AERU

A Review of Research on Economic Impacts of Climate Change

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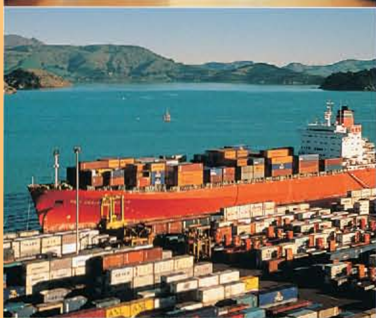

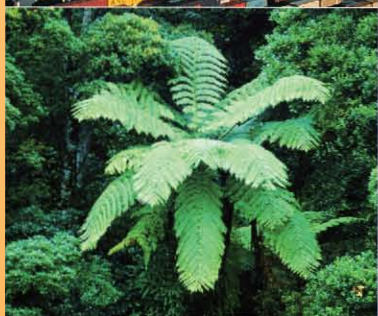

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Summary

This report reviews prior research on several topics associated with anthropogenic climate change resulting from concentration of CO_2 and other gases in the atmosphere. It represents the first step in a project whose aim is to translate this prior research into scenarios that can be modelled with the Lincoln Trade and Environment Model. The report does not attempt to provide a full discussion of the many issues surrounding climate change. Instead, the intent is to summarise prior findings to provide specific parameter values that can be used as model inputs and to link those parameter values to the larger body of research on climate change.

The IPCC and others have considered the impact of population growth and other trends on production of greenhouse gases and the implications for climate change. The associated changes in temperature, rainfall, and concentration of CO_2 are expected to have impacts on agricultural and forestry production. The impacts vary by country and commodity, and vary according to the timeframe considered. In addition, there is uncertainty in the results, indicated by the ranges of values presented in some cases.

There are also technologies and strategies available for mitigating the effects of production on the environment. Some of these technologies reduce the creation of gasses from agriculture, by reducing emissions from soils and animals. Other technologies attempt to capture the gasses that are produced. Still other technologies and processes work to remove carbon from the atmosphere and sequester it for extended periods.

The literature on consumer behaviour clearly indicates the willingness on the part of some consumers to support environmental values by paying more for goods and services. Consumers are clearly heterogeneous in this willingness to pay, however, and there are confounding impacts from labelling, information, social norms, uncertainty, and more. As a result, although there is a clear willingness to pay for green products, the size of the premium and the products to which it applies are unclear. In addition, gatekeeper effects may increase or decrease the impact of consumer preferences on producer behaviour.

The research reviewed in this report provides the necessary data for analysing the economic impacts of climate change using a model of international trade in agricultural commodities. Research is currently underway to build such a model on the platform of the Lincoln Trade and Environment Model (LTEM), with a country and commodity mix specific to the issue of climate change. The prior research reviewed in this report can be considered partial: it tends to consider climate change without prices and their consequences for production and consumption. By subjecting the trade model to a combination of supply and demand shocks, the aim of this research is to build a better picture of economic impacts of climate change on New Zealand.

Chapter 1
Introduction

This report reviews prior research on several topics associated with anthropogenic climate change resulting from concentration of CO_2 and other gases in the atmosphere. The aim is to translate the research into scenarios that can be modelled with the Lincoln Trade and Environment Model. The report does not attempt to provide a full discussion of the many issues surrounding climate change. Instead, the intent is to summarise prior findings to provide specific parameter values that can be used as model inputs and to link those parameter values to the larger body of research on climate change.

To begin, this report reviews the climate modelling undertaken as part of IPCC work and related research. The IPCC has defined a number of potential futures for the world, or ‘scenarios’, that vary in assumptions regarding population growth, technology, and other key dimensions. These scenarios have then been incorporated into computer models of the Earth’s climate, resulting in predictions about greenhouse gas concentration, temperature, and CO_2 concentration. This review describes the major scenarios, key dimensions of the scenarios, and findings from climate models.

The next section of the report discusses the expected impacts of climate change on production in agriculture and forestry. The findings from climate models, in particular the temperature, CO_2 concentrations, and water availability findings, have served as inputs into production models for crops and forests. These models translate the projected physical changes to climate into projected impacts on production. Production is affected in several ways. First, temperature and CO_2 concentrations have direct impacts on the growth of plants, affecting crop, pasture and timber output. Secondly, changes in temperature can also affect the geographic distribution of production, changing where certain crops can be grown productively and profitably. Thirdly, changes in water availability, over both time and space, affect plant growth and crop selection. The findings from these models are discussed and summarised.

Another issue facing land-based production is the potential for mitigation of greenhouse gas emissions. Because mitigation can ameliorate the negative impacts of production, it can have a significant effect on the ability to produce agricultural and forestry products, especially in the presence of a mechanism that requires payment for carbon emissions. The available mitigation technologies and their potential impact are therefore reviewed.

The report then turns to issues affecting consumer demand. In a market, such as the international market for commodities, it is also important to consider consumers’ responses. These responses could harm New Zealand trade, as when concern over the distance that food travels from farm to fork (‘food miles’) leads to reduced demand in the Northern Hemisphere for New Zealand exports. On the other hand, concern for the environmental impacts of production could support demand for pasture-based livestock systems over feedlot production, and for sustainably managed plantation forestry over felling of tropical rainforests. In those cases, New Zealand could benefit from increased demand and higher prices.

The final section of the report provides an indication of the future direction of this research. This section sets out the next phase of research, which will be to develop a set of scenarios based on the reviewed literature and model them in order to analyse the potential impacts of climate change on New Zealand’s international trade in agricultural and forestry products. Using the LTEM will allow the research to model the complex impacts of changes in production and consumption on emissions of greenhouse gases both in New Zealand and abroad as well as the feedback effects on prices, production, consumption, and trade. Also important in this work will be capturing the interactions between agricultural and forestry land uses. These interaction effects are important for understanding the net impact of emissions, because it is insufficient to consider the changes in production and emissions in a single country (Sengupta and Bhardwaj, 2004). The prior research that will be reviewed should thus be considered partial: it considers climate change without prices and their consequences for production and consumption. The aim of this research is to build a better picture of economic impacts of climate change.

Chapter 2
IPCC Emissions Scenarios

The IPCC Special Report on Emissions Scenarios (SRES) has since its release in 2000 become a widely used aid in the literature on projected climate change. The 40 emissions scenarios cover most of the projected GHG and SO_2 emissions scenarios found in literature, leaving out only the 5th and 95th percentiles of the emissions distribution range found in literature (Nakicenovic & Swart, 2000).

The scenarios are meant to serve the IPCC working groups and research in general as well as providing inputs for discussion and negotiation of policies concerning mitigation and adaption measures. Furthermore, they are extensively used in research to model projected global average surface warming and sea level rise from year 1990 until year 2100 (Pachauri & Reisinger, 2007) and to project possible implications for future production, food security, and the economy.

The climate change scenarios have developed over time, starting with the six IS92 emission scenarios and resulting in the 2007 IPCC 'Fourth Assessment Report', referred to as AR4 or FAR. There have been several reasons for the changes. One main reason for changes since 1994 was that the IS92 used predicted 1990 data, and not the actual values. It was also found that the IS92 CO_2 emission scenarios covered only a limited range of emissions scenarios found in the literature. Finally, there was no scenario covering a strong convergence between the developing and developed economies (Nakicenovic & Swart, 2000). The evaluation of the IS92 scenarios also brought about changes of the driving factors for the emission scenarios. The population ranges were reduced to three different scenarios, but the projections of resource availability and technology changes were multiplied, reflecting the IPCC WGII Second Assessment Report (SAR) (Nakicenovic & Swart, 2000). Furthermore, the scenarios account for the interactions of the different driving factors, recognising the implications this has for future emissions.

The SRES are currently divided into four major emissions scenario families. The families are again sub-divided into seven scenarios groups and further into different scenarios, giving a total of 40 emissions scenarios. Each emissions scenario family is defined by different levels of the factors driving emissions. The driving factors have been chosen by climate scientists because of their ability to influence the future development path and hence projected emissions.

The drivers include:

- Population growth
- GDP growth
- Degree of economic convergence
- Primary energy use
- Land-use changes
- Technology change, both globally and regional
- The extend to which global and/or regional environmental concerns influences development

2.1 Emissions scenario families

To provide background for this research, the families of emissions scenarios are described below. This description presents the main drivers of the families; the details of the families and the individual scenarios can be found in the IPCC reports.

A1 scenarios assume rapid economic growth and convergence of the world economy, leading to a general rise in income. The population peaks in 2050, declining to a relatively low population in 2100 of only seven billion. As incomes rise during the century, environmental policies are implemented. These policies deal mostly with environmental amenities such as air and water qualities, but also with concerns such as traffic congestions and land-use policies (Nakicenovic & Swart, 2000) The economies converge and there is more and more global interaction amongst countries and societies. Primary energy use is high, but at the same time technology innovation in efficient energy use is also high (Nakicenovic & Swart, 2000).

Furthermore, the A1 family is divided into four different scenario groups depending on which energy source they use most intensely. For example, the A1B scenario group assumes a balanced energy source and technology use (Nakicenovic & Swart, 2000). Here 'balance' is defined as not relying on one particular energy and technology source too heavily, assuming that the improvement and innovation rates for the different energy uses and technology developments are equal for all the sources (Watson & the Core Writing Team (eds.), 2001).

A2 scenarios assume the highest projected population of 15 billion by 2100. There is no economic convergence as such: the developing countries continue to have a low GDP per capita and industrialised countries are projected to have a medium GDP per capita and a medium economic growth in general. International development is considered heterogeneous and there is great emphasis on regional identity and self-reliance (Watson & the Core Writing Team (eds.), 2001). Primary energy use is high, mostly relying on coal and nuclear energy. Due to the strain of the large world population, there are no environmental barriers to development of nuclear energy and fossil energy use (Nakicenovic & Swart, 2000). However, it is assumed that there are stringent environmental policies controlling air and soil quality as well as water availability.

B1 scenarios assumes the same low population growth as A1, resulting in seven billion people in 2100. These scenarios generally reflect an environmentally aware world society and an economy that relies on services and information. Solutions to sustainability concerns are approached globally; however, there is no further emphasis on climate change (Watson & the Core Writing Team (eds.), 2001). Primary energy use is low, and the technology efficiency of converting energy is high. Both economic growth and GDP per capita are high.

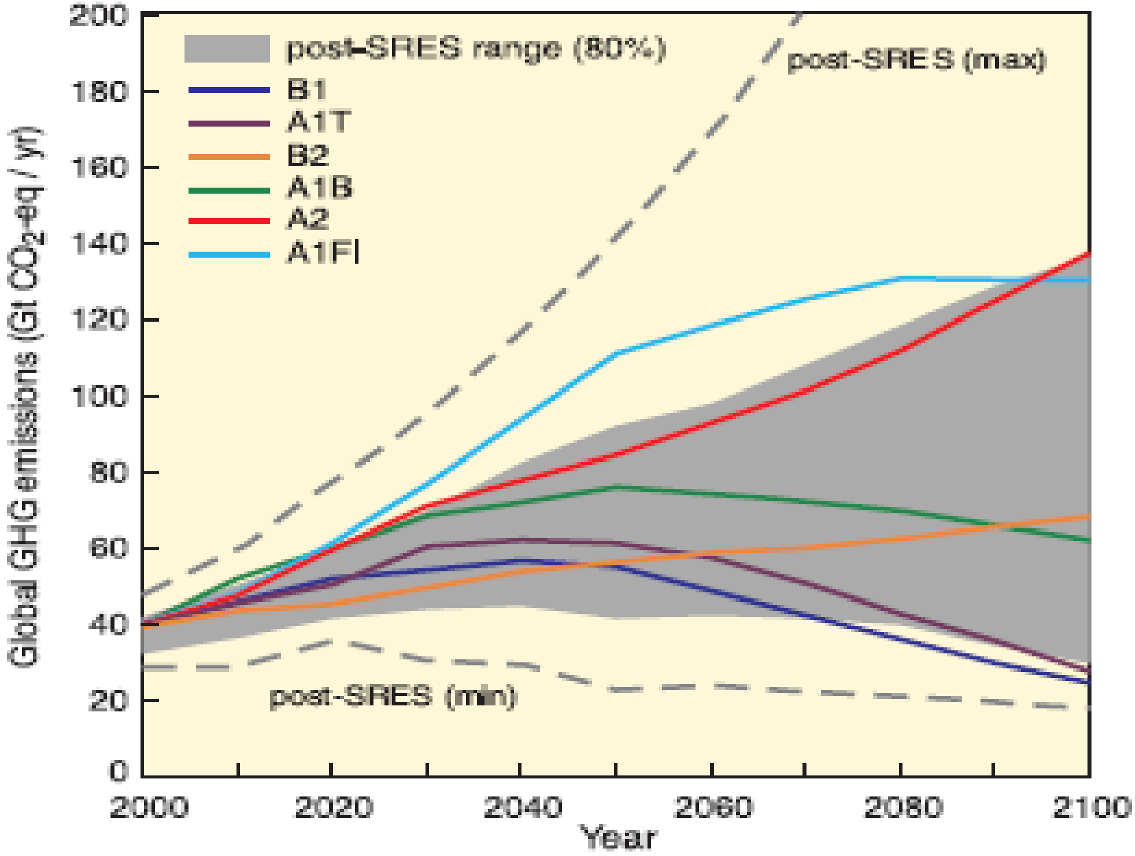
B2 scenarios reflect an overall medium projection in regards to the different driving factors. The world population is projected to reach ten billion by 2100, and medium economic growth and GDP per capita are expected along with no real convergence of industrialised and developing economies. Primary energy use is assumed to be at a medium level; new low-emissions technology developments happen mostly regionally and at a medium pace, due to the relatively low convergence of societies and economies. Environmental policies and sustainability concerns are noteworthy, but occur regionally rather than globally.

Table 2.1 summarises the factors underlying the SRES scenarios (Nakicenovic & Swart, 2000).

Table 2.1: Summary of SRES scenarios

Family	--- A1 ---				A2	B1	B2
Scenario group	A1C	A1G	A1B	A1T	A2	B1	B2
Total scenarios	3	3	8	3	6	9	8
Population growth	Low (~7billion)	Low (~7billion)	Low (~7billion)	Low (~7billion)	High (~15billion)	Low (~7billion)	Medium (~10billion)
GDP growth	Very High	Very High	Very High	Very High	Low	High	Medium
Energy use	Very High	Very High	Very High	High	High	Low	Medium
Land-use changes	Low-medium	Low-medium	Low	Low	Medium/ high	High	Medium
Technology change	Rapid	Rapid	Rapid	Rapid	Slow	Medium	Medium
Change favoring	Coal	Oil & Gas	Balanced	Non-fossils	Regional	Efficiency & dematerialisation	'Dynamics as usual'

Figure 2.1: GHG emissions under the 6 different SRES emissions scenario groups from year 2000 to 2100 with no additional climate policies



Source: (Pachauri & Reisinger, 2007)

Figure 2.1 is from the AR4, the 2007 climate change synthesis report. It portrays the range of post-SRES GHG emissions (including CO_2, CH_4, N_2O and F-gases) scenarios found in the literature under the then-current climate policies. The dashed lines represent the maximum and minimum emissions for the scenarios. The coloured lines indicate the central tendency for emissions paths for the different scenarios. The shaded area gives the collective 80 per cent confidence interval for all emissions scenarios. This comparison indicates the divergence of modelled GHG emissions as the century progresses, depending on the levels of the driving factors of population change, economic growth, and energy use.

The writing team of the SRES emissions scenarios deliberately excluded the most extreme projections found in the literature, hence the SRES emissions scenarios largely fall within the 80 per cent margin of all emissions scenarios found in post-SRES literature. The shaded area in the figure above thus represents a consensus view of GHG emissions until 2100.

It can be seen that the A2 scenario group results in the highest emissions projections in year 2100, increasing almost steadily throughout the 21st century. In contrast, A1T and B1 end almost with similarly low emissions at the end of the century and follow more or less the same GHG emissions path until 2030, with emissions post-2030 being slightly higher for A1T. B2 and A1B both have medium emissions projections by the end of the century; however, they have quite different emissions pathways. B2 steadily rises throughout the period, while A1B has a concave emissions path with decreasing GHG emissions in the last two decades. One important thing to note, when looking at the different groups, is that different driving factors (hence different groups) can lead to same outcomes in emissions projections.

However, a trend can be observed between expected population size, economic convergence, technology change and primary energy use. The A2 groups with the projected high population, economic and technological divergence are in the very high percentage of the projected emissions, while the B1 groups with the smaller projected population and advanced, dematerialized, and economically converged word-society are projected to emit less CO_2 in 2100.

2.2 SRES and climate change

The different parameters or driving factors discussed above are used as inputs for climate change computer models, which then produce outputs regarding temperature, CO_2 concentrations, sea-level, precipitation and more. Several research groups maintain such models. A frequently referenced computer model is the HadCM3, the third version of a coupled atmosphere-ocean global climate model developed by the UK Hadley Centre for Climate Predictions and Research (Fischer, Shah, Tubiello, & Velhuizen, 2005). Other global climate models (GCM's) include HadCm2 (uses data from the Third Assessment Report)(Pachauri & Reisinger, 2007), CSIRO, NCAR-PCM and CGCM2 (Fischer et al., 2005). They all process the different SRES emissions scenarios to determine the relationship between CO_2 concentrations on the one hand and temperature changes and precipitation changes on the other (Fischer et al., 2005). CSIRO, The Commonwealth Scientific and Industrial Research Organisation's coupled model, is based on global atmospheric, oceanic, sea-ice and biospheric sub-models (Fischer et al., 2005). It uses the A1B, A2, B2 and B1 emissions scenarios as inputs in the model. NCAR-PCM, is the Parallel Climate Model operated by the National Center for Atmospheric Research, and contains atmospheric and oceanic variables (http://www.ipcc-data.org/ar4/model-NCAR-PCM.html). It uses the A2 and B2 emissions scenarios to make climate projections. CGCM2, the Canadian Global Coupled Model, also uses the A2 and B2 emissions scenarios. This is the second version of the model developed by the Canadian Center for Climate Modelling and Analysis (http://www.cccma.ec.gc.ca/models/cgcm2.shtml).

The results of the GCM's can then be fed into models that estimate crop, animal, and forest production. For example, dynamic crop models like the DSSAT or EPIC. DSSAT, the Decision Support System for Agrotechnology Transfer, is a widely-used tool that combines crop, soil and weather data to project outcomes of different crop-management strategies (http://www.icasa.net/dssat/). It was developed in collaboration between ICASA and several US universities. EPIC, the Erosion Productivity Impact Calculator, is also a plant growth model, and it calculates the potential growth of crops as a function of solar irradiance, temperature, precipitation and crop characteristics (http://daac.gsfc.nasa.gov/agriculture/ais_sup/crop_mod.shtml). It has been modified to simulate the direct effects of CO_2 on plant growth and water use (Easterling, Chen, Hays, Brandle, & Zhang, 1996).

The GCM results can also be inputs into ecosystem models like the Terrestrial Ecosystem Model (TEM), which is a part of the NASA-Earth Observing System (http://www.eos-ids.sr.unh.edu/ids-cycles.html) and describes the carbon and nitrogen dynamics of plants and soils for terrestrial ecosystems (http://www.archive.arm.gov/Carbon/dataneeds/TEM.html).

The results from the agricultural and ecological models can then in turn be used together with the Agro-Ecological Zones (AEZ), an FAO-IIASA modelling framework, to find present and future land resources.

Finally, the agricultural and forestry models and the ecological models provide information useful for economic modelling. They can be used, for example, with the Basic Linked System (BLS), an economic and food-trade model, or the Lincoln Trade and Environmental Model (LTEM) (Cagatay & Saunders, 2003; Saunders, Moxey, & Roningen, 2001) to find the projected impacts on different countries, regions, and commodities (Fischer et al., 2005).

An example of this type of integrated modelling leading to policy information is the IMAGE/FAIR model. IMAGE (Integrated Model to Assess the Greenhouse Effect) is a dynamic integrated assessment modelling framework for global change. It quantifies the relative importance of processes and interactions in the society-biosphere-climate system (http://www.pbl.nl/en/dossiers/modelsanddata/Models/index.html). It has been used by the IPCC to model some of the SRES emissions scenarios (http://www.meas.ncsu.edu/aqforecasting/ICAP/PDF/ICAP_PhaseII_final_JRE.pdf) and by the UNEP for the Global Environment Outlook (http://www.pbl.nl/en/dossiers/modelsanddata/FAQs/index.html). The FAIR (Framework to Assess International Regimes for the differentiation of commitments) model is an integrated part of the IMAGE framework (http://www.mnp.nl/en/themasites/fair/overview/FAIR_region_model/index.html). It is a policy decision-support tool that aims to assist in evaluating and exploring environmental and economic implications of international climate regimes for differentiation of future commitment beyond the Kyoto protocol (2012), corresponding to the Climate Change Convention of stabilising atmospheric GHG concentrations (http://www.rivm.nl/bibliotheek/rapporten/550015001.pdf).

The estimates of temperature change and sea-level rise in Table 2.2 are multi-climate model averages for each scenario group as shown in the AR4 for the predicted global warming compared with the baseline years average.

Table 2.2: Projected temperature increase and sea level rise under the different SRES scenarios

	Temperature increase (°C at 2090-2099 compared with the baseline of 1980 to 1999) Best estimate (likely range)	Sea level rise (metres at 2090-2099 compared with the baseline of 1980 to 1999) Model based range, excl. future rapid dynamic changes in ice flow
B1 Scenario	1.8 (1.1-2.9)	0.18-0.38
A1T Scenario	2.4 (1.4-3.8)	0.20-0.45
B2 Scenario	2.4 (1.4-3.8)	0.20-0.43
A1B Scenario	2.8 (1.7-4.4)	0.21-0.48
A2 Scenario	3.4 (2.0-5.4)	0.23-0.51
A1F1 Scenario	4.0 (2.4-6.4)	0.26-0.59

Source: (Pachauri & Reisinger, 2007)

One important thing to note is that these predictions do not convey the likely risk of increased frequency and intensity in extreme weather events such as longer droughts, heavier rainfalls and stronger winds (Pachauri & Reisinger, 2007).

2.3 Impacts on global agricultural production

The IPCC cited FAO research indicating that the growth in world agricultural production would decline from the historic 2.2 per cent per year over the last three decades, to an annual rate of 1.6 per cent in 2000-2015 and 1.3 per cent in 2015 to 2030 (Pachauri & Reisinger, 2007). The sections below will look at some of the major agricultural outputs and highlight different projections in the literature of how climate change is expected to alter agricultural production over the next few decades from a global and regional perspective.

2.3.1 Impact on crop production

Table 2.3 below is taken from Fischer et al. (2002), which uses the A1F1 SRES scenario in the HadCM3 model and hence assumes a future where world population peaks in 2050 and declines to seven billion in 2100. It furthermore assumes an economic convergent society – industrialised and developing countries becoming technologically similar – that relies heavily on fossil fuels as energy sources. As seen in the table, this scenario produces large regional differences in potential projected cereal production. Northern hemisphere countries as well as most parts of Asia and South and Central America are the regions favoured under these projections. Regions such as Africa, Oceania & Polynesia, Western and Southern Europe all show declines in cereal production compared to the 1961-1990 average baseline.

Table 2.3: Impact of climate change on cereal production potentials

	All land					Current cultivated land				
	Reference 1961–1990	HadCM3-A1FI (relative to reference)				Reference 1961–1990	HadCM3-A1FI (relative to reference)			
Region	(1,000 tons)	1990	2020	2050	2080	(1,000 tons)	1990	2020	2050	2080
North America	2,579,314	101	109	114	128	1,760,002	99	106	99	96
Eastern Europe	952,308	104	99	92	91	925,596	104	99	92	91
Northern Europe	298,436	98	111	114	118	239,877	98	107	98	98
Southern Europe	248,701	97	92	90	82	223,471	97	92	89	80
Western Europe	498,449	98	89	88	80	486,705	98	89	88	79
Russian Federation	1,257,656	110	127	165	191	953,060	105	106	113	106
Central America & Caribbean	284,772	99	109	117	105	137,143	99	107	119	94
South America	3,592,333	104	109	115	113	699,762	105	108	107	106
Oceania & Polynesia	644,053	101	96	97	87	81,652	102	100	110	92
Eastern Africa	2,126,133	100	100	102	98	514,856	100	102	103	101
Middle Africa	1,321,918	102	104	107	102	123,308	103	105	110	103
Northern Africa	56,824	107	93	59	24	34,167	106	97	72	34
Southern Africa	145,724	88	53	56	59	51,928	93	58	67	72
Western Africa	1,050,120	99	99	98	94	207,466	99	98	95	86
Western Asia	121,028	102	112	88	99	106,551	101	111	87	99
Southeast Asia	487,360	103	104	110	109	368,162	103	105	111	111
South Asia	1,377,772	103	99	101	97	1,283,493	103	99	100	96
East Asia & Japan	881,479	102	99	108	113	788,031	101	95	101	102
Central Asia	61,297	114	123	143	148	50,460	112	121	138	145
Developed	6,517,580	103	107	116	124	4,701,290	101	102	99	94
Developing	11,468,097	102	103	107	104	4,334,400	102	101	103	100
World	17,985,677	102	105	110	111	9,035,690	102	101	101	97

Source: (Fischer, Shah, & Velthuizen, 2002)

Another perspective on the changes in the global cereal production comes from Parry et al. (2004); Figures 2 to 7 of that article are summarised in Table 2.4. The table indicates potential percentage changes in cereal yields in the 2020s compared to the 1990 baseline under different SRES scenarios, using the HadCM3 model. The results are presented with and without CO_2 fertilisation effects.

Table 2.4: Effects of climate change on food production, with and without CO_2 fertilisation effect

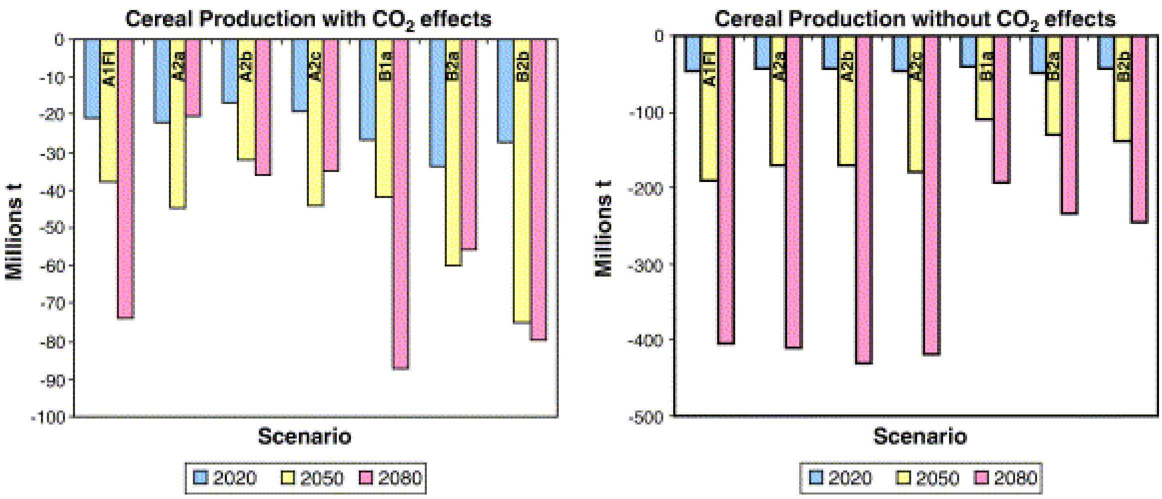
	-- A1F1 --		-- A2a --		-- A2b --		-- A2c --		-- B2a --	
Country/Region	**with**	**w/o**	**with**	**w/o**	**with**	**w/o**	**with**	**w/o**	**with**	**w/o**
Canada	+5 to 10	+5 to 10	+5 to 10	+ 0 to 2.5	+5 to 10	+2.5 to 5	+2.5 to 5	+ 0 to 2.5	+2.5 to 5	+ 0 to 2.5
North America	+2.5 to 5	+ 0 to 2.5	+2.5 to 5	+ 0 to 2.5	+2.5 to 5	-2.5 to 0	+2.5 to 5	-2.5 to 0	+ 0 to 2.5	-2.5 to 0
Central America	-2.5 to 0	-5 to -2.5	-2.5 to 0	-5 to -2.5	-5 to -2.5	-10 to -5	-2.5 to 0	-5 to -2.5	-5 to -2.5	-10 to -5
South America	-2.5 to 0	-5 to -2.5	+ 0 to 2.5	-5 to -2.5	-2.5 to 0	-10 to -5	-2.5 to 0	-5 to -2.5	-2.5 to 0	-5 to -2.5
Africa	-2.5 to 0	-10 to -2.5	-2.5 to 0	-5 to -2.5	-2.5 to 0	-5 to -2.5	-2.5 to 0	-5 to -2.5	-5 to -2.5	-10 to -5
Russia	-10 to -5	-10 to -5	-10 to -5	-10 to -5	-10 to -5	-10 to -5	-5 to -2.5	-10 to -5	-10 to -5	-30 to -10
China	-2.5 to 0	-5 to -2.5	-2.5 to 0	-10 to -5	+ 0 to 2.5	-5 to -2.5	-2.5 to 0	-10 to -5	-2.5 to 0	-5 to -2.5
Australia	0 to 2.5	-2.5 to 0	0 to 2.5	-2.5 to 0	0 to 2.5	-2.5 to 0	2.5 to 5	0 to 2.5	2.5 to 5	0 to 2.5
Europe	0 to 2.5	-2.5 to 0	2.5 to 5	-2.5 to 0	0 to 2.5	-2.5 to 0	0 to 2.5	-2.5 to 0	0 to 2.5	-2.5 to 0
India	-5 to -2.5	-10 to -5	-5 to -2.5	-10 to -5	-5 to -2.5	-10 to -5	-5 to -2.5	-10 to -5	-10 to -5	-10 to -5

Source: (Parry et al., 2004)

The results in the table show that the CO_2 fertilization effect has a positive impact on production in all regions. North America's and Canada's cereal production seems to be most positively effected by the different emissions and hence climate scenarios whereas Russia, Central and South America, and Africa (in general) seem to be most negatively affected by the different projected emissions scenarios. As before, the CO_2 fertilisation effect is shown to have a great impact.

The charts in Figure 2.2 illustrate these changes in production on a global scale with and without CO_2 fertilisation effects in millions of tonnes. There is an obvious negative impact on production yields in all the scenarios, but it can be seen that once more, the positive consequence of the CO_2 fertilization effect is illustrated in all the time periods for all the SRES scenarios, although mostly in the near future.

Figure 2.2: Changes in cereal production



Source: (Parry et al., 2004)

The review of the literature conducted as part of this research revealed a large amount of research on China. The concern of researchers appears to be that China is a populous country and a large producer of agricultural products. Any climate change impacts on agriculture could thus be magnified when viewed through the lens of China. Although China is not the most important market or competitor for New Zealand, the volume of prior research warrants some attention.

A general decline in China's rice production is expected by the IPCC in this century. However, data from Lin et al. (2005) show a projected general increase in rice production under the A2 and the B2 SRES scenarios for China, in the second decade of this century, if the CO_2 fertilization effect is taken into account (see Table 2.5).

Table 2.5: Projected changes in China's rice production yields compared with production yields from baseline years 1961-1990 (change in average yield (%) in the 2020s)

Scenario	With CO_2 fertilization effect	Without CO_2 fertilization effect
A2: Rain fed	2.1	-12.9
A2: Irrigated	3.8	-8.9
B2: Rain fed	0.2	-5.3
B2: Irrigated	-0.4	-1.1

Source: (Lin et al., 2005)

Not allowing for the possible CO_2-fertilization effect from the emissions scenarios leads to reduced yield estimations under both scenarios and under both production technologies (rain fed and irrigation).

China's maize production is also expected to be affected, as shown in Table 2.6. The A2-rainfed projection yields the largest increase in production compared with the baseline. By contrast, the B2-rainfed projection without CO_2 fertilization effect produces the largest decline in production, followed by the A2-rainfed projection without CO_2 fertilization effect. This implies a strong link between the CO_2 fertilization effect and growing rainfed maize, and a much smaller effect of the CO_2 fertilization effect when using irrigation technologies.

Table 2.6: Projected changes in China's maize production yields compared with production yields from baseline years 1961-1990 (change in average yield (%) in the 2020s)

Scenario	With CO_2 fertilization effect	Without CO_2 fertilization effect
A2: Rain fed	9.8	-10.3
A2: Irrigated	-0.6	-5.3
B2: Rain fed	1.1	-11.3
B2: Irrigated	-0.1	0.2

Source: (Lin et al., 2005)

China's wheat production also exhibits the same large impacts from CO_2 fertilisation. Table 2.7 presents figures for the same scenarios and production technologies as before. It indicates large CO_2 fertilization effects on projected yields, especially the A2-rainfed scenario. If the CO_2 fertilization effects are unaccounted for, production yields fall by as much as 18.5 per cent under the A2 rain fed scenario. Again the CO_2 fertilisation effect is diminished somewhat when using irrigation technologies.

Table 2.7: Projected changes in China's rice production yields compared with production yields from baseline years 1961-1990 (change in average yield (%) in the 2020s)

Scenario	With CO_2 fertilization effect	Without CO_2 fertilization effect
A2: Rain fed	15.4	-18.5
A2: Irrigated	13.3	-5.6
B2: Rain fed	4.5	-10.2
B2: Irrigated	11.0	-0.5

Source: (Lin et al., 2005)

Nor is China the only country or region where these impacts are found, as described in the FAR (Pachauri & Reisinger, 2007). For example, rainfed crop production is expected to increase in North America by as much as 5 to 20 per cent in the early decades of this century under moderate climate change projections. In Northern Europe, wheat yield is expected to increase by three to four per cent by 2020. However, rainfed crop production could be reduced by as much as 50 per cent in some African countries by 2020.

2.3.2 Impact on livestock production

The FAR identified several regions around the world that are expected to experience changes compared to the baseline year of 1990. Generally, the report anticipated an increase in temperature until 2030, ranging from one to three degrees Celsius, along with a CO_2 fertilisation effect. These conditions would tend to favour pasture production in temperate regions like China and Argentina and New Zealand. Furthermore, the HadCM3 model under the SRES A2 emissions scenario simulated that the Argentinean and Uruguayan pampas production would increase by one to nine per cent by 2020 (Pachauri & Reisinger, 2007). Warmer regions like Australia are, however, expected to experience an average 15 per cent decline in pasture growth as 20 per cent decreases in rainfall are projected (Pachauri & Reisinger, 2007).

2.4 Impact on forestry

The IPCC has also considered the impact of climate change on forestry production. In background information, the FAR cited FAO research indicating that about 60 per cent of wood harvested in 2004 was industrial roundwood (Easterling et al., 2007), which is used for manufacturing sawnwood, panels, pulp, fibreboards, etc. (Raunikar, Buongiorno, Turner, & Zhu, 2008). The remainder of forest production would be for fuelwood. The FAR also distinguishes between plantation forests as versus 'natural forests' (Easterling et al., 2007). Plantations accounted for 20 per cent to 34 per cent of industrial roundwood at the beginning of the century, and are expect to increase their contribution to 44 per cent in 2020 and 75 per cent in 2050 (Easterling et al., 2007).

The FAR reviewed around a dozen publications that estimate the impacts of climate change on forestry production. By and large, the expectation is that increased CO_2 and increased temperatures will lead to greater production. The findings are not, however, unanimous in the specific impacts. For example, the impact on North America is unclear, with findings of decreases for the continent overall, but increase for the US and decreases for Canada. Production in Russia was found to decrease in one publication, but another report that Siberian production would increase. Impacts in Europe are mixed, with increases in the North and West and decreases in the East. Finally, New Zealand was found to have a 10 per cent to 12 per cent increase in production (Easterling et al., 2007).

An example of the type of modelling undertaken for forestry is Raunika, et al. (2008). The authors used the IPCC SRES emissions scenarios for simulations with the Global Forest Products Model (GFPM) and projected several implications for forest production. Using the A1B and the A2 scenario, they predicted the per cent change in fuelwood production (per cent) in different countries between year 2006 and 2060. As shown in Table 2.8, under these two IPCC SRES emissions scenarios, fuelwood production will increase by 2060, with Japan and USA experiencing the largest increases.

Table 2.8: Predicted growth in fuelwood production, 2006-2060 (%)

Country	Scenario A1B	Scenario A2
Canada	3.9	1.1
USA	5.8	2.3
Brazil	3.2	1.1
Indonesia	3.1	1.3
Japan	10.1	2.3
Finland	5.0	2.0
Russian Federation	4.2	1.3
Sweden	4.1	1.5

Source: (Raunikar et al., 2008)

As a result of these impacts, the FAR projects that prices for forestry products would be expected to fall. The price decrease would benefit consumers of forestry products but disadvantage producers.

2.5 Projected changes for New Zealand's pasture production

The IPCC's fourth report projects that pasture production in New Zealand's Western, Southern and high altitude areas is likely to increase 10 to 20 per cent by 2030, although gains may decline thereafter (Pachauri & Reisinger, 2007). By 2030, the Eastern and Northland area pasture productivity are likely to decrease with higher drought occurrences (Pachauri & Reisinger, 2007).

Pasture production projections for the 2020s are also described in the MAF report by Baisden et al. (2008). In order to create the estimates in the report, researchers started with results from the IPCC TAR, using a temperature scenario corresponding the lower 25 per cent of the entire IPCC TAR climate scenarios range. NIWA then downscaled results from the HadCM2 model to provide a more detailed picture of climate change impacts on New Zealand. Additional modelling was also performed using results from the FAR and the HadCM3 model.

The Baisden et al. (2008) research obtained a range of results. Using an IS92 IPCC mid-range emissions scenario and the HadCM2 model, an averaged yield projection of five sites in New Zealand (Gisborne, Gore, Kerikeri, New Plymouth and Winchmore) was estimated. The result was a projected increase in pasture dry matter of eight to ten per cent compared to baseline year 1990. On the other hand, using the latest IPCC FAR emissions scenarios and the HadCM3 model, the research estimated that average production levels of high-producing pasture areas in 2030-2040 period would be 100.2 per cent of baseline production – essentially unchanged. The research also investigated the impact of weather variability, and found that production in dry years would be only 51.9 per cent compared to median year of the 1989/90 baseline.

Projections for sheep and beef production were made in the Baisden et al. (2008) report, based on both the average changes in production and the 'worst year' impacts with low rainfall. Again, a number of projections were obtained. Some estimates examined the impact of both low temperature changes and high temperature changes using the IPCC TAR data and the HadCM2 model. In those cases, production in the 2030s was projected to change by -6.1 per cent and -8.8 per cent, respectively, compared with 1972-2002 average baseline (Baisden et al., 2008). Other projections considered production with the same low and high temperature changes but in dry, 'worst year' conditions. Those estimates found production change of -42.7 per cent with low temperature changes and -46.0 per cent with high temperature changes (Baisden et al., 2008). These estimates were further compared to 'worst year' data from 1972 to 2002. In that period, the 'worst year' average corresponded to a change of -33.5 per cent in production, compared with the average production over the whole period. This result suggests that production variability can be expected to be greater in the future than in the past, as a result of climate change.

Baisden et al. (2008) also made projections of dairy production for New Zealand. Projected production changes for the 2030s were -2.8 per cent for low temperature changes and -4.3 per cent for high temperature changes, compared to the 1972-2002 average baseline. These results were based on the TAR emissions scenarios and the HadCM2. These projections were small compared to the 'worst year' projected impacts. Those impacts were estimated at -43.4 per cent and -46.3 per cent of the base using low and high temperature changes, respectively. By comparison, the historical 'worst year' estimate for 1972 to 2002 was -36.7 per cent. Thus, New Zealand dairy production will also have greater variability of production with climate change.

2.6 Summary of climate change impacts

This chapter has reviewed some of the research undertaken by the IPCC and others to consider the impact of population growth and other trends on production of greenhouse gases and the implications for climate change. The associated changes in temperature, rainfall, and concentration of CO_2 are expected to have impacts on agricultural and forestry production; findings regarding these impacts were also summarised. The impacts varied by country and commodity, and varied according to the timeframe considered. In addition, there was some uncertainty in the results, indicated by the ranges of values presented in some cases. The values will serve as parameters for defining modelling scenarios to be considered using the Lincoln Trade and Environmental Model.

Chapter 3
Currently Available Mitigation Technologies

A number of options have been developed for mitigating greenhouse gas emissions from agricultural sources. They are reviewed and discussed in this chapter.

3.1 Mitigation of gases

Recently, there have been several peer-reviewed articles published about greenhouse gas abatement and mitigation for the agricultural sector. Methods for abatement of enteric methane (CH_4) emissions are discussed in detail in Beauchemin et al. (2007) and de Klein and Eckard (2008) have reviewed the literature on nitrous oxide (N_2O) abatement and mitigation technologies. N_2O abatement technologies were found to have a higher probability of success if they either reduced the availability of soil nitrates or improved soil aeration (de Klein & Eckard, 2008). Technologies discussed in these and other articles are explained below.

Animal breeding: The breeding of animals for higher milk production efficiency has an added benefit of decreasing the amount of nitrogen (N) excreted as comparatively more N goes to milk production than with low milk producing cows (de Klein & Eckard, 2008). de Klein and Eckard (2008) suggest this may also decrease methane production although this is not discussed in great detail.

Dietary amendments: Some of the dietary amendments discussed for N_2O abatement do not reduce nitrogen (N) losses, but distribute N more evenly across paddocks, avoiding intensive urine patches (de Klein & Eckard, 2008). Urine patches are undesirable as they are highly concentrated and localised sources of readily available N. Particular dietary amendments can also reduce the amount of N leached from soils. For example, feeding a diet high in salt supplements to cattle increases water intake decreasing the concentration of N as the animals produce urine more frequently (Ledgard *et al.*, 2007). Adding 400g of salt per day to diet can reduce N in urine to 3g/L compared to 9.6g/L where no salt was added (Ledgard *et al.*, 2007). Adding condensed tannins (extracted from tree bark) to the diets of cattle has also been shown to reduce the concentration of N in urine and to reduce emissions of CO_2 from urine by 45 mg C m^{-2} h^{-1} over normal urine (Liebig, Kronberg, & Gross, 2008). However, when greenhouse gas flux was measured over experimental urine patches of N enhanced and normal urine there were no differences in N_2O emissions. This study was conducted for a short period in a single grassland environment. Condensed tannins are also present in legumes and are thought to be a contributing factor to the observation that animals whose pasture is substituted partially by legumes, have lower CH_4 emissions (Beauchemin *et al.*, 2007).

Nitrogen efficiency can also be improved by varying the relative proportions of nutrients within animal diets. For example, in a comparison of N use efficiency between dairy cows fed on low-protein maize based diet or a control diet of white clover and perennial ryegrass, it was found that the maize fed cows had higher milk production efficiency (Luo, Ledgard, de Klein, Lindsey, & Kear, 2008). In simple terms, there was 22 per cent less N_2O emissions for every kg of milk produced. Maize may also reduce CH_4 emissions (Beauchemin *et al.*, 2007).

Dietary amendments can also reduce CH_4 emissions. Adding lipids to animal diets and substituting feed with concentrates have both been shown to decrease the amount of CH_4

produced (Beauchemin *et al.*, 2007). Both lipids and concentrates must be used according to the recommended guidelines. For example, it is not recommended that lipids exceed 7 per cent of dry matter intake, and in dairy cattle, milk production deteriorates when concentrates account for more than 50 per cent of feed but each technology can yield emissions reductions of around 10 per cent compared with a control diet.

The broad-spectrum antibiotic, monensin, which is approved for use in New Zealand, can be pre-mixed into animal feed or inserted directly into the rumen of animals where it can decrease ruminal protozoan numbers and increase the level of propionates. This has anti-methanogenic effects (Beauchemin *et al.*, 2007). In New Zealand though, monensin has been ineffective in reducing cattle CH_4 emissions but effective for sheep (Pastoral Greenhouse Gas Research Consortium, 2007). Preliminary results from sheep CH_4 trials found that monensin and a monensin/coconut oil mix reduced CH_4 emissions by 20 and 33 per cent respectively (Pastoral Greenhouse Gas Research Consortium, 2007). When pasture was substituted with chicory, CH4 reductions were as high as 37 per cent (Pastoral Greenhouse Gas Research Consortium, 2007).

Nitrification inhibitors: There are currently three nitrification inhibiting products available for sale in NZ, all of which have the same active ingredient, dicyandiamide (DCD). DCD works by inhibiting nitrification of N, slowing nitrification, increasing ammonia retention in soils and reducing N_2O emission rates (Kelliher, Clough, Clark, Rys, & Sedcole, 2008). Even across a wide temperature gradient, DCD appears affective on a range of different soil types in New Zealand with average emissions reductions of 70 per cent (H. J. Di & Cameron, 2006; H. J. Di, Cameron, & Sherlock, 2007). Nitrification inhibitors can be delivered to pasture by feeding a bolus to stock which would pass unaltered through a ruminant’s digestive system and are deposited onto urine patches (de Klein & Eckard, 2008).

3.2 Methane capture

In some cases, livestock manure can be collected and held in heated tanks, and the resulting decomposition gases (i.e., CH_4)used to produce electricity, or flared to release the CO_2 which has a smaller global warming potential than CH_4 (McIntosh, 2000). The potential of using biogas instead of a fossil based fuel is large; it is estimated that biogas from manure capture is capable of replacing 4 per cent of annual electricity which is currently produced by coal in the United States (Cuellar & Webber, 2008). In New Zealand, anaerobic ponds are used to treat waste water and are a source of considerable emissions (Craggs, Park, & Heubeck, 2007).

3.3 Sequestration

Soil carbon sequestration is a method of fixing carbon into soil by way of soil organic matter, also called soil organic carbon (SOC) (Lal, 2004).

Conservation tillage/no till farming: Conservation tillage is the umbrella term for farming methods that reduce the number of times an area is tilled. Conservation tillage reduces energy use (Uri, 1999), decreases soil erosion and increases carbon storage in soils (Jacobs, Rauber, & Ludwig, 2009; Lal, Follett, Stewart, & Kimble, 2007). Conservation tillage covers no tillage (where crops are planted directly into previous years crop residue; McIntosh 2000, Sullivan (2003), strip tillage (where a raised mound is planted while strips of crop residue between each mound are left undisturbed; (2000)), and minimum tillage (where soil is not turned over).

A long term (40 year) study on two sites in Germany found that minimum tillage treatments increased storage of organic matter and in turn an increase in soil organic carbon and nitrogen compared to conventional tillage on the same soil (Jacobs *et al.*, 2009). A comparative study of 10 different uses of the same soil type showed that carbon sequestration always occurred in the presence of macroaggregates, that is particles larger than 250 micrometers (Grandy & Robertson, 2007). When macroaggregates are disturbed or destroyed on a regular basis, for example if soil is tilled annually, the long term persistence of stored carbon in the soil is jeopardised (Grandy & Robertson, 2007).

Carbon sequestration potential of afforestation: Sequestration from agroforestry is an option for the mitigation of agricultural greenhouse gases. In a study of degraded land in Brazil, a severely eroded gully was replanted with nitrogen fixing leguminous species. The rates of soil nutrients were compared to a patch of undisturbed native forest and a deforested area colonised naturally by a pasture grass (Macedo *et al.*, 2008). After 13 years soil C and N levels were higher in the replanted area than in deforested area, but not as high as the undisturbed forest (Macedo *et al.*, 2008). In an Australian study, the above (including leaf litter) and below ground carbon and nitrogen storage of a 16 year old pine plantation was compared with an adjacent native pasture (Guo, Cowie, Montagu, & Gifford, 2008). Although soil stored carbon and nitrogen were lower in the forested area than the grassland, the above ground biomass and the leaf litter storage were significantly higher than for native pasture (Guo *et al.*, 2008). Below ground carbon storage has also been shown to be lower in hoop pine plantations in Australia, than in neighbouring native pasture and secondary rainforest (Richards, Dalal, & Schmidt, 2007).

Although it may not be practical to replace pasture with plantation timber in many areas, it may be possible to incorporate stands of plantation trees such as radiata pine on marginal areas of farms, such as eroded gullies.

Chapter 4
Consumer Responses

The model of international trade that will be used to analyse the economic impacts of climate change on New Zealand, the LTEM, includes demand equations. By modifying the parameters of these equations, the reactions of consumers to climate change and other environmental issues can be incorporated into the model. Prior economic research on climate changes has tended not to include demand effects. However, prior trade modelling has found that demand impacts can be larger than supply impacts in the agricultural sector (Kaye-Blake, Saunders, & Cagatay, 2008; Saunders & Cagatay, 2003). They are thus an important consideration from the point of view of New Zealand's economic future.

Generally speaking, consumer or final demand is a function of consumer preferences and commodity prices. This general statement, however, belies the complexities of consumer demand and its relationship to the environment. This section of the report provides a brief look at the literature on consumption and the environment. The challenge for the next phase of the research will be to decide how to model consumer reactions in a way that provides meaningful results concerning New Zealand economy.

A key parameter in the model will be the demand for sustainable goods. This demand will be incorporated into the model by a shift in demand that represents the higher prices consumers are willing to pay for sustainable goods. The amount of the shift will be determined by a review of the economic literature on willingness to pay for environmental benefits. This literature is reviewed below. However, before it is reviewed, there are a number of issues that should be considered.

4.1 Environmental impacts

The basic framework is that agricultural and forestry products can be produced using a number of different techniques with different environmental consequences. A simple distinction can be made between commodities produced using conventional technologies and those that are more environmentally friendly or sustainable. As Kotchen (2005) has discussed, these 'green products' or sustainably produced commodities can be seen as impure public goods: they have both private and public characteristics. The private characteristics are shared in common with the conventional products, and the green products may also have additional private characteristics. The public characteristics are those concerning the environmental impacts. These impacts may be non-rival and non-excludable – my enjoyment of a stable climate does not reduce your enjoyment of it, and I cannot prevent you from enjoying the stability that my purchases support. The demand for green products will depend on prices, production technologies, the state of the environment, and the availability of substitutes.

The concern about the role of consumption in producing environmental outcomes is not new. Mitchell (2001) pointed to the contributions made by Thorstein Veblen a hundred years ago (Veblen, 1970[1899]), especially on the topics of waste and over-consumption. Since the topic has a long history, it also has a large literature, more than can be summarised here. However, the key point with regard to the present research is that the link between consumers' preferences and environmental impacts is loose and uncertain. There are several reasons for this.

One reason for the weak link is the presence of substitutes. If consumers want greater environmental benefits, they may be able to have them either through buying green products or through other means, such as donating to environmental causes. This means that environmental preferences of consumers will be only partly expressed through their purchases. The trade model considers only purchases within private markets, so can only consider the environmental impacts from these bundled impure public goods. The impact of consumers' full portfolio of behaviours is not included.

A second issue has been raised with regard to the link between preferences and environmental outcomes: the systematic nature of consumption. For this modelling work, a key assumption is that consumer preferences are an important consideration in the market. Preferences regarding environmentally friendly or sustainable production methods directly affect demand for products and therefore prices. Price acts as a signal to producers to change production technologies. However, the importance of this mechanism has been disputed by a number of authors, who approach consumption from a systems perspective (Paterson, 2007; Conca, Princen, and Maniates, 2002). Consumption is seen as embedded in a social system, especially as a central part of the consumer-focused economy. The products consumed, such as automobiles, are part of systems of provision, institutional structures, and personal identities build up over many years. Eco-consumerism may not be the best way to achieve environmental reforms, because of the systemic nature of consumption and the fact that decisions regarding what to produce and how are made by producers (Buttel, 2003). These concerns echo the work of Galbraith on the organisation of industrial capitalism (Galbraith, 1967).

Furthermore, even where consumers are able to signal their environmental preferences through the market, the distribution of preferences for sustainably produced goods in the population will affect the extent of the environmental benefits from these goods (Eriksson, 2004). If support for green products is concentrated, then firms can establish profitable niche markets targeting those consumers, but the environmental benefits would be comparatively small.

It is also important to consider the type of consumer when investigating the impact of prices. An assumption of price theory is that consumers are willing to make trade-offs across their different preferences, so that a lower price can compensate for a worse environmental profile of a product. However, the ethical position of consumers has been shown to be an important consideration (Gelso & Peterson, 2005). Individuals with consequentialist perspectives will fit in a cost-benefit framework, where price is a key factor. People with a deontological worldview – one based on duties and rights – are more likely to have an ethical approach to behaviour and therefore fixed demand regardless of price, at least within some range of prices and incomes.

Another consideration is the difference between perceived environmental impacts and actual impacts. Highly visible or highly publicised efforts, such as reducing the use of stand-by modes for televisions, may have only small impacts on the environment (Biebeler, Mahammadzadeh, & Bardt, 2007). If consumers with strong environmental preferences are mistaken about the environmental consequences of their purchases (or use of purchases), then the link between preferences and outcomes may be weak. In addition, it may be difficult to provide consumers with the information they want. One important source of information for consumers is product labelling. The idea that labels can provide environmental information has therefore gained currency, and led to different labels purporting to indicate the environmental impact of specific products. Eco-labels may not be able provide full and complete information to consumers regarding the environmental consequences of production, especially for products with complex processes or supply chains (Bruce & Laroiya, 2007).

Although the link between consumer preferences and environmental outcomes may in fact be weak for the reasons indicate above, these concerns do not completely remove the importance of thinking about price and consumer demand. Given the priority of market-led approaches to sustainability by governments in industrialised countries (Seyfang, 2004), it is important to examine the potential environmental impacts of prices and preferences. Price-based policies can be effective in reaching environmental goals (Van den Bergh, 2008). There may be a number of other policies that could also work, such as setting environmental standards for products or supporting information provision, but prices will continue to be a key market and policy consideration. It is therefore important to understand how changing prices for conventional commodities and green products, combined with shifts in consumer preferences, affect international trade movements and New Zealand's economic future.

4.2 Willingness to pay

A key parameter for the trade model, and a central focus of economists, is willingness to pay. Consumers are willing to pay to obtain products that satisfy their preferences. If consumers have preferences for environmentally friendly products, then it is axiomatic that they will pay for these products. Some important questions that arise are how much consumers are willing to pay, how many consumers or what fraction of the market shares those preferences, and who these consumers are. These topics are all discussed below.

It is important first to recognise the limitations of the economic values estimated for environmental goods. The problem of hypothetical bias – that what people say is not necessary what they will do – is well known (Bateman et al., 2002). A lot of work has gone into reducing the impact of hypothetical bias (e.g., Lusk, 2003), and research does suggest that well-designed surveys can generate accurate economic values of non-market goods (Murphy, Allen, Stevens, & Weatherhead, 2005). However, there are still a number of other limitations with regard to these valuations. For example, technical issues arise when trying to measure the impact of changes in the environment on consumers. One technical issue is whether to measure the impact by willingness to pay (WTP) or by willingness to accept (WTA), which can yield different values (Bateman et al., 2002; Ebert, 2008). Another issue is whether consumer surplus accurately measures the change in welfare (Ebert, 2008). In addition, the survey techniques used to gather WTP data, such as the payment method or the mechanism for providing the environmental benefit, can significantly affect the price estimates (Bateman et al., 2002; Wiser, 2007).

Regardless of these known limitations, the prices that consumers appear to be willing to pay for products with environmental benefits are important market considerations. They are also important inputs for the modelling to be undertaken. Therefore, the following discusses some of the findings regarding willingness to pay.

Values from tourism. Parts of the tourism industry rely on natural spaces for in their appeal to tourists. Environmental values derived from studying consumer can therefore give an indication of the sorts of monetary values that consumers could assign to environmentally friendly products. In particular, it can indicate consumer behaviour when a commodity goes from being free to having a cost, as may happen with carbon emissions. In one study on the national marine park in Zakynthos, Greece, is such an example with 80 per cent of participants willing to pay between 1 and 100 Euros for visitation (Togridou, Hovardas, & Pantis, 2006). Although Greeks displayed more environmental appreciation than foreigners, nationality was not an important factor when willing to pay. Therefore regionalism was not a factor with consumer willingness to pay, however different environmental priorities did exist between local and foreign visitors. In Uganda, a case study discovered that bio-diversity played an important factor in determining which park tourists were willing to visit (Naidoo & Adamowicz, 2005). The study discovered that the differing number of bird species played an important factor in the desirability of each park. Consumers were willing to pay for the variety of birds; $18.032 for 20 species and $40.413 for 80. However, doubt remains as to the sustainability of these plans when factoring in the cost of park maintenance.

Values from energy. Energy consumption is the main source of carbon emissions therefore environmentally sustainable power is often initially embraced by consumers. Alternative power sources were the focus of research in Norway undertaken to understand consumer's willingness to pay for conservation. The results showed that the majority of Norwegians preferred investing in wind farms as opposed to importing coal and building more hydropower or gas fired plants. Preference was shown towards a collectivisation of wind farms, with fewer large scale farms over many smaller ones to preserve scenery. Consumers were willing to pay an annual rate of 1087 Norwegian Kroner per household for wind power. However this figure dropped to 567 Kroner if many wind farms were built instead of fewer large scale projects. This increased to 698 Kroner if medium sized turbines were used (Navrud & Braten, 2007). These results suggest that sustainably produced energy has a value, but that individuals are making judgements about the desirability of different types of projects. Consumers are evaluating the method or process for achieving sustainability.

Values from conservation. The island of Crete is facing pressure on its water supplies. From 2007, Crete has faced severe fresh water shortages, forcing farmers to consider using alternatives to fresh water. Research was undertaken to assess whether farmers were willing to use recycled water (Menegaki, Hanley, & Tsagarakis, 2007). For farmers, recycled water is an inferior good and has potential consequences for their marketing. Thus, farmers were willing to pay for recycled water at 55 per cent of the fresh water price. This example demonstrates that environmentally friendly products are not necessary more highly valued; in some cases, user of these products may demand a discount.

In the United States consumer willingness to pay for conservation was measured against uncertainty (Roberts, Boyer, & Lusk, 2008). This was used to approximate how consumers would respond to environmental measures aimed at reducing algae and agricultural run-off. Results found that including uncertainty in the survey instrument affected how consumers responded: the estimated willingness to pay for environmental improvements was greater under uncertainty than under certainty. Given the uncertainty associated with climate change, this issue of the interaction of willingness to pay and outcome uncertainty is important.

Values from consumer goods. Consumer goods can be produced in a number of different ways. The method of production becomes part of a bundle of attributes represented by the commodity. The production method may not be verifiable at the point of sale, in which case it becomes a *credence attribute* (Darby & Karni, 1973). Consumers must believe or have faith that the good delivers this attribute without having proof that it does. Labels are a key source of product information regarding credence attributes, and have been included in a number of studies. Labelling was the focal point of research conducted in the United States regarding attitudes towards fair trade, shade grown and organic coffee (Heidkamp, Hanink, & Cromley, 2008). The results found that ranking the value placed on each of the initiatives, shade grown and fair trade were more important to consumers than organic. The consumer willingness to pay was higher for coffee that was labelled as being shade grown or conducive to fair trade. However a possible amalgamation of the causes remains a possibility. Some consumers were willing to pay an extra $1.50 a pound for fair trade coffee and an additional $1.50 on top of that if it was organic. This is an extra $3.00 a pound some consumers were willing to pay for a combination of fair trade or shade grown and organic coffee. Consumers were therefore willing to pay substantially more for a product that they believed was produced in an environmentally friendly fashion.

Organic food has been examined in other research. In Bangkok over a third of respondents in a study involving 848 people reported purchasing organic vegetables (Roitner-Schobesberger, Darnhofer, Somsook, & Vogl, 2008). According to their research, organic produce had a price between 100 per cent and 170 per cent higher than conventional produce. This research provides evidence that there is willingness to pay for organic products, even in developing countries. However, the author described a lack of a single certified label in Thailand. The issue of willingness to pay for credence attributes, such as method of production, is thus confounded with the issue of credible labelling.

An additional issue highlighted in the coffee example above is that consumers appear to make distinctions between different environmentally friendly products. In another example, a survey of catalogue data from the United States showed that a significant price premium existed for garments made with organic cotton. Organic cotton enjoyed a 38 per cent increase over ordinary apparel (Dasgupta, Meisner, & Wheeler, 2007). In contrast no price premiums were found in the area of either low impact or environmental dyes. The implication for producers is that although a production input or method may be environmentally friendly, it may not be embraced by consumers. Again, credible labelling and the existence of standards may also play a part in consumers' decisions.

Summary of values. This section has presented a few examples of research demonstrating the value of environmentally friendly or green products. They indicate that methods of production with environmental benefits can be of greater value to some consumers. The results also indicate, however, that green products are not necessarily of value to all consumers; that some green products are more highly valued than others; that a host of other issues like uncertainty and labelling are also important; and that individuals may want to be compensated for taking steps to care for the environment. In the realm of non-market valuation, some effort has gone towards producing transferable values of environmental goods for New Zealand (http://www.lincoln.ac.nz/nonmarketvaluation/), but widely accepted values for environmental benefits or impacts have yet to be established.

4.3 Consumer variables and preferences

When discussing consumers' attitudes towards environmental goods it is necessary to consider the factors that motivate consumers' willingness to pay for these products. In some instances consumers will be motivated by personal benefit when deciding to purchase environmental goods. Environmental goods may directly benefit the consumer through a reduction of price or health benefits. Alternatively consumers may be influenced by indirect concerns such as a sense of civic duty or fairness. The consumer's income, age, gender, even level of education can all factor into the decision making process. A personal commitment to the environment as a whole or perhaps an individual environmental issue may be of personal significance to the consumer.

One of the most effective methods in ensuring that environmental goods are attractive to consumers is by offering benefits that accrue to the consumer. For example, a key driver of consumption of organic food is the belief that they provide greater nutrition for the consumer (Hughner, McDonagh, Prothero, Shultz II, & Stanton, 2007). This general result affected results from some of the survey discussed above (e.g., Roitner-Schobesberger et al., 2008).

Another example of the importance of personal benefit comes from a study based in Spain on willingness to pay for agricultural development (Kallas, Gomez-Limon, & Arriaza, 2007). The rural population displayed a greater willingness to pay for new employment in the agriculture sector. The maintenance of rural numbers was also cited as a priority. These goals were in marked contrast to the urban population which displayed a preference towards reducing endangered species and food safety. Job creation in the agriculture sector as well as maintaining rural numbers are obvious examples of self interest.

Personal variables play a factor when analysing consumers' attitudes towards environmental goods. These variations can relate to gender, parental status, income, age and more. A striking example in which personal circumstances have directly effected consumers' decisions is the gender study concerning water quality in Canada. The results found that parents were more willing to pay for an improvement in water quality than non-parents (Dupont, 2004). This suggests that parents have an increased personal stake in reducing environmental damage inherited by the next generation. Concern for their children elevates a parents' willingness to pay over their childless counterparts. However parental differences are not the only factor when discussing consumer variables. The study also revealed marked differences in the importance placed on water quality between males and females. This can be attributed to the fact that water activities were divided into three categories, boating, fishing and swimming. Fathers were prepared to pay significantly more than mothers for two out of the three activities. Ultimately this means that consumers' willingness to pay can be directly influenced by the personal stake they have in the environment.

Alternatively this stake can be based on the location within a country the consumer resides. As covered earlier, research suggests that Norwegians collectively show a strong willingness to use environmentally friendly power. However the rural population experienced a lower willingness to pay in contrast to consumers located in urban centres. This is thought to be a result of the fact that any wind farms built will be centred in the countryside away from urban areas. Consumers' experienced a lower willingness to pay for wind power when they had a house in a region with wind turbines (Dupont, 2004). A notion strengthened due to the preference by Norwegians for fewer large scale farms over many smaller ones. The reason echoes a major argument against wind farms; less farms necessary to preserve the rural landscape.

Some environmental goods will be significantly more attractive towards consumers who fit certain characteristics. The market for organic vegetables in Bangkok is a prime example (Roitner-Schobesberger et al., 2008). Consumers that were willing to pay for organic produce tended to be older, highly educated and commanded higher incomes. These three variables all factor into the consumer willingness to pay for organic vegetables. The fact that consumers of organic produce were generally on a higher income is relevant when considering the pricing the goods command. Clearly a higher income would be beneficial towards consumers adopting the product over standard vegetables. As covered previously, one of the main reasons for consuming organic was a perceived health benefit. This is likely to be an important theme amongst older participants who it can be assumed are more health conscious.

The willingness to pay for environmental benefits is not uniformly distributed across the population. A number of personal variables have been assessed for their impacts on intentions to purchase and willingness to pay for environmentally friendly goods. For example, personal attitudes and social norms are associated with intentions to purchase green products (Vermeir & Verbeke, 2008). In addition, the level of confidence consumers have the information they are provided about the products also significantly affects their demand (Vermeir & Verbeke, 2008). Another factor affecting consumer demand is the civic-mindedness of the population;

consumer who are more civic-minded are more willing to contribute to environmental efforts (Owen & Videras, 2006). Other researchers have linked an individual's ethical stance to willingness to pay for environmental improvements (Spash, 2000). Individuals who view the environment from a deontological perspective not only have higher willingness to pay for environmental outcomes, but view the issue cost-benefit tradeoffs in a different way than other people.

4.4 Supply chain issues

Another facet of consumption to bear in mind is the ability of firms in the supply chain to affect the flow of goods to the market, thereby constraining the choice set of consumers. This is known as the 'gatekeeper' effect: firms may act as gatekeepers or nightclub bouncers, selecting products for entry while excluding others.

Highly visible in this gatekeeper role have been supermarkets. One example is Waitrose, which has indicated that its produce will be produced more sustainably by 2010. Sustainability, in this case, is achieved by minimising pesticide use, protecting wildlife, and conserving natural resources like water and soil. Another UK supermarket company, Tesco, sets environmental standards for its food through its Nature Choice programme. Tesco also announced an initiative to carbon footprint all the products in its shops. The high-end retailer Marks & Spencer introduced a label to indicate that products had been shipped by air. Other carbon labelling schemes are being trialled or developed in Sweden, France, Germany, Japan, and other countries.

The examples above are a combination of types of schemes. Some schemes provide consumers with information, which allows consumers to determine how much they care about buying products with high carbon footprints. Other schemes require products to meet specific minimum standards. This is true, for example, of Waitrose's initiative regarding sustainable produce, and is also true of audit schemes like EurepGAP and GlobalGAP. With the first type of scheme, it is ultimately consumer preferences that will determine the price differentials between products with small and large carbon footprints, or between products that are 'climate friendly' and those that are not. With the second type of scheme, the gatekeepers make decisions about which products will be offered to consumers. In those cases, producers must meet the requirements of the gatekeepers, regardless of the potential consumer demand for their products.

4.5 Summary of consumer responses

The research reviewed above – and other literature on consumer behaviour – clearly indicate the willingness on the part of some consumers to support environmental values by paying more for goods and services. Consumers are clearly heterogeneous in this willingness to pay, however, and there are confounding impacts from labelling, information, social norms, uncertainty, and more. As a result, although there is a clear willingness to pay for green products, the size of the premium and the products to which it applies are unclear. To inform the trade modelling, some simplifying assumption will need to be made.

Chapter 5
Future Research

The research reviewed in this report provides the necessary data for analysing the economic impacts of climate change using a model of international trade in agricultural commodities. Research is currently underway to build such a model on the platform of the Lincoln Trade and Environment Model (LTEM) (Saunders et al., 2001), with a country and commodity mix specific to the issue of climate change. The LTEM is a non-spatial, partial equilibrium model of international agricultural trade developed originally from SWOPSIM (Roningen, 1986), later VORSIM (Roningen, 2007; Roningen, Dixit, Sullivan, & Hart, 1991), and its model structure. Furthermore, it is a synthetic model, based on parameters taken from the literature. The modelling will include 17 specific countries or regions plus the Rest of the World (ROW), and will contain 25 commodities, including three for the oilseed complex, five for the dairy industry, and three forestry products.

The LTEM can explicitly consider various domestic and border policies, including production quotas, set-aside policies, input and/or output related producer subsidies/taxes, consumer subsides/taxes, minimum prices, import tariffs and quotas, and export subsidies and taxes. The parameters associated with these policies can be modified to simulate policy changes in order to estimate their economic impacts.

The dynamic framework of the LTEM allows the paths of endogenous variables to be assessed through the modelled time period, and a comparative statics analysis can be conducted by comparing different years or the final results of different policies. The model seeks a price equilibrium of a series of production, consumption, and trade equations for each year, solving each year in succession until the final period. The structure of the model is based on a set of supply and demand equations and one economic identity for each commodity in each country.

For each country and each commodity, it will be possible to specify impacts on the supply and demand sides of the market. These impacts will be derived from the prior research discussed above. Where prior research had indicated a potential range of impacts, it will be possible to use the trade model to assess the impacts of the high and low values of the range.

The result of this future research will be a set of estimates of potential economic impacts of climate change on agriculture and forestry in New Zealand.

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