Economic implications of the KYOTO PROTOCOL FOR NEW ZEALAND

sensitivity analysis

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introduction

As part of an ongoing contribution to New Zealand's preratification assessment of the Kyoto Protocol, ABARE has been commissioned by the New Zealand Department of Prime Minister and Cabinet (NZPM&C) to conduct sensitivity analysis for a range of issues associated with modeling the Kyoto Protocol. Three issues of importance are focused on in this assessment of the impact of the Kyoto Protocol for New Zealand:

- the assumed modeling parameters relating to New Zealand's domestic ability to reduce greenhouse gas emissions through energy efficiency and import and energy substitution;
- the availability of quota from and variations in the profit maximising behaviors of the Russian Federation, the Ukraine and eastern Europe; and
- the application of policies relating to the Kyoto Protocol in New Zealand.

NZPM&C provided ABARE with details of eleven scenarios to be analysed. These scenarios model specific assumptions and policy alternatives that are relevant to analysing the effects of the Kyoto Protocol on New Zealand's economy. A detailed description of these scenarios is provided in box 1. It should be noted that scenario 3 was not analysed in this report, as data required for this scenario were not available in time.

Box 1: Description of scenarios

Reference case

No climate change policies are implemented in any country — 'business as usual' projections of economic activity. This scenario is used as a basis against which to compare policy scenarios. See appendix B for further detail.

Scenario 1: Base case

- Implementation of the Kyoto Protocol by all Annex B countries except the United States, which is assumed to undertake domestic policies to reduce the emission intensity of its economy.
- Each country's greenhouse gas inventory includes carbon dioxide emissions from combustion and noncombustion sources, nitrous oxide and methane (excluding waste) emissions (see appendix A).
- The emissions charge is applied to all modeled emissions except methane and nitrous oxide emissions from agriculture.
- The global emissions price is determined within the model, assuming profit maximising behavior by the Russian Federation and the Ukraine.

Continued ➪

Box 1: Description of scenarios *continued*

- New Zealand has 22.6 million tonnes of carbon dioxide equivalent sink credits in each year of the analysis. The surplus sink credits not required for meeting New Zealand's first commitment period target are sold on the international emissions market.

Scenario 2

As in the base case but natural gas is unavailable in key industries on the South Island. The industries affected are nonferrous metals, cement (nonmetallic minerals), dairy products and meat and other food processing.

Scenario 3

As in the base case but including endogenous sink credits

- Data necessary for this scenario were not available from NZPM&C in time for this scenario to be analysed.

Scenario 4

As in the base case but the global emissions price is set at NZ$25 a tonne of carbon dioxide equivalent at 2010.

Scenario 5

As in the base case but the global emissions price is set at NZ$15 a tonne of carbon dioxide equivalent at 2010.

Scenario 6

The base case is rerun with alternative Armington elasticities of substitution derived from NZIER (2001).

Scenario 7

As in the base case but the New Zealand government uses carbon tax revenue to reduce income taxes.

Scenario 8

The base case is rerun with alternative elasticities of substitution between fuel inputs. The elasticities of substitution were increased from around 0.2 to 1.0.

Scenario 9

As in the base case but the emission response function is switched off, preventing no regrets reductions in emission intensity though still allowing fuel substitution as a means of reducing emissions.

Scenario 10

As in the base case but only 75 per cent of surplus sink credits not required for meeting New Zealand's first commitment period target are sold on the international emissions market.

Scenario 11

As in the base case but New Zealand excludes iron and steel and nonferrous metals from the global emissions price.

assumptions for climate change modeling

For this analysis ABARE's global trade and environment model (GTEM) was used (appendix A). GTEM was also used for other ABARE studies undertaken for the New Zealand government, including analysis of policy package scenarios (Hansard, Burns and Hester 2003), and previous studies (ABARE 2001a,b; Heyhoe et al. 2001).

It should be noted that since the provision of analysis of the Kyoto Protocol to the New Zealand government in 2001 (ABARE 2001a,b; Heyhoe et al. 2001), ABARE has made revisions to the GTEM reference case. This means that results from the current modeling are not directly comparable with results from the earlier studies. Further details about the GTEM modeling framework are provided in appendix A, while the characteristics of the revised reference case are described in appendix B.

There are also some differences between the reference case used in this report and the reference case used for analysing the climate change policy package proposals for New Zealand (see Hansard et al. 2003). Specifically, the differences are:

- the social accounting (or input–output) matrix used in Hansard et al. (2003) was updated with the latest data published by Statistics New Zealand (2001);
- Hansard et al. (2003) uses the most recent New Zealand National Greenhouse Gas Inventory (NGGI); and
- the reference case in Hansard et al. (2003) incorporates the restriction of natural gas on New Zealand's South Island and higher Armington elasticities for New Zealand's domestically produced and imported commodities.

In addition to the assumptions for the scenarios presented in table 1, there are several assumptions that were provided by NZPM&C for this report that specifically address characteristics of the Kyoto Protocol. These are:

- The Kyoto Protocol emission targets for participating Annex B countries are held constant for all years over the first commitment period (2008–12). No other commitment periods were modeled for this analysis.
- Banking of emissions quota (by quota sellers) under Article 3.13 of the Kyoto Protocol is modeled. In equilibrium, the global emissions price satisfies the intertemporal arbitrage condition derived according to Hotelling (1931) and leads to the global emissions price rising at the discount rate. A real discount rate of 7 per cent is assumed.

- For scenarios where the global emissions price is determined within the GTEM model the Russian Federation and the Ukraine are assumed to have and to use their market power in the international emissions quota market to influence the global emissions price and maximise the net present value of their real gross national product over the first commitment period;.
- All scenarios assume that there are no emissions reduction units available from the clean development mechanism (CDM) This si because of the uncertainty surrounding the potential volume of emission reduction units that could be available from the CDM.

key modeling results

The results from the base case (scenario 1) are presented as changes relative to the reference case, while results for the sensitivity scenarios are presented as changes relative to the base case.

Scenario 1: Base case

Under this scenario it is assumed that New Zealand and all other Annex B countries except the United States ratify the Kyoto Protocol. The global emissions price for this scenario is projected to be US$11.30 a tonne of carbon dioxide equivalent at 2010 (in 2002 terms) (table 1). This represents the price at which the Russian Federation and the Ukraine maximise their welfare, measured by gross national product (GNP). To achieve this price, the combined sales of emissions quota by the Russian Federation, the Ukraine and eastern Europe are projected to be 685.1 million tonnes of carbon dioxide equivalent at 2010. New Zealand is projected to sell 7.1 million tonnes of carbon dioxide equivalent of sink credits at 2010.

The implementation of the Kyoto Protocol under the base case assumptions is projected to result in some restructuring of New Zealand's economy and a decrease in gross domestic product (GDP) relative to the reference case in 2010. However, returns from the sale of sink credits to the international emissions trading market more than offset the contraction in domestic activity. As a result, GNP is projected to increase by 0.07 per cent relative to the reference case level in 2010 (table 1).

Foreign revenue from the sale of sink credits to the international market is projected to result in a relative appreciation of the New Zealand dollar by 0.14 per cent at 2010.

As a result, the value of net exports from New Zealand is projected to fall by 0.17 per cent in real terms at 2010 relative to the

1 Emissions market and economic impacts in New Zealand under the base case at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	79.6
Sink credit sales	Mt CO_2 equiv.	7.1
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.3
Economic impact relative to the reference case scenario		%
Real GDP		–0.03
Real GNP		0.07
Exchange rate (US$/NZ$)		0.14
Real exports		–0.17
Real imports		0.08
Terms of trade		0.05
Real investment		0.03
Real saving		0.20
Real consumption		–0.01
Real wages		–0.54

Note: All dollar values in 2002 terms.

reference case, while the real value of imports increases by 0.08 per cent above reference case levels.

At a sectoral level, there are large reductions in the output of emission intensive products, such as iron and steel and nonferrous metals, relative to the reference case (table 2). However, in contrast to other energy intensive products, the output from the primary aluminium sector in New Zealand is projected to increase, relative to the reference case. This is because the price of electricity, a significant cost component in primary aluminium production, is projected to rise by a lesser amount in New Zealand than for other Annex B countries. Electricity prices in New Zealand are projected to increase above the reference case, by around 5.7 per cent in 2010, compared with an average of 8 per cent for other participating Annex B countries.

2 Sectoral output, exports and imports for New Zealand under the base case at 2010 relative to the reference case scenario

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	–5.64	..	..	–0.07
Steaming coal	–7.04	20.53	..	–3.21
Coking coal	–4.21	–4.20	..	–0.81
Oil	0.17	1.04	–1.40	0.19
Gas	–2.75	..	..	–8.55
Petroleum and coal products	–1.09	–1.21	–0.10	–2.75
Electricity	–2.26	..	..	–14.94
Iron and steel	–8.61	–15.30	2.53	–9.91
Alumina	..	..	3.19	..
Primary aluminium	3.19	3.23	–6.74	4.31
Nonferrous metals	–4.11	–6.38	–1.22	–4.29
Chemicals, rubber and plastic	0.31	0.65	–0.08	3.55
Wood and paper products	0.13	0.25	0.03	2.23
Dairy products	–0.04	–0.04	0.29	–0.57
Meat and other food processing	0.12	0.26	0.12	1.69
Bauxite	..	..	..	..
Other mineral products	–0.82	–0.29	–1.08	–0.87
Nonmetallic minerals	–0.11	–1.35	0.54	–0.17
Manufacturing	–0.18	–0.34	0.09	–4.50
Trade and transport	–0.03	–0.24	0.19	–7.01
Services	0.14	0.28	0.01	21.15
Rice	..	..	..	..
Wheat	0.07	..	0.14	0.06
Crops	0.14	0.21	0.01	0.89
Fisheries and forestry	0.23	0.34	0.04	1.89
Beef and other livestock	0.02	0.02	0.12	–0.09
Dairy cattle	–0.02	..	..	–0.04
Sheep and wool	0.04	0.04	0.07	0.12
Total change				–21.69

.. Not a significant activity.
Note: All dollar values in 2002 terms.

New Zealand has one of the least emission intensive electricity sectors among Annex B countries, with around 65 per cent of electricity generated using hydro power (McDougall et al. 1998; National Communication 2001). As a result, aluminium producers in New Zealand increase their cost competitiveness against other aluminium producers in Annex B countries. The losses in competitiveness of aluminium producers in Annex B countries (excluding New Zealand) result in some losses in production and exports of aluminium. These losses are projected to be partly offset by increases in aluminium exports from New Zealand.

Output from the beef and sheep sectors are projected to increase slightly relative to the reference case because livestock methane emissions are excluded from the emissions charge under this scenario. However, there is projected to be lower demand for New Zealand's dairy products in key export markets such as the European Union and Japan. This will contribute to lower domestic output in both the dairy products and dairy cattle industries. New Zealand's services sector is projected to expand slightly as it benefits from lower labor and capital costs associated with the lower level of activity in the economy.

Scenario 2: Restriction of natural gas use on the South Island

The same assumptions used in scenario 1 are used in this scenario but it is also assumed that the availability of natural gas for key industries on New Zealand's South Island is restricted to current levels. Specifically, it is assumed that there is no change in direct gas use in the primary aluminium, cement (nonmetallic minerals), dairy products and meat and other food processing industries in the South Island relative to 2001 levels. To expand output, these industries must use more expensive fuels, increasing the costs of production above those estimated in the base case scenario.

In this scenario, economic activity in New Zealand is projected to fall below base case levels by 0.03 per cent in 2010 (table 3). There is a projected increase in domestic abatement in New Zealand relative to the base case, even though the restriction of natural gas use would be expected to increase the marginal cost of abatement. This is because the assumed restriction on natural gas limits economic activity and emissions growth in New Zealand's economy. As a result, an additional 0.3 million tonnes of sink credits are sold on the international emissions quota market compared with the base case in 2010.

There is a slight increase in the proportion of electricity generated using natural gas in 2010. This occurs because the reduction in natural gas use in the South Island causes

3 Emissions market and economic impacts in New Zealand under scenario 2 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	83.0
Sink credit sales	Mt CO_2 equiv.	7.4
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.6
Economic impact relative to the base case		%
Real GDP		–0.03
Real GNP		0.00
Exchange rate (US$/NZ$)		–0.09
Real exports		–0.28
Real imports		–0.22
Terms of trade		0.09
Real investment		0.00
Real saving		0.02
Real consumption		–0.02
Real wages		–0.13

Note: All dollar values in 2002 terms.

the price of natural gas to fall slightly below base case levels, improving its competitiveness against other fuels. In turn, the proportion of electricity in the fuel mix of those sectors restricted from using gas increases.

At a sectoral level, the largest decline in output is projected for the dairy products sector relative to the base case, with an associated reduction in dairy cattle in 2010 (table 4). This is because, of the sectors where gas use is restricted, dairy has the highest share of natural gas in its total fuel use. Output from the meat and other food products sector is also projected to decline. The lower outputs in these sectors combine to reduce demand for some agricultural products, specifically dairy cattle and wheat. The nonmetallic minerals sector is also affected by the restriction on natural gas use, while the restriction on availability means natural gas output is also lower in this scenario.

4 Sectoral output, exports and imports for New Zealand under scenario 2 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	2.58	..	..	–0.01
Steaming coal	0.55	–0.88	..	0.65
Coking coal	1.10	1.22	..	–0.04
Oil	0.12	–0.05	0.21	0.34
Gas	–0.81	..	..	–2.73
Petroleum and coal products	0.20	0.49	–0.25	0.14
Electricity	0.21	..	..	2.73
Iron and steel	0.57	0.70	–0.09	1.89
Alumina	..	..	0.26	..
Primary aluminium	0.14	0.02	0.23	–0.01
Nonferrous metals	0.18	0.16	0.23	0.01
Chemicals, rubber and plastic	0.29	0.52	–0.62	4.30
Wood and paper products	0.27	0.60	–0.64	8.56
Dairy products	–3.48	–4.83	8.21	–21.73
Meat and other food processing	–1.14	–1.99	1.03	–19.88
Bauxite	..	..	..	..
Other mineral products	0.07	0.69	–0.17	0.10
Nonmetallic minerals	–0.11	–0.39	0.31	–0.46
Manufacturing	0.48	0.95	–0.24	18.92
Trade and transport	0.06	0.53	–0.01	6.67
Services	0.02	0.69	–0.33	5.14
Rice	..	..	..	..
Wheat	–0.37	..	–1.48	–1.00
Crops	0.43	0.81	–1.28	4.61
Fisheries and forestry	0.17	1.73	–1.33	1.66
Beef and other livestock	0.45	1.00	–0.91	6.94
Dairy cattle	–3.12	..	..	–44.65
Sheep and wool	0.37	0.82	–1.52	7.87
Total change				–19.97

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Primary aluminium output is projected to increase above the base case. This occurs because the manufacturing sector benefits from not being restrained in using natural gas and increases output relative to the base case. Because around 50 per cent of primary aluminium is sold to New Zealand's manufacturing sector, there is a greater derived demand for primary aluminium relative to the base case.

The contribution of some sectors to New Zealand's GDP is projected to decline slightly despite higher output in these sectors. This is because the constraint on gas use within the South Island of New Zealand results in a reduction in the returns to primary factors. Although there is a projected increase in output from some sectors, such as brown coal, above the base case level, lower factor returns result in a lower overall value of primary factor consumption and a lower contribution to GDP (table 4).

Scenario 3: Endogenous sink credits

Not modeled as data necessary for this scenario were not available from NZPM&C.

Scenario 4: Global emissions price set at NZ$25 a tonne of carbon dioxide at 2010

Under this scenario the impact on New Zealand of a global emissions price that is higher than that estimated in the base case scenario is examined. The global emissions price and the domestic emissions charge are set at NZ$25 a tonne of carbon dioxide equivalent (in 2002 terms) at 2010.

In this scenario it is assumed that the Russian Federation and the Ukraine do not use their market power in the global emissions trading market in a manner that maximises their projected welfare (GNP). To achieve the price assumed for the scenario it is estimated that the Russian Federation, the Ukraine and eastern Europe restrict the sale of emissions quota in the first commitment period, relative to the base case, to 576.3 million tonnes of carbon dioxide equivalent emissions quota at 2010. The higher domestic emissions charge results in New Zealand meeting a larger proportion of its Kyoto target through domestic abatement (table 5), and to sell more sink credits on the international market. Revenue from the sale of sink credits is projected to be 76 per cent above the base case.

5 Emissions market and economic impacts in New Zealand under scenario 4 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	17.6
Sink credit income	US$m	140.4
Sink credit sales	Mt CO_2 equiv.	8.0
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	3.2
Economic impact relative to the base case		%
Real GDP		–0.02
Real GNP		0.05
Exchange rate (US$/NZ$)		0.08
Real exports		–0.13
Real imports		0.03
Terms of trade		0.02
Real investment		0.00
Real saving		0.12
Real consumption		0.00
Real wages		–0.29

Note: All dollar values in 2002 terms

The higher level of domestic abatement results in a lower level of economic activity in the New Zealand economy, relative to the base case. Real GDP is projected to be 0.02 per cent below the base case. However, the combined effect of higher sink credit sales and the higher global emissions price leads to a higher level of real GNP relative to the base case in 2010 (table 5).

The revenue from the sale of sink credits leads to an appreciation of the dollar which, together with the lower level of economic activity both in New Zealand and other participating Annex B countries, results in a lower level of exports relative to the base case.

The higher domestic emissions price leads to a higher level of abatement in New Zealand, relative to the base case in 2010. Consequently, there are larger reductions in energy intensive output, particularly in the iron and steel and nonferrous metals sectors, and associated reductions in the demand for energy, including electricity, than for the base case. There is

6 Sectoral output, exports and imports for New Zealand under scenario 4 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$million
Brown coal	–2.47	..	..	–0.03
Steaming coal	–3.60	5.95	..	–1.92
Coking coal	–2.26	–2.26	..	–0.59
Oil	0.15	0.77	–0.73	0.27
Gas	–1.49	..	..	–6.45
Petroleum and coal products	–0.56	–0.44	–0.12	–2.16
Electricity	–1.19	..	..	–10.50
Iron and steel	–4.78	–8.93	1.27	–7.78
Alumina	..	..	0.01	..
Primary aluminium	0.01	0.01	–3.68	0.08
Nonferrous metals	–2.39	–3.85	–0.50	–3.73
Chemicals, rubber and plastic	0.10	0.19	–0.02	1.89
Wood and paper products	0.06	0.09	0.02	1.67
Dairy products	–0.03	–0.03	0.12	–0.51
Meat and other food processing	0.06	0.13	0.05	1.50
Bauxite	..	..	..	..
Other mineral products	–0.51	–0.41	–0.49	–0.84
Nonmetallic minerals	–0.06	–0.84	0.29	–0.15
Manufacturing	–0.10	–0.20	0.04	–4.08
Trade and transport	–0.01	–0.13	0.10	–4.74
Services	0.08	0.17	–0.02	20.92
Rice	..	..	..	..
Wheat	0.04	..	0.06	0.06
Crops	0.09	0.13	–0.01	1.01
Fisheries and forestry	0.09	0.12	–0.03	1.10
Beef and other livestock	0.00	–0.01	0.05	–0.06
Dairy cattle	–0.02	..	..	–0.09
Sheep and wool	0.02	0.03	–0.02	0.37
Total change				–14.76

.. Not a significant activity.
Note: All dollar values in 2002 terms.

also projected to be an increase in output from the services sector, relative to the base case in 2010 (table 6).

Scenario 5: Global emissions price set at NZ$15 a tonne of carbon dioxide at 2010

This scenario examines the impact for New Zealand of changing the global emissions price. For this scenario the price is assumed to be NZ$15 a tonne of carbon dioxide equivalent at 2010 (in 2002 terms).

To obtain the assumed global quota price for this scenario, it is assumed that the Russian Federation and the Ukraine sell more emissions quota in this scenario than was estimated to maximise their long run welfare (GNP) in the base case. In total, the Russian Federation, the Ukraine and eastern Europe are estimated to sell 699.5 million tonnes of carbon dioxide equivalent emissions quota at 2010, slightly more than estimated in the base case in 2010.

The lower emissions price results in a lower quantity of sink credits sold by New Zealand, relative to the base case at 2010.

The lower domestic emissions charge is not sufficient to affect overall economic activity in New Zealand, relative to the base case. Real GNP is projected to decline slightly relative to the base case in 2010 as a result of the lower global emissions price and reduced quota sales (table 7).

The lower level of impact on New Zealand's economy results in a higher level of exports, relative to the base case. Imports are not significantly affected. Lower revenues from quota trading results in a slight depreciation of the New Zealand dollar, relative to the base case in 2010.

New Zealand's energy intensive sectors benefit from the lower domestic emissions charge relative to the base case (table 8). The iron and steel, coal and nonferrous metals sectors experience the largest benefit, implying that there is less restructuring under the lower emissions price, relative to the base scenario in 2010.

7 Emissions market and economic impacts in New Zealand under scenario 5 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	10.5
Sink credit income	US$m	72.7
Sink credit sales	Mt CO_2 equiv.	6.9
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.1
Economic impact relative to the base case		%
Real GDP		0.00
Real GNP		–0.01
Exchange rate (US$/NZ$)		–0.01
Real exports		0.01
Real imports		0.00
Terms of trade		0.00
Real investment		0.00
Real saving		–0.01
Real consumption		0.00
Real wages		0.04

Note: All dollar values in 2002 terms.

8 Sectoral output, exports and imports for New Zealand under scenario 5 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	0.32	..	..	0.00
Steaming coal	0.42	–1.18	..	0.24
Coking coal	0.10	0.10	..	0.03
Oil	–0.02	–0.10	0.09	–0.04
Gas	0.18	..	..	0.82
Petroleum and coal products	0.07	0.05	0.02	0.28
Electricity	0.15	..	..	1.38
Iron and steel	0.60	1.13	–0.15	1.00
Alumina	..	..	–0.05	..
Primary aluminium	–0.05	–0.05	0.46	–0.11
Nonferrous metals	0.29	0.46	0.07	0.46
Chemicals, rubber and plastic	–0.01	–0.02	0.00	–0.24
Wood and paper products	–0.01	–0.01	0.00	–0.21
Dairy products	0.00	0.00	–0.02	0.05
Meat and other food processing	–0.01	–0.02	–0.01	–0.20
Bauxite	..	..	..	..
Other mineral products	0.06	0.04	0.06	0.10
Nonmetallic minerals	0.01	0.10	–0.04	0.02
Manufacturing	0.01	0.02	–0.01	0.50
Trade and transport	0.00	0.02	–0.01	0.60
Services	–0.01	–0.02	0.00	–2.63
Rice	..	..	..	..
Wheat	0.00	..	–0.01	–0.01
Crops	–0.01	–0.02	0.00	–0.13
Fisheries and forestry	–0.01	–0.02	0.00	–0.15
Beef and other livestock	0.00	0.00	–0.01	0.00
Dairy cattle	0.00	..	..	0.01
Sheep and wool	0.00	0.00	0.00	–0.05
Total change				1.74

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Scenario 6: Armington elasticities of import substitution increased

This scenario examines the implications of increasing the Armington elasticities of import substitution used in GTEM for New Zealand. As a result there is a greater degree of homogeneity between domestically produced output and imported products relative to the other scenarios analysed in this report. As a result, the share of domestic consumption between domestic and imported goods will be more responsive to relative price changes. This also implies that New Zealand industries will be more able to adjust their consumption to purchase inputs from the cheapest source and enhance competitiveness relative to the situation with lower Armington elasticities. The specific changes to the parameters are given in appendix C.

As these changes only apply to New Zealand's economy, the impact on the global emissions price is insignificant. There are only minor changes to international emissions quota sales, with the Russian Federation, the Ukraine and eastern Europe selling 685.3 million tonnes of carbon dioxide equivalent emissions quota at 2010. New Zealand's sale of sink credits remains virtually unchanged at 7.1 million tonnes. The global emissions price remains US$11.30 a tonne of carbon dioxide equivalent at 2010 (in 2002 terms).

Under this scenario, real GDP and real GNP are relatively unchanged from the levels projected in the base case at 2010 (table 9). As expected, imports are projected to increase above the base case, in particular imports of iron and steel, petroleum and coal products and nonmetallic minerals.

The greater availability of cheaper inputs produces some benefits to New Zealand's domestic production and exports (table 10). The level of imports from primary aluminium and chemicals, rubber and plastic decline because the lower input costs increase the competitiveness of the domestic industry and leads to a higher level of output relative to the base case in 2010. The increase in the Armington elasticities does result in significant declines in the output of other emission intensive industries relative to the base case, because domestic consumers of these goods in New Zealand are more able to purchase cheaper imports.

Those sectors that are not directly disadvantaged by the imposition of a domestic emissions charge are relatively unaffected by the changes to the Armington elasticities because the relative price changes between domestic and imported goods are not as significant as those of emission intensive goods.

9 Emissions market and economic impacts in New Zealand under scenario 6 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	80.3
Sink credit sales	Mt CO_2 equiv.	7.1
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.4
Economic impact relative to the base case		%
Real GDP		0.00
Real GNP		0.00
Exchange rate (US$/NZ$)		–0.01
Real exports		0.02
Real imports		0.01
Terms of trade		0.00
Real investment		0.00
Real saving		0.00
Real consumption		0.00
Real wages		0.01

Note: All dollar values in 2002 terms.

10 Sectoral output, exports and imports for New Zealand under scenario 6 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	–0.05	..	..	0.00
Steaming coal	–0.35	2.17	..	–0.15
Coking coal	0.01	0.00	..	–0.03
Oil	0.25	–0.92	–0.39	0.29
Gas	–0.23	..	..	–0.47
Petroleum and coal products	–0.03	–0.14	0.69	–0.05
Electricity	–0.24	..	..	–1.11
Iron and steel	–1.62	0.77	4.81	–1.83
Alumina	..	..	0.20	..
Primary aluminium	0.21	0.13	–3.51	0.28
Nonferrous metals	–0.19	0.20	–0.20	–0.23
Chemicals, rubber and plastic	0.22	–0.01	–0.22	1.64
Wood and paper products	0.03	0.05	–0.06	0.58
Dairy products	0.01	0.02	0.60	0.04
Meat and other food processing	0.01	0.01	0.01	0.09
Bauxite	..	..	..	..
Other mineral products	–0.07	0.21	–0.29	–0.05
Nonmetallic minerals	–0.23	0.05	0.77	–0.52
Manufacturing	0.00	0.03	0.01	–0.02
Trade and transport	0.02	–0.02	–0.13	1.53
Services	0.00	0.01	0.00	0.73
Rice	..	..	..	..
Wheat	–0.01	..	0.10	–0.01
Crops	0.02	–0.02	–0.11	0.12
Fisheries and forestry	0.00	–0.02	–0.10	0.06
Beef and other livestock	0.00	–0.01	–0.03	–0.02
Dairy cattle	0.01	..	..	0.04
Sheep and wool	–0.01	–0.01	0.06	–0.04
Total change				0.87

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Scenario 7: Revenue from carbon penalties used to reduce income taxes

Under this scenario it is assumed that the revenue collected through the imposition of the domestic emissions charge in New Zealand is used to reduce the taxes imposed on labor primary factor inputs to production in New Zealand.

In GTEM it is assumed that all labor markets operate at 'full employment'. This assumption implies that policy changes do not change the level of unemployment in any economy. Unemployment is assumed to remain at the 'natural rate', with any downward shifts in the demand for labor offset by reductions in real wages growth. In GTEM the recycling of taxation revenue to lower other taxes has no effect on household demand in the economy. This is because the GTEM modeling framework assumes that all primary factor payments and taxation revenue are allocated to a single regional household, which then allocates this income between savings and private and government consumption based on a fixed proportion formula.

In this scenario, revenue from the domestic emissions charge and the sale of sink credits are recycled back into the economy through lower income taxes. The reduction in taxes results in an increase in after tax real wages, and consequently there is no change in the cost of labor to firms. This means that there is no inducement for firms to change their use of labor from current levels.

There is no net change in the household's income (the reduction in income taxes is equal to the amount of revenue collected from the emissions charge and sink credit sales) and no direct change in household demand for commodities.

The only notable result from this scenario is the increase in after tax real wages (table 11). There are no macroeconomic implications, and no changes to sectoral output (table 12).

11 Emissions market and economic impacts in New Zealand under scenario 7 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	79.6
Sink credit sales	Mt CO_2 equiv.	7.1
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.3
Economic impact relative to the base case		%
Real GDP		0.00
Real GNP		0.00
Exchange rate (US$/NZ$)		0.00
Real exports		0.00
Real imports		0.00
Terms of trade		0.00
Real investment		0.00
Real saving		0.00
Real consumption		0.00
Real wages		0.83

Note: All dollar values in 2002 terms.

12 Sectoral output, exports and imports for New Zealand under scenario 7 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	0.00	..	..	0.00
Steaming coal	0.00	0.00	..	0.00
Coking coal	0.00	0.00	..	0.00
Oil	0.00	0.00	0.00	0.00
Gas	0.00	..	..	0.00
Petroleum and coal products	0.00	0.00	0.00	0.00
Electricity	0.00	..	..	0.00
Iron and steel	0.00	0.00	0.00	0.00
Alumina	..	..	0.00	..
Primary aluminium	0.00	0.00	0.00	0.00
Nonferrous metals	0.00	0.00	0.00	0.00
Chemicals, rubber and plastic	0.00	0.00	0.00	0.00
Wood and paper products	0.00	0.00	0.00	0.00
Dairy products	0.00	0.00	0.00	0.00
Meat and other food processing	0.00	0.00	0.00	0.00
Bauxite	..	..	..	..
Other mineral products	0.00	0.00	0.00	0.00
Nonmetallic minerals	0.00	0.00	0.00	0.00
Manufacturing	0.00	0.00	0.00	0.00
Trade and transport	0.00	0.00	0.00	0.00
Services	0.00	0.00	0.00	0.00
Rice	..	..	..	..
Wheat	0.00	..	0.00	0.00
Crops	0.00	0.00	0.00	0.00
Fisheries and forestry	0.00	0.00	0.00	0.00
Beef and other livestock	0.00	0.00	0.00	0.00
Dairy cattle	0.00	..	..	0.00
Sheep and wool	0.00	0.00	0.00	0.00
Total change				0.00

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Scenario 8: Elasticity of substitution between fuel inputs increased

Under this scenario it is assumed that there is greater substitutability between each fuel type in response to fuel price changes than there was in the base case. In other words, the use of each fuel as an input in production will be more sensitive to changes in its price. Emission intensive industries are assumed to have more scope to reduce their emission intensity through fuel substitution under climate change scenarios. Compared with the base case, these elasticities have been increased from 0.2 to 1.0 for almost all sectors of the New Zealand economy. The exceptions are petroleum products (where the industry is constrained to using crude oil inputs), electricity and iron and steel (both of which substitute using a technology bundle approach, the elasticities of which were greater than unity in the base case).

As these changes correspond only to the New Zealand economy, there are no implications for the global emissions price under this scenario, which remains at US$11.30 a tonne of carbon dioxide equivalent at 2010 (in 2002 terms). However, with the lower abatement costs derived from higher fuel substitutability, New Zealand is projected to undertake significant additional domestic abatement (3.2 million tonnes of carbon dioxide equivalent) at 2010 compared with the base case (2.3 million tonnes). The higher substitutability of fuels in New Zealand implies a lower marginal cost of emission abatement. As a result the economic costs of domestic abatement are relatively small (table 13).

With a larger proportion of New Zealand's Kyoto target achieved through domestic abatement, sales of surplus sink credits are projected to increase by 13 per cent above base case levels, to 8.0 million tonnes. In order to maintain the global emissions price at the level that maximises welfare for the Russian Federation and the Ukraine, the amount of quota sales from these countries and eastern Europe is projected to decline slightly relative to the base case to 683.8 million tonnes of carbon dioxide equivalent at 2010.

Because the global emissions price is relatively unaffected by domestic activity in New Zealand, the assumed changes to fuel substitutability shifts the level of output at which the marginal cost of abatement in New Zealand equals the quota price. The benefits of the change are not projected to result in a significant reallocation of resources between sectors in the economy. As some sectors are more fuel dependent than others, there is some potential for these sectors to benefit relative to the base case.

Output from the nonferrous metals and nonmetallic minerals sectors is higher, relative to the base case in 2010 (table 14). The increase in output offsets a significant proportion of the decline in output projected in these sectors under the base case (that is, through the implementation of the Kyoto Protocol in New Zealand). In particular, the increase in nonmetallic minerals production completely matches the decline projected under the base case. However, only around 10 per cent of the base case decline in nonferrous metals sector output is offset.

In most sectors there is a general switch to electricity as a fuel source. This occurs because New Zealand has a significant amount of hydroelectric generation capacity and, to a lesser extent, gas fired generating capacity. Electricity represents a less emission intensive source of energy for most sectors. The potential for these sectors to switch to electricity is constrained by the elasticity of fuel substitution. With the higher elasticities assumed under this scenario, there is a larger switch to electricity.

13 Emissions market and economic impacts in New Zealand under scenario 8 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	89.8
Sink credit sales	Mt CO_2 equiv.	8.0
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	3.2
Economic impact relative to the base case		%
Real GDP		–0.01
Real GNP		0.01
Exchange rate (US$/NZ$)		0.02
Real exports		–0.03
Real imports		0.01
Terms of trade		0.01
Real investment		0.00
Real saving		0.01
Real consumption		0.00
Real wages		0.00

Note: All dollar values in 2002 terms.

14 Sectoral output, exports and imports for New Zealand under scenario 8 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	–12.78	..	..	–0.28
Steaming coal	–1.58	8.99	..	–1.70
Coking coal	0.12	0.10	..	0.04
Oil	0.06	0.10	–0.01	0.36
Gas	–0.19	..	..	–1.88
Petroleum and coal products	0.01	0.02	–0.09	0.12
Electricity	0.43	..	..	6.79
Iron and steel	–0.25	–0.60	0.32	–0.77
Alumina	..	..	–0.22	..
Primary aluminium	–0.21	–0.22	0.41	–0.68
Nonferrous metals	0.38	0.77	–0.36	0.90
Chemicals, rubber and plastic	0.00	0.01	0.00	–0.23
Wood and paper products	–0.04	–0.10	0.03	–1.69
Dairy products	–0.03	–0.03	0.01	–0.34
Meat and other food processing	–0.02	–0.04	0.02	–0.74
Bauxite	..	..	..	..
Other mineral products	0.02	–0.09	0.10	0.06
Nonmetallic minerals	0.12	0.75	–0.33	0.74
Manufacturing	–0.03	–0.05	0.01	–1.62
Trade and transport	–0.01	–0.05	0.02	–2.59
Services	0.00	–0.05	0.02	–0.65
Rice	..	..	..	..
Wheat	–0.01	..	–0.02	–0.04
Crops	0.00	0.00	–0.01	–0.10
Fisheries and forestry	–0.01	0.00	–0.02	–0.32
Beef and other livestock	–0.01	0.01	–0.02	–0.21
Dairy cattle	–0.02	..	..	–0.33
Sheep and wool	0.00	0.02	–0.02	–0.06
Total change				–5.21

.. Not a significant activity.
Note: All dollar values in 2002 terms.

The higher demand for electricity has consequences for those sectors heavily dependent on electricity (and without significant scope for substitution into other fuel sources). The higher demand for electricity leads to higher electricity prices relative to the base case in 2010. This increases production costs in New Zealand, and adversely affects output in some sectors, particularly in iron and steel and primary aluminium.

Scenario 9: Emission response function reduced for energy sectors

This scenario assumes that there is a smaller response in reducing fugitive emissions in the production of coal and natural gas as a result of an increase in the emissions price. For a given emissions price, the emission reduction response in this scenario is assumed to be half that assumed in the base case.

This scenario has no effect on the global emissions price, which remains at US$11.30 (2002 terms) a tonne of carbon dioxide equivalent. The volume of quota sales by the Russian Federation, the Ukraine and eastern Europe are projected to increase slightly by 2010 to 685.3 million tonnes of carbon dioxide equivalent. In this scenario there are fewer opportunities for costless emission abatement, and consequently New Zealand is projected to use more of its surplus sink credits to meet its Kyoto target, with sink credit sales to the international market projected to be 6.8 million tonnes, which is lower than the base case.

There are no significant changes to New Zealand's macroeconomic variables in relation to the base case (table 15). This is because the lower emission response functions are modeled for the coal and natural gas industries, which are not significant to the New Zealand economy. At the sectoral level, only coal is projected to be affected by the changed assumptions, with output and exports of both coking and steaming coal declining by 1.3 per cent and 0.2 per cent relative to the base case respectively (table 16). There are also some minor flow on implications for iron and steel, with exports projected to decline slightly.

15 Emissions market and economic impacts in New Zealand under scenario 9 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	72.0
Sink credit sales	Mt CO_2 equiv.	6.4
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	1.6
Economic impact relative to the base case		%
Real GDP		0.00
Real GNP		–0.01
Exchange rate (US$/NZ$)		–0.01
Real exports		0.01
Real imports		–0.01
Terms of trade		0.00
Real investment		0.00
Real saving		–0.01
Real consumption		–0.01
Real wages		–0.01

Note: All dollar values in 2002 terms.

16 Sectoral output, exports and imports for New Zealand under scenario 9 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	–0.06	..	..	0.00
Steaming coal	–0.36	–2.97	..	–0.34
Coking coal	–2.19	–2.19	..	–1.13
Oil	–0.04	–0.07	0.02	–0.14
Gas	–0.04	..	..	–0.30
Petroleum and coal products	0.00	–0.01	0.01	0.02
Electricity	–0.02	..	..	–0.36
Iron and steel	–0.07	–0.14	0.04	–0.21
Alumina	..	..	0.02	..
Primary aluminium	0.02	0.02	–0.02	0.07
Nonferrous metals	–0.01	–0.02	0.00	–0.04
Chemicals, rubber and plastic	0.01	0.02	0.00	0.35
Wood and paper products	0.01	0.03	–0.01	0.58
Dairy products	0.02	0.02	–0.01	0.26
Meat and other food processing	0.01	0.02	–0.01	0.52
Bauxite	..	..	..	..
Other mineral products	0.00	0.03	–0.03	–0.01
Nonmetallic minerals	0.00	0.03	–0.02	0.03
Manufacturing	0.02	0.04	–0.01	1.17
Trade and transport	0.00	0.04	–0.02	0.85
Services	0.00	0.04	–0.02	–3.12
Rice	..	..	..	..
Wheat	0.01	..	0.01	0.03
Crops	0.00	0.00	0.00	0.10
Fisheries and forestry	0.01	0.01	0.00	0.25
Beef and other livestock	0.01	0.00	0.01	0.23
Dairy cattle	0.01	..	..	0.24
Sheep and wool	0.00	–0.01	0.01	0.09
Total change				–0.87

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Scenario 10: Amount of sink credits available for sale reduced

Under this scenario it is assumed that 25 per cent of the sink credits that are sold to the international market in the base case are unavailable. This may be the case, for instance, if some of New Zealand's surplus sink credits were banked for future commitment periods. This effectively reduces New Zealand's assumed volume of available sink credits from 22.6 million tonnes to 20.8 million tonnes.

New Zealand's net quota sales are estimated to decline to 5.3 million tonnes at 2010, matching the decline in sink credits. However, the sale of credits by the Russian Federation, the Ukraine and eastern Europe are projected to increase to maintain carbon price at US$11.30 a tonne of carbon dioxide equivalent (2002 terms) at 2010 (table 17).

In this scenario, real GDP is projected to remain at base case levels, although the lower sink revenue results in lower real GNP. As a result of the decline in sink credit sales, New Zealand's exchange rate declines slightly, leading to higher exports and lower imports relative to the base case in 2010.

At the sectoral level, changes to output reflect the increase in export competitiveness resulting from the depreciation of the exchange rate. Metal products, manufacturing and services increase output above base case levels in 2010 (table 18).

17 Emissions market and economic impacts in New Zealand under scenario 10 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	59.6
Sink credit sales	Mt CO_2 equiv.	5.3
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	0.5
Economic impact relative to the base case		%
Real GDP		0.00
Real GNP		–0.03
Exchange rate (US$/NZ$)		–0.01
Real exports		0.04
Real imports		–0.02
Terms of trade		–0.01
Real investment		0.00
Real saving		–0.03
Real consumption		–0.03
Real wages		–0.01

Note: All dollar values in 2002 terms.

18 Sectoral output, exports and imports for New Zealand under scenario 10 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	0.00	..	..	0.00
Steaming coal	0.02	0.00	..	0.01
Coking coal	0.01	0.01	..	0.00
Oil	0.01	0.01	0.00	0.02
Gas	0.01	..	..	0.04
Petroleum and coal products	0.00	0.03	–0.01	0.00
Electricity	0.00	..	..	0.03
Iron and steel	0.05	0.05	0.02	0.03
Alumina	..	..	0.05	..
Primary aluminium	0.05	0.05	0.04	0.14
Nonferrous metals	0.05	0.06	0.01	0.02
Chemicals, rubber and plastic	0.02	0.04	–0.01	0.30
Wood and paper products	0.01	0.06	–0.03	0.44
Dairy products	0.03	0.03	–0.02	0.09
Meat and other food processing	0.02	0.04	–0.03	0.23
Bauxite	..	..	..	..
Other mineral products	0.02	0.03	0.00	0.04
Nonmetallic minerals	0.00	0.07	–0.04	0.02
Manufacturing	0.03	0.08	–0.02	1.03
Trade and transport	0.00	0.06	–0.04	0.01
Services	–0.01	0.06	–0.04	–5.15
Rice	..	..	..	..
Wheat	0.01	..	0.01	0.03
Crops	0.00	0.00	0.00	0.09
Fisheries and forestry	0.01	0.02	0.00	0.22
Beef and other livestock	0.01	0.00	0.02	0.22
Dairy cattle	0.03	..	..	0.17
Sheep and wool	0.00	–0.01	0.02	0.11
Total change				–1.85

.. Not a significant activity.
Note: All dollar values in 2002 terms.

Scenario 11: Iron and steel and primary aluminium excluded from the domestic emissions charge in New Zealand

In this scenario the implications for New Zealand of unilaterally excluding key emission intensive industries from the domestic emissions charge are examined. It is assumed that the iron and steel and primary aluminium sectors are excluded from the domestic emissions charge.

In this scenario there is no change to the global emissions price. Aggregate quota sales by the Russian Federation, the Ukraine and eastern Europe are also projected to remain unchanged from the base case at 685.1 million tonnes of carbon dioxide equivalent at 2010.

The macroeconomic effects of this change in policy are projected to be relatively small (table 19). However, the lower cost of producing iron and steel leads to higher export demand for output from this sector relative to the base case, resulting in an overall appreciation in the New Zealand dollar. This leads to a slight improvement in the capital account and GNP. Real GDP is projected to decline slightly because the economy restructures away from trade and transport and services toward iron and steel and primary aluminium (table 20).

Primary aluminium output is projected to decline below the base case in this scenario. This is because primary aluminium is a large consumer of electricity and does not directly account for a significant volume of greenhouse gas emissions. The increase in iron and steel output leads to an increase in the demand for electricity and increased electricity prices. There is also an increase in the costs of production in electricity intensive sectors such as primary aluminium. These additional costs largely outweigh the effect of excluding the sector from the domestic emissions charge.

Some other sectors also benefit indirectly from this policy. For example, the higher level of activity in the iron and steel sector promotes growth in both the manufacturing and nonferrous metals sectors. There are also some flow-on benefits projected for some fuel sectors, such as steaming coal, natural gas and electricity.

19 Emissions market and economic impacts in New Zealand under scenario 11 at 2010

The emissions market		
Global emissions price	US$/t CO_2-e	11.3
Sink credit income	US$m	77.3
Sink credit sales	Mt CO_2 equiv.	6.8
Domestic abatement (excl. sinks)	Mt CO_2 equiv.	2.1
Economic impact relative to the base case		%
Real GDP		–0.01
Real GNP		0.01
Exchange rate (US$/NZ$)		0.05
Real exports		0.00
Real imports		–0.01
Terms of trade		0.01
Real investment		0.00
Real saving		0.07
Real consumption		–0.01
Real wages		–0.01

Note: All dollar values in 2002 terms

20 Sectoral output, exports and imports for New Zealand under scenario 11 at 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$m
Brown coal	0.06	..	..	0.00
Steaming coal	1.30	–5.66	..	0.61
Coking coal	–0.03	–0.03	..	–0.01
Oil	–0.22	–0.40	0.06	–0.37
Gas	0.54	..	..	1.87
Petroleum and coal products	–0.02	–0.14	0.05	–0.06
Electricity	0.47	..	..	3.38
Iron and steel	4.00	7.53	–1.63	4.81
Alumina	..	..	–0.35	..
Primary aluminium	–0.35	–0.36	1.34	–0.57
Nonferrous metals	1.26	1.56	0.35	1.61
Chemicals, rubber and plastic	–0.09	–0.17	0.02	–1.19
Wood and paper products	–0.10	–0.25	0.07	–2.38
Dairy products	–0.11	–0.12	0.05	–0.65
Meat and other food processing	–0.07	–0.14	0.05	–1.48
Bauxite	..	..	..	..
Other mineral products	0.10	–0.59	0.57	0.14
Nonmetallic minerals	–0.05	–0.27	0.10	–0.20
Manufacturing	0.05	0.11	–0.02	1.51
Trade and transport	–0.03	–0.14	0.05	–4.44
Services	–0.01	–0.17	0.07	–4.22
Rice	..	..	..	..
Wheat	–0.05	..	–0.05	–0.08
Crops	–0.02	0.00	–0.04	–0.24
Fisheries and forestry	–0.04	–0.01	–0.06	–0.49
Beef and other livestock	–0.03	–0.01	–0.03	–0.35
Dairy cattle	–0.09	..	..	–0.63
Sheep and wool	–0.01	0.04	–0.06	–0.05
Total change				–3.47

.. Not a significant activity.
Note: All dollar values in 2002 terms.

analytical framework

The analysis of the impacts of climate change policies in this report is based on simulation results from ABARE's general equilibrium model of the world economy, GTEM. Anthropogenic greenhouse gas emissions arise from many activities throughout the economy and therefore policies designed to constrain emissions will influence almost every part of the economy. Models such as GTEM are able to capture the impacts of policy changes on large numbers of economic variables such as prices, output and trade and investment flows between regions.

GTEM is a dynamic model developed at ABARE to address policy issues with long term, global dimensions, such as climate change. A detailed description of GTEM features can be found in Brown et al. (1999) and a full specification of the model can be viewed on ABARE's web page (www.abareconomics.com).

The GTEM database (based on the GTAP 4.0e database, McDougall et al. 1998) contains 55 sectors and 45 regions. For this study, the database is aggregated to the 23 regions and 28 sectors that allow the most detailed representation of Annex B countries and emission intensive industries (table 21).

The current GTEM database now contains a complete disaggregation of the coal sector into brown coal, coking coal and thermal coal. This disaggregation is important in improving the accuracy of GTEM results in climate analysis because of the very different characteristics of the three types of coal. Brown coal is much more emission intensive, and is not traded internationally. Thermal coal is a key input into electricity generation, whereas coking coal is used in the iron and steel sector, and the two have very different trade patterns.

GTEM's emission database includes combustion and noncombustion carbon dioxide, methane and nitrous oxide emissions, which account for around 99 per cent of global anthropogenic greenhouse gas emissions (IPCC 1996). All 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 1996). Most major sources and sectors are represented:; emissions from waste and agricultural residues, and methane and nitrous oxide emissions from combustion and some industrial processes are not.

In modeling the impact of greenhouse gas abatement policies in GTEM, emission abatement opportunities are available in combustion related carbon dioxide emissions through energy efficiency improvements and fuel switching, and 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.

22 Coverage of sectors and regions for this study

Sectors	Regions
Brown coal	Australia
Steaming coal	United States
Coking coal	Canada
Oil	Japan
Gas	European Union
Petroleum and coal products	Russian Federation and the Ukraine
Electricity	Eastern Europe
Iron and steel	New Zealand
Alumina	European Free Trade Area
Primary aluminium	China
Nonferrous metals	Chinese Taipei
Chemicals, rubber and plastic	India
Wood and paper products	Korea
Dairy products	Indonesia
Meat and other food processing	Rest of ASEAN
Bauxite	Middle East
Other mineral products	South Africa
Nonmetallic minerals	Argentina
Manufacturing	Brazil
Trade and transport	Venezuela
Services	Colombia
Rice	Rest of South America
Wheat	Rest of the world
Crops	
Fisheries and forestry	
Beef and other livestock	
Dairy cattle	
Sheep and wool	

Modeling emission abatement policies

The policy simulations presented in this report include representations of the outcomes from Marrakesh on sinks, the clean development mechanism, emissions trading and the commitment period reserve. The simulations are run for four commitment periods, although only the results of the first commitment period are reported. The specific climate change policy assumptions relating to country participation and sectoral coverage of emissions prices used in this analysis are discussed in the main report.

Most of the significant decisions on the operational rules for the Kyoto Protocol were agreed at Marrakesh, but two other key areas with potentially large economic implications remain open. One is Annex B participation, and the other is the nature of agreements for subsequent commitment periods, a crucial aspect of which will be the negotiated abatement targets.

The United States is assumed to not ratify the protocol in all the simulations. It is assumed that in the United States the greenhouse gas emission intensity of the economy is reduced by 18.0 per cent between 2002 and 2012. This is consistent with President Bush's stated

goal, and represents a reduction below reference case levels, where emission intensity over the same period declined by 14.2 per cent. It is also assumed that the rate of decline in emissions intensity continues over the entire analysis period to 2027.

All participating Annex B parties are assumed to comply with their first commitment period Kyoto targets. Parties' targets are assumed to be held constant in each year of the analysis period. Other studies by ABARE have included tightening emission targets, which results in a considerably higher global emissions price than projected for this analysis (Jakeman, Hester, Woffenden and Fisher 2002).

A further assumption is that methane and nitrous oxide emissions from agriculture are not included in the emission abatement policy of participating countries. Any policy measure designed to reduce greenhouse gas emissions will incur monitoring and enforcement costs. In agriculture these costs are likely to be particularly high as the emission sources tend to be either small and numerous, such as livestock, or diffuse, such as cropping. The cost effectiveness of including these emissions in the abatement policy is subject to much uncertainty at this point, and for these reasons it is assumed that they are excluded in all Annex B countries. However, despite not being subject to the emissions charge, these emissions still contribute to country's greenhouse gas inventories.

In all participating Annex B countries other than New Zealand, all other sectors of the economy and sources of emissions are assumed to be included in the abatement policy. As described in the main report, in New Zealand the steel, aluminium, cement, oil refining and milk powder production sectors are excluded from the domestic emissions charge but are subject to emission intensity reduction requirements. A number of other assumptions are made about the emissions trading market, the behavior of market participants, and the clean development mechanism. These are described in the following sections.

Emissions trading

The cost of meeting Annex B emission abatement commitments depends to a large degree on access to the Kyoto mechanisms, such as emissions trading. Unrestricted international emissions trading allows more abatement to be undertaken in countries where the marginal cost of abatement (at the given quota allocation) is lowest. There will be no incentive for further trade in quota once the marginal abatement cost from each emissions source is equal to the price of the quota. At this point, the cost of Annex B abatement will be minimised, ignoring the effect of transaction costs and the feedback effects of emissions trading on other taxes and distortions in the economy.

In GTEM, modeling international emissions trading requires the aggregate emissions of participating regions to be constrained to their emission reduction commitments under the Kyoto Protocol and in the subsequent commitment periods. The model determines a uniform carbon equivalent penalty across Annex B regions (equivalent to the price of an internationally traded emissions quota) sufficient to meet the aggregate emissions target. The individual Kyoto commitments represent an initial allocation of obligations, or emissions quota, among the participating regions. This can be traded between regions. Income from the sale

of emissions quota is accounted for as foreign income transfers and added to GNP, while payment for purchases is subtracted from GNP.

Restrictions and distortions in emissions trading

Emissions trading can deliver the least cost solution to emission abatement, but this assumes that the market is unrestricted, that transaction costs associated with the transfer of emissions quota are negligible and that existing taxation and subsidy distortions in the greenhouse gas producing sectors of economies are accounted for in the implementation of the trading system.

Restrictions on emissions quota sales limit the extent to which abatement is shifted from countries with high marginal abatement costs (at a given quota allocation), such as Japan, to countries where the marginal abatement cost is lower, such as the Russian Federation and the Ukraine. As a result, marginal abatement costs will not be equalised across regions and the total cost of abatement will not be minimised.

The commitment period reserve requires each party to hold a minimum amount of emissions quota over the commitment period. For each Annex B party, the commitment period reserve is equal to a percentage of each country's assigned amount or its most recently reviewed national inventory, whichever is lower.

The assigned amount rule would apply to parties with emissions above their assigned amount over the commitment period while the most recent inventory rule would apply to parties (such as the Russian Federation and the Ukraine) with the latest inventory levels below their assigned amount over the commitment period. In this analysis, where the commitment period reserve is calculated using the most recent inventory, the level of the reserve is recalculated annually (in line with the annual revision of the inventory). A two-year lag is assumed between the year in which the inventory applies and the application of that inventory to the calculation of the reserve. For example, the 2008 reserve calculation is based on the 2006 inventory.

Market behavior

As a result of the very significant fall in their emissions since 1990, the Russian Federation and the Ukraine are projected to have a zero marginal abatement cost associated with meeting their emissions targets. As a result, these countries are expected to overwhelmingly dominate the emissions quota in terms of sales. Consequently, in this analysis the Russian Federation and the Ukraine are assumed to exercise market power in the emissions quota market, which enables them to restrict their quota sales, and increase the emissions quota price and to maximise the present value of their GNP over the analysis period. Unsold emissions quota is banked for future use.

Banking and intertemporal quota price dynamics

Banking of emissions quota is permitted under Article 3.13 of the Kyoto Protocol, which allows parties whose emissions are below their emission target in one commitment period to carry that additional abatement over to the next commitment period.

In equilibrium, the quota price satisfies the intertemporal arbitrage condition derived by Hotelling (1931). In the context of quota banking, the condition has been derived in Hinchy et al. (1998) and leads to the present value of the emissions quota price being equalised over time. A real discount rate of 7 per cent a year — consistent with the average Annex B rate of interest obtained in the GTEM reference case — was assumed. A more detailed description of modeling the impact of forward looking behavior in the context of quota banking in GTEM is provided in Jakeman et al. (2001).

Clean development mechanism

The clean development mechanism (CDM) was not modeled in this analysis.

reference case

The GTEM reference case provides a representation of the world economy over the simulation period, from 1990 to 2027, in the absence of policies designed to reduce greenhouse gas emissions. Comparing the projections from a policy simulation with results from the reference case allows the effects of implementing a policy change under the Kyoto Protocol to be isolated. Results from the policy simulations are presented only for the first commitment period (2008–12) and are reported at the midpoint (2010).

The GTEM reference case incorporates the impacts of ongoing and future policy changes unrelated to climate change issues, such as the introduction of the goods and services tax in Australia in July 2000. For each commodity in GTEM, Australia's consumption tax rates for 2000 are based on estimates provided by the Centre for Policy Studies at Monash University (P. Adams, Centre for Policy Studies, personal communication, August 2001; Dickson and Rimmer 1999).

The GTEM database starts at 1995 and is updated with the most recent emissions and gross domestic product (GDP) data. Historical data for GDP are included from 1996 to 2000, and emissions for Annex B countries are updated using the most recent available official national inventory data. GDP projections to 2006 in GTEM are based on ABARE (2001c), IMF (2000) and US Department of Energy (2002) forecasts.

Long term GTEM GDP projections are derived by fitting an autoregessive integrated moving average (ARIMA) econometrics forecasting model to the historical GDP data of each economy. Before applying the ARIMA models, data are denoised using the wavelet technique. Wavelet denoising is able to accurately separate the longer term trend from the 'noise' (Percival and Walden 2000). ARIMA models are used to estimate the future path of a variable, in this case GDP, based on its historical, statistical relationship with itself and other variables. A simplified version is employed here, in which GDP projections are based solely on historical trends in GDP.

In the GTEM reference case, the shares of various technologies in electricity generation are based on IEA (2001) projections. As fuel combustion in electricity generation is the largest source of greenhouse gas emissions in most Annex B countries, changes in energy mix over the projection period are likely to be the most important factor affecting emissions intensity.

The GTEM Annex B reference case includes estimates of carbon sequestration under Articles 3.3 and 3.4 of the Kyoto Protocol (table 22). The estimates of Article 3.3 sinks and Article

3.4 agricultural sinks are derived from parties' 1 August 2000 submissions to the IPCC, with the following exceptions:

- the estimates of Australian afforestation/reforestation credits reflect the impact of the short rotation harvesting subrule agreed in Bonn;
- the estimate for New Zealand afforestation/deforestation credits are updated to reflect revised information from the New Zealand Ministry of Agricuture and Forestry;
- the Russian Federation did not present an estimate for Article 3.3 in its 1 August 2000 submission; it is assumed that the Russian Federation will cancel out any Article 3.3 debit using its allowance from forest management activities under Article 3.4.

The estimates of Article 3.4 forest management credits are derived from the Bonn agreement, except where the estimate provided by parties in their August 2000 submissions to the IPCC is lower than the allowance provided in the Bonn agreement, in which case the lower estimate has been used. In Marrakesh the Russian Federation negotiated a significant increase in its allowable ceiling for forest management credits, which is included in this analysis. Based on previous analysis by ABARE, New Zealand was assumed not to derive any credits from Article 3.4 sinks, with all credits attributable to Article 3.3.

22 Carbon sequestration under Articles 3.3 and 3.4 in Annex B during the first commitment period, 2008–12

	Article 3.3	Article 3.4
	Mt CO_2 equiv. a year	Mt CO_2 equiv. equiv. a year
New Zealand	22.6	0.0
Australia	–34.7	0.0
Canada	–15.8	51.7
Japan	–3.7	35.9
European Union	2.0	25.1
Russian Federation and the Ukraine	0.0	125.1 **b**
Eastern Europe	0.0	13.8
EFTA **a**	0.1	2.7

a European Free Trade Area: comprises Switzerland, Norway and Iceland. **b** Includes 121.0 million tonnes carbon dioxide equivalent for the Russian Federation (33 million tonnes carbon equivalent) and 4.1 million tonnes carbon dioxide equivalent for the Ukraine.

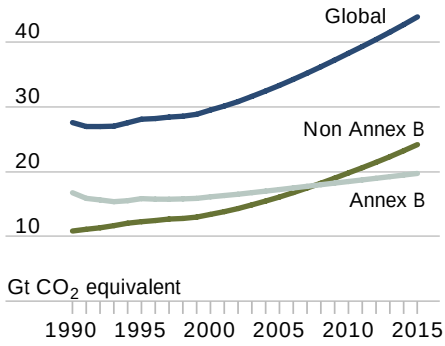
For parties where land use change and forestry are estimated to be a net source of emissions in 1990, such as Australia, Article 3.7 allows 1990 net emissions from land clearing to be added to the 1990 baseline for the purposes of calculating the assigned amount. For this analysis, Australian emissions from land clearing activities were assumed to be 65 million tonnes of carbon dioxide equivalent in 1990 and 56 million tonnes in 2010 and beyond.

Global emissions growth

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 38 billion tonnes by 2010, and over 43 billion tonnes at 2015 (figure A). 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 by 2009. The share of non-Annex B countries in global emissions is projected to increase from around 40 per cent in 1990 to 55 per cent in 2015. For a detailed examination of the driving forces behind developing country emissions growth, see Polidano et al. (2000).

Emissions growth in Annex B regions

A Total emissions of greenhouse gases in the reference case



For Annex B countries, the difference between the projected reference case emissions and emission targets represents the magnitude of their abatement tasks and is therefore a key determinant of the economic impact of the Kyoto Protocol on economies. In general, higher reference case emissions growth in an Annex B region will increase the size of their abatement task and therefore increase the cost of meeting their abatement commitments under the Kyoto Protocol.

The primary determinants of emissions growth are the growth in economic activity (GDP), changes in the emissions 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 emissions intensity reduce the emissions generated from increased economic activity. Changes in emissions intensity over the reference case reflect changes in the structure of the economy, in energy and process efficiency and in energy sources, particularly the fuel mix in electricity generation.

Emissions in the Russian Federation, the Ukraine and eastern Europe are projected to fall between 1990 and 2010. The economic growth rates assumed for the Russian Federation, the Ukraine and eastern Europe over the projection period do not generate sufficient growth in fossil fuel consumption to offset the fall in emissions between 1990 and 1996 resulting from economic restructuring (table 23). 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.

Among Annex B regions, the highest rates of emissions growth between 1990 and 2010 are projected to be in Australia, Canada and the United States. An important determinant of high emissions growth in these countries is the assumed high rates of GDP growth.

In the United States between 1990 and 2000, the decline in emissions intensity was greater than the Annex B average as a result of the increased use of nuclear power in electricity generation and a reduction in methane emissions from coal mining (US Environmental Protection Agency 2001). This trend is not expected to continue over the period 2000–10, as the United States is projected to become increasingly reliant on gas fired electricity at the expense of nuclear power and hydroelectricity over the reference case (IEA 2001).

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). Over the reference case, substitution of gas for coal fired electricity is

23 Projected average annual change in real GDP, emissions and emissions intensity of output, reference case, 1990–2010 a

	Real GDP		Carbon dioxide equivalent emissions		Emissions intensity of output	
	1990–2000	2000–10	1990–2000	2000–10	1990–2000	2000–10
	%	%	%	%	%	%
Australia	3.6	3.6	1.8	1.6	–1.8	–1.9
United States	3.2	3.1	1.1	1.9	–2.1	–1.2
Canada	2.8	3.1	1.9	1.1	–0.9	–2.0
Japan	1.4	0.4	0.9	0.2	–0.5	–0.2
European Union	2.0	2.3	–0.1	0.7	–2.1	–1.6
Russian Federation and the Ukraine	–4.7	4.1	–4.4	1.8	0.3	–2.3
Eastern Europe	0.7	3.9	–1.7	0.8	–2.4	–3.1
New Zealand	2.5	2.7	0.7	1.6	–1.8	–1.1
EFTA b	1.9	2.3	1.2	1.5	–0.7	–0.8
Annex B	1.6	2.7	–0.4	1.4	–2.0	–1.3
Non-Annex B	5.7	5.3	2.2	4.0	–3.5	–1.3
Global	3.1	3.8	0.7	2.6	–2.5	–1.2

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

expected to continue, leading to considerable reductions in emissions intensity and to emissions growth below the Annex B average. In Japan, assumed GDP growth between 1990 and 2010 is below the Annex B average and is projected to lead to relatively low growth in fossil fuel consumption.

changes to the Armington elasticities

A key feature of GTEM is that it models bilateral trade flows of all commodities between all regions. In GTEM an 'Armington' preference structure is adopted. This implies that a good produced in one region is an imperfect substitute for goods produced by the same industry in other regions. The magnitude of the Armington coefficient represents the degree of substitutability between these goods, with a lower number indicating relatively differentiated, and hence less substitutable, products (table 24).

24 Comparison of Armington elasticities used in base case and Scenario 6 for New Zealand

	Base case	Scenario 6
Brown coal	2.8	6.0
Steaming coal	2.8	6.0
Coking coal	2.8	6.0
Oil	2.8	8.0
Gas	2.8	6.0
Petroleum and coal products	1.9	4.0
Electricity	2.8	0.0
Iron and steel	2.8	6.0
Alumina	2.8	6.0
Primary aluminium	2.8	6.0
Nonferrous metals	2.8	4.0
Chemicals, rubber and plastic	1.9	6.0
Wood and paper products	2.1	6.0
Dairy products	2.2	6.0
Meat and other food processing	2.5	4.0
Bauxite	2.8	6.0
Other mineral products	2.8	4.0
Nonmetallic minerals	2.8	6.0
Manufacturing	3.6	4.0
Trade and transport	1.9	0.1
Services	1.9	2.0
Rice	2.2	6.0
Wheat	2.2	6.0
Crops	2.2	6.0
Fisheries and forestry	2.8	6.0
Beef and other livestock	2.8	6.0
Dairy cattle	2.8	6.0
Sheep and wool	2.2	6.0

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Snowy Mountains Engineering Corporation

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