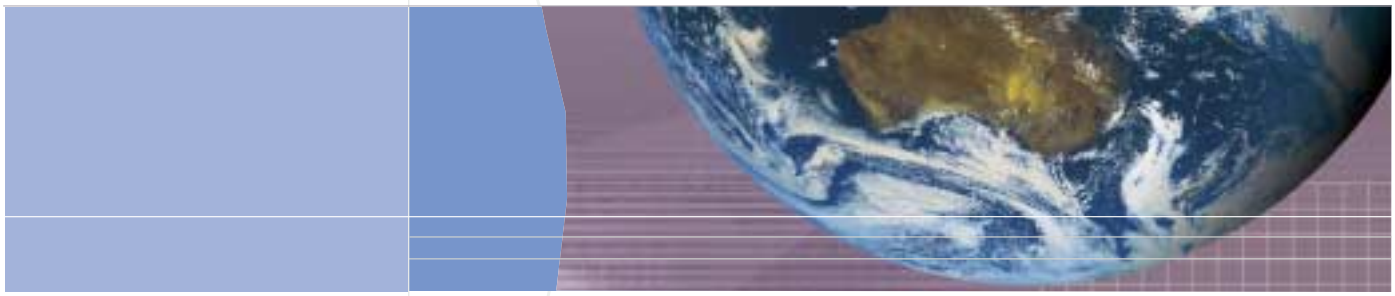
The economic implications of the Kyoto Protocol for New Zealand

Analysis of the first commitment period



ABARE report for the
New Zealand Department of the Prime Minister and Cabinet

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ABARE project 2802

Contents

Figures

Tables

Summary

As part of an ongoing contribution to New Zealand's pre-ratification assessment of the Kyoto Protocol, ABARE was commissioned by the New Zealand Department of the Prime Minister and Cabinet (NZPM&C) to conduct policy analysis for a range of proposals associated with New Zealand's ratification of the Kyoto Protocol.

The scenarios provided to ABARE by NZPM&C for this analysis are summarised in table A. They include a reference case, where no climate change policies are implemented by any country; a base case, where New Zealand, Australia and the United States are the only countries not to ratify the Kyoto Protocol; and three 'policy package simulations' (PPSs) for New Zealand. The policy package simulation scenarios take into account the principal suite of policies that the New Zealand Government proposes to implement. However, in agreement with NZPM&C, some modifications were made to some aspects of the policies in order to meet technical modeling requirements.

For this analysis ABARE's global trade and environment model (GTEM) was used (described in appendix A). GTEM was also used for previous studies for the New Zealand Government on the implications of the Kyoto Protocol (for example, ABARE 2001a). A detailed discussion of the structure of GTEM and its use in analysing climate change issues, particularly for New Zealand, can be found in Heyhoe, Hester, Jakeman, Brown and Hansard (2001).

Underlying assumptions for climate change modeling

In addition to the assumptions for each climate change scenario discussed above, NZPM&C also requested that a number of other assumptions covering climate change issues be included in this analysis:

- Kyoto Protocol emission targets for participating Annex B countries are held constant for all years over the first four commitment periods 2008–12, 2013–17, 2018–22 and 2023–27. Although the simulations were run for these four commitment periods, only the results for the first commitment period were requested by NZPM&C for this analysis;
- banking of emissions quotas (by quota sellers) under Article 3.13 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;

A Description of scenarios modeled in this study

Scenario	Description
Reference case	No climate change policies 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.
Base case	• Implementation of the Kyoto Protocol by all Annex B countries except Australia, New Zealand and the United States. Australia's and New Zealand's policies are unchanged from the reference case, but the United States is assumed to undertake policies to reduce the emission intensity of its economy. • Methane and nitrous oxide emissions from agriculture are excluded from the emissions charge in participating countries. • The global emissions price is determined within the model assuming profit maximising behavior by the Russian Federation and the Ukraine.
Policy Package Simulation 1 (PPS 1)	As for the base case, but: • New Zealand participates in the Protocol with an exogenously set (that is, determined outside the model) domestic emissions charge of NZ$25 per tonne of CO_2 equivalent. The global emissions price is still determined within the model; • the domestic charge is imposed on all industries except those deemed 'competitiveness at risk', which for modeling purposes only are steel, aluminium, cement, oil refining and milk powder production (all of which are required to undertake emission intensity reductions of 2 per cent a year), and methane and nitrous oxide emissions from agriculture (which are exempt from the charge); • New Zealand has 22.6 million tonnes of CO_2 equivalent of sink credits in each year of the analysis; • New Zealand is assumed to bank 25 per cent of sink credits not required for meeting New Zealand's first commitment period target; and • revenue from sinks and the emissions charge are recycled into the New Zealand economy through reduced income taxes.
Policy Package Simulation 2 (PPS 2)	As for PPS1, except the global emissions price and the domestic emissions charge are assumed to be NZ$15 a tonne of CO_2 equivalent in 2008.
Policy Package Simulation 3 (PPS 3)	As for PPS1, but 50 per cent of sink credits not required for meeting New Zealand's first commitment period target are banked for future periods.

- the Russian Federation and the Ukraine are assumed to have and to use market power in order to maximise the net present value of their real gross national product over the four commitment periods; and
- the clean development mechanism (CDM) is assumed to generate 37.2 million tonnes of carbon dioxide equivalent (CO_2-e) of permits in 2010.

Key modeling results

A summary of key macroeconomic results for New Zealand under each scenario is presented in table B. It should be noted that the results presented in this paper are for the year 2010, the midpoint of the first commitment period, and are not the results for the whole of that commitment period. More detailed information on the scenarios and their implications for New Zealand at a macroeconomic and sectoral level is provided in the main body of this report.

Base case

- Under the base scenario the Russian Federation, the Ukraine and eastern Europe (countries with surplus emissions quotas) are projected to sell 535.3 million tonnes CO_2 equivalent of emission quotas on the interna-

B Emissions market and economic impacts in New Zealand under all scenarios in 2010

Scenario	Global emissions price	Domestic emissions charge	Emissions charge revenue	Sink credit sales	Sink credit income
	US$/t CO_2-e	US$/t CO_2-e	US$m	Mt CO_2-e	US$m
Base case	16.6	na	na	na	na
PPS1	16.6	12.5	340.0	7.1	117.8
PPS2	8.6	8.6	238.2	6.6	56.9
PPS3	16.6	12.5	340.1	4.7	78.2

Scenario	Domestic abatement	Real GDP		Real GNP	
	Mt CO_2-e	% diff from ref. case	% diff from base case	% diff from ref. case	% diff from base case
Base case	na	0.01	na	0.03	na
PPS1	2.6	–0.08	–0.10	0.08	0.04
PPS2	2.0	–0.06	–0.08	0.02	–0.01
PPS3	2.6	–0.09	–0.10	0.03	–0.01

Note: na – not applicable.

tional market, and the global emissions price is projected to be US$16.61 a tonne of CO_2 equivalent in 2010.

- With New Zealand not participating in the Protocol, the country's economy is projected to grow relative to the reference case. This is due to the competitive advantage gained as the participating Annex B countries impose an emissions charge on their economies.
- Most macroeconomic variables are projected to rise relative to the reference case, including gross domestic product, wages and investment. But lower economic activity in participating Annex B countries results in reduced demand for New Zealand's commodities, and hence lower exports, relative to the reference case.
- New Zealand's competitive advantage in the base case moves towards more energy and emission intensive commodities and away from traditional sectors such as agriculture. The main stimulus to domestic activity is projected to be from increases in output of chemicals, rubber and plastics, aluminium and services. Food processing, manufacturing (non-energy intensive) and trade and transport also decline, principally as a result of changes in production in participating Annex B countries.

Policy package simulation 1

- Under this scenario New Zealand is assumed to join the Kyoto Protocol. New Zealand is projected to sell 7.1 million tonnes CO_2 equivalent of sink credits in 2010 (worth US$117.8 million), banking 2.4 million tonnes for future commitment periods. The global emissions price remains unchanged from the base case (with the Russian Federation, the Ukraine and eastern Europe projected to reduce total quota sales from the base case level to 528.2 million tonnes CO_2 equivalent), while New Zealand's domestic emissions charge was assumed to be US$12.50 a tonne of CO_2 equivalent (assuming a US$/NZ$ exchange rate of 0.50).
- Economic activity declines slightly in New Zealand and some restructuring is projected relative to both the reference and base cases. However, gross national product is projected to increase relative to both because of the income derived from sink credit sales. This cushions the negative impacts on the economy by increasing total income and hence demand.
- The use of revenue from the domestic emissions charge and the sale of surplus sink credits into reducing taxes on labor offsets the effects of lower domestic activity. Consequently, real after-tax wages remain unchanged from the reference case.
- The output of a number of sectors in New Zealand's economy is projected to decline relative to the base case, particularly energy intensive

manufacturing. Other sectors, such as the services sector, will experience increases in output. Though the services sector contributes significantly to New Zealand's gross domestic product, the increase in output is insufficient to offset the negative effect on gross domestic product from reduced output in other sectors.

- Some activities within these sectors are assumed not to face the domestic emissions charge in this scenario because they are considered 'competitiveness at risk' from climate change policy. Instead, they are required to reduce their emission intensity by 2 per cent a year. This still imposes costs, but is intended to be less costly than the domestic emissions charge. Note that this is a simplification chosen in an attempt to model the impact of a Negotiated Greenhouse Agreement and might produce results that would not actually occur under a Negotiated Greenhouse Agreement. In the case of the steel and oil refining activities, the cost of achieving these efficiency improvements was estimated to be greater than the domestic emissions charge. However, Negotiated Greenhouse Agreement policy, and the right of a company to refuse any such agreement, should prevent this from occurring. For these activities, a cost was imposed equal to that estimated for the aluminium sector in achieving the 2 per cent reduction in emissions intensity. While these industries are exempt from the domestic emissions charge, the emission intensity reduction requirement, together with the higher domestic cost of energy and energy intensive commodities, may reduce the competitiveness of these activities relative to those in countries outside the Protocol.

Policy package simulation 2

- Under this scenario the global emissions price and domestic emissions charge are both assumed to be US$8.59 a tonne of CO_2 equivalent in 2010. The global emissions price was estimated outside the modeling framework and may not represent the profit maximising level for the Russian Federation and the Ukraine.
- Under this scenario, the global emissions price (and hence the charge faced by all participating Annex B countries except New Zealand) is 48 per cent lower than that estimated under PPS1 in 2010, while the domestic charge in New Zealand is only 31 per cent lower. As a result, some participating Annex B countries gain competitiveness against New Zealand compared with PPS1.
- The lower global emissions price reduces New Zealand's sink credit income from the sale of credits to the international market. The lower price also provides less financial incentive for firms to undertake emissions abatement measures, resulting in a lower level of domestic abatement and an increase in the use of sink credits to meet New Zealand's Kyoto target.

As a result, New Zealand's gross national product is projected to be slightly lower under this scenario, relative to PPS1.

- The lower global emissions price and domestic emissions charge also reduce the level of revenue recycling, resulting in lower real after-tax wage rates projected under this scenario than under PPS1.
- This scenario results in less sectoral restructuring than PPS1, with smaller changes to sectoral output. Services account for the largest positive impact on domestic activity, though the impact is significantly less than under PPS1.

Policy package simulation 3

- Under this scenario New Zealand banks 4.7 million tonnes of carbon dioxide equivalent permits in 2010. Compared with PPS1, New Zealand earns less sink credit revenue in the first commitment period, reflecting the lower level of credits made available for sale. This results in lower gross national product than projected under PPS1, and a lower level of domestic demand and economic activity in New Zealand.
- The lower sink credit sales result in a smaller appreciation of the New Zealand dollar, and hence exports are slightly higher in this scenario compared with PPS1. This slight stimulus to demand offsets some of the effect of lower sink credit sales.
- There are only slight differences in the level of restructuring of New Zealand's economy projected under this scenario, compared with PPS1.

1. Introduction

As part of an ongoing contribution to New Zealand's pre-ratification assessment of the Kyoto Protocol, ABARE has been commissioned by the New Zealand Department of the Prime Minister and Cabinet (NZPM&C) to conduct policy analysis for a range of proposals associated with New Zealand's ratification of the Kyoto Protocol. The scenarios modeled and described here include:

- a reference case simulation (no policies associated with the Kyoto Protocol are implemented in any country);
- the base case (all Annex B countries except Australia, the United States and New Zealand implement the protocol); and
- three 'policy package simulations' (PPSs) (reflecting potential circumstances that the New Zealand Government could face in implementing its policy package domestically).

For this analysis ABARE's global trade and environment model (GTEM) was used (appendix A). GTEM was also used for previous studies for the New Zealand Government on the implications of the Kyoto Protocol (for example, ABARE 2001a). A detailed discussion of the structure of GTEM and its use in analysing climate change issues, particularly for New Zealand, can be found in Heyhoe, Hester, Jakeman, Brown, and Hansard (2001).

Reference case

For this analysis the reference case was developed primarily as a basis for establishing model parameters. As all policy scenarios are compared against the base case, this paper does not include detailed analysis of the reference case in relation to scenario results. However, appendix B provides more detail on the reference case. Readers are also referred to other ABARE publications, for example Jakeman, Hester, Woffenden and Fisher (2002).

For this analysis ABARE has made four main changes to the reference case used in previous ABARE analysis undertaken for the New Zealand Government. These changes are:

- The social accounting (or input output) matrix for New Zealand has been updated with latest (1996) data published by Statistics New Zealand (2001). Previous ABARE analyses have used information from the GTAP

model (Hertel 1997) based on New Zealand's 1992-3 input output tables. The new data have been reconciled with other country information and New Zealand's emission inventory.

- New Zealand's latest national greenhouse gas inventory for 2000 has been incorporated into this analysis, whereas previous ABARE analyses used the 1998 inventory. This will imply some changes to the emission coefficients of each sector in New Zealand's economy. See Ministry for Economic Development (2002) for further detail about the inventory.
- In consultation with NZPM&C, ABARE has modeled a restriction on the use of natural gas in particular industries on New Zealand's South Island, reflecting the absence of natural gas or appropriate infrastructure. The industries affected are aluminium, cement, meat products, food processing and dairy products. The restriction will constrain the expansion of output in these industries and the potential for fuel switching in response to climate change policies. Note that the possible introduction of new hydro capability or other fuel sources in the South Island by 2010 could counter this constraint. These possibilities were not included in this analysis.
- The substitutability between domestically produced and imported commodities for New Zealand was increased by adjusting the values of the Armington coefficients for New Zealand (appendix C). Policies that increase the price of domestic goods (such as imposing an emissions charge) will lead to a higher increase in imports and a more significant decline in domestic output than previously, other things being equal.

Because of these changes to the reference case, results from this analysis may not be directly comparable with results from previous studies.

Base case

In this scenario all Annex B countries except Australia, the United States and New Zealand implement policies to achieve their Kyoto Protocol commitments. All the PPSs analysed in this paper are compared with this base case as a measure of the implications for New Zealand's ratification of the Kyoto Protocol. Discussion of ABARE's modeling of the Kyoto Protocol is provided in appendix A. Further analysis of other potential climate change scenarios are presented in Jakeman, Hester, Woffenden and Fisher (2002).

Assumptions used in modeling this scenario were provided by NZPM&C and include:

- first commitment period Kyoto Protocol targets are maintained for all subsequent periods;

- banking of emissions units by the Russian Federation, the Ukraine and eastern Europe;
- a global emissions price determined internationally which increases over time as a result of profit maximising behavior by the Russian Federation and the Ukraine;
- all greenhouse gas emissions in participating Annex B countries are exposed to the global emissions price, except methane and nitrous oxide from agriculture. These emissions are still included in countries' national greenhouse gas inventories;
- the United States implements least cost policies to reduce its emission intensity by 18 per cent over the period 2002 to 2012, while remaining outside the Kyoto Protocol; and
- Australia and New Zealand do not undertake any emission related policies beyond those already in place.

Policy package simulation 1

This scenario is based on the assumptions for the base case, with the following changes:

- the Kyoto Protocol is ratified by New Zealand;
- the domestic emissions charge for New Zealand is assumed to be NZ$25 a tonne of carbon dioxide equivalent, which remains constant throughout the analysis period;
- all greenhouse gas emissions in New Zealand are exposed to the domestic emissions charge except:
  - methane and nitrous oxide from agriculture;
  - sectors considered to be 'competitiveness at risk' as a result of climate change policy. These sectors are not exposed to the domestic emissions charge but are instead required to reduce emission intensity to world's best practice levels (provided by NZPM&C and assumed to be 2 per cent a year) between 2005 and 2012. This emissions intensity reduction has been simplified to model the impact of Negotiated Greenhouse Agreements. As the sectors qualifying for this status have not yet been determined by the New Zealand Government, it has been assumed here that the steel, aluminium, cement, oil refining and milk powder production sectors qualify; and
  - all emissions from the agricultural and 'competitiveness at risk' sectors are still included in New Zealand's greenhouse gas inventory;

- New Zealand has 22.6 million tonnes CO_2 equivalent greenhouse sink credits in each year of the analysis. In practice, resource constraints will tend to reduce the availability of sink credits over time, which will increase the costs of climate change policies in later commitment periods;
- 25 per cent of sink credits not required for meeting New Zealand's first commitment period target are banked for future commitment periods, with the remainder sold on the international market; and
- revenue from sink credit sales and the domestic emissions charge are recycled into the New Zealand economy through reduced income taxes. This is implemented in the model by reducing the rate of tax paid on labor use by all sectors of the economy by an equal proportion.

Policy package simulation 2

The assumptions for this scenario are the same as those for PPS1, with the following exception:

- the global emissions price and New Zealand's domestic emissions charge are set exogenously (outside the modeling framework) at NZ$15 a tonne of CO_2 equivalent at 2008, and increase over time. Because this charge is not determined within the model, it may not represent the profit maximising level of quota sales by the Russian Federation and the Ukraine.

Policy package simulation 3

The assumptions for this scenario are the same as those for PPS2, with the following exception:

- 50 per cent of sink credits not required for meeting New Zealand's first commitment period target are sold on the international market, and the remainder are banked and used in later commitment periods.

2. Key modeling results for the first commitment period (2008 to 2012)

Base case scenario

Macroeconomic impacts

Under this scenario New Zealand is projected to benefit slightly from not ratifying the Kyoto Protocol (relative to the reference case where no countries ratify), with both gross domestic product and gross national product increasing above reference case levels (table 1). The global emissions price is estimated to be US$16.61 (in 2002 dollars) a tonne of CO_2 equivalent in 2010 under this scenario, with the Russian Federation, the Ukraine and eastern Europe (those countries with surplus emissions quotas) estimated to sell around 535 million tonnes CO_2 equivalent of emission permits. New Zealand's emissions are projected to increase above reference case levels as a result of the increased level of overall domestic activity.

1 Macroeconomic impacts in New Zealand under the base scenario in 2010

	% difference from reference case
Real GDP	0.01
Real GNP	0.03
Exchange rate (US$/NZ$)	–0.08
Real exports	–0.05
Real imports	0.09
Terms of trade	0.03
Real investment	0.12
Real saving	0.03
Real consumption	0.04
Real wages	0.03

However, emissions from some sectors of New Zealand's economy are projected to decline. These sectors include fossil fuels and agricultural activities. Fossil fuels' emissions decline as a result of lower world demand and hence production. Agricultural activities' emissions decline slightly due to increased agricultural output in participating Annex B countries. Increased competition in world agricultural markets from lower cost producers slightly lowers the level of output from New Zealand's agricultural sector, relative to the reference case.

Increases in production costs in participating Annex B countries relative to the reference case improve New Zealand's overall competitive position and increase investment in the economy. Nevertheless, the overall value of exports is projected to decline relative to the reference case, while imports increase. This reflects changes in world economic activity. Exports decline owing to

lower demand among New Zealand's major trading partners (participating Annex B countries), while imports increase as a result of the higher level of domestic activity. The fact that Australia, one of New Zealand's main competitors in agricultural markets, is also assumed not to ratify the Protocol tempers New Zealand's potential competitive advantage. These changes in New Zealand's trade balance lead to a slight depreciation of the New Zealand dollar relative to the US dollar.

Sectoral impacts

The implementation of climate change policies in participating Annex B countries alters New Zealand's competitive advantage. Factors contributing to these changes include:

- shifts in world demand and prices;
- altered production in participating Annex B countries; and
- the absence of a domestic emissions charge in New Zealand in this scenario.

The economy is projected to restructure towards energy intensive sectors such as iron and steel, primary aluminium, chemicals, rubber and plastics and nonferrous metals (table 2). This is because higher costs associated with the global emissions price increase the world prices of these commodities, enhancing the returns available to New Zealand producers, who do not pay an emissions charge. The increase in overall domestic activity and incomes in the economy also induces growth in the services sector relative to the reference case. The relative significance of this sector to the economy results in a considerable increase in its contribution to gross domestic product, despite only slight output growth in this sector.

Agricultural production is generally projected to decline under this scenario relative to the reference case. This reflects the shift in New Zealand's economy towards more energy intensive goods, as well as changing patterns of production in some participating Annex B countries. For instance, in Canada and eastern Europe, shifts occur towards livestock and food processing activities. This move is largely driven by the assumption that methane and nitrous oxide emissions from agriculture are omitted from the emissions in this scenario. The United States, which is assumed to be reducing emissions intensity, is also projected to increase agricultural output under this scenario. The higher level of supply of these commodities leads to lower world agricultural prices.

New Zealand's comparative advantage in agricultural activities, particularly sheep, wool, beef and other livestock, means the decline in these activities is less pronounced than for downstream processing activities such as food and

2 ***Change in sectoral output, exports and imports for New Zealand under the base scenario in 2010 relative to the reference case***

	Output	Exports	Imports	GDP change
	%	%	%	(US$ million)
Brown coal	0.01	..	..	0.00
Steaming coal	–0.43	–14.02	..	–0.28
Coking coal	–2.06	–2.06	..	–0.63
Oil	–0.59	–0.92	0.46	–1.29
Gas	0.03	..	..	0.15
Petroleum and coal products	0.12	–0.45	0.58	0.40
Electricity	0.26	..	..	3.30
Iron and steel	1.86	4.06	–0.24	2.91
Alumina	..	..	2.82	..
Primary aluminium	2.82	2.85	0.63	4.63
Nonferrous metals	0.75	1.25	0.13	1.24
Chemicals, rubber and plastic	0.46	0.66	–0.26	7.16
Wood and paper products	–0.03	–0.02	0.16	–0.76
Dairy products	–0.07	–0.08	0.22	–0.55
Meat products	–0.13	–0.21	0.34	–1.14
Food	–0.12	–0.28	0.16	–2.21
Bauxite	..	..	..	..
Other mineral products	0.42	0.45	–0.13	0.71
Nonmetallic minerals	0.07	1.01	–0.08	0.36
Manufacturing	–0.09	–0.23	0.11	–3.28
Trade and transport	–0.02	–0.33	0.04	–4.39
Services	0.01	–0.51	0.32	4.62
Rice	..	..	..	..
Wheat	–0.06	..	–0.09	–0.12
Crops	–0.05	–0.02	0.07	–0.76
Forestry	0.04	0.09	..	0.38
Fisheries	0.00	0.16	–0.36	–0.02
Livestock	–0.01	0.10	–0.02	–0.27
Dairy cattle	–0.06	..	..	–0.66
Sheep and wool	–0.03	0.07	0.47	–0.82
Total change				8.68

.. Not a significant activity.

meat production. Exports of these primary commodities increase relative to the reference case.

Policy package simulation 1

In this scenario New Zealand's domestic emissions charge is assumed to be US$12.50 a tonne of CO_2 equivalent, which is lower than the global emissions price. Some activities are exempt from this charge and are required to achieve emission intensity reductions consistent with world's best practice over the

period 2005 to 2012. Based on advice from NZPM&C, the world's best practice was assumed to be an average 2 per cent a year reduction in emissions intensity.

In the ABARE model in some instances, such as for steel and oil refining activities, this level of reduction results in an effective cost that is greater than the domestic emissions charge. In such cases it would be less costly for those activities to face the domestic emissions charge. It is also unlikely that in such cases a Negotiated Greenhouse Agreement would be structured around a 2 per cent a year reduction in emissions intensity.

The intention of the Negotiated Greenhouse Agreement was to reduce the impact of climate change policies on 'competitiveness at risk' activities in the economy. As such, a cost was imposed on these activities equal to that estimated for the aluminium sector in achieving the 2 per cent reduction in emissions intensity. As a result, the emission intensity reduction in some sectors was less than 2 per cent a year (table 3).

3 Estimated average annual emission intensity reduction in key industries in New Zealand under the PPS1 between 2005 and 2012

Activity	GTEM sector	%
Oil refining **a**	Oil	0.44
Aluminium	Primary aluminium	2.00
Steel **a**	Iron and steel	0.52
Cement	Nonmetallic minerals	2.00
Milk powder production	Dairy products	2.00

a Assumes a cost on emissions equal to that estimated for the aluminium activity.

Despite having lower direct costs, these activities may face higher input costs, in particular for energy and energy intensive inputs, as a result of the abatement policy package. Modeling results indicate that the competitiveness of these activities, compared with countries not participating in the Kyoto Protocol, is sensitive to increases in input costs.

Macroeconomic impacts

The introduction of an emissions charge into the New Zealand economy is projected to result in a small decline in overall economic activity relative to the base scenario (table 4). This reflects the loss in competitive advantage, particularly in energy intensive commodities. However, the significant amount of sink credits estimated for New Zealand enables the country to become a net seller of sink credits in the first commitment period. As a result, gross national product, which includes net income transfers, is projected to increase above base case levels. And real consumption is not projected to decline below base case levels to the same extent as the decline in gross domestic product.

The impacts of New Zealand's participation in the emissions market are presented in table 5. There is no projected change in the global emissions price relative to the base case, despite the changes in international trade in permits caused by the addition of permits from New Zealand. This is because the Russian Federation and the Ukraine are assumed to adjust their market behavior to maximise the net present value of their quota sales over the period to 2027 (this aspect of ABARE's climate change modeling is described further in appendix A). As a result of New Zealand's participation in the international emissions market, sales of emission credits from the Russian Federation, the Ukraine and eastern Europe are projected to fall from 535.3 million tonnes CO_2 equivalent of permits in the base case to 528.2 million tonnes in this scenario.

4 Macroeconomic impacts in New Zealand under the PPS1 scenario in 2010

	Difference relative to:	
	Reference case	**Base case**
	%	%
Real GDP	–0.08	–0.10
Real GNP	0.08	0.04
Exchange rate (US$/NZ$)	0.12	0.20
Real exports	–0.27	–0.22
Real imports	0.14	0.05
Terms of trade	0.09	0.06
Real investment	0.03	–0.09
Real saving	0.23	0.21
Real consumption	–0.02	–0.06
Real wages	–0.11	–0.13

New Zealand is projected to sell 7.1 million tonnes CO_2 equivalent of emission permits in 2010, at a value of almost US$118 million (in 2002 dollars), or around 0.2 per cent of projected gross domestic product. It was also estimated that 2.4 million tonnes of emission permits (that is, 25 per cent of surplus sink credits) would be banked for future commitment periods. Over the course of the first commitment period, New Zealand's emissions are projected to continue to increase, although at a lower rate than under the base case scenario.

5 Emissions market impacts in New Zealand under the PPS1 scenario in the first commitment period

		2008	**2009**	**2010**	**2011**	**2012**
Global emissions price	US$/t CO_2-e	14.5	15.5	16.6	17.8	19.0
Domestic emissions charge	US$/t CO_2-e	12.5	12.5	12.5	12.5	12.5
New Zealand emissions	Mt CO_2-e	78.9	80.1	81.4	82.8	84.3
Domestic abatement (excl. sinks)	Mt CO_2-e	2.4	2.6	2.7	2.9	3.0
Total sink credits	Mt CO_2-e	22.6	22.6	22.6	22.6	22.6
Banking	Mt CO_2-e	3.0	2.7	2.4	2.0	1.6
Sink credit sales	Mt CO_2-e	8.9	8.0	7.1	6.0	4.9
Emissions charge revenue	US$m	391.5	396.6	401.9	409.0	416.3
Sink credit income	US$m	129.8	124.6	117.8	106.8	93.2

The introduction of the domestic emissions charge reduces overall domestic economic activity and encourages economic restructuring and rationalisation of fuel use to reduce emissions intensity. Through these changes, New Zealand is projected to reduce emissions by 2.7 per cent relative to the base case in 2010. Emissions decline in all sectors of the economy relative to the base case, particularly in energy and energy intensive manufacturing sectors. This is despite some of these sectors obtaining a concessionary charge rather than the full domestic emissions charge.

Agricultural emissions decline only marginally relative to the base case. This is partly a reflection of methane and nitrous oxide emissions not being subject to the emissions charge, but also because agricultural activity was projected to decline under the base scenario.

The higher production costs associated with the emissions charge are also projected to result in lower investment in New Zealand relative to the base case. However, because the carbon charge imposed in New Zealand in this scenario is lower than the prevailing global emissions price, investment is projected to be higher than in the reference case. The lower domestic emissions charge creates a small cost advantage for New Zealand over other participating Annex B countries. There is still some reallocation of investment funds towards New Zealand, though the change is not as pronounced as projected under the base case.

Sectoral impacts

In this scenario the competitiveness of energy intensive commodities in the New Zealand economy declines relative to the base case. As a result, the economy is projected to restructure away from these sectors (table 6). Domestic production of iron and steel, primary aluminium, nonferrous metals and chemicals, rubber and plastics declines below base case levels and imports of most of these commodities increase. These relative reductions in output occur despite a concessionary emissions charge that is lower than the domestic emissions charge being applied to these sectors.

The energy sector is also projected to contract, although exports of some primary energy sources, such as coal and crude oil, increase as a result of higher energy demand in nonparticipating countries. The demand for final energies in New Zealand, such as gas, petroleum products and electricity, is projected to decline.

Output from both beef and dairy livestock production is also projected to decline slightly below the base case. Even though methane and nitrous oxide

6 Change in sectoral output, exports and imports for New Zealand under the PPS1 scenario in 2010 relative to the base case

	Output	Exports	Imports	GDP change
	%	%	%	US$ million
Brown coal	–6.16	..	..	–0.10
Steaming coal	–9.03	55.27	..	–4.39
Coking coal	–2.64	–2.64	..	–0.56
Oil	0.39	1.38	–2.03	0.65
Gas	–2.23	..	..	–7.15
Petroleum and coal products	–1.30	0.10	–0.90	–4.32
Electricity	–2.53	..	..	–19.45
Iron and steel	–11.34	–14.38	7.87	–14.39
Alumina	..	..	–1.98	..
Primary aluminium	–1.98	–1.93	–3.34	–2.70
Nonferrous metals	–4.11	–5.26	0.44	–5.35
Chemicals, rubber and plastic	–0.57	–0.61	0.37	–6.93
Wood and paper products	–0.03	–0.11	0.15	–1.31
Dairy products	–0.07	–0.07	0.08	–1.59
Meat products	–0.18	–0.29	0.22	–1.04
Food	0.12	0.25	–0.17	1.01
Bauxite	..	..	..	..
Other mineral products	–1.04	–0.20	–1.15	–1.38
Nonmetallic minerals	–0.01	–0.24	0.29	–0.07
Manufacturing	0.02	0.11	–0.07	0.34
Trade and transport	–0.05	–0.17	0.00	–12.74
Services	0.11	0.55	–0.28	16.88
Rice	..	..	..	..
Wheat	0.03	..	–0.22	0.01
Crops	0.15	0.20	–0.22	1.26
Forestry	0.20	0.35	..	1.50
Fisheries	0.02	–0.12	0.26	0.07
Livestock	–0.07	–0.08	0.03	–1.12
Dairy cattle	–0.06	..	..	–0.30
Sheep and wool	0.07	0.20	–0.31	0.79
Total change				–62.36

.. Not a significant activity.

emissions from the agricultural sectors are assumed not to be subject to the domestic emissions charge, these sectors still incur higher energy costs under this scenario. In contrast, output in some other agricultural sectors (such as wheat, crops and sheep/wool) is projected to increase above the base case.

There is also some restructuring of the economy towards the service sector, which contributes significantly to total gross domestic product. This structural move reflects a shift in the economy towards less energy intensive sectors.

Policy package simulation 2

Macroeconomic impacts

In this scenario the overall economic activity in the New Zealand economy is projected to decline slightly below the base case level (table 7). However, gross domestic product is higher than projected under the PPS1 scenario. This is because the global emissions price and the domestic emissions charge for this scenario were set at levels below those for PPS1 (tables 5 and 8). The lower global emissions price implies higher quota sales by the Russian Federation and the Ukraine in the first commitment period relative to the base case and PPS1 scenarios. In this scenario, it is projected that these countries sell 648.9 million tonnes of carbon dioxide equivalent emissions quota in 2010.

7 Macroeconomic impacts in New Zealand under the PPS2 scenario in 2010

	Difference relative to		
	Reference case	**Base case**	**PPS1**
	%	%	%
Real GDP	–0.06	–0.08	0.02
Real GNP	0.02	–0.01	–0.06
Exchange rate (US$/NZ$)	0.04	0.12	–0.08
Real exports	–0.13	–0.08	0.14
Real imports	0.07	–0.02	–0.07
Terms of trade	0.05	0.02	–0.04
Real investment	0.00	–0.12	–0.03
Real saving	0.13	0.10	–0.11
Real consumption	–0.05	–0.08	–0.03
Real wages	–0.16	–0.18	–0.05

8 Emissions market impacts in New Zealand under the PPS2 scenario in the first commitment period

		2008	**2009**	**2010**	**2011**	**2012**
Global emissions price	US$/t CO_2-e	7.5	8.0	8.6	9.2	9.8
Domestic emissions charge	US$/t CO_2-e	7.5	8.0	8.6	9.2	9.8
New Zealand emissions	Mt CO_2-e	79.7	80.8	82.0	83.4	84.8
Domestic abatement (excl. sinks)	Mt CO_2-e	1.7	1.9	2.1	2.3	2.5
Total sink credits	Mt CO_2-e	22.6	22.6	22.6	22.6	22.6
Banking	Mt CO_2-e	2.8	2.5	2.2	1.9	1.5
Sink credit sales	Mt CO_2-e	8.4	7.5	6.6	5.6	4.5
Emissions charge revenue	US$m	240.5	260.3	281.6	306.0	332.3
Sink credit income	US$m	62.9	60.3	56.8	51.3	44.6

The global and domestic emissions charges are assumed to be equal in this scenario. The effect of this in comparison to results from PPS1 is evident in some of the macroeconomic and sectoral results. For example, investment is projected to be lower under this scenario than under PPS1. This is because the larger reduction in the global emissions price implies a larger reduction in costs in all participating Annex B countries relative to New Zealand. As a result, a greater share of investment is projected to be diverted to these countries.

In contrast to PPS1, gross national product is projected to fall below base case levels. This is because of the reduction in the value and volume of New Zealand's sink credit sales in this scenario relative to PPS1.

The lower level of revenue from the sale of sink credits also has some implications for revenue recycling within the New Zealand economy. As a result, income taxes and real after tax wages are projected to be significantly below PPS1 levels.

The lower global emissions price results in a higher level of global economic activity and a higher level of exports from New Zealand relative to PPS1. The lower level of income from sink credit sales contributes to lower overall domestic demand and lower projected levels of imports.

Sectoral impacts

Under this scenario there would be less restructuring of New Zealand's economy relative to PPS1. However, in most cases the general direction of restructuring is the same (table 9). The energy and energy intensive manufacturing sectors (comprising iron and steel, aluminium and nonferrous metals) are projected to decline relative to the base case, with the exports of some primary energy commodities increasing.

However, output from some manufacturing sectors in New Zealand, such as aluminium and nonmetallic minerals, is projected to decline by more than under PPS1. This is because under the base case, output from these industries was projected to decline considerably in some participating Annex B countries, such as Canada and Japan. This shortfall in production was matched by increases in Australia, New Zealand and non-Annex B countries. However, under this scenario (with a lower emissions charge), production in Canada and Japan is projected to be higher relative to PPS1. As a result, production in other countries, including New Zealand, would decline.

In this scenario the lower global emissions price also reduces the level of restructuring in other participating Annex B countries. As a result, compared

9 ***Change in sectoral output, exports and imports for New Zealand under the PPS2 scenario in 2010 relative to the base case***

	Output	Exports	Imports	GDP change
	%	%	%	US$ million
Brown coal	–4.53	..	..	–0.07
Steaming coal	–6.57	47.90	..	–3.33
Coking coal	–1.06	–1.06	..	–0.21
Oil	0.45	1.15	–1.59	0.78
Gas	–1.60	..	..	–5.15
Petroleum and coal products	–0.96	–0.06	–0.61	–3.12
Electricity	–1.96	..	..	–16.18
Iron and steel	–9.26	–12.43	6.12	–11.60
Alumina	..	..	–2.15	..
Primary aluminium	–2.15	–2.13	–2.80	–2.93
Nonferrous metals	–3.21	–4.15	0.16	–4.16
Chemicals, rubber and plastic	–0.48	–0.59	0.28	–5.79
Wood and paper products	0.02	0.02	–0.07	0.28
Dairy products	0.02	0.02	–0.11	–0.41
Meat products	–0.04	–0.07	–0.04	–0.14
Food	0.16	0.36	–0.24	1.67
Bauxite	..	..	..	..
Other mineral products	–0.86	–0.16	–0.87	–1.15
Nonmetallic minerals	–0.08	–0.68	0.35	–0.35
Manufacturing	0.08	0.23	–0.12	2.09
Trade and transport	–0.03	0.11	–0.04	–7.42
Services	0.06	0.67	–0.36	5.49
Rice	..	..	..	..
Wheat	0.07	..	–0.11	0.08
Crops	0.12	0.14	–0.15	1.08
Forestry	0.18	0.29	..	1.36
Fisheries	0.03	–0.15	0.37	0.11
Livestock	–0.02	–0.08	0.05	–0.46
Dairy cattle	0.02	..	..	0.23
Sheep and wool	0.07	0.11	–0.36	0.78
Total change				–48.54

.. Not a significant activity.

with both the base case and PPS1, there is less restructuring toward agriculture and food processing activities in some countries.

The services sector accounts for the largest positive impact on domestic activity in this scenario. However, the increase in activity in the services sector is significantly less than under PPS1. Two main factors contribute to this outcome:

- the lower level of sink credit revenue reduces the effectiveness of revenue recycling, resulting in a smaller reduction in operating costs of labor intensive industries such as services; and
- the lower sink credit revenue reduces household demand, and the general demand for services.

Policy package simulation 3

This scenario is identical to the PPS1 scenario, except New Zealand is assumed to bank a higher proportion (50 per cent) of its surplus sink credits in the first commitment period. The scenario therefore assesses the implications of changes in sink credit income to the New Zealand economy.

Macroeconomic impacts

There are only slight differences in the macroeconomic effects projected under this scenario relative to PPS1. The effects are driven by the lower level of sink credit income, which is projected to affect household and government demand and the level of revenue recycling.

Overall, gross domestic product is unchanged compared with the PPS1 scenario. Gross national product is projected to be slightly lower as a result of the lower sink credit revenue (table 10). Lower household and government consumption reduces the demand for domestic products and imports, while the lower level of sink credit sales results in a smaller appreciation of the New Zealand dollar. As a result, there is a slight increase in export competitiveness.

10 *Macroeconomic impacts in New Zealand under the PPS3 scenario in 2010*

	Difference relative to		
	Reference case	**Base case**	**PPS1**
	%	%	%
Real GDP	–0.09	–0.10	0.00
Real GNP	0.03	–0.01	–0.05
Exchange rate (US$/NZ$)	0.09	0.17	–0.03
Real exports	–0.19	–0.14	0.08
Real imports	0.09	0.00	–0.05
Terms of trade	0.07	0.04	–0.02
Real investment	0.03	–0.10	–0.01
Real saving	0.18	0.15	–0.05
Real consumption	–0.07	–0.11	–0.05
Real wages	–0.12	–0.14	–0.01

11 ***Emissions market impacts in New Zealand under the PPS3 scenario in the first commitment period***

		2008	2009	2010	2011	2012
Global emissions price	US$/t CO_2-e	14.5	15.5	16.6	17.8	19.0
Domestic emissions charge	US$/t CO_2-e	12.5	12.5	12.5	12.5	12.5
New Zealand emissions	Mt CO_2-e	78.9	80.2	81.4	82.9	84.3
Domestic abatement (excl. sinks)	Mt CO_2-e	2.4	2.6	2.7	2.9	3.0
Total sink credits	Mt CO_2-e	22.6	22.6	22.6	22.6	22.6
Banking	Mt CO_2-e	6.0	5.4	4.7	4.0	3.3
Sink credit sales	Mt CO_2-e	5.9	5.3	4.7	4.0	3.3
Emissions charge revenue	US$m	391.6	396.8	402.0	409.1	416.4
Sink credit income	US$m	86.2	82.7	78.2	70.9	61.8

This increases the level of consumption by domestic firms, offsetting the lower level of household and government demand.

The global emissions price and the domestic emissions charge (table 11) are unchanged from the PPS1 scenario (table 5). Sales of emission credits from the Russian Federation, the Ukraine and eastern Europe increase to 530.6 million tonnes CO_2 equivalent, offsetting the decrease in New Zealand's sink credit sales. In New Zealand the changes in household and government demand, as well as slightly increased demand for New Zealand's exports, cause small sectoral shifts which increase emissions slightly above PPS1 levels.

Sectoral impacts

The sectoral changes are not significantly different from those estimated in the PPS1 scenario (table 12). Production in some manufacturing and agricultural sectors is slightly above PPS1 levels, largely as a result of a lower New Zealand exchange rate. A lower level of sink credit revenue also reduces the effectiveness of revenue recycling, with impacts on the amount of value added (and hence gross domestic product contribution) by each sector of the economy.

12 *Sectoral output, exports and imports for New Zealand under the PPS3 scenario in 2010 relative to the base case*

	Output	Exports	Imports	GDP change
	%	%	%	US$ million
Brown coal	–6.16	..	..	–0.10
Steaming coal	–9.00	55.29	..	–4.54
Coking coal	–2.62	–2.62	..	–0.57
Oil	0.41	1.39	–2.03	0.71
Gas	–2.22	..	..	–7.36
Petroleum and coal products	–1.29	0.15	–0.96	–4.44
Electricity	–2.52	..	..	–20.06
Iron and steel	–11.25	–14.30	7.89	–14.80
Alumina	..	..	–1.88	..
Primary aluminium	–1.88	–1.83	–3.28	–2.66
Nonferrous metals	–4.02	–5.15	0.44	–5.42
Chemicals, rubber and plastic	–0.50	–0.53	0.31	–6.20
Wood and paper products	0.01	0.00	0.01	–0.21
Dairy products	–0.01	–0.01	–0.02	–1.01
Meat products	–0.15	–0.23	0.18	–0.82
Food	0.15	0.35	–0.26	1.50
Bauxite	..	..	..	..
Other mineral products	–0.99	–0.16	–1.13	–1.35
Nonmetallic minerals	0.02	–0.11	0.16	0.04
Manufacturing	0.09	0.25	–0.12	2.47
Trade and transport	–0.06	–0.05	–0.04	–14.18
Services	0.09	0.68	–0.35	10.07
Rice	..	..	..	..
Wheat	0.06	..	–0.21	0.06
Crops	0.16	0.20	–0.21	1.44
Forestry	0.24	0.40	..	1.88
Fisheries	0.04	–0.13	0.30	0.14
Livestock	–0.04	–0.07	0.06	–0.80
Dairy cattle	–0.01	..	..	0.05
Sheep and wool	0.08	0.18	–0.26	0.94
Total change				–65.24

.. Not a significant activity.

Appendix A: Analytical framework

The analysis of the impacts of climate change policies in this paper 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; 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 explore 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 18 regions and 30 commodities that allow the most detailed representation of Annex B countries and emission intensive industries (table 13).

The current GTEM database now contains a complete disaggregation of the coal sector into brown coal, coking coal and steaming 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. Steaming 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 emissions 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 100 year time horizon (IPCC 1996). Most major sources and sectors are represented. However, emissions from waste and agricultural residues, and methane and nitrous oxide emissions from combustion and some industrial processes are not included.

13 GTEM 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 products	Rest of Association of South East Asian Nations (ASEAN)
Food products	
Bauxite	Middle East
Other mineral products	South America
Nonmetallic minerals	Rest of the world
Manufacturing	
Trade and transport	
Services	
Rice	
Wheat	
Crops	
Forestry	
Fisheries	
Beef cattle	
Dairy cattle	
Wool/sheep	

In modeling the impact of greenhouse gas abatement policies in GTEM, combustion related carbon dioxide emissions can be reduced by incorporating energy efficiency improvements and fuel switching, and in noncombustion sources by adopting new technologies and management practices. Other things being equal, reduced activity levels in emitting sectors will also reduce emissions.

Modeling emission abatement policies

The policy simulations presented in this paper 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 body of this 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; the other is the targets for subsequent commitment periods.

Both the United States and Australia are assumed not to ratify the Protocol in all the simulations. Australia is assumed not to undertake any additional emission abatement policies other than those described in the reference case. However, for this analysis it is assumed that the United States economy's greenhouse gas emission intensity is reduced by 18 per cent between 2002 and 2012. This is consistent with President Bush's stated goal, and is lower than 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 simulation period to 2027.

All participating Annex B parties are assumed to comply with their first commitment period Kyoto targets. Parties' targets in each year of the analysis period are assumed to be held constant. 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 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 countries' 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 body of this 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 quotas 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 confines the aggregate emissions of participating regions 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 emission quota) sufficient to meet the aggregate emission target. The individual Kyoto commitments represent an initial allocation of obligations, or emission quotas, among the participating regions. These can be traded between regions. Income from the sale of emission quotas is accounted for as foreign income transfers and added to gross national product, while payment for purchases is subtracted from gross national product.

Restrictions and distortions in emissions trading

Emissions trading can be the cheapest approach to emission abatement, but this assumes that the market is unrestricted; that transaction costs associated with the transfer of emission quotas 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 emission 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 emission quotas 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. The most recent inventory rule would apply to parties (such as the Russian Federation and the Ukraine) with 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 emission quota market, which enables them to restrict their quota sales, increase the emission quota price and maximise the present value of their gross national product over the four commitment periods. Unsold emission quotas are banked for future use. Further detail on the banking of emissions in GTEM is provided in Jakeman et al. 2001.

Banking and intertemporal quota price dynamics

Banking of emission quotas is permitted under Article 3.13 of the Kyoto Protocol. This 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 model-

ing 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 policy analysis presented in this paper contains an illustrative representation of clean development mechanism (CDM) projects in forestry, and technology transfer in thermal electricity generation and in reduction of fugitive emissions in the oil and gas sectors. Projects in these sectors offer potentially significant abatement opportunities at a relatively low cost (Gibbs 1998; Seroa da Motta, Ferraz and Young 2000; World Bank 2000; Zou and Junfeng 2000). In line with the Marrakesh Accords, credits derived from nuclear electricity projects and avoidance of deforestation emissions are not considered.

It is assumed that certified emission reductions generated from the clean development mechanism projects are perfectly substitutable with Annex B emission quotas (assigned amount units) in an Annex B emissions trading scheme. This is in line with Article 3.12 of the Kyoto Protocol. As a consequence, the price of a certified emission reduction (including allowance for the adaptation and administrative levies) is the same as the international quota price. It is further assumed that the net revenue from the sale of certified emission reductions is shared equally between the non-Annex B hosts and Annex B investors.

To analyse comprehensively the economic impacts of technology transfer in the clean development mechanism, large amounts of project specific data would be required. In previous analyses by ABARE (Polidano et al. 2001) it has been assumed that developing countries catch up 10 per cent of the efficiency gap between non-OECD and OECD countries, in half the current stock of thermal power generation capacity. This is equivalent to a 2.5 per cent efficiency improvement in thermal electricity generation by 2010. In addition, the clean development mechanism allows for afforestation and reforestation projects that are additional to abatement that would occur in the absence of the certified project activity (Article 12.5c). ABARE had previously assumed, under full Annex B participation, that each non-Annex B region is able to generate certified emission reductions equal to an additional 10 per cent of carbon sequestration in reference case plantings of commercial forests by 2010 (Polidano et al. 2001). In this analysis, projects that reduce fugitive methane emissions associated with oil and gas production, processing, storage and distribution in developing countries are also represented. Under full Annex B participation, a maximum 10 per cent reduction from reference case levels is assumed to be reached by 2010.

14 *Certified emission reductions (CERs) from forestry and technology transfer in electricity generation and fugitive emission abatement*

	Forestry [a]	Electricity generation [b]	Fugitive emissions [c]	Total	
	2010 Mt CO_2 equiv.	2010 Mt CO_2 equiv.	2010 Mt CO_2 equiv.	2010 Mt CO_2 equiv.	2001–10 Mt CO_2 equiv.
China	1.1	7.5	0.6	9.2	44.8
Chinese Taipei	0.0	0.7	0.0	0.8	3.9
India	0.2	4.6	0.3	5.2	26.0
South Korea	0.0	0.6	0.0	0.7	3.6
Indonesia	0.1	1.0	1.9	2.9	14.3
Rest of ASEAN	0.1	1.8	0.6	2.5	11.4
Middle East	0.0	2.1	1.9	4.0	21.1
South and central America	1.2	3.1	1.8	6.1	29.9
Rest of non-Annex B	0.3	3.8	1.9	5.9	28.2
Total	3.1	25.2	12.2	37.2	183.4

a CERs generated from an additional 10 per cent of sequestration from reference case plantings in non-Annex B countries. **b** CERs generated from a 2.5 per cent efficiency improvement in thermal electricity generation in non-Annex B regions. **c** CERs generated from an additional 10 per cent reduction in fugitive emissions from the oil and gas sectors.

However, under the assumption that the United States will not ratify the Kyoto Protocol, it is likely that the overall investment in the clean development mechanism will be less than implied by the above assumptions. To reflect the absence of the United States, the volume of credits generated from these projects has been scaled down in proportion to the US abatement task. The resulting assumed certified emission reductions generated are shown in table 14.

Projections of sequestration from reference case plantings are based on a study on the global outlook for plantations by ABARE and Jaako Pöyry Consulting (1999). The study focused on the change in supply of timber from plantation forests; hence the estimates do not incorporate sequestration from afforestation and reforestation activities for reasons other than timber supply. It is assumed that any projected increase in the area of plantations occurs on land that is not currently forested and the composition of tree species in each forest is assumed to be constant over the reference case.

Appendix B: Reference case

The GTEM reference case represents the world economy over the simulation period, from 1990 to 2027. It assumes there are no 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 to 2012) and are reported at the midpoint (2010).

The GTEM reference case does incorporate 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 (Adams, P., 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 data. Historical data for gross domestic product are included from 1996 to 2000, and emissions for Annex B countries are updated using the most recent available official national inventory data. For this study, New Zealand's National Greenhouse Gas Inventory for 2000 was used. Gross domestic product projections to 2006 in GTEM are based on ABARE (2001b), IMF (2000) and US Department of Energy (2002) forecasts.

Long term GTEM gross domestic product projections are derived by fitting an autoregressive integrated moving-average (ARIMA) econometrics forecasting model to the historical gross domestic product 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 gross domestic product, based on its historical, statistical relationship with itself and other variables. A simplified version is used here, with gross domestic product projections based solely on historical trends in gross domestic product.

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 15). The estimates of Article 3.3 sinks and Article 3.4 agricultural sinks are derived from parties' 1 August 2000 submissions to the Intergovernmental Panel on Climate Change (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 Agriculture and Forestry; and
- 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 this 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.

15 *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.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

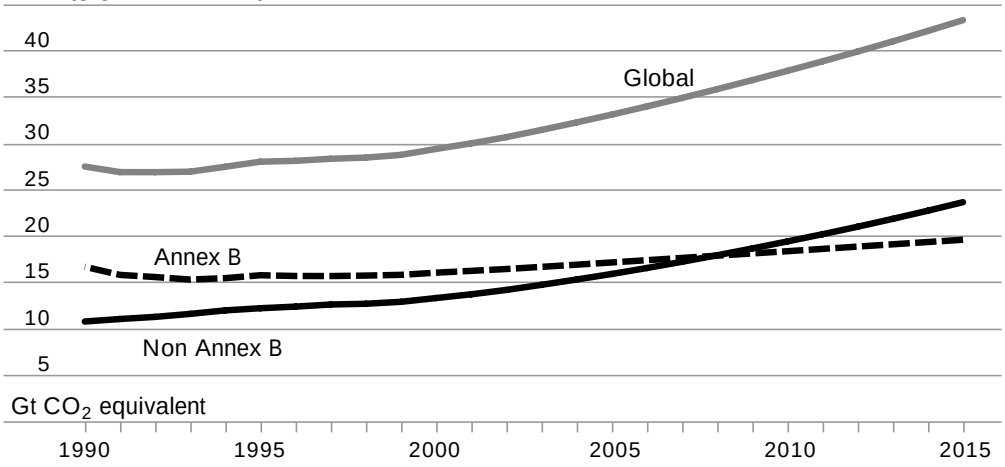
a European Free Trade Area: comprises Switzerland, Norway and Iceland. **b** Includes 121 million tonnes carbon dioxide equivalent for the Russian Federation (33 million tonnes carbon equivalent) and 4.1 million tonnes carbon dioxide equivalent for the Ukraine.

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 CO_2 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 to over 43 billion tonnes in 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).

A Total emissions of greenhouse gases in the reference case 1990–2015 (gigatonnes – Gt)



Emissions growth in Annex B regions

For Annex B countries, the difference between the projected reference case emissions and emission targets represents the magnitude of their abatement tasks; this is therefore a key determinant of the 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 (gross domestic product), 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 lower 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 2015. 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 16). It should be noted that uncertainty about the medium term economic development in these regions means that the emission projections are also subject to uncertainty.

16 ***Projected average annual change in real GDP, emissions and emissions intensity of output, reference case, 1990–2015 a***

	Real GDP		Carbon dioxide equivalent emissions		Emissions intensity of output	
	1990 –2000	2000 –2015	1990 –2000	2000 –2015	1990 –2000	2000 –2015
	%	%	%	%	%	%
New Zealand	2.5	2.7	0.7	1.6	–1.9	–1.1
Australia	3.6	3.6	1.8	1.6	–1.8	–2.0
United States	3.2	3.1	1.1	1.8	–2.1	–1.4
Canada	2.8	3.1	1.9	1.1	–0.9	–2.0
Japan	1.4	0.7	0.9	0.3	–0.5	–0.4
European Union	2.0	2.3	–0.1	0.8	–2.1	–1.6
Russian Federation and the Ukraine	–4.7	3.8	–4.4	1.7	0.2	–2.1
Eastern Europe	0.7	3.7	–1.8	0.7	–2.4	–3.0
EFTA **b**	1.9	2.3	1.2	1.4	–0.7	–0.8
Annex B	1.6	2.7	–0.4	1.3	–2.0	–1.3
Non-Annex B	5.7	5.4	2.1	3.9	–3.5	–1.5
Global	3.1	3.9	0.7	2.6	–2.5	–1.3

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

Among Annex B regions, the highest rates of emissions growth between 1990 and 2015 are projected to be in Australia, Canada and the United States. An important determinant of high emissions growth in these countries is the high assumed rates in growth of gross domestic product.

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 from 2000 to 2015, 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 2015. 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 expected to continue, leading to considerable reductions in emissions intensity and to emissions growth below the Annex B average. In Japan, assumed gross domestic product growth between 1990 and 2015 is below the Annex B average and is projected to lead to relatively low growth in fossil fuel consumption.

Between 2015 and 2027, total Annex B emissions are projected to grow at an average annual rate of 1 per cent. Over the same period, emissions intensity is projected to decline at an average annual rate of 1.6 per cent. Non-Annex B emissions are projected to grow at an average of 4 per cent a year.

Appendix C: Changes to the Armington parameters

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.

17 *Comparison of Armington parameters used in all scenarios*

	Previous studies	Current study
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
Food	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
Other animal products	2.8	6.0
Dairy cattle	2.8	6.0
Wool	2.2	6.0

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