.
- Fiscal surplus, personal income tax rates endogenous.

The first two macroeconomic closure rules imply that the overall level of resource use in the economy is not dependent on climate change. Other closure rules are possible. For example instead of fixed employment, wage rates could be fixed at BAU levels. This implies, however, that the long run level of total employment is driven more by the climate than by the forces of labour supply and demand, which we consider unlikely. The climate is more likely to affect people's incomes.

The third rule ensures that the cost of any adverse external shock such as lower demand for New Zealand exports is not met simply by borrowing more offshore, as this is not sustainable. Relaxing this constraint would mean that in the long term New Zealand could run a larger external deficit than it otherwise would – not a view likely to be shared by foreign lenders and investors.

The fourth rule prevents the results from being confounded by issues around the optimal size of government.

Model results

Table 4 shows the results, excluding those for Scenario 3a which are shown in Table 5. The changes refer to the levels of the variables in the various scenarios relative to the levels in the BAU. While the changes ostensibly relate to 2070, they apply to any year that the scenarios are valid. For example if the 15% price shift in Scenario 2 was also to prevail in 2050 or 2080, then the effect on RGNDI will be about 1% in those years too, albeit that the absolute dollar amounts would probably be different.

Table 4: Effects of Climate Change in 2070

	BAU	Scen 1	Scen 2	Scen 3	Scen 4
Macroeconomy	% pa on '05		% change on BAU		
Private Consumption	2.4	0.8	1.2	2.7	2.2
Exports	2.5	1.2	-0.2	-0.2	0.6
Imports	3.0	1.4	2.5	5.5	5.0
GDP	2.0	0.4	-0.2	-0.4	-0.2
RGNDI	2.4	0.6	1.0	2.3	1.9
RGNDI/capita	1.9				
CO_2e emissions (Mt)	1.5	5.0	6.4	12.5	12.8
of which CH_4 & N_2O	1.9	7.2	9.3	18.2	18.6
(BAU CO_2e = 193 Mt)					

Comparing Scenarios 1 and 2; both show a favourable effect on RGNDI, but the latter is considerably greater. Thus a 15% increase in the prices of unprocessed foods has a better effect on New Zealand's aggregate economic welfare than a 5% increase in prices coupled with 15% higher agricultural productivity.

Any increase in productivity will raise the volume of production (GDP) for given inputs, but by enhancing the competitiveness of exports it also means that exporters move down the demand curve

Export demand curves are downward sloping, not horizontal, so New Zealand exports can rise or fall as our price is below or above the world price. (At a very fine level of commodity disaggregation the demand curve facing New Zealand may well be horizontal, but the model's commodity definitions are not that homogeneous. For example 'dairy products' includes everything from milk powder to lactoferrins and gourmet cheeses.)

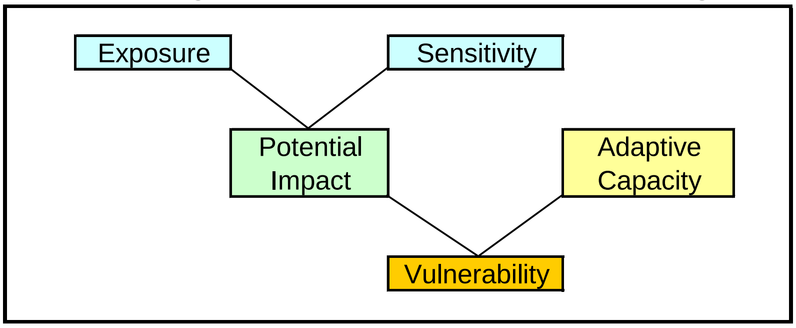
Hence there is a positive and negative effect on RGNDI – higher GDP but lower terms of trade. In contrast, higher world agricultural prices have the same effect as an outward movement of the demand curve for New Zealand exports, enabling an increase in average export prices and thus an increase in the terms of trade. The value of exports of unprocessed products exceeds the value of imports of unprocessed products by a factor of about seven.

There is a small offsetting negative effect on GDP as resources get pulled into agriculture in the presence of diminishing returns to land – clearly demonstrating the inadequacy of GDP as a measure of economic welfare.

We infer therefore that New Zealand would be better off if there is no carbon fertilization effect from climate change. Essentially this is because while we benefit from carbon fertilization, so do other countries. Such a result was also noted by Darwin (2004) and discussed in Infometrics (2007). Furthermore, if the carbon fertilization effect is so strong that agricultural commodity prices fall, New Zealand's economic welfare could actually decline.

In terms of a framework presented in Stern (2006, 94) - shown below – even though New Zealand's Adaptive Capacity in agriculture is high, a larger agricultural sector driven by higher productivity from carbon fertilization raises Sensitivity to climate change, so the net effect could be an increase in overall Vulnerability.

Figure 4: Vulnerability to Climate Change



The powerful effect of higher agricultural commodity prices (no carbon fertilization) is reinforced in Scenario 3. Based on a low world agricultural price elasticity of supply, a relative world price rise of 30% leads to an increase in RGNDI of 2.3% and in private consumption of 2.7% relative to BAU. The former corresponds to an increase of about $2700 per person (in 2005/06 prices).

Greenhouse gas emissions, however, rise by 12.5%, driven largely by an 18% rise in emissions of methane and nitrous oxide as agricultural output expands in response to the higher world prices. As noted above, there is no obligation on New Zealand to take responsibility for emissions in excess of some agreed amount – as long as the carbon tax is paid on all emissions.

By 2070 there may or may not be an international agreement to limit GHG emissions. Assuming that such an agreement exists and that New Zealand is party to it, under Scenario 3 there is another 24Mt of CO_2e for which New Zealand has to purchase emission permits on the international market at US$100/tonne (the carbon price in the BAU – refer Appendix A),[7] implying higher net factor payments to foreigners. This is simulated in Scenario 4.

The higher value of payments to foreigners lowers the increase in RGNDI from 2.3% to 1.9%. Resources are diverted out of private consumption and into exports in order to obtain the foreign exchange needed to buy the emission permits.

Thus even though a carbon price of US$100/tonne in the context of an emissions cap reduces the benefit to New Zealand under a climate scenario that leads to a 30% increase in world agricultural commodity prices, the benefit (RGNDI) is still positive.

Of course this raises an interesting question; if carbon fertilization occurs and all countries increase agricultural output, would the price of carbon rise? New Zealand agriculture is relatively GHG intensive because of emissions of CH_4 and N_2O, and the coefficients currently used to convert those emissions into CO_2 equivalent units. In some other countries, however, agriculture is more directly CO_2 intensive, so a world agriculture and trade model would be needed to determine the effect of carbon fertilization on the price of carbon, for a given stabilisation scenario.

Sensitivity test

As we have seen above, any increase in world agricultural commodity prices improves the competitiveness of New Zealand agricultural exporters. Does the impact on New Zealand change if foreign consumers are less sensitive to the cheaper New Zealand price? This is explored in Scenario 3a, where the price elasticity of demand for all exports (including non-agricultural goods and services) is arbitrarily halved. Table 5 shows the results along with those for Scenario 3.

With a potential decline in demand for New Zealand exports relative to Scenario 3, as world consumers are now less inclined to switch to cheaper New Zealand products, the real exchange rate needs to fall in order to prevent the balance of payments from deteriorating. The volume of exports rises in response, but a larger part of the required adjustment occurs on the import side. Imports rise by 4.7% in Scenario 3a compared to 5.5% in Scenario 3.

---

[7] Note that the US$100/tonne carbon price is intended to be a plausible projection of a worlds carbon price in 2070/71, but is essentially arbitrary.

With lower terms of trade, private consumption and RGNDI both increase by less than in Scenario 3, but still well above BAU levels, so there is still a strong gain to New Zealand if global warming is not accompanied by significant carbon fertilization.

Table 5: Effects of Climate Change in 2070

	Scen 3	Scen 3a
Macroeconomy	% change on BAU	
Private Consumption	2.7	2.2
Exports	-0.2	0.1
Imports	5.5	4.7
GDP	-0.4	-0.3
RGNDI	2.3	1.9
Real exchange rate	8.4	5.4
Terms of Trade	5.4	4.3
CO_2e emissions (Mt)	12.5	7.5
of which CH_4 & N_2O	18.2	10.7

The increase in GHG emissions in Scenario 3a is markedly lower than in Scenario 3 – about 14 Mt versus 24 Mt. From Table 4, Scenarios 3 & 4, the effect of having to account for another 24 Mt of GHG emissions by purchasing international emission permits lowers the change in RGNDI from 2.3% to 1.9%. So, having to account for another 14Mt would lower the change in RGNDI observed in Scenario 3a from 1.9% to about 1.7%.

Overall then, while overstated export price elasticities of demand would overstate the effect on national welfare of the effects of climate change on global food prices without carbon fertilization, such overstatement is small and is reduced further if New Zealand is part of an international emissions reduction agreement.

5. Results in Perspective

Direct and Indirect Effects

EcoClimate (2007) looked at the direct effects of climate change on New Zealand agriculture. It summarised the findings of other research based on econometric analysis, provisionally concluding that a change of one standard deviation in the number of days of soil moisture deficit (DSMD, a commonly used metric for measuring climate change effects on agriculture), reduces agricultural gross output by less than 5% in most cases. The flow-on effect on New Zealand's GDP of such a change is around 0.1%. However, the effects are not linear. A change of three standard deviations in DSMD reduces national GDP by around 1%.

These estimates do not include economic loss from short term catastrophic events such floods and landslides.

As noted previously using GDP as a welfare measure is not ideal. Still, when dealing with the direct impact of climate change on domestic agricultural output one not would expect any significant changes in New Zealand's international payment obligations, and only small changes in the terms of trade. Hence we can probably interpret the effect on GDP as being very similar to the effect on RGNDI.

A change of three standard deviations in DSMD on a national scale is severe. We are not aware of projections of climate change over the next 50 years or so having this degree of permanent impact. Thus a 1% pure impact on RGDP/RGNDI from the effect of climate change on agricultural production is probably at the high end, for the given horizon. Also, as noted by Cline (*op cit*) cross-section econometric modelling cannot pick up carbon fertilisation which raises output. (Time series econometric modelling could in principle capture the carbon fertilization effect, but it has presumably been too small to capture in such analysis to date. Further, while time series modelling is good at estimating the effects on output from deviations in DSMD relative to what is currently considered normal in climate terms, long run responses to a slow change in the climate could be quite different.)

Accordingly our assessment based on research to date is that the direct impact of climate change on New Zealand's RGDP/RGNDI via its effect on agricultural output, could be a small negative number – probably not more negative than about 0.5%. In view of Cline's results, however, a positive effect of similar magnitude is also plausible.

In contrast Table 4 shows that RGNDI could rise by over 2% as a consequence of higher world agricultural commodity prices if there is no carbon fertilization effect, easily outweighing the direct effects of climate change on agriculture. Again this ignores changes in the frequency of extreme events.

All scenarios examined above are assessed against a BAU that has no climate change, but does have some climate change mitigation policy in the form of a carbon price. The BAU is therefore useful for understanding the various ways by which climate change could affect the economy, but is somewhat misleading as it is an artifice – climate change is certain.

Hence, given that climate change will occur, it seems sensible to investigate how New Zealand's comparative advantage in agriculture can be preserved if carbon fertilization delivers a significant fillip to world agricultural production – adaptive capacity in the framework of Figure 4 above. The greater the positive direct effect of global warming on New Zealand's agricultural output, the less valuable that output will be in terms of enhancing our economic welfare. The net effect could even be negative.

Future Research

None of the above research represents the final word on the effects of climate change on agriculture and thereby on the national economy. Future research could overturn current findings and there are other industries such as energy, tourism and fishing that will also be affected by climate change – whether positively or negatively.

With regard to agriculture an expanded literature review may help to reduce uncertainty, but we think it unlikely that we have missed anything of significant relevance to New Zealand. Instead we believe that the priority for future research should be joint modelling that uses the results of world-wide modelling of the production and trade of agricultural commodities (those relevant to New Zealand) as input into the ESSAM general equilibrium model. The Global Trade Analysis Project (GTAP) modelling project is a candidate in this regard as there are experts in New Zealand who could undertake such work, though the GTAP model in turn may require inputs derived from Integrated

Assessment Models. Hopefully any such joint modelling could also capture the effect of carbon fertilization on the price of carbon.[8]

Another large gap relating to agriculture is an assessment of the effects on New Zealand of more of the world's biomass production being used for producing energy, especially liquid fuels, rather than for food. We recommend this area as another priority for future research.

Finally, research to date has largely ignored the economic impacts of changes in the frequency and/or extent of extreme events under a warmer climate. Thus this is an important area for future research.

---

[8] Infometrics and Motu are currently discussing GTAP options with Massey and Waikato Universities. The Lincoln (University) Trade and Environment Model could also be useful in this regard.

6. References

Cline, W. (2007): *Global Warming and Agriculture: Impact Estimates by Country.* , Center for Global Development and the Peterson Institute for International Economics.

Darwin R. (2004) "Effects of greenhouse gas emissions on world agriculture, food consumption, and economic welfare," *Climatic Change* 66 (1-2): 191-238.

Diebold, F.X. & R.L. Lamb (1996): Why Are Estimates of Agricultural Supply Response so Variable? Federal Reserve Board.

EcoClimate (2007): *Costs and Benefits of Climate Change and Adaptation to Climate Change in New Zealand Agriculture: What do we know so far*? report to Ministry of Agriculture and Fisheries.

Fischer G, M. Shah, F.N. Tubiello, H. van Velhuizen (2005) "Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990-2080," *Philosophical Transactions of the Royal Society B-Biological Sciences* 360 (1463): 2067-2083.

Infometrics (2007): *Some Aspects of the Indirect International Effects of Climate Change on New Zealand – A Quantitative Overview*, paper prepared for Morgan Family Charitable Trust.

Infometrics (2009): *Long Term Emission Scenarios for New Zealand*, report to NIWA.

Martin, L. R, (ed), (1991): *A* Survey of Agricultural Economics Literature, American Agricultural Economics Association, University of Minnesota.

Msangi, S. & M. Rosegrant (2007): A Closer Look at the IMPACT of Climate Change on Country-Level Food Security and Nutrition, paper presented at the Annual GTAP Conference, Purdue University, Indiana, June 7th-9th.

Parry M., C. Rosenzweig A. Iglesias, M. Livermore, G. Fischer (2004) "Effects of climate change on global food production under SRES emissions and socio-economic scenarios," *Global Environmental Change-Human and Policy Dimensions* 14 (1): 53-67.

Scion (2009): *Bioenergy Options for New Zealand, Analysis of Large-Scale Bioenergy from Forestry: Productivity, Land use and Environmental & Economic Implications.*

Stern (2006): 'Review on the Economics of Climate Change', HM Treasury, UK.

Stroombergen, A. (2008): "ESSAM General Equilibrium Model: Estimation of 2005/06 Input-Output Tables", *Motu Working Paper* 08-01.

Tebaldi, C., and D. B. Lobell (2008): Towards probabilistic projections of climate change impacts on global crop yields, Geophys. Res. Lett., 35.

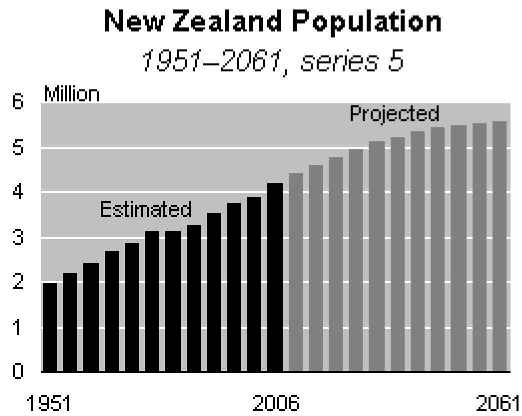
7. Appendix A: BAU Scenario Input Assumptions

The projection period is to 2070/71, implying 65 years from model's 2005/06 base year. The main input assumptions for the model are discussed below.

Population

Official projections by SNZ reach as far as 2060/61. Hence we have extrapolated the annual growth rate over 2055/56 to 2060/61 for another ten years. This yields a population projection of 5,652,000. In 2005/06, which is the base year for SNZ's projections, the population was 4,185,000, implying an average growth rate of 0.46% per annum.

The Series 5 projection (shown in the graph below) assumes a middle path with respect to fertility, mortality and migration; namely medium fertility, medium mortality and net immigration of an average 10,000 people per annum. Changing the migration assumption to 5000 or 15,000 per annum changes the projected population to 5,174,000 or 6,129,000 respectively. The effects of changing from medium fertility to low or high fertility are similar. Changing the mortality assumption has smaller effects.



Source: SNZ

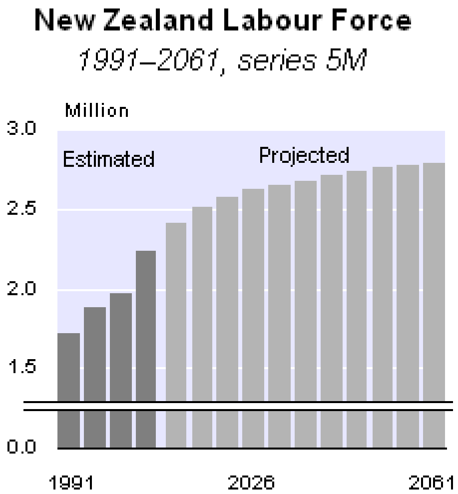
Labour Force

A projection of the labour force is obtained in the same manner, again based on Series 5, with medium (as opposed to low or high) labour force participation rates.

The projected figure for 2070/71 is 2,808,000, with the low and high participation rate assumptions yielding 2,694,000 and 2,922,000 respectively; about ±4%. The labour force in 2005/06 was 2,240,000, implying average growth of 0.35% pa.

For such a long term projection the model requires either total employment or the average wage rate to be set exogenously. Our preferred approach is make an assumption about the rate of unemployment and let the model produce whatever profile of wage rates is consistent with this, rather than the other way around.

In a modern economy the rate of unemployment in the long run is driven primarily by demographic factors and labour market regulations, whereas wage rates are ultimately a function of the growth of the economy. Thus it is more plausible to assume some rate of unemployment that society is prepared to tolerate, which is likely to cover a fairly narrow range, than to assume some set growth path for wages – which could easily produce totally unrealistic projections of unemployment.



We assume an unemployment rate of 3.5%; on the low side of historical rates, but recognising the projected aging of the population and the associated slow growth in labour force.

Energy and Energy Efficiency

The model requires projections of rates of improvement in energy efficiency – often referred to in energy models as the AEEI; the autonomous energy efficient improvement parameter. This is fuel specific and hence is required for coal, natural gas, oil products and electricity.

Typically in our modelling we have used 1% pa for all fuels except for electricity use by households where a lower rate of 0.5% pa has been used. This is not because the efficiency of household appliances is assumed to improve at a slower rate than industrial machinery. Rather it is a crude way to capture the increasing use of electrical appliances (such as computers and television decoders) that were previously less prevalent and that are frequently left on, even if only in stand-by mode, for extended periods of time. To this one might add the increasing use of clothes driers associated with the move to apartment living, and heat pumps which, while very efficient, are often used for air conditioning in homes which had no air conditioning prior to installation of a heat pump.

In MED (2006) the AEEI is about 0.5-1.0% pa. We assume 1.0% pa for industrial and commercial use of all fuels. Assumptions for road transport and household energy are as follows.

Household electricity use

We assume an underlying AEEI of 0.5% pa as a crude balance between the increasing technical efficiency of household appliances, the use of in-home solar power and the offsetting effect of more appliances. However, Beacon Pathway (2007) looked in detail at some key opportunities for improvements in household energy efficiency, notably in space heating (retrofit insulation and more efficient heating mechanisms such as heat pumps), water heating and lighting. By 2025 expected cost-effective household energy savings amount to over 30%. Not all houses are amenable to cost-effective retrofitting insulation. Nor do we expect 100% penetration of compact fluorescent lighting (barring legislation) or efficient heating appliances. Nevertheless, by 2071 the efficiency gains could easily reach 50%, thereby raising the AEEI for household electricity to almost 1.6% pa in total.

Private road transport

Private road transport is a particularly difficult area, with improvements in vehicle fuel efficiency and diesel-petrol substitution being offset by a trend to larger petrol vehicles and diesel SUVs (at least up to the recent sharp increases in oil prices). Further offset comes from the increasing weight of cars caused by more stringent safety standards. Based on MED (2006) estimates which take into account real income growth, greater diesel use, better technical energy efficiency and a changing fleet mix, the implicit efficiency gain is about 1.2% pa up to 2030.

For commercial vehicle use we assume a lower figure of 1% pa (up to 2070/71), as the relative shift to diesel vehicles is much smaller. To maintain the MED average this implies a rate for vehicle use by private households of 1.6% pa up to 2051 (to capture the shift to diesel), followed by 1% pa thereafter.

Another issue around energy is the large scale 'step changes' that could occur with a shift to plug-in electric or hybrid vehicles, or the widespread use of biofuels in transport. These possibilities are not explored here by see Scion (2009) with regard to the latter.

Electricity generation

Left to itself the model will configure a generation mix that is similar to the 2005/06 mix, subject to changes in relative prices such as may be caused by a carbon price. Clearly this is unsatisfactory – the gas supply may much lower than anticipated or there maybe significant technological advances in generation from tidal or wave power, or from waste.

The assumed profile below is based on the MED (2006) 'renewables' scenario to 2030. Coal-fired generation has disappeared on the assumption that carbon capture and storage is not competitive with wind and tidal power.

Solar-generated electricity on a large scale is assumed to be insignificant in New Zealand, although this is not to discount its potential. Direct use of solar (photovoltaic) power by households is captured with the household energy efficiency parameter – see above.

Electricity Supply by Fuel (%)

	2005/06	2030	2070/71	
Hydro	58	58		}
Wind	1	17	87	}
Tidal/wave		6		} renewables
Geothermal	7	9		}
Cogen	5	5		}
Gas	17	5	11	includes gas cogen
Coal	12	0	2	>0 for dry years
	145 PJ	174 PJ	21	

Carbon Price

Forecasting the international price of carbon in 2070/71 is impossible. Critical factors are which countries participate in international agreements to lower emissions, the tightness of international obligations, and the path of emissions over the intervening four decades. We take the view that by 2070/71 a carbon charge will have had a strong enough impact on GHG emissions such that the price of carbon will have declined from a peak during the 2030s. We assume a price of US$100/tonne CO_2e. This might be seen as an optimistic scenario, but could equally reflect a lack of international political will to accept a high carbon price.

Oil Price

The oil price is almost as difficult to forecast as the price of carbon. We defer to the comprehensive discussion and analysis in NZTA (2008) which shows a number of projections for the price of oil in 2028 ranging between US65/bbl and US$230/bbl, with an average of about US$115/bbl (all in 2008 prices). Most of the projections estimate a higher price before 2028.

We assume an average increase in price of 2.5% pa from 2028 to 2050, which is roughly its rate of real price increase over the last fifty years – albeit with much volatility. This gives a price in 2050 of about US$200/bbl, a price which is retained for 2070/71.

Exchange Rate and Balance of Payments

The model does not simulate price levels – it deals entirely in relative prices. The price *numéraire* is the average import price, excluding oil. With a fixed balance of payments constraint, the change in the real exchange rate – inflation in New Zealand relative to world inflation, multiplied by the change in the nominal exchange rate – is endogenous to the model. Any given value of the change in the real exchange rate is consistent with many different combinations of relative inflation rates and changes in the nominal exchange rate. For example, New Zealand inflation at 2% pa, world inflation at 3% pa and an appreciation of the nominal exchange rate of 1% pa, would leave the real exchange rate unchanged. Doubling all of these amounts would yield the same outcome, as would New Zealand inflation of 2% pa, world inflation of 1% pa and a devaluation of the nominal exchange rate of 1% pa.

We can express the change in the price of oil (or of any international commodity) relative to the change in world prices in general but, given a model-endogenous value for the change in the real exchange rate, the change in the real price of oil in New Zealand dollars is independent of the nominal exchange rate.

To illustrate, let us assume a change in the international oil price from US$70/bbl in 2005/06 (the model's base year) to $200 in 2050/51. Without loss of generality, we further assume zero inflation in other world prices.

If the model produces a change in the real exchange rate of plus 10%, then either New Zealand inflation is 10% over the period with no change in the nominal exchange rate, or New Zealand inflation is zero and the exchange rate appreciates by 10%, or some linear combination of these two scenarios prevails.

It might appear that this means that the price of oil in New Zealand currency could be anywhere between NZ$200/bbl and NZ$180/bbl. This is indeed the case, but the point is that the difference is irrelevant. If the former price prevails it means that the real price of oil in 2005/06 prices is NZ$180/bbl – because of New Zealand's 10% general inflation. This is exactly the real price that occurs if New Zealand has no inflation, but the nominal exchange rate appreciates by 10%.

What matters in the model is the real or relative price of oil, not its nominal price. This is no different than saying that if all prices in the economy doubled, there would be no real effects. In economics this is known as the principle of *no money illusion*. It is fundamental to the model.

Returning then to the issue of the balance of payments, we presume that New Zealand's long record of balance payments deficits cannot continue. With other countries improving their economic management and providing profitable opportunities for investment, New Zealand will find it more difficult to attract foreign investment to cover a persistent balance of payments deficit. Hence we assume a small balance of payments surplus of 1% on GDP in 2070/71. With positive net factor payments (servicing of past debt) this will likely imply a larger surplus on the balance of trade in goods and services.

8. Appendix B: The ESSAM Model

The ESSAM (Energy Substitution, Social Accounting Matrix) model is a general equilibrium model of the New Zealand economy. It takes into account all of the main inter-dependencies in the economy, such as flows of goods from one industry to another, plus the passing on of higher wage costs in one industry into prices and thence the costs of other industries.

The ESSAM model has previously been used to analyse the economy-wide and industry specific effects of a wide range of issues. For example:

- Energy pricing scenarios
- Changes in import tariffs
- Faster technological progress
- Policies to reduce carbon dioxide emissions
- Funding regimes for roading
- Release of genetically modified organisms

Some of the model's features are:

- 53 industry groups, as detailed in the table below.
- Substitution between inputs into production - labour, capital, materials, energy.
- for energy types: coal, oil, gas and electricity, between which substitution is also allowed.
- Substitution between goods and services used by households.
- Social accounting matrix (SAM) for complete tracking of financial flows between households, government, business and the rest of the world.

The model's output is extremely comprehensive, covering the standard collection of macroeconomic and industry variables:

- GDP, private consumption, exports and imports, employment, etc.
- Demand for goods and services by industry, government, households and the rest of the world.
- Industry data on output, employment, exports etc.

- Import-domestic shares.
- Fiscal effects.

Production Functions

These equations determine how much output can be produced with given amounts inputs. A two-level standard translog specification is used which distinguishes four factors of production – capital, labour, and materials and energy, with energy split into coal, oil, natural gas and electricity.

Intermediate Demand

A composite commodity is defined which is made up of imperfectly substitutable domestic and imported components - where relevant. The share of each of these components is determined by the elasticity of substitution between them and by relative prices.

Price Determination

The price of industry output is determined by the cost of factor inputs (labour and capital), domestic and imported intermediate inputs, and tax payments (including tariffs). World prices are not affected by New Zealand purchases or sales abroad.

Consumption Expenditure

This is divided into Government Consumption and Private Consumption. For the latter eight household commodity categories are identified, and spending on these is modelled using price and income elasticities in an AIDS framework. An industry by commodity conversion matrix translates the demand for commodities into industry output requirements and also allows import-domestic substitution.

Government Consumption is usually either a fixed proportion of GDP or is set exogenously. Where the budget balance is exogenous, either tax rates or transfer payments are assumed to be endogenous.

Stocks

Owing to a lack of information on stock change, this is exogenously set as a proportion of GDP, domestic absorption or some similar macroeconomic aggregate. The industry composition of stock change is set at the base year mix, although variation is permitted in the import-domestic composition.

Investment

Industry investment is related to the rate of capital accumulation over the model's projection period as revealed by demand for capital in the horizon year. Allowance is made for depreciation. Rental rates or the service price of capital (analogous to wage rates for labour) also affect capital formation. Investment by industry of demand is converted into investment by industry of supply using a capital input- output table. Again, import-domestic substitution is possible between sources of supply.

Exports

These are determined from overseas export demand functions in relation to world prices and domestic prices inclusive of possible export subsidies, adjusted by the exchange rate. It is also possible to set export quantities exogenously.

Supply-Demand Identities

Supply-demand balances are required to clear all product markets. Domestic output must equate to the demand stemming from consumption, investment, stocks, exports and intermediate requirements.

Balance of Payments

Receipts from exports plus net capital inflows (or borrowing) must be equal to payments for imports; each item being measured in domestic currency net of subsidies or tariffs.

Factor Market Balance

In cases where total employment of a factor is exogenous, factor price relativities (for wages and rental rates) are usually fixed so that all factor prices adjust equi-proportionally to achieve the set target.

Income-Expenditure Identity

Total expenditure on domestically consumed final demand must be equal to the income generated by labour, capital, taxation, tariffs, and net capital inflows. Similarly, income and expenditure flows must balance between the five sectors identified in the model – business, household, government, foreign and capital.

Industry Classification

The 53 industries identified in the ESSAM model are defined below. Industries definitions are according to Australian and New Zealand Standard Industrial Classification (ANZSIC).

1	**HFRG**	Horticulture and fruit growing
2	**SBLC**	Livestock and cropping farming
3	**DAIF**	Dairy and cattle farming
4	**OTHF**	Other farming
5	**SAHF**	Services to agriculture, hunting and trapping
6	**FOLO**	Forestry and logging
7	**FISH**	Fishing
8	**COAL**	Coal mining
9	**OIGA**	Oil and gas extraction, production & distribution
10	**OMIN**	Other Mining and quarrying
11	**MEAT**	Meat manufacturing
12	**DAIR**	Dairy manufacturing
13	**OFOD**	Other food manufacturing
14	**BEVT**	Beverage, malt and tobacco manufacturing
15	**TCFL**	Textiles and apparel manufacturing
16	**WOOD**	Wood product manufacturing
17	**PAPR**	Paper and paper product manufacturing
18	**PPRM**	Printing, publishing and recorded media
19	**PETR**	Petroleum refining, product manufacturing
20	**CHEM**	Fertiliser and other industrial chemical manufacturing
21	**RBPL**	Rubber, plastic and other chemical product manufacturing
22	**NMMP**	Non-metallic mineral product manufacturing
23	**BASM**	Basic metal manufacturing
24	**FABM**	Structural, sheet and fabricated metal product manufacturing
25	**MAEQ**	Machinery and other equipment manufacturing
26	**OMFG**	Furniture and other manufacturing
27	**EGEN**	Electricity generation
28	**EDIS**	Electricity transmission and distribution
29	**WATS**	Water supply
30	**WAST**	Sewerage, drainage and waste disposal services
31	**CONS**	Construction
32	**TRDE**	Wholesale and retail trade
33	**ACCR**	Accommodation, restaurants and bars
34	**RDFR**	Road freight transport
35	**RDPS**	Road passenger transport
36	**RAIL**	Rail transport
37	**WATR**	Water transport
38	**AIRS**	Air transport and transport services
39	**COMM**	Communication services
40	**FIIN**	Finance and insurance
41	**REES**	Real estate
42	**EHOP**	Equipment hire and investors in other property
43	**OWND**	Ownership of owner-occupied dwellings
44	**SRCS**	Scientific research and computer services
45	**OBUS**	Other business services
46	**GOVC**	Central government administration and defence
47	**GOVL**	Local government administration
48	**SCHL**	Pre-school, primary and secondary education
49	**OEDU**	Other education
50	**HOSP**	Hospitals and nursing homes
51	**OHCS**	Other health and community services
52	**CULT**	Cultural and recreational services
53	**PERS**	Personal and other community services

Recent Motu Working Papers

All papers in the Motu Working Paper Series are available on our website www.motu.org.nz, or by contacting us on info@motu.org.nz or +64 4 939 4250.

10-13 Olssen, Alex; Hugh McDonald, Arthur Grimes, and Steven Stillman. 2010. “A State Housing Database: 1993–2009”.

10-12 Cochrane, William; Arthur Grimes; Phillip McCann and Jacques Poot. 2010. “The Spatial Impact of Local Infrastructural Investment in New Zealand”.

10-11 Grimes, Arthur and Chris Young. 2010. “Anticipatory Effects of Rail Upgrades: Auckland’s Western Line”.

10-10 Grimes, Arthur and Chris Young. 2010. “A Simple Repeat Sales House Price Index: Comparative Properties Under Alternative Data Generation Processes”.

10-09 Evans, Lewis; Greame Guthrie and Andrea Lu. 2010. "A New Zealand Electricity Market Model: Assessment of the Effect of Climate Change on Electricity Production and Consumption".

10-08 Coleman, Andrew and Hugh McDonald. 2010. "“No country for old men”: a note on the trans-Tasman income divide".

10-07 Grimes, Arthur; Mark Holmes and Nicholas Tarrant. 2010. "New Zealand Housing Markets: Just a Bit-Player in the A-League?"

10-06 Le, Trinh; John Gibson and Steven Stillman. 2010. "Household Wealth and Saving in New Zealand: Evidence from the Longitudinal Survey of Family, Income and Employment".

10-05 Grimes, Arthur. 2010. "The Economics of Infrastructure Investment: Beyond Simple Cost Benefit Analysis".

10-04 van Benthem, Arthur and Suzi Kerr. 2010. “Optimizing Voluntary Deforestation Policy in the Face of Adverse Selection and Costly Transfers”.

10-03 Roskruge, Matthew; Arthur Grimes; Philip McCann and Jacques Poot. 2010. "Social Capital and Regional Social Infrastructure Investment: Evidence from New Zealand”.

10-02 Coleman, Andrew. 2010. "Uncovering uncovered interest parity during the classical gold standard era, 1888-1905".

10-01 Coleman, Andrew. 2010. "Squeezed in and squeezed out: the effects of population ageing on the demand for housing".

09-17 Todd, Maribeth and Suzi Kerr. 2009. "How Does Changing Land Cover and Land Use in New Zealand relate to Land Use Capability and Slope?"

09-16 Kerr, Suzi and Wei Zhang. 2009. "Allocation of New Zealand Units within Agriculture in the New Zealand Emissions Trading System”.

09-15 Grimes, Arthur; Cleo Ren and Philip Stevens. 2009. "The Need for Speed: Impacts of Internet Connectivity on Firm Productivity”.

09-14 Coleman, Andrew and Arthur Grimes. 2009. "Fiscal, Distributional and Efficiency Impacts of Land and Property Taxes”.

09-13 Coleman, Andrew. 2009. "The Long Term Effects of Capital Gains Taxes in New Zealand”.

09-12 Grimes, Arthur and Chris Young. 2009. "Spatial Effects of 'Mill' Closure: Does Distance Matter?"

09-11 Maré, David C and Steven Stillman. 2009. "The Impact of Immigration on the Labour Market Outcomes of New Zealanders”.