Economic outcomes of the Kyoto Protocol for New Zealand

ABARE Report to

New Zealand Ministry of Agriculture and Forestry

November 2001

Introduction

In August 2001 the New Zealand Ministry of Agriculture and Forestry commissioned ABARE to undertake a second round of analysis of the potential economic impacts on New Zealand of implementing the Kyoto Protocol. This paper provides briefing for the New Zealand government on that analysis.

The analysis is based on policy simulations specified by the client, and the results presented here do not reflect the outcomes of the negotiations at the resumed sixth Conference of the Parties in Bonn in July 2001. Results of ABARE's most recent analysis, including the Bonn outcome, are contained in ABARE conference paper 2001.28, 'The Kyoto Protocol: economic impacts under the terms of the Bonn agreement' (Jakeman et al. 2001), which is available on the ABARE website (www.abareconomics.com).

As this paper is designed as briefing material only, comprehensive background detail on the modeling and analysis is not included here. This information will be available in a forthcoming ABARE paper, which reports on the first round of analysis commissioned by the New Zealand Ministry of Agriculture and Forestry and examines a wider range of climate change issues.

The issues examined

Two issues of importance to New Zealand in its potential ratification of the Kyoto Protocol are examined here.

Country participation in the Kyoto Protocol

In March 2001 President Bush announced that the United States would not ratify the Kyoto Protocol. As the United States is the world's largest economy and largest emitter of greenhouse gases, its nonparticipation in the protocol is likely to substantially alter the nature of any international emissions trading under the protocol.

US participation in the international climate change response could be important for Australian ratification. The New Zealand and Australian economies are closely linked both through extensive bilateral trade and in their positions as two of the world's major exporters of wool and dairy products. Accordingly, Australia's ratification decision is likely to have implications for the New Zealand economy.

Abatement policies in agriculture

Livestock industries account for over half of New Zealand's greenhouse gas emissions and offer significant potential low cost emission abatement. These industries, in particular the wool and dairy industries, also generate a significant share of New Zealand's export revenue.

Under the Kyoto Protocol, each Annex B country is responsible for determining how it meets its emission target. Responses may involve exempting certain sectors from any abatement action. The extent to which New Zealand and other Annex B countries expose their livestock industries to abatement policies will determine the impact that

the Kyoto Protocol has on the international competitiveness of New Zealand's livestock industries.

Outline of the brief

These two issues are explored in a set of six scenarios with differing assumptions about Australia's participation in the Kyoto Protocol and about agriculture's inclusion in abatement policy in Annex B countries. In the main body of the brief the major macroeconomic and sectoral results from each scenario are presented and discussed. Appendix A provides further detail on some of the key assumptions underlying the analysis. Detailed results are provided in appendix B. The GTEM reference case is described in appendix C, while appendix D lists some of the important parameters used in GTEM.

Analytical framework

The modeling and analysis contained in this brief are based on results from ABARE's global trade and environment model (GTEM), a multiregion, multisector, general equilibrium model of the world economy. GTEM was developed by ABARE specifically to undertake analysis of global policy issues such as climate change. GTEM is particularly suited to this because of its ability to capture the impacts of policies on large numbers of economic variables (a discussion of the types of models used for climate change policy analysis is included in box 1). A detailed description of GTEM can be found in Polidano et al. (2000).

Box 1: Climate change models

IPCC (1996b) characterises models used in climate change policy analysis as either 'top down' or 'bottom up' models. Those in the bottom up category tend to have their origins in energy sector modeling and have detailed representations of the energy intensive industries. Top down models (primarily general equilibrium, such as GTEM) have a broader economic coverage and are better able to show the linkages between different sectors of the economy.

The way in which economic impacts are calculated within the models is critical to determining their likely applications. Bottom up models use aggregated economic models to project economic impacts. Aggregated economic models have a small number of endogenously determined economic variables and limited capacity for estimating the overall economic impacts of climate change policy. Top down models can be divided into two groups: disaggregated economic models and disaggregated macroeconomic models. Disaggregated economic models assume that economies are in equilibrium and are well suited to medium to long term analysis. Aggregated macroeconomic models do not assume equilibrium and are better able to examine short term structural impacts such as changes in unemployment.

In GTEM climate change analysis the impacts of a particular policy or set of policies are presented as changes relative to a reference case. The reference case scenario provides a representation of the ways in which economies will develop over the projection period in the absence of proposed policy responses to climate change. To isolate the impact of proposed policy responses to climate change, the results of policy scenarios are then compared with the reference case results. A detailed description of reference case projections is provided in appendix C.

The GTEM database (based on the GTAP 4.0e database) contains 55 sectors and 45 regions. For this study, the database is aggregated to the 23 regions and 33 sectors that allow a detailed representation of Annex B countries and emissions intensive industries, particularly in agriculture.

Combustion and noncombustion carbon dioxide, and methane and nitrous oxide emissions account for around 99 per cent of global anthropogenic greenhouse gas emissions (IPCC 1996a). GTEM includes almost all sources of these gases. Emissions from waste, emissions from agricultural residues, methane and most nitrous oxide emissions from combustion, and methane emissions from industrial processes are not included in GTEM. However, nitrous oxide emissions from combustion in the transport sector are included. The gases are expressed in carbon dioxide equivalent terms in GTEM, based on their global warming potentials over a one hundred year time horizon (IPCC 1996a).

A preliminary representation of carbon sequestration in Annex B countries is included in the modeling in this report: work is under way to improve this representation. Sinks are not linked to the forestry industry in the current GTEM modeling, which results in incomplete analysis of the impacts on the forestry and forestry products industries of climate change policies.

In GTEM, least cost modeling of emission abatement involves imposing a ‘charge’ on greenhouse gas emissions in each period for which emission restrictions apply. The charge represents the broad class of least cost economic instruments that could be used by governments to reduce emissions (Fisher et al. 1996). The charge could represent a domestic emissions trading scheme or a uniform carbon charge applied in a particular region. The charge raises the costs associated with activities that produce emissions and encourages a shift of resources into less emissions intensive activities. The marginal cost of achieving a given emission reduction target is referred to here as a carbon charge.

Any government revenue raised from the imposition of emission abatement policies is assumed to be returned to the economy in a lump sum fashion, thus having a neutral effect on the economy. It is also assumed that there is perfect compliance with the policy instrument, and that compliance is achieved at negligible cost. Similarly, it is assumed that emission monitoring is perfect and costless and that carbon charges are applied at the same point that emissions are generated (point taxation). This implies that complete information on actual emissions is available to the regulating authority, and that there are no administrative costs associated with the policy instrument.

An international emissions trading scheme allowing participating Annex B countries to buy and sell emissions quota is assumed to operate. In GTEM, modeling international emissions trading requires the aggregate emissions of participating regions to be constrained at or below their emission reduction commitments under the Kyoto Protocol. The model determines a uniform carbon charge across participating Annex B regions (equivalent to the price of a unit of internationally traded quota) sufficient to meet the aggregate emissions target. The individual Kyoto commitments represent an initial allocation of obligations, or emission quota, among the participating regions. These can be traded between parties. Income from the sale of quota is accounted for as foreign income transfers and added to GNP, while payment for purchases is subtracted from GNP

Policy scenarios

A brief description of the six policy scenarios considered in this analysis is shown in table 1.

Table 1: **Description of scenarios**

Scenario	Country participation		Carbon charge coverage	
	United States	**Australia**	**New Zealand**	**Rest of participating Annex B**
1	out	in	full	full
2	out	in	full	agriculture excluded
3	out	in	agriculture excluded	agriculture excluded
4	out	out	full	full
5	out	out	full	agriculture excluded
6	out	out	agriculture excluded	agriculture excluded

In all the scenarios the United States is assumed not to participate in the Kyoto Protocol. Under scenario 1, all other Annex B parties are assumed to ratify the protocol and the carbon charge is applied to all gases and sectors. Scenario 2 differs from scenario 1 in that New Zealand is the only Annex B party to expose its agricultural industries to the carbon charge. Under this scenario the other participating Annex B parties do not apply the carbon charge to emissions of methane and nitrous oxide from agriculture. Carbon dioxide emissions from fossil fuel combustion in the agriculture sector are subject to the carbon charge. In scenario 3 New Zealand is also assumed to exclude agricultural methane and nitrous oxide emissions from abatement action.

Scenarios 4, 5 and 6 are identical to scenarios 1, 2 and 3 but with Australia as well as the United States assumed not to participate in the Kyoto Protocol.

In all scenarios parties are assumed to have access to unrestricted emissions trading. The Russian Federation and the Ukraine are assumed to have and to use market power in the international quota market, and to act to maximise their quota revenue. To maximise quota revenue the Russian Federation and the Ukraine will respond to the potential demand for and supply by other parties. Generally speaking as demand for quota decreases, they would be expected to restrict supply of quota. Other parties are assumed to behave competitively in the emission quota market.

Annex B countries are assumed to have access to carbon sequestration through forest sinks under Article 3.3 in meeting their emission targets. More detailed explanations of revenue maximisation and of the Article 3.3 sinks assumptions are in appendix A.

As mentioned earlier, the scenarios undertaken in this analysis do not incorporate all elements of the agreement reached at the sixth Conference of the Parties to the United Nations Framework Convention on Climate Change, which was completed in Bonn in July 2001.

The Bonn agreement requires each Annex B country to retain a commitment period reserve of 90 per cent of their assigned amount (or 100 per cent of their most recently reviewed national greenhouse gas inventory) in their national inventory throughout the commitment period. The Bonn agreement also allows for sink activities additional to afforestation, deforestation and reforestation, which are covered under Article 3.3. These activities, under Article 3.4 of the protocol, include revegetation, and

management of cropland, grazing land and forests (the latter subject to some restrictions). The Kyoto protocol includes a 'clean development mechanism' — a project based mechanism that allows Annex B parties to gain credits from financing emission reduction or sink enhancement activities in non-Annex countries. The Bonn agreement specifies that afforestation and deforestation activities are eligible projects under this mechanism.

The analysis presented here does not include the commitment period reserve — in all scenarios, Annex B countries are assumed to have access to unrestricted emissions trading. The clean development mechanism and Article 3.4 sinks are not included in the modeling, and representation of Article 3.3 sinks does not reflect all aspects of the Bonn agreement.

These elements of the Bonn agreement are represented in the ABARE analysis in Jakeman et al. (2001). In addition, the work reported here is focused on the first commitment period, 2008–12 and there is no banking of credits, whereas in Jakeman et al. (2000) the analysis is over four commitment periods and parties are able to bank emission quota between periods.

A further difference is that in the analysis reported here the abatement options available in the livestock sectors in New Zealand were specified by the New Zealand Ministry of Agriculture and Forestry (see appendix D for details).

Economic impacts

In the scenarios reported here, the economic impacts of emission abatement policies are measured as the percentage changes in both real gross national product (GNP) and real gross domestic product (GDP) relative to the reference case levels. GNP is equal to GDP plus foreign income transfers, and therefore provides a complete measure of the flow of income available to an economy for consumption and savings. In the New Zealand context, changes in GNP can be attributed to three main areas.

GNP effect = output effects (GDP) + terms of trade effect + net quota transfer

Output effects

A major source of the economic costs of implementing the Kyoto Protocol are the direct effects of imposing a carbon charge on greenhouse gas emitters. These include increased costs of producing emissions intensive products and increased consumer prices. The increase in costs encourages Annex B producers and consumers to substitute away from emissions intensive goods into more expensive, but less emissions intensive, alternatives. The increase in costs to industry and consumers tends to dampen economic activity, leading to a reduction in GDP.

In addition, as the costs of producing emissions intensive commodities increase, the incentive to relocate these industries to non-Annex B regions is increased. For example, the competitiveness of New Zealand's agricultural exports is likely to decline relative to agricultural exports from non-Annex B regions when methane emissions are subject to a carbon charge. There may also be competitiveness effects within Annex B regions. These can result from differing production techniques and reflect differences in the capacity for emission abatement at given output levels among Annex B producers.

As a consequence of these two effects, there is a strong correlation between the size of the carbon charge and the projected reduction in GDP from reference case levels.

Terms of trade effects

The effects of implementing the Kyoto Protocol on world prices of commodities are also important determinants of the economic costs of implementing the protocol. The terms of trade will be affected because actions to limit emissions in Annex B countries affect the relative prices of products traded on world markets. For example, the imposition of a carbon charge (on a comprehensive basis) will lead to higher costs of production in livestock industries and in energy intensive sectors, such as iron and steel production. Higher costs of production in livestock industries will result in higher world prices for wool, meat and dairy products, which would lead to an improvement in New Zealand's terms of trade over the commitment period. All things being equal, an increase in agricultural export prices would lead to an improvement in New Zealand's economic welfare. (Of course, any positive impacts on economic welfare from increasing world prices will be tempered by the adverse competitiveness effects discussed above.)

Income transfers

Income transfers under international emissions trading arise from the purchase and sale of emission quota and sink credits. The extent of quota purchases or sales also affects the economic cost of emission abatement under the protocol. The value of these income transfers depends on two things: the international price of quota and the amount purchased in order to meet the emission targets under the Kyoto Protocol.

For New Zealand, which is a small economy, the quota price will be given. That is, it will be determined by prevailing supply and demand conditions in the international quota market.

Scenario results

This study was designed to assess the implications of two key issues for New Zealand, the coverage of a carbon charge and the participation of Australia in the protocol. The key economic results for New Zealand at 2010 under the six scenarios are shown in table 2. Each scenario is then discussed in more detail in the following sections and more extensive results are provided in appendix B.

Table 2: **Carbon market and macroeconomic outcomes for New Zealand at 2010**

		Scenario					
		1	**2**	**3**	**4**	**5**	**6**
Carbon charge	2001 US$/t C	75.8	108.4	109.7	78.4	107.6	109.5
Carbon charge	2001 US$/t CO_2 equiv.	20.7	29.6	29.9	21.4	29.4	29.9
Net quota income	US$m	280.7	560.2	258.2	307.2	558.8	261.8
Net quota sales		13.6	19.0	8.6	14.4	19.0	8.8
Domestic abatement	Mt CO_2 equiv.	9.5	14.9	4.6	10.3	15.0	4.7
Change relative to the reference case							
GDP	%	-0.13	-0.26	-0.10	-0.13	-0.24	-0.08
GNP	%	0.19	0.05	0.43	0.19	0.14	0.52

Scenario 1

International emission quota market

Implementing the Kyoto Protocol is projected to impose economic costs on each participating region, with the exception of the Russian Federation and the Ukraine, eastern Europe and New Zealand (table 3). These regions are able to exploit their low marginal abatement costs to sell quota on the international market. The United States is also projected to benefit economically from not participating in the protocol as a result of greater international competitiveness associated with not imposing a carbon charge on emissions.

Participating Annex B countries are projected to trade 956 million tonnes of carbon dioxide equivalent in 2010 at a quota price of US$76 a tonne of carbon equivalent (in 2001 dollars). The Russian Federation and the Ukraine maximise the value of their emission quota sales by supplying 620 million tonnes of carbon dioxide equivalent (table 3). Most of the remaining quota is supplied by eastern Europe, while New Zealand is projected to sell more than 13 million tonnes of carbon dioxide equivalent on the international market.

Table 3: **Quota transfers, income transfers and change in real GNP relative to the reference case under scenario 1 at 2010**

	Quota transfers a	**Income transfers b**	**Change in real GNP**
	Mt CO_2 equivalent	2001 US$m	%
New Zealand	–13.6	281	0.19
Australia	86.8	–1 796	–0.66
United States	0.0	0	0.02
Canada	207.1	–4 283	–0.73
Japan	241.7	–4 999	–0.13
European Union	394.2	–8 154	–0.20
Russian Federation and the Ukraine	–619.9	12 822	1.83
Eastern Europe	–322.5	6 670	0.83
EFTA **c**	26.1	–541	–0.17
Total	956.0	19 773	–0.07

a A negative number indicates quota sales. **b** A negative number indicates net quota expenditure. **c** European Free Trade Area: comprises Switzerland, Norway and Iceland.

The United States' decision not to participate in the protocol is projected to have significant impacts on the international emission quota market. The most notable effect of its nonparticipation is the greatly reduced international demand for emission quota in this scenario relative to scenarios where the United States does participate in the protocol. The reduced demand results in less emission quota being traded and a lower carbon charge compared with similar simulations with the United States included. For example, in forthcoming work undertaken by ABARE for the New Zealand Ministry of Agriculture and Forestry, the total projected global trade is 2.4 billion tonnes when the United States is assumed to participate in the protocol.

Macroeconomic impacts in New Zealand

Implementation of the Kyoto Protocol under scenario 1 is projected to reduce economic activity (GDP) but increase national income (GNP) in New Zealand. At 2010, New Zealand's GDP is projected to be 0.13 per cent below the reference case level as a result of the negative output effects of imposing the carbon charge (table 4).

These economic costs are projected to be more than offset by the inflow in 2010 of US$281 million generated by New Zealand's sales of emission quota on the international market. At 2010 New Zealand's GNP is projected to be 0.19 per cent above the reference case level. The projected increase in New Zealand's real GNP would be larger were it not for the projected 0.68 per cent depreciation in the New Zealand dollar, which increases the cost of international debt payments and the cost to domestic investors of accessing international investment markets. The currency depreciation under this scenario is attributable to a loss in trade competitiveness.

The decline in economic activity in New Zealand associated with the introduction of the carbon charge is projected to lower the rate of return on capital and depress real wages in New Zealand relative to the reference case at 2010.

Table 4: **The carbon market and economic impacts in New Zealand under scenario 1 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	75.8
Net quota income	2001 US$m	280.7
Net quota sales	Mt CO_2 equiv.	13.6
Domestic abatement	Mt CO_2 equiv.	9.5
Economic impact relative to the reference case		
GDP	%	–0.13
GNP	%	0.19
Exchange rate	%	–0.68
Exports	%	–1.77
Imports	%	–0.93
Savings	%	–0.49
Investment	%	–0.08
Export cost index	%	0.29
Import cost index	%	–0.03
Terms of trade	%	0.32
Rate of return on capital	%	–1.87
Real wage	%	–1.59

How New Zealand meets its Kyoto commitments

Table 5 provides an indication of New Zealand's projected abatement task under the protocol, and of how this is met under the conditions of scenario 1. Reference case emissions are projected to be 86.8 million tonnes of carbon dioxide equivalent at 2010. Under this scenario New Zealand undertakes domestic emission abatement of 32.1 million tonnes of carbon dioxide equivalent (comprising 9.5 million tonnes from non-sink activities and 22.6 million tonnes from Article 3.3 sinks). This domestic abatement reduces emissions in New Zealand below the annual equivalent of its assigned amount and New Zealand sells 13.6 million tonnes of carbon dioxide equivalent on the international market. These sales leave New Zealand with an emissions inventory at 2010 equal to the annual equivalent of its assigned amount of 68.3 million tonnes of carbon dioxide equivalent.

Table 5: **How New Zealand meets its Kyoto commitments at 2010 under scenario 1**

	Mt CO_2 equiv.
Projected reference case emissions	86.8
less domestic abatement through non-sink activities	–9.5
less domestic abatement through Article 3.3 sinks	–22.6
Emissions before net quota sales	54.7
plus net quota sales	+13.6
Reported emissions at 2010 under the Kyoto Protocol	68.3
Assigned amount **a**	68.3

a Assumed to be the assigned amount at 2010 — that is, the assigned amount divided by 5.

Sectoral impacts in New Zealand

At the sectoral level, the implementation of the Kyoto Protocol under scenario 1 is projected to shift production in New Zealand from emissions intensive sectors, such as agriculture, metals and electricity production, into less emissions intensive industries, such as services, light manufacturing, cropping and forestry (table 6).

Within the agricultural sector, the results reflect a restructuring of production away from emissions intensive agricultural commodities toward less emissions intensive commodities. Wool and dairy production, and to a lesser extent production of livestock for meat, is being substituted by crop production. This is because livestock production is more emissions intensive than cropping. The cost of production in the livestock industries rises relative to the reference case, leading to a loss in international competitiveness. The projected reduction in activity in livestock leads to a fall in the price of land relative to the reference case. The lower land price results in increased competitiveness of crop producers in New Zealand and other participating Annex B countries relative to other competitors.

In this scenario, with lower land prices generally, output from the forestry sector is projected to rise by 1.7 per cent relative to the reference case. As noted earlier, GTEM does not capture the full impact of emission abatement policies on the forestry sector as sinks development is not explicitly linked to production incentives in forestry.

Table 6: **Change in sectoral outputs in New Zealand under scenario 1 at 2010, relative to the reference case**

	%
Coal	–10.3
Gas	–4.5
Petroleum and coal products	–1.6
Electricity	–4.2
Iron and steel	–13.6
Nonferrous metals	–5.5
Meat products	–1.1
Dairy products	–17.4
Food products	1.2
Light manufacturing	1.8
Trade and transport	0.6
Private services	0.5
Crops	7.1
Forestry	1.7
Livestock for meat	–3.3
Other animal products	2.5
Dairy cattle	–14.0
Wool	–14.3

Output from energy intensive industries is also projected to fall. Iron and steel production is the most heavily hit of these industries because of its high emissions intensity. In the electricity generation sector, output is projected decline and there is also a shift in the shares of generation technologies. Coal fired power is projected to decline relative to gas fired power because of its higher emissions intensity.

Scenario 2

International emissions quota market

Scenario 2 is similar to scenario 1 except that only New Zealand applies the carbon charge to emissions of methane and nitrous oxide from agriculture. The carbon charge is projected to be US$108 a tonne of carbon equivalent, higher than that under scenario 1 because low cost abatement possibilities in agriculture are no longer being realised other than in New Zealand.

Under this scenario the Russian Federation and the Ukraine maximise revenue from quota sales by restricting the supply of emission quota to 560 million tonnes of carbon dioxide equivalent (compared with 620 million tonnes of carbon dioxide equivalent in scenario 1). The total quota traded in Annex B is 942 million tonnes of carbon dioxide equivalent.

Macroeconomic impacts in New Zealand

Implementing the Kyoto Protocol under this scenario is projected to reduce economic activity in New Zealand, leading to a reduction in real GDP of 0.26 per cent relative to the reference case at 2010 (table 7). This reduction is projected to be just offset by the US$560 million that New Zealand earns through selling 19 million tonnes of carbon dioxide equivalent on the emission quota market. Real GNP in New Zealand is projected to rise by 0.05 per cent relative to the reference case at 2010.

As New Zealand is the only Annex B country to apply the carbon charge to agricultural emissions of methane and nitrous oxide, the international competitiveness of its emissions intensive agricultural industries is significantly reduced. This loss of competitiveness is projected to reduce the volume of New Zealand's total exports relative to the reference case at 2010 and relative to scenario 1. While agricultural production costs are forced up in New Zealand by the carbon charge, agricultural producers in the other Annex B countries benefit from lower capital and labor costs as resources shift out of the taxed industries.

Table 7: **The carbon market and economic impacts in New Zealand under scenario 2 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	108.4
Net quota income	2001 US$m	560.2
Net quota sales	Mt CO_2 equiv.	19.0
Domestic abatement	Mt CO_2 equiv.	14.9
Economic impact relative to the reference case		
GDP	%	–0.26
GNP	%	0.05
Exchange rate	%	–1.22
Exports	%	–2.60
Imports	%	–1.72
Savings	%	–1.15
Investment	%	–0.22
Export cost index	%	–0.22
Import cost index	%	–0.03
Terms of trade	%	–0.19
Rate of return on capital	%	–2.78
Real wage	%	–2.36

Sectoral impacts in New Zealand

At the sectoral level, implementing the Kyoto Protocol under this scenario is projected to result in a shift of resources in New Zealand away from emissions intensive industries such as livestock and metals production and into less emissions intensive industries such as manufacturing, services, forestry and cropping (table 8). The shift of production from emissions intensive industries into less emissions intensive industries under this scenario is greater than under scenario 1 as a result of the higher carbon charge under this scenario.

Output from the New Zealand wool and dairy industries is projected to fall to a greater extent than under scenario 1. The effect of the imposition of the carbon charge is compounded by the fact that other participating Annex B parties, such as the European Union, are assumed not to expose their agricultural industries to the carbon charge.

In cropping, the impact of the carbon charge on production costs is more than offset by the effect of the decline in land prices. Output is projected to rise relative to the reference case as the competitive position of cropping industries in New Zealand, with respect to land use, improves relative to livestock.

Table 8: **Change in sectoral outputs in New Zealand under scenario 2 at 2010, relative to the reference case**

	%
Coal	–14.7
Gas	–6.1
Petroleum and coal products	–2.1
Electricity	–5.6
Iron and steel	–17.6
Nonferrous metals	–6.9
Meat products	–4.7
Dairy products	–25.2
Food products	2.2
Light manufacturing	3.2
Trade and transport	1.0
Private services	0.8
Crops	12.3
Forestry	2.7
Livestock for meat	–6.8
Other animal products	6.2
Dairy cattle	–20.5
Wool	–28.8

Scenario 3

International emissions quota market

In scenario 3 all participating Annex B countries implement the Kyoto Protocol without applying the carbon charge to agricultural methane and nitrous oxide emissions. This is projected to lead to a carbon charge of almost US$110 a tonne of carbon equivalent, higher than under the previous two scenarios. Again, as abatement options in agriculture are no longer taken up, the marginal cost of abatement in participating Annex B countries as a whole is projected to rise. The total volume of emission quota traded in Annex B is 934 million tonnes of carbon dioxide equivalent.

Macroeconomic impacts in New Zealand

Implementing the Kyoto Protocol under scenario 3 is projected to lead to a fall in real GDP in New Zealand of 0.10 per cent at 2010 relative to the reference case, as resources are shifted out of carbon dioxide emissions intensive industries following the imposition of the carbon charge (table 9). Total domestic abatement is less than under the scenarios 1 and 2 because agriculture is not subject to the carbon charge and there is very little domestic abatement in the agriculture sector in this scenario. The lower level of domestic abatement results in a smaller decline in GDP than in scenarios 1 and 2.

In this scenario New Zealand's sales of emission quota are projected to fall to 8.6 million tonnes, compared with 13.6 million tonnes of carbon dioxide equivalent in the scenario 1. Although exports are projected to decline slightly relative to the reference case, the quota income of US$258 million has a more than offsetting impact, leading to a slight appreciation in the New Zealand dollar and an increase in real GNP of 0.43 per cent relative to the reference case at 2010. This is a greater increase than in scenario 1 because here the appreciation of the exchange rate relative to the reference case leads to a reduction in the cost of funding debt payments and a reduction in the cost of capital formation.

The appreciation in the New Zealand dollar and the rise in real GNP are projected to increase import demand relative to reference case levels.

Table 9: **The carbon market and economic impacts in New Zealand under scenario 3 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	109.7
Net quota income	2001 US$m	258.2
Net quota sales	Mt CO_2 equiv.	8.6
Domestic abatement	Mt CO_2 equiv.	4.6
Economic impact relative to the reference case		
GDP	%	–0.10
GNP	%	0.43
Exchange rate	%	0.03
Exports	%	–0.04
Imports	%	0.16
Savings	%	0.46
Investment	%	–0.05
Export cost index	%	0.08
Import cost index	%	–0.03
Terms of trade	%	0.12
Rate of return on capital	%	–1.85
Real wage	%	–1.36

Sectoral impacts in New Zealand

The impacts on outputs from nonagricultural sectors are similar to those in scenario 2. This is because the carbon charge is similar, leading to broadly similar changes in costs and competitiveness in these sectors (table 10). Under this scenario output in the agriculture sectors is largely unaffected by the carbon charge.

Table 10: **Change in sectoral outputs in New Zealand under scenario 3 at 2010, relative to the reference case**

	%
Coal	–16.4
Gas	–6.9
Petroleum and coal products	–2.5
Electricity	–6.2
Iron and steel	–22
Nonferrous metals	–12
Meat products	–1
Dairy products	–0.4
Food products	0.4
Light manufacturing	–0.9
Trade and transport	0
Private services	0.4
Crops	0.6
Forestry	0.8
Livestock for meat	–0.1
Other animal products	0.3
Dairy cattle	–0.3
Wool	0

Scenario 4

International emissions quota market

Under this scenario it is assumed that the protocol is implemented with the carbon charge applying to all greenhouse gas emissions and sectors but without Australian participation. The carbon charge is projected to be US$78 a tonne of carbon equivalent as the Russian Federation and the Ukraine limit their supply of emission quota to 520 million tonnes of carbon dioxide equivalent.

With Australia assumed to be out of the quota market in this simulation, the total quota traded between participating Annex B countries is projected to fall relative to the first three scenarios to 861 million tonnes of carbon dioxide equivalent. Given the theoretical structure of GTEM, whether the quota price rises or falls as a result of a country being excluded from quota trading depends on the relative slopes of the abatement cost curves in participating countries relative to non-participating countries. In this scenario Australia's demand for quota is highly elastic relative to other Annex B countries. The removal of Australia from the international quota market causes the Russian Federation and the Ukraine to act to further increase the quota price to maximise revenue.

Macroeconomic impacts in New Zealand

Implementing the Kyoto Protocol under this scenario is projected to reduce economic activity in New Zealand, leading to a reduction in real GDP of 0.13 per cent relative to the reference case at 2010 (table 11). The reduction is projected to be more than offset by the US$307 million that New Zealand earns through selling 14 million tonnes of carbon dioxide equivalent, and real GNP in New Zealand is projected to rise by 0.19 per cent relative to the reference case at 2010.

Table 11: **The carbon market and economic impacts in New Zealand under scenario 4 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	78.4
Net quota income	2001 US$m	307.2
Net quota sales	Mt CO_2 equiv.	14.4
Domestic abatement	Mt CO_2 equiv.	10.3
Economic impact relative to the reference case		
GDP	%	–0.13
GNP	%	0.19
Exchange rate	%	–0.61
Exports	%	–1.90
Imports	%	–1.10
Savings	%	–0.42
Investment	%	–0.09
Export cost index	%	0.27
Import cost index	%	0.07
Terms of trade	%	0.19
Rate of return on capital	%	–1.89
Real wage	%	–1.65

Sectoral impacts in New Zealand

In this scenario, the production and exports of wool, dairy products and, to a lesser extent, meat products in New Zealand are projected to fall substantially as the carbon charge reduces the competitiveness of New Zealand producers against producers in Australia, the United States and non-Annex B countries (table 12). Output in all emissions intensive industries including agricultural industries is projected to fall by further in this scenario than in scenario 1 because Australian industry is not subject to a carbon charge.

Table 12: **Change in sectoral outputs in New Zealand under scenario 4 at 2010, relative to the reference case**

	%
Coal	–10.1
Gas	–4.8
Petroleum and coal products	–1.7
Electricity	-4.6
Iron and steel	–15.4
Nonferrous metals	–7.5
Meat products	–2.0
Dairy products	–18.5
Food products	1.4
Light manufacturing	2.3
Trade and transport	0.7
Private services	0.6
Crops	7.9
Forestry	1.7
Livestock for meat	–4.2
Other animal products	3.3
Dairy cattle	–14.9
Wool	–16.5

Less emissions intensive industries in New Zealand, such as light manufacturing, are projected to expand as resources are shifted away from emissions intensive industries after the imposition of the carbon charge. The projected expansion in these sectors is higher than in scenario 1, resulting from increased demand from Australia.

Scenario 5

International emissions quota market

Under scenario 5, the Kyoto Protocol is implemented without Australian participation and with only New Zealand applying the carbon charge to agricultural emissions of methane and nitrous oxide. Under this scenario the carbon charge is projected to be US$108 a tonne of carbon equivalent, similar to the carbon charge in scenario 2. The Russian Federation and the Ukraine restrict supply of emission quota to 480 million tonnes of carbon dioxide equivalent to maximise quota revenue. The total volume of emission quota traded between participating Annex B countries is projected to be 861 million tonnes carbon dioxide equivalent.

Macroeconomic impacts in New Zealand

Implementing the Kyoto Protocol under this scenario is projected to reduce economic activity in New Zealand, leading to a fall in real GDP of 0.24 per cent relative to the reference case at 2010 (table 13). This reduction in economic activity enables New Zealand to sell 19 million tonnes of carbon dioxide equivalent on the emission quota market, for which it receives US$559 million. This quota income is projected to more than offset the decline in domestic economic activity and lead to a rise in real GNP in New Zealand of 0.14 per cent relative to the reference case at 2010.

Table 13: **The carbon market and economic impacts in New Zealand under scenario 5 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	107.6
Net quota income	2001 US$m	558.8
Net quota sales	Mt CO_2 equiv.	19.0
Domestic abatement	Mt CO_2 equiv.	15.0
Economic impact relative to the reference case		
GDP	%	–0.24
GNP	%	0.14
Exchange rate	%	–1.01
Exports	%	–2.68
Imports	%	–1.69
Savings	%	–0.86
Investment	%	–0.21
Export cost index	%	–0.08
Import cost index	%	0.06
Terms of trade	%	–0.14
Rate of return on capital	%	–2.63
Real wage	%	–2.30

As in scenario 2, New Zealand's exports are projected to fall significantly relative to the reference case as a result of the high carbon charge. The high carbon charge in this scenario results in a significant loss of competitiveness for New Zealand agriculture. The projected increase in GNP relative to the reference case is somewhat higher in New Zealand under this scenario than under scenario 2, in which Australia participates in the protocol, because of improvements in terms of trade on both the current and capital accounts for New Zealand relative to the reference case. When Australia does not participate in the protocol, demand for New Zealand commodities by Australia rises, especially for light manufacturing. The increased demand for these products results in a smaller fall in returns to labor and capital leading to a reduction in the fall in export prices relative to scenario 2 and a projected improvement in terms of trade. An increase in terms of trade has the effect of reducing the projected depreciation of the New Zealand currency relative to scenario 2, which results in a reduction in the cost of debt servicing and the cost of accessing international capital markets. These factors offset any reduction in the competitiveness of New Zealand agriculture relative to Australia.

Sectoral impacts on New Zealand

Introduction of the carbon charge in this scenario is projected to lead to significant reductions in the output of all emissions intensive industries relative to the reference case, in particular the livestock industries, metals production, fossil fuel production

and electricity generation (table 14). As resources are moved out of these sectors, production in some less emissions intensive sectors, such as trade and transport and light manufacturing is projected to increase.

In agriculture, the reduction of wool, dairy and meat production is projected to lead to a decline in the price of land relative to the reference case, which benefits less emissions intensive agriculture sectors such as cropping.

Table 14: **Change in sectoral outputs in New Zealand under scenario 5 at 2010, relative to the reference case**

	%
Coal	–13.8
Gas	–6.3
Petroleum and coal products	–2.1
Electricity	–6.0
Iron and steel	–19.7
Nonferrous metals	–9.4
Meat products	–4.8
Dairy products	–25.1
Food products	2.1
Light manufacturing	3.6
Trade and transport	1.0
Private services	0.8
Crops	12.1
Forestry	2.5
Livestock for meat	–6.9
Other animal products	5.9
Dairy cattle	–20.4
Wool	–28.5

Scenario 6

International emissions quota market

In this scenario the Kyoto Protocol is implemented without Australian or US participation and without applying the carbon charge to agricultural emissions of methane and nitrous oxide. This is projected to lead to a carbon charge of nearly US$110 a tonne of carbon equivalent, slightly lower than the corresponding scenario when Australia participated in the protocol. The Russian Federation and the Ukraine restrict supply of emission quota to 480 million tonnes of carbon dioxide equivalent to maximise quota revenue. The total volume of emission quota traded between participating Annex B countries is projected to be 854 million tonnes carbon dioxide equivalent.

Macroeconomic impacts in New Zealand

Implementing the Kyoto Protocol is projected to lead to a fall in real GDP in New Zealand of 0.08 per cent at 2010 relative to reference case, as resources are shifted out of carbon dioxide emissions intensive industries following the imposition of the carbon charge (table 15). This fall in real GDP is less than in scenarios 4 and 5 because agriculture is not subject to the carbon charge, New Zealand exports do not fall by as much and New Zealand does not undertake as much domestic abatement as in those scenarios.

In this scenario New Zealand is projected to sell 8.8 million tonnes of carbon dioxide equivalent, which generates a net quota income of nearly US$262 million. As in scenario 3, this foreign income is projected to lead to an appreciation in the New Zealand dollar and a rise in New Zealand's real GNP of 0.52 per cent relative to the reference case at 2010.

Table 15: **The carbon market and economic impacts in New Zealand under scenario 6 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	109.5
Net quota income	2001 US$m	261.8
Net quota sales	Mt CO_2 equiv.	8.8
Domestic abatement	Mt CO_2 equiv.	4.7
Economic impact relative to the reference case		
GDP	%	–0.08
GNP	%	0.52
Exchange rate	%	0.23
Exports	%	–1.14
Imports	%	0.18
Savings	%	0.75
Investment	%	–0.03
Export price index	%	0.22
Import price index	%	0.06
Terms of trade	%	0.17
Rate of return on capital	%	–1.71
Real wage	%	–1.32

Sectoral impacts in New Zealand

In this scenario, as in scenario 3, implementing the Kyoto Protocol without applying the carbon charge to agricultural emissions of methane and nitrous oxide is projected to result in large output reductions in the metals production, electricity generation and fossil fuels sectors (table 16). The projected declines in output in these sectors in New Zealand are slightly larger with Australia out of the protocol as Australian production of these goods is not subject to the carbon charge.

In agriculture, implementation of the Kyoto Protocol in this scenario is projected to lead to a shift of resources from dairy and meat production to cropping in much the same way as in scenario 3.

Table 16: **Change in sectoral outputs in New Zealand under scenario 6 at 2010, relative to the reference case**

	%
Coal	–15.6
Gas	–7.1
Petroleum and coal products	–2.5
Electricity	–6.6
Iron and steel	–24.1
Nonferrous metals	–14.6
Meat products	–1.1
Dairy products	–0.5
Food products	0.3
Light manufacturing	–0.6
Trade and transport	0
Private services	0.4
Crops	0.5
Forestry	0.6
Livestock for meat	–0.2
Other animal products	0
Dairy cattle	–0.4
Wool	0.1

Appendix A: Key modeling assumptions

Article 3.3 sinks

Article 3.3 allows Annex B parties to count net changes in emissions by sources or removals by sinks resulting from afforestation, reforestation and deforestation activities toward meeting their emission targets in the first commitment period, provided these activities are directly human induced and have taken place since 1990. Table A.1 shows the projected net emissions or sequestration from activities under Article 3.3 assumed in this analysis for each Annex B country. In scenarios where the United States and Australia are assumed not to participate in the protocol their sinks are excluded from the total.

Table A.1: **Carbon sequestration under Article 3.3 in each Annex B region at 2010 a**

	Mt CO_2 equiv.
New Zealand **b**	22.6
Australia	–24.9
United States	–26.4
Canada	–16.1
Japan	–2.7
European Union	5.0
Russian Federation and the Ukraine **c**	–44.5
Eastern Europe	0.0
EFTA **d**	0.0
Total	–82

a From Annex B party submissions to the SBSTA of the UNFCCC unless otherwise specified. **b** Provided by New Zealand Ministry of Agriculture. **c** From Schlamadinger and Karjalainen (2000). **d** European Free Trade Area: comprises Switzerland, Norway and Iceland.
Note: A negative number indicates that activities under Article 3.3 are estimated to result in net greenhouse gas emissions in that country at 2010.

Revenue maximising by the Russian Federation and the Ukraine

In an international emission quota market, the Russian Federation and the Ukraine are projected to be the largest supplier of emission quota and, as such, could wield significant power in this market (Polidano et al. 2001). In this analysis their market power is compounded by the nonparticipation of the United States, which would be expected to be the largest buyer of emission quota if it were part of the Kyoto Protocol (Polidano et al. 2001). In this analysis, the Russian Federation and the Ukraine are assumed to restrict their quota sales in order to maximise sales revenue over the first commitment period. The model is solved iteratively in each scenario to estimate the level of emission quota sales that maximises the value of emission quota sold by the Russian Federation and the Ukraine.

Appendix B : Modeling results

Table B.1: **Change in emissions in New Zealand under scenario 1 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–15.2	–7.5	..	–20.1	..	–14.9
Oil	..	..	..	1.2	–1.4	..	1.0
Gas	..	..	..	–4.5	–6.9	..	–6.0
Petroleum and coal products	..	–18.1	–1.5	..	..	..	–15.1
Electricity	–26.6	–10.3	–72.4	..	..	..	–15.9
Iron and steel	–16.9	..	–16.9	–13.6	..	..	–16.9
Nonferrous metals	–20.9	..	–2.0	..	..	..	–8.9
Chemicals, rubber and plastic	..	–0.6	0.8	..	..	..	0.6
Clothing	..	..	..	..	..	..	..
Meat products	–18.4	..	..	..	..	..	–18.3
Dairy products	–31.6	..	–16.3	..	..	..	–29.7
Food	–17.0	..	2.9	..	..	..	–16.4
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–13.9	..	6.1	–2.6	..	..	–7.2
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–3.1	4.2	..	..	..	–3.0
Trade and transport	..	1.1	0.0	..	..	0.6	0.0
Private services	..	..	–1.2	..	..	..	–1.1
Public services	–2.6	–5.0	–0.4	..	..	..	–2.9
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.2	..	..	–23.7	–20.5
Other cereal grains	..	..	–5.3	..	..	–23.0	–19.9
Crops	..	..	1.7	..	..	–17.3	–14.2
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.6	..	..	..	–2.6
Livestock for meat	..	..	–7.6	..	–5.0	–3.3	–4.7
Other animal products	..	..	–1.8	..	0.6	2.5	0.6
Dairy cattle	..	..	–18.5	..	–16.7	–14.0	–15.8
Wool	..	..	–18.4	..	–15.9	–14.3	–15.5

.. No significant emissions from this sector.

Table B.2: **The carbon market and economic impacts in New Zealand under scenario 1 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	75.8
Net quota income	2001 US$m	280.7
Net quota sales	Mt CO_2 equiv.	13.6
Domestic abatement	Mt CO_2 equiv.	9.5
Economic impact relative to the reference case		
GDP	%	–0.13
GNP	%	0.19
Exchange rate	%	–0.68
Exports	%	–1.77
Imports	%	–0.93
Savings	%	–0.49
Investment	%	–0.08
Export cost index	%	0.29
Import cost index	%	–0.03
Terms of trade	%	0.32
Rate of return on capital	%	–1.87
Real wage	%	–1.59

Table B.3: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand under scenario 1 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–10.3	–14.7	–2.1	..	–4.2
Oil	1.2	1.7	3.0	–2.4	–0.8
Gas	–4.5	–5.9	..	..	–4.3
Petroleum and coal products	–1.6	–1.4	0.2	–0.5	0.4
Electricity	–4.2	–2.5	..	..	11.2
Iron and steel	–13.6	–13.4	–26.7	7.1	8.8
Nonferrous metals	–5.5	–5.3	–9.6	–5.3	3.8
Chemicals, rubber and plastic	0.7	0.9	3.2	–0.9	–0.1
Clothing	–2.8	–2.7	–5.3	0.8	1.5
Meat products	–1.1	–1.0	–2.4	–2.5	2.1
Dairy products	–17.4	–17.3	–19.9	3.1	4.6
Food	1.2	1.3	3.7	–1.7	–0.1
Pulp, paper and publishing	1.5	1.6	4.3	–1.3	–0.6
Other wood products	0.8	1.0	2.6	–0.8	0.0
Minerals	0.0	0.2	4.0	–3.2	0.1
Nonmetallic minerals	0.4	0.6	3.8	–2.0	0.2
Light manufacturing	1.8	1.9	4.5	–0.8	0.0
Other manufacturing	3.5	3.6	4.6	–0.3	–0.3
Construction	–0.2	0.0	1.8	–1.2	–0.1
Trade and transport	0.6	0.8	3.3	–1.0	–0.4
Private services	0.5	0.7	5.5	–2.3	–1.0
Public services	1.0	1.0	5.0	–3.6	–0.8
Other services	0.7	0.9	..	..	–1.0
Wheat	–1.2	–2.3	..	–4.8	–1.6
Other cereal grains	–0.3	–1.4	11.3	–5.1	–1.5
Crops	7.1	6.1	11.4	–5.4	–2.0
Forestry	1.7	2.0	2.3	..	0.2
Fisheries	0.5	1.1	–1.0	1.5	0.9
Livestock for meat	–3.3	–4.8	2.2	–9.1	3.4
Other animal products	2.5	1.2	2.6	–5.2	0.4
Dairy cattle	–14.0	–15.4	..	..	9.8
Wool	–14.3	–16.2	–25.7	–12.1	9.8

.. Not a significant activity.

Table B.4: **Change in emissions in New Zealand under scenario 2 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–20.4	–11.1	..	–25.6	..	–19.2
Oil	..	..	..	1.6	–2.1	..	1.3
Gas	..	..	..	–6.1	–9.5	..	–8.2
Petroleum and coal products	..	–22.1	–1.9	..	..	..	–18.5
Electricity	–34.1	–14.0	–79.3	..	..	..	–20.7
Iron and steel	–21.9	..	–21.9	–17.6	..	..	–21.9
Nonferrous metals	–24.9	..	–2.2	..	..	..	–10.6
Chemicals, rubber and	..	–0.7	1.4	..	..	..	1.0
Clothing	..	..	..	..	..	..	..
Meat products	–24.4	..	..	..	..	..	–24.3
Dairy products	–40.7	..	–23.8	..	..	..	–38.5
Food	–19.7	..	4.5	..	..	..	–19.1
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–16.3	..	8.3	–2.3	..	..	–8.0
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–4.2	5.6	..	..	..	–4.1
Trade and transport	..	1.6	0.1	..	..	1.0	0.1
Private services	..	..	–1.6	..	..	..	–1.5
Public services	–3.8	–6.6	–0.6	..	..	..	–3.9
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.0	..	..	–21.6	–18.8
Other cereal grains	..	..	–5.2	..	..	–20.9	–18.1
Crops	..	..	1.6	..	..	–15.3	–12.5
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.5	..	..	..	–2.5
Livestock for meat	..	..	–7.4	..	–4.9	–3.1	–4.6
Other animal products	..	..	–1.7	..	0.6	2.4	0.6
Dairy cattle	..	..	–17.9	..	–16.3	–13.5	–15.4
Wool	..	..	–17.7	..	–15.4	–13.8	–15.0

.. No significant emissions from this sector.

Table B.5: **The carbon market and economic impacts in New Zealand under scenario 2 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	108.4
Net quota income	2001 US$m	560.2
Quota sales	Mt CO_2 equiv.	19.0
Domestic abatement	Mt CO_2 equiv.	14.9
Economic impact relative to the reference case		
GDP	%	–0.26
GNP	%	0.05
Exchange rate	%	–1.22
Exports	%	–2.60
Imports	%	–1.72
Savings	%	–1.15
Investment	%	–0.22
Export cost index	%	–0.22
Import cost index	%	–0.03
Terms of trade	%	–0.19
Rate of return on capital	%	–2.78
Real wages	%	–2.36

Table B.6: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand under scenario 2 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–14.7	–19.9	–6.1	..	–3.9
Oil	1.6	2.4	4.1	–3.1	–0.7
Gas	–6.1	–7.9	..	..	–5.4
Petroleum and coal products	–2.1	–1.6	0.7	–0.7	0.7
Electricity	–5.6	–3.1	..	..	16.1
Iron and steel	–17.6	–17.2	–34.9	10.5	12.7
Nonferrous metals	–6.9	–6.5	–12.6	–7.0	5.5
Chemicals, rubber and plastic	1.3	1.5	5.3	–1.6	0.0
Clothing	–2.5	–2.3	–4.3	0.4	1.8
Meat products	–4.7	–4.5	–9.8	3.0	2.5
Dairy products	–25.2	–25.0	–28.7	7.0	6.2
Food	2.2	2.4	6.3	–2.9	–0.3
Pulp, paper and publishing	2.6	2.8	7.1	–2.2	–0.9
Other wood products	1.6	1.8	5.1	–1.9	0.0
Minerals	0.5	0.7	6.3	–4.3	0.2
Nonmetallic minerals	0.8	1.0	6.9	–3.5	0.3
Light manufacturing	3.2	3.4	8.0	–1.5	0.0
Other manufacturing	5.9	6.2	8.0	–0.7	–0.4
Construction	–0.3	–0.1	3.8	–2.5	–0.1
Trade and transport	1.0	1.3	5.9	–1.9	–0.6
Private services	0.8	1.1	9.1	–3.9	–1.4
Public services	1.3	1.3	8.5	–6.3	–1.2
Other services	0.7	1.1	..	..	–1.5
Wheat	–2.2	–4.1	..	–9.8	–3.1
Other cereal grains	–0.8	–2.6	19.9	–9.4	–2.9
Crops	12.3	10.7	19.8	–9.3	–3.5
Forestry	2.7	3.3	3.6	..	0.4
Fisheries	0.9	1.9	–2.0	3.0	1.7
Livestock for meat	–6.8	–9.3	–11.4	2.9	3.9
Other animal products	6.2	4.3	6.4	–9.2	0.1
Dairy cattle	–20.5	–22.4	..	..	13.4
Wool	–28.8	–31.6	–52.1	17.4	12.3

.. Not a significant activity.

Table B.7: **Change in emissions in New Zealand under scenario 3 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–22.1	–12.9	..	–27.1	..	–20.4
Oil	..	..	..	0.7	–3.0	..	0.4
Gas	..	..	..	–6.9	–10.3	..	–9.0
Petroleum and coal products	..	–22.5	–2.4	..	..	..	–19.0
Electricity	–35.1	–15.3	–79.5	..	..	..	–21.9
Iron and steel	–26.1	..	–26.1	–22.0	..	..	–26.1
Nonferrous metals	–29.0	..	–7.6	..	..	..	–12.4
Chemicals, rubber and plastic	..	–1.8	0.4	..	..	..	0.0
Clothing	..	..	..	..	..	..	..
Meat products	–21.4	..	..	..	..	..	–21.3
Dairy products	–21.0	..	1.5	..	..	..	–18.1
Food	–21.1	..	2.8	..	..	..	–20.5
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–17.0	..	7.4	–4.2	..	..	–9.4
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–3.9	6.0	..	..	..	–3.8
Trade and transport	..	0.5	–0.8	..	..	0.0	–0.8
Private services	..	..	–2.0	..	..	..	–1.8
Public services	–4.1	–7.0	–0.9	..	..	..	–4.3
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.0	..	..	–21.6	–18.8
Other cereal grains	..	..	–5.2	..	..	–20.9	–18.1
Crops	..	..	1.6	..	..	–15.3	–12.5
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.5	..	..	..	–2.5
Livestock for meat	..	..	–7.4	..	–4.9	–3.1	–4.6
Other animal products	..	..	–1.7	..	0.6	2.4	0.6
Dairy cattle	..	..	–17.9	..	–16.3	–13.5	–15.4
Wool	..	..	–17.7	..	–15.4	–13.8	–15.0

.. No significant emissions from this sector.

Table B.8: **The carbon market and economic impacts in New Zealand scenario 3 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	109.7
Net quota income	2001 US$m	258.2
Quota sales	Mt CO_2 equiv.	8.6
Domestic abatement	Mt CO_2 equiv.	4.6
Economic impact relative to the reference case		
GDP	%	–0.10
GNP	%	0.43
Exchange rate	%	0.03
Exports	%	–1.04
Imports	%	0.16
Savings	%	0.46
Investment	%	–0.05
Export cost index	%	0.08
Import cost index	%	–0.03
Terms of trade	%	0.12
Rate of return on capital	%	–1.85
Real wages	%	–1.36

Table B.9: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand under scenario 3 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–16.4	–22.0	–8.4	..	–4.6
Oil	0.7	0.9	2.8	–3.2	–1.7
Gas	–6.9	–8.9	..	..	–5.6
Petroleum and coal products	–2.5	–2.6	–1.9	–0.2	0.2
Electricity	–6.2	–3.6	..	..	15.8
Iron and steel	–22.0	–21.7	–38.5	7.9	12.6
Nonferrous metals	–12.1	–12.0	–17.9	–9.2	5.4
Chemicals, rubber and plastic	0.2	0.2	0.6	0.0	0.0
Clothing	0.6	0.6	0.8	0.0	–0.4
Meat products	–1.0	–0.9	–2.1	1.6	0.0
Dairy products	–0.4	–0.4	–0.4	1.0	–0.2
Food	0.4	0.4	0.9	0.4	–0.4
Pulp, paper and publishing	0.7	0.6	1.5	–0.2	–0.5
Other wood products	–0.7	–0.7	–2.3	1.3	0.2
Minerals	–1.6	–1.8	2.4	–4.4	–0.2
Nonmetallic minerals	–0.1	–0.1	–0.9	0.0	0.6
Light manufacturing	–0.9	–1.0	–1.5	0.3	0.2
Other manufacturing	0.3	0.2	0.2	0.3	–0.2
Construction	0.0	0.0	–2.2	0.9	0.2
Trade and transport	0.0	–0.1	–0.4	0.6	–0.2
Private services	0.4	0.3	2.1	–0.8	–0.9
Public services	0.9	0.9	1.0	0.9	–0.6
Other services	0.9	0.8	..	..	–1.0
Wheat	0.0	0.1	..	0.0	–0.3
Other cereal grains	0.1	0.2	1.2	–0.5	–0.3
Crops	0.6	0.8	0.9	–0.2	–0.3
Forestry	0.8	0.9	1.5	..	–0.4
Fisheries	0.2	0.5	–0.3	0.4	0.1
Livestock for meat	–0.1	0.0	0.0	0.5	–0.1
Other animal products	0.3	0.5	0.3	–0.1	–0.1
Dairy cattle	–0.3	–0.2	..	..	0.0
Wool	0.0	0.1	0.2	–0.2	–0.2

.. Not a significant activity.

Table B.10: **Change in emissions in New Zealand under scenario 4 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–15.0	–7.1	..	–19.9	..	–14.7
Oil	..	..	..	1.4	–1.2	..	1.2
Gas	..	..	..	–4.8	–7.2	..	–6.3
Petroleum and coal products	..	–18.4	–1.5	..	..	..	–15.4
Electricity	–27.9	–11.3	–73.3	..	..	..	–17.0
Iron and steel	–18.8	..	–18.8	–15.4	..	..	–18.8
Nonferrous metals	–22.8	..	–4.0	..	..	..	–9.7
Chemicals, rubber and plastic	..	–0.7	0.8	..	..	..	0.5
Clothing	..	..	..	..	..	..	..
Meat products	–19.4	..	..	..	..	..	–19.3
Dairy products	–32.8	..	–17.4	..	..	..	–30.9
Food	–17.2	..	3.1	..	..	..	–16.6
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–14.3	..	6.1	–2.7	..	..	–7.5
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–3.2	4.3	..	..	..	–3.1
Trade and transport	..	1.3	0.0	..	..	0.7	0.1
Private services	..	..	–1.3	..	..	..	–1.2
Public services	–2.8	–5.2	–0.4	..	..	..	–3.0
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.0	..	..	–21.6	–18.8
Other cereal grains	..	..	–5.2	..	..	–20.9	–18.1
Crops	..	..	1.6	..	..	–15.3	–12.5
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.5	..	..	..	–2.5
Livestock for meat	..	..	–7.4	..	–4.9	–3.1	–4.6
Other animal products	..	..	–1.7	..	0.6	2.4	0.6
Dairy cattle	..	..	–17.9	..	–16.3	–13.5	–15.4
Wool	..	..	–17.7	..	–15.4	–13.8	–15.0

.. No significant emissions from this sector.

Table B.11: **The carbon market and economic impacts in New Zealand under scenario 4 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	78.4
Net quota income	2001 US$m	307.2
Quota sales	Mt CO_2 equiv.	14.4
Domestic abatement	Mt CO_2 equiv.	10.3
Economic impact relative to the reference case		
GDP	%	–0.13
GNP	%	0.19
Exchange rate	%	–0.61
Exports	%	–1.90
Imports	%	–1.10
Savings	%	–0.42
Investment	%	–0.09
Export cost index	%	0.27
Import cost index	%	0.07
Terms of trade	%	0.19
Rate of return on capital	%	–1.89
Real wages	%	–1.65

Table B.12: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand under scenario 4 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–10.1	–14.3	0.0	..	–3.8
Oil	1.4	2.1	4.4	–2.2	–0.6
Gas	–4.8	–6.3	..	..	–4.6
Petroleum and coal products	–1.7	–1.4	0.0	–0.6	0.5
Electricity	–4.6	–2.8	..	..	11.2
Iron and steel	–15.4	–15.2	–28.1	9.7	8.6
Nonferrous metals	–7.5	–7.3	–9.9	–0.3	3.1
Chemicals, rubber and plastic	0.7	0.9	3.1	–1.0	–0.1
Clothing	–2.4	–2.3	–4.4	0.7	1.4
Meat products	–2.0	–1.8	–4.1	1.1	2.0
Dairy products	–18.5	–18.4	–21.1	4.2	4.6
Food	1.4	1.5	3.9	–2.5	–0.1
Pulp, paper and publishing	1.6	1.7	4.4	–1.5	–0.6
Other wood products	1.1	1.2	3.3	–1.3	0.0
Minerals	–0.1	–0.1	4.8	–3.6	0.0
Nonmetallic minerals	0.3	0.5	3.5	–1.5	0.2
Light manufacturing	2.3	2.4	5.3	–1.1	–0.1
Other manufacturing	4.3	4.4	5.7	–0.4	–0.4
Construction	–0.2	0.0	2.5	–1.3	–0.1
Trade and transport	0.7	0.9	3.8	–1.3	–0.4
Private services	0.6	0.7	6.0	–2.6	–1.0
Public services	1.0	1.0	5.5	–4.9	–0.9
Other services	0.7	0.9	..	..	–1.1
Wheat	–1.2	–2.5	..	–7.0	–1.9
Other cereal grains	–0.4	–1.7	12.3	–5.7	–1.8
Crops	7.9	6.9	12.7	–6.5	–2.3
Forestry	1.7	2.0	2.1	..	0.1
Fisheries	0.5	1.1	–1.4	2.0	0.9
Livestock for meat	–4.2	–5.9	–5.2	–1.9	3.1
Other animal products	3.3	1.9	3.4	–6.2	0.2
Dairy cattle	–14.9	–16.4	..	..	9.9
Wool	–16.5	–18.6	–29.6	–12.5	9.6

.. Not a significant activity.

Table B.13: **Change in emissions in New Zealand under scenario 5 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–19.6	–10.2	..	–24.8	..	–18.6
Oil	..	..	..	1.9	–1.9	..	1.6
Gas	..	..	..	–6.3	–9.8	..	–8.4
Petroleum and coal products	..	–22.0	–1.9	..	..	..	–18.4
Electricity	–34.8	–14.9	–79.4	..	..	..	–21.6
Iron and steel	–23.9	..	–23.9	–19.7	..	..	–23.9
Nonferrous metals	–26.9	..	–5.0	..	..	..	–11.4
Chemicals, rubber and plastic	..	–0.9	1.2	..	..	..	0.8
Clothing	..	..	..	..	..	..	..
Meat products	–24.4	..	..	..	..	..	–24.3
Dairy products	–40.6	..	–23.8	..	..	..	–38.5
Food	–19.8	..	4.3	..	..	..	–19.1
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–16.5	..	7.9	–2.5	..	..	–8.3
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–4.2	5.5	..	..	..	–4.0
Trade and transport	..	1.7	0.2	..	..	1.0	0.2
Private services	..	..	–1.7	..	..	..	–1.5
Public services	–3.8	–6.6	–0.6	..	..	..	–3.9
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.0	..	..	–21.6	–18.8
Other cereal grains	..	..	–5.2	..	..	–20.9	–18.1
Crops	..	..	1.6	..	..	–15.3	–12.5
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.5	..	..	..	–2.5
Livestock for meat	..	..	–7.4	..	–4.9	–3.1	–4.6
Other animal products	..	..	–1.7	..	0.6	2.4	0.6
Dairy cattle	..	..	–17.9	..	–16.3	–13.5	–15.4
Wool	..	..	–17.7	..	–15.4	–13.8	–15.0

.. No significant emissions from this sector.

Table B.14: **The carbon market and economic impacts in New Zealand under scenario 5 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	107.6
Net quota income	2001 US$m	558.8
Quota sales	Mt CO_2 equiv.	19.0
Domestic abatement	Mt CO_2 equiv.	15.0
Economic impact relative to the reference case		
GDP	%	–0.24
GNP	%	0.14
Exchange rate	%	–1.01
Exports	%	–2.68
Imports	%	–1.69
Savings	%	–0.86
Investment	%	–0.21
Export cost index	%	–0.08
Import cost index	%	0.06
Terms of trade	%	–0.14
Rate of return on capital	%	–2.63
Real wages	%	–2.30

Table B.15: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand under scenario 5 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–13.8	–18.9	–3.0	..	–3.6
Oil	1.9	2.8	5.8	–2.9	–0.5
Gas	–6.3	–8.1	..	..	–5.6
Petroleum and coal products	–2.1	–1.7	0.2	–0.8	0.7
Electricity	–6.0	–3.4	..	..	15.5
Iron and steel	–19.7	–19.3	–35.7	13.6	11.9
Nonferrous metals	–9.4	–9.1	–12.7	0.1	4.3
Chemicals, rubber and plastic	1.1	1.4	4.8	–1.5	0.0
Clothing	–2.4	–2.2	–4.2	0.5	1.7
Meat products	–4.8	–4.6	–10.0	1.7	2.4
Dairy products	–25.1	–25.0	–28.6	6.0	6.2
Food	2.1	2.3	5.8	–3.4	–0.3
Pulp, paper and publishing	2.4	2.6	6.7	–2.2	–0.8
Other wood products	1.7	1.9	5.3	–2.1	–0.1
Minerals	0.1	0.2	6.8	–4.8	0.1
Nonmetallic minerals	0.5	0.8	5.7	–2.5	0.3
Light manufacturing	3.6	3.8	8.4	–1.7	–0.2
Other manufacturing	6.5	6.7	8.7	–0.7	–0.5
Construction	–0.3	–0.1	4.2	–2.3	–0.2
Trade and transport	1.0	1.3	6.0	–2.1	–0.6
Private services	1.3	1.4	8.4	–7.3	–1.2
Public services	0.8	1.1	9.0	–3.8	–1.4
Other services	0.8	1.2	..	..	–1.4
Wheat	–2.3	–4.2	..	–10.1	–3.1
Other cereal grains	–0.9	–2.8	19.3	–9.3	–3.0
Crops	12.1	10.4	19.4	–9.3	–3.6
Forestry	2.5	3.0	3.1	..	0.3
Fisheries	0.8	1.8	–2.1	3.0	1.5
Livestock for meat	–6.9	–9.3	–11.3	2.5	3.8
Other animal products	5.9	3.8	6.1	–9.3	0.0
Dairy cattle	–20.4	–22.3	..	..	13.3
Wool	–28.5	–31.4	–51.5	17.2	12.1

.. Not a significant activity.

Table B.16: **Change in domestic emissions in New Zealand under scenario 6 at 2010 relative to the reference case**

	Coal combustion	Gas combustion	Petroleum and coal products combustion	Non combustion carbon dioxide	Methane	Nitrous oxide	Total emissions
	%	%	%	%	%	%	%
Coal	..	–21.3	–12.1	..	–26.4	..	–19.8
Oil	..	..	..	0.9	–2.8	..	0.6
Gas	..	..	..	–7.1	–10.6	..	–9.2
Petroleum and coal products	..	–22.5	–2.4	..	..	..	–18.9
Electricity	–35.9	–16.2	–79.7	..	..	..	–22.8
Iron and steel	–28.1	..	–28.1	–24.1	..	..	–28.1
Nonferrous metals	–31.0	..	–10.3	..	..	..	–13.2
Chemicals, rubber and plastic	..	–1.9	0.2	..	..	..	–0.1
Clothing	..	..	..	..	..	..	..
Meat products	–21.5	..	..	..	..	..	–21.5
Dairy products	–21.1	..	1.3	..	..	..	–18.3
Food	–21.2	..	2.6	..	..	..	–20.5
Pulp, paper and publishing	..	..	..	..	..	..	..
Other wood products	..	..	..	..	..	..	..
Minerals	..	..	..	..	..	..	..
Nonmetallic minerals	–17.3	..	7.1	–3.4	..	..	–9.1
Light manufacturing	..	..	..	..	..	..	..
Other manufacturing	..	..	..	..	..	..	..
Construction	..	–3.9	6.0	..	..	..	–3.7
Trade and transport	..	0.6	–0.8	..	..	0.0	–0.8
Private services	..	..	–2.0	..	..	..	–1.8
Public services	–4.1	–6.9	–0.9	..	..	..	–4.3
Other services	..	..	..	..	..	..	..
Wheat	..	..	–6.0	..	..	–21.6	–18.8
Other cereal grains	..	..	–5.2	..	..	–20.9	–18.1
Crops	..	..	1.6	..	..	–15.3	–12.5
Forestry	..	..	–2.1	..	..	..	–2.0
Fisheries	..	..	–2.5	..	..	..	–2.5
Livestock for meat	..	..	–7.4	..	–4.9	–3.1	–4.6
Other animal products	..	..	–1.7	..	0.6	2.4	0.6
Dairy cattle	..	..	–17.9	..	–16.3	–13.5	–15.4
Wool	..	..	–17.7	..	–15.4	–13.8	–15.0

.. No significant emissions from this sector.

Table B.17: **The carbon market and economic impacts in New Zealand under scenario 6 at 2010**

The carbon market		
Carbon charge	2001 US$/t C	109.5
Net quota income	2001 US$m	261.8
Quota sales	Mt CO_2 equiv.	8.8
Domestic abatement	Mt CO_2 equiv.	4.7
Economic impact relative to the reference case		
GDP	%	–0.08
GNP	%	0.52
Exchange rate	%	0.23
Exports	%	–1.14
Imports	%	0.18
Savings	%	0.75
Investment	%	–0.03
Export cost index	%	0.22
Import cost index	%	0.06
Terms of trade	%	0.17
Rate of return on capital	%	–1.71
Real wages	%	–1.32

Table B.18: **Change in sectoral output, employment, exports, imports and supply prices in New Zealand scenario 6 at 2010 relative to the reference case**

	Output	**Employment**	**Exports**	**Imports**	**Supply price**
	%	%	%	%	%
Coal	–15.6	–21.0	–5.3	..	–4.3
Oil	0.9	1.2	4.5	–2.9	–1.5
Gas	–7.1	–9.2	..	..	–5.8
Petroleum and coal products	–2.5	–2.6	–2.3	–0.3	0.2
Electricity	–6.6	–3.9	..	..	15.3
Iron and steel	–24.1	–23.8	–39.5	11.0	11.8
Nonferrous metals	–14.6	–14.5	–18.0	–2.3	4.2
Chemicals, rubber and plastic	0.1	0.0	0.1	0.1	0.0
Clothing	0.7	0.6	0.8	0.1	–0.4
Meat products	–1.1	–1.1	–2.5	0.4	0.0
Dairy products	–0.5	–0.6	–0.6	0.0	–0.2
Food	0.3	0.3	0.5	–0.1	–0.4
Pulp, paper and publishing	0.6	0.5	1.2	–0.2	–0.5
Other wood products	–0.6	–0.6	–2.1	1.1	0.1
Minerals	–2.0	–2.2	2.9	–4.9	–0.3
Nonmetallic minerals	–0.4	–0.4	–1.9	1.1	0.6
Light manufacturing	–0.6	–0.6	–1.1	0.2	0.0
Other manufacturing	0.8	0.7	0.9	0.4	–0.3
Construction	0.0	0.0	–1.8	1.0	0.2
Trade and transport	0.0	–0.1	–0.4	0.4	–0.2
Private services	0.4	0.3	2.0	–0.8	–0.8
Public services	0.9	0.9	1.0	–0.2	–0.6
Other services	1.0	0.8	..	..	–1.0
Wheat	–0.1	–0.1	..	–0.4	–0.4
Other cereal grains	0.0	0.0	0.8	–0.4	–0.4
Crops	0.5	0.6	0.7	–0.3	–0.4
Forestry	0.6	0.6	1.1	..	–0.5
Fisheries	0.1	0.3	–0.4	0.4	–0.1
Livestock for meat	–0.2	–0.1	0.0	0.1	–0.2
Other animal products	0.0	0.1	0.0	–0.3	–0.2
Dairy cattle	–0.4	–0.4	..	..	–0.1
Wool	0.1	0.2	0.6	–0.2	–0.3

.. Not a significant activity.

Appendix C: Reference case

The GTEM reference case provides a representation of the world economy over the period 1996–2010 in the absence of policies designed to reduce greenhouse gas emissions. Comparing the results from a policy simulation with projections from the reference case allows the effects of implementing a policy change under the Kyoto Protocol to be isolated.

The GTEM reference case incorporates the impacts of ongoing and future energy policy changes unrelated to climate change issues, such as the effect of electricity market deregulation on the fuel mix in electricity generation. The shares of electricity generated by each electricity technology are exogenously imposed in the GTEM reference case. The shares are based on International Energy Agency projections (IEA 1999).

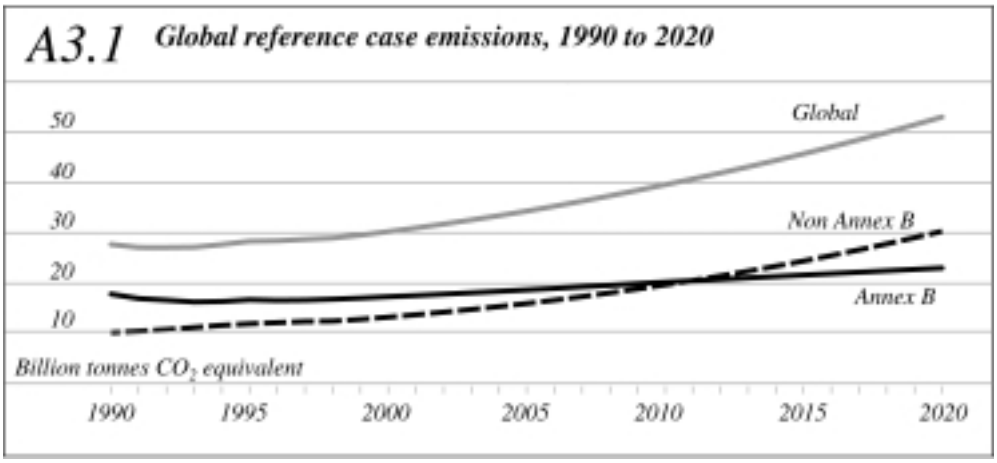
Historical data for GDP are included from 1996 to 2000. GDP projections in GTEM are based on ABARE (2000) and IMF (2000) forecasts and on convergence theory, under which it is assumed that per worker GDP begins to converge toward that of the United States after 2005. The New Zealand GDP data used in this report were supplied by the New Zealand Ministry of Agriculture and Forestry.

The GTEM Annex B reference case includes estimates of carbon sequestration under Articles 3.3 of the Kyoto Protocol. The estimate for the Russian Federation and the Ukraine is taken from Schlamadinger and Karjalainen (2000) while the estimate for New Zealand is provided by the New Zealand Ministry of Agriculture and Forestry. For all other parties, the estimates for sequestration under Article 3.3 are from Annex B party submissions to the Subsidiary Body for Scientific and Technological Advice of the UNFCCC (www.unfccc.int/resource/docs/2000/sbsta/09a1.pdf).

Carbon sequestration in GTEM is modeled as a net addition to or subtraction from each country's assigned amount, rather than as a result of, for example, production in the forestry industry. For this reason the value of carbon sequestered by each sector does not influence profitability and growth in that sector.

Global emissions projections

Global emissions of the three major greenhouse gases (carbon dioxide, methane and nitrous oxide) are projected to rise from 28 billion tonnes of carbon dioxide equivalent in 1990 to 39 billion tonnes by 2010 (figure C.1). The growth in global emissions is driven largely by high emissions growth in non-Annex B countries, which are projected to overtake emissions from Annex B sources in 2011. The share of emissions from non-Annex B countries in global emissions is projected to increase from around 40 per cent in 1990 to 49 per cent in 2010 and to 57 per cent in 2020.



The primary determinants of emissions growth are the growth in economic activity (GDP), changes in the emission intensity of output (measured as greenhouse gas emissions per dollar of output), and the assumed level of carbon sinks. All things being equal, reductions in emission intensity reduce the emissions generated from increased economic activity. Changes in emission intensity over the reference case are caused by changes in the structure of the economy, in energy and process efficiency and in energy sources, in particular the fuel mix in electricity generation.

Table C.1: **Projected average annual change in emissions, GDP and emission intensity of output, reference case, 1990–2010 a**

	Carbon dioxide equivalent emissions %	**Real GDP** %	**Emission intensity of output a** %
New Zealand	1.2	2.7	–1.5
Australia	1.6	3.6	–2.0
United States	1.8	3.0	–1.2
Canada	1.9	3.0	–1.1
Japan	0.9	1.8	–0.9
European Union	0.5	2.5	–2.0
Russian Federation and Ukraine	–1.3	–0.1	–1.2
Eastern Europe	–0.2	2.4	–2.5
EFTA **b**	1.3	2.5	–1.1
Annex B	0.6	2.5	–1.8
Non–Annex B	3.4	5.1	–1.6
Global	1.8	3.0	–1.2

a Excluding emissions from land use change and forestry. **b** European Free Trade Area: comprises Switzerland, Norway and Iceland.

The projected average annual changes in emissions, GDP and the emissions intensity of output over the reference case are shown in table C.1. Emissions in the Russian Federation, the Ukraine and eastern Europe are projected to fall over the reference case. The economic growth rates assumed for the Russian Federation, the Ukraine and eastern Europe over the projection period are not sufficient to offset the fall in emissions between 1990 and 1996 resulting from economic restructuring. It should be noted that uncertainty about the medium term economic development in these regions means that the emission projections are also subject to a high degree of uncertainty.

Reference case emissions in the European Union and Japan are projected to rise by less than 1 per cent a year between 1990 and 2010. In the European Union, emissions fell by around 2 per cent a year between 1990 and 1998 and low emissions growth is projected thereafter. The decline in emissions between 1990 and 1998 was mainly a result of the substitution of gas for coal in electricity generation in the United Kingdom and economic restructuring in east Germany (Jotzo et al. 2000). In Japan, projected GDP growth between 1990 and 2010 is lower than the Annex B average, leading to relatively low emissions growth.

The highest rates of emissions growth are projected to be in Canada, the United States and Australia. An important factor for high emissions growth in these countries is the high assumed rates of GDP growth.

New Zealand reference case projections

Macroeconomic projections

It should be noted that GTEM is a long run sectoral model of the world economy. It is not designed to capture the detailed interaction of macroeconomic variables over the business cycle. However, the GTEM reference case used in this analysis does capture the following characteristics of New Zealand's recent macroeconomic history.

- Growth in domestic investment exceeds growth in domestic savings, leading to an accumulation of foreign debt.
- The value of exports in New Zealand grows with the value of imports.
- The current account continues to deteriorate due to the large interest payments New Zealand must make on its foreign debt.
- These interest payments lead to growth in real GDP being more rapid than the growth in real GNP in New Zealand.
- Projected real GDP growth in New Zealand is lower than in most other OECD countries. In this analysis, Japan is the only OECD country where real GDP growth is projected to be slower than in New Zealand.

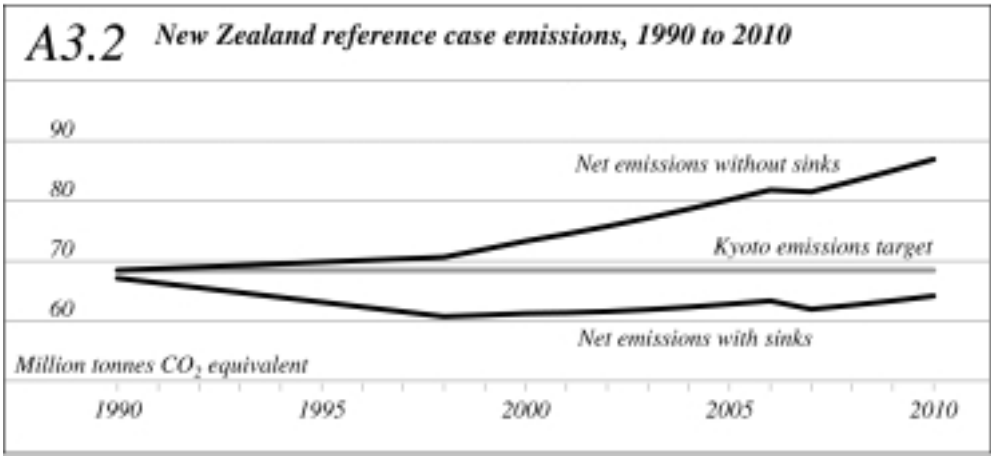
The resulting reference case projections for key macroeconomic variables are shown in table C.2.

Table C.2: **Projected average annual change in New Zealand macroeconomic indicators, reference case, 1995–2010**

	%
GDP	2.6
GNP	1.7
Exchange rate	0.1
Exports	2.5
Imports	2.8
Terms of trade	0.3
Savings	1.7
Investment	5.8

Emission projections

Under the Kyoto Protocol, New Zealand is required to maintain its net greenhouse gas emissions at 1990 levels over the first commitment period, 2008–12. Over the reference case New Zealand's net greenhouse gas emissions, excluding carbon sequestered by forestry activities under Article 3.3, are projected to rise from 68.3 million tonnes of carbon dioxide equivalent in 1990 to 86.8 million tonnes at 2010 (figure C.2). However, carbon sequestration by forest sinks under Article 3.3 is an important element in New Zealand's reference case emissions profile. The replacement of grasslands, shrublands and marginal agricultural land with commercial and farm forestry plantations in New Zealand since 1990 is projected to generate 113.0 million tonnes of carbon sinks under Article 3.3 between 1990 and 2010 (New Zealand Ministry for the Environment 2000a). These carbon sinks, which translate into a carbon sequestration of 22.6 million tonnes of carbon dioxide equivalent in each year of the first commitment period, are projected to reduce New Zealand's net greenhouse gas emissions to 64.2 million tonnes of carbon dioxide equivalent at 2010.



The emissions coverage in GTEM accounts for almost 96 per cent of greenhouse gas emissions in New Zealand (table C.3). GTEM does not include emissions from waste, emissions from agricultural residues or methane and most nitrous oxide emissions from combustion and some industrial processes. Nitrous oxide emissions from combustion in the transport sector are included in GTEM.

Table C.3: **GTEM coverage of New Zealand emissions, 1998 a**

	Emissions kt CO_2 equiv.	**Share of total emissions** %
Livestock	39 974	54.4
Transport and trade	6 381	8.7
Private household emissions	5 825	7.9
Electricity production	4 044	5.5
Construction and services	2 747	3.7
Other primary production	2 477	3.4
Metals production	2 423	3.3
Chemicals production	2 366	3.2
Fossil fuel production	2 346	3.2
Minerals production	1 048	1.4
Manufacturing, textiles and processing	821	1.1
GTEM coverage total	70 451	95.9
Emissions omitted from GTEM coverage		
Other energy sector emissions	163	0.2
Other industrial processes: including perfluorocarbons and sulfur hexafluoride	96	0.1
Other agriculture: agricultural residues	3	0.0
Waste	2 785	3.8
NGGI total	73 498	100.0

a Includes CO_2, CH_4 and N_2O emissions
Source: New Zealand Ministry for the Environment (2000b).

In 1998, emissions from the livestock industry, mainly methane, accounted for over half of New Zealand's greenhouse gas emissions (table C.4). Over the reference case, emissions from dairy cattle are projected to grow rapidly while emissions from livestock for meat production are projected to increase slightly and emissions from wool production are projected to fall slightly. These disparate emission growth rates reflect the assumed continuation of the current movement of livestock producers toward dairy production over the period to 2010. Despite the projected growth in emissions from livestock over the reference case, the share of livestock emissions in total greenhouse gas emissions is projected to fall between 1998 and 2010. This is a result of more rapid projected emissions growth elsewhere in the economy, notably in the transport and electricity generation sectors.

Emissions from the trade and transport sector are projected to increase from 6.4 million tonnes of carbon dioxide equivalent to 8.2 million tonnes, growing as a share of national emissions over the period.

Table C.4: **New Zealand reference case sectoral emissions in 1998 and 2010a**

	1998 Mt CO_2 equiv.	**2010** Mt CO_2 equiv.
Livestock	40.0	46.0
Transport and trade	6.4	8.2
Private household emissions	5.8	7.1
Electricity production	4.0	8.1
Construction and services	2.7	4.1
Other primary production	2.5	3.7
Metals production	2.4	3.3
Chemicals production	2.4	0.7
Fossil fuel production	2.3	2.9
Minerals production	1.0	1.6
Manufacturing, textiles and processing	0.8	0.9
Total	70.5	86.8

a Includes CO_2, CH_4 and N_2O emissions.
Source: New Zealand Ministry for the Environment (2000b).

Electricity generation contributed just over 6 per cent of New Zealand's emissions in 1998, compared with almost a third of total emissions in Australia in 1998. About 75 per cent of electricity in New Zealand was generated using hydroelectric technology, which produces virtually no greenhouse gas emissions. Over the reference case, emissions from electricity generation are projected to increase more rapidly than those from any other sector as limited expansion possibilities in hydroelectric generation are projected to lead to greater use of relatively emissions intensive coal and gas fired electricity plants (table C.5).

Table C.5: **Technology shares in New Zealand electricity generation, reference case, 1995 and 2010**

	1995 %	**2010** %
Coal	2.0	8.2
Oil	0.0	0.1
Gas	17.5	22.4
Nuclear	0.0	0.0
Hydro	80.5	68.6
Other renewables	0.0	0.8

Source: New Zealand Ministry of Agriculture and Forestry – personal communication.

Emissions from the chemicals, rubber and plastic sector are projected to fall from 2.4 million tonnes of carbon dioxide equivalent to 0.7 million tonnes between 1998 and 2010 as a result of the assumed closure of New Zealand's methanol plants in 2007.

Appendix D: The emission response function and Armington elasticities of substitution

The emission response function

In modeling the impact of greenhouse gas abatement policies in GTEM, emission reductions are available from reductions in combustion related carbon dioxide emissions through energy efficiency improvements and fuel switching, and from reductions in noncombustion sources through adoption of new technologies and management practices. Other things being equal, reduced activity levels in emitting sectors will also lead to emission reductions.

Emission reduction responses in the electricity and iron and steel industries are modeled using the technology bundle approach. These industries are able to substitute between different production technologies, which each contain fixed but different input mixes. Electricity can be generated from coal, petroleum, gas, nuclear, hydroelectric and renewable based technologies, while iron and steel can be produced using blast furnace or electric arc technologies. All other industries can substitute between fuels, which include coal, gas, petroleum and electricity, and can also substitute fuels for primary factors, which include land, labor, capital and natural resources.

Where industries are able to reduce emissions without reducing inputs to the production process, GTEM uses emission response functions to model emissions in these industries. The emission response functions apply to noncombustion carbon dioxide and to methane and nitrous oxide from the majority of emitting industries but not to the combustion of fossil fuels. The magnitude of an emission reduction response is determined by the size of the carbon charge and, for methane emissions from coal mining, livestock and natural gas production, energy prices. Captured methane can be used to generate electricity or be pumped directly into a natural gas pipeline. Although the carbon charge must reach certain thresholds before efficiency improvements are available, they are then assumed to be implemented at no additional cost to the industry.

The emission response data for most industries were taken largely from Gibbs (1998) and Cheminfo (1998), with additional information on methane emission reductions in paddy rice production and the ability to reduce fertiliser use taken from Watson, Zingowera and Moss (1996). Gibbs (1998) and Cheminfo (1998) provide estimates based on industry studies in the United States and Canada. Because data are limited, it is assumed that the abatement options are available for each noncombustion carbon dioxide gas by source, with the exception of livestock, are the same in each Annex B region. The emission response coefficients for all industries except the livestock industry are shown in table D.1.

Table D.1: **Emission reduction coefficients in non-livestock industries**

Industry	Greenhouse gas	Percentage emission reduction for a given carbon equivalent charge					
		US$10/t carbon equiv.	US$50/t carbon equiv.	US$100/t carbon equiv.	US$150/t carbon equiv.	US$200/t carbon equiv.	US$500/t carbon equiv.
Nonmetallic minerals (lime production) **a**	CO_2	0	10	10	10	10	80
Nonferrous metals (aluminium) **a**	CO_2	5	25	25	25	25	25
Coal **b**	Methane	19	37	37	37	37	37
Oil **b**	Methane	15	18	24	25	25	25
Natural gas **b**	Methane	15	18	24	25	25	25
Paddy rice **c**	Methane	10	50	50	50	50	50
Chemicals, rubber and plastics **a**	Nitrous oxide	95	95	95	95	95	95
Fertiliser use (all crops) **c**	Nitrous oxide	20	40	70	72	73	75

a Cheminfo (1998). **b** Gibbs (1998). **c** Watson, Zingowera and Moss (1996).

For this study, the emission response function for methane emissions from the livestock sector was revised to account for differing abatement possibilities in enteric fermentation and manure management. The revised function was weighted according to the proportion of methane emissions from enteric fermentation and manure in each Annex B country except New Zealand and Australia. Data on enteric manure management for this revision were taken from the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 1996). For New Zealand, methane emission response parameters for dairy and beef cattle and sheep were supplied by the New Zealand Ministry of Agriculture and Forestry. The methane emission response parameters for dairy and beef cattle and sheep in Australia were derived by ABARE from the values in Gibbs (1998). The revised emission response coefficients for the livestock industry in each region are shown in table D.2.

Table D.2: **Methane emission reduction coefficients in the livestock industry**

Region	Percentage emission reduction for a given carbon equivalent charge					
	US$10/t carbon equivalent	US$50/t carbon equivalent	US$100/t carbon equivalent	US$150/t carbon equivalent	US$200/t carbon equivalent	US$500/t carbon equivalent
Australia	3	11	16	16.75	17.25	17.25
Japan	6.8	24.9	36.3	38.0	39.1	39.1
Canada	6.5	23.8	34.6	36.2	37.3	37.3
United States	7.4	27.0	39.2	41.1	42.3	42.3
European Union	6.9	25.1	36.6	38.3	39.4	39.4
EFTA **a**	6.1	22.3	32.5	34.0	35.0	35.0
Eastern Europe	7.3	26.8	38.9	40.8	42.0	42.0
Russian Federation and Ukraine	5.8	21.3	31.1	32.5	33.5	33.5
New Zealand – dairy **b**	3.0	11.0	16.0	16.8	17.3	17.3
New Zealand – beef and sheep **b**	1.7	6.4	9.3	9.7	10.0	10.0

a European Free Trade Area: comprises Switzerland, Norway and Iceland. **b** Sourced by the New Zealand Ministry of Agriculture and Forestry.
Source: Gibbs (1998).

Armington elasticities of substitution

In GTEM Armington elasticities of substitution are used to represent the extent to which certain goods or factors can be substituted for certain other goods or factors. GTEM contains the following five different types of Armington elasticities:

- elasticities of substitution between domestic and imported goods;
- elasticities of substitution among imports from different sources;
- elasticities of substitution between labor and capital;
- the interfuel substitution elasticity, which is equal to 0.2 between all fuels; and
- the elasticity of substitution between fuel and other primary factors of production, which is equal to 0.04 between all fuels and primary factors.

Apart from the interfuel substitution elasticity and the elasticity of substitution between fuel and other primary factors of production, the elasticities vary by sector (table A4.3).

Table D.3: **Armington elasticities of substitution**

Sector	Imports – different sources	Labor and capital	Domestic and imported goods
Coal	5.6	0.2	2.8
Oil	5.6	0.2	2.8
Gas	5.6	0.2	2.8
Petroleum and coal products	3.8	1.3	1.9
Electricity	5.6	1.3	2.8
Iron and steel	5.6	1.3	2.8
Nonferrous metals	5.6	1.3	2.8
Chemicals, rubber and plastic	3.8	1.3	1.9
Clothing	7.6*****	1.3	3.5*****
Meat products	8.8	1.1	2.2
Dairy products	8.8	1.1	2.2
Food	4.7*****	1.1	2.4*****
Pulp, paper and publishing	3.6	1.3	1.8
Other wood products	5.6	1.3	2.8
Minerals	5.6	0.2	2.8
Nonmetallic minerals	5.6	1.3	2.8
Light manufacturing	6.9*****	1.3	3.5*****
Other manufacturing	5.6	1.3	2.8
Construction	3.8	1.4	1.9
Trade and transport	3.8	1.7	1.9
Private services	3.8	1.3	1.9
Public services	3.8	1.3	1.9
Other services	4.7*****	1.3	2.0*****
Rice	4.4	0.2	2.2
Wheat	4.4	0.2	2.2
Other cereal grains	4.4	0.2	2.2
Crops	4.4	0.2	2.2
Forestry	5.6	0.2	2.8
Fisheries	5.6	0.2	2.8
Cattle	5.6	0.2	2.8
Other animal products	5.6	0.2	2.8
Livestock for meat	5.6	0.2	2.8
Wool	8.8	0.2	2.2

Note: ***** denotes sectors where the Armington varies between countries as a result of different weights being placed on certain commodities in that sector in each country. The Armington reported in this case represents an average across a small range.

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