Impacts on the New Zealand economy of commitments for abatement of carbon dioxide emissions

Final report

Prepared for the New Zealand Ministry of Commerce

Centre for International Economics
Canberra & Sydney

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This report

- This report uses the G-Cubed model of the world economy to examine the economic impact of a variety of policies designed to achieve particular carbon dioxide emission targets.

- The report focuses on the implications for New Zealand and attempts to derive lessons for New Zealand's policy decisions and stance in international negotiations.

Policies examined

- The analysis considers three broad sets of policies.
  - Carbon taxes, which are designed to achieve specific carbon abatement targets in each country by encouraging substitution to noncarbon sources of energy. These taxes differ by country.
  - Internationally tradable carbon emission permits, in which each country is allocated 'permits' for a particular level of carbon dioxide emissions. That country can then buy or sell permits. The total quantity of permits issued is set by the overall Annex I carbon dioxide emissions target.
  - A uniform carbon tax scheme in which each country imposes the same carbon tax, with the uniform tax chosen to achieve a total Annex I carbon dioxide emissions target.

Key results

Specific abatement targets

- Compared with other countries, New Zealand has a high 'marginal cost of abatement'. The marginal cost of abatement measures the incremental cost of each additional tonne of carbon (or carbon dioxide) abatement.

- New Zealand's high marginal cost of abatement is reflected in the size of the carbon tax required to reach stabilisation targets. For example, under a scenario that targets 1990 carbon dioxide emissions by 2010, the tax required in 2010 in New Zealand is almost four times that required in the US and one and a half times that required in Australia.

- The marginal cost of abatement is determined by a number of factors including:
  - the projected level of carbon dioxide emissions under a 'business as usual' scenario; and
  - the ease with which energy users can substitute to low or zero emitting energy sources.
- New Zealand's high use of nonfossil fuel energy sources as well as its limited supply of low emitting fuels (such as gas) means that substitution is more difficult than for other countries.
- The model results indicate that, depending on the scenario, New Zealand's GDP could fall by up to 1 per cent (relative to 'business as usual'), with a long term reduction in GDP of between 0.2 and 0.5 per cent
- New Zealand's real consumption declines by between 0.1 and 0.7 per cent, depending on the scenario. In the short term, the consumption losses are higher, up to 6 per cent in some cases.
- New Zealand's consumption path has quite a different shape to that of other countries, with New Zealand experiencing larger losses in the short term. This is the result of a number of factors including: the size of the tax in New Zealand; the timing of the tax; and the costs of adjustment to the tax in the short term.
- It is relatively more difficult for New Zealand to adjust to the tax in the short term. Higher adjustment costs directly translate to lower consumption.
- Because of its high marginal cost of abatement, a given level of global abatement is less costly for New Zealand under a scheme that recognises differences in marginal costs of abatement and allows different levels of abatement by country. Economic costs are lowered under an internationally tradable permit scheme or under a uniform carbon tax scheme.

An internationally tradable permit scheme

- A tradable permit scheme is less costly for New Zealand because the price of permits is between 60 and 80 per cent lower than New

Zealand's marginal cost of abatement. Compared with the carbon tax scheme that requires uniform abatement by country, the permit scheme lowers New Zealand's cost of abatement (in terms of reduced GDP) by 60 percent in 2005 and 20 per cent in 2020.

- Under a permit scheme, New Zealand buys permits and does less abatement. Other low abatement cost countries (such as the United States, and Eastern Europe and the former Soviet Union) sell permits and do more abatement. The overall carbon dioxide emissions target is met, but at a lower economic cost.

A uniform carbon tax scheme

- A uniform carbon tax scheme is less costly for New Zealand because the uniform carbon tax required to achieve the overall Annex I carbon dioxide emission target is 70 per cent lower than New Zealand's marginal cost of abatement.
- Compared with the carbon tax scheme that requires uniform abatement by country, the uniform carbon tax scheme lowers New Zealand's cost of abatement (in terms of reduced GDP) by 70 percent in 2005 and 60 per cent in 2020.
- The uniform carbon tax scheme is less costly than the permit scheme because New Zealand gets to keep the carbon tax revenue, which reduces the impact on GDP, consumption and other economic outcomes.

Qualifications

- Model results such as those presented in this report are, of course, sensitive to a variety of settings, including assumptions made in establishing a 'business as usual' scenario, the value of particular model parameters and assumptions about how the revenue from carbon tax is used.
- This report undertakes some limited sensitivity analysis, which indicates that the results are not highly sensitive to some parameters. This is not to say there are not parameters that are crucial in determining model results, but full sensitivity analysis is beyond the scope of this report

- Crucial to the results, however, are assumptions about the use of carbon tax revenue.
- The standard assumption in this report is that the revenue is used to reduce the fiscal deficit. Changing this assumption significantly changes the impact on New Zealand of reduction in carbon dioxide emissions.
- Using the carbon tax revenue to reduce the petroleum excise and corporate and personal income taxes provides a boost to the economy that may offset the negative impact of the carbon tax itself.

Are the qualitative conclusions robust?

- While the precise numerical results from the model depend on a variety of assumptions and settings, the important question is whether the qualitative conclusions from the model, outlined above, are robust.
- Changing these conclusions would require significant changes in model settings and would imply unrealistic assumptions.
- For example, the finding that New Zealand is significantly better off under a tradable permit scheme is determined by the finding that New Zealand has a high marginal cost of abatement *relative to other countries*. This in turn depends on New Zealand having fewer opportunities to substitute to low carbon emission fuels compared with other countries. Reversing the finding would thus require changing this relative substitution setting. Given the structure of New Zealand's energy use, this is unrealistic.

Implications

- New Zealand should be wary of any international scheme that does not recognise differences in marginal costs of abatement. This is not to argue for special treatment, but simply to recognise that some instruments are better than others in minimising the total cost of achieving a particular level of abatement. Tradable emission permits are a good example of this.
- If some sort of carbon tax scheme is implemented, New Zealand needs to consider carefully the uses to which the revenue from the carbon tax is put. This consideration needs to be both in terms of New Zealand's

current tax structure and in terms of the likely uses to which other countries will put their carbon tax revenue.

1 Introduction

Background

Reducing greenhouse gas emissions inevitably involves some economic costs — at least the cost of discovering, changing to and operating lower emitting energy technologies. Although the precise magnitude of these costs — and the nature of other indirect economic effects — is uncertain, soundly based estimates are an important input into policy, and international negotiation, processes.

Estimating the effects of reducing greenhouse emissions requires two things. First, estimates of future emissions under the assumption that no policies are introduced to limit them ('business as usual' estimates) and second, an economic model capable of tracing the various direct and indirect effects of reducing those emissions from the 'business as usual' levels.

'Business as usual' projections

Estimates of the economic cost involved in reducing future emissions to a particular target will clearly depend on the estimated level of emissions under a 'business as usual' scenario.

Future greenhouse gas emissions from energy sources within New Zealand depend on a range of factors on both the demand and supply sides of the New Zealand and world economies. These factors include future:

- population growth;
- reliance on fossil fuels for energy generation;
- productivity growth in energy and nonenergy sectors (including technical change and energy efficiency improvements); and
- demand for energy intensive products.

Predicting future emissions is fraught with problems. This is illustrated by looking at the evolution of the world economy over recent decades. The world economy in 1996 is not a simple scaling of the world economy in 1966. Indeed, many of the key features of the New Zealand and world economies in 1996 would have been impossible to predict from the information available in 1966.

History holds a number of important lessons. First, projections for New Zealand cannot be made in isolation from what is happening in the rest of the world. Second, the most interesting and important events often lie in the details of individual industries and countries. The third lesson, demonstrated vividly by the oil shocks of the 1970's, is that people respond to changes in prices. Together, these lessons mean that projecting aggregate GDP is unlikely to be useful, will almost certainly be wrong and will fail to capture the most important events. Similarly, it is misleading to infer future energy use and carbon emissions from future trends in GDP alone.

The need for an economic model

A ‘business as usual’ projection is not sufficient to estimate the impacts of greenhouse emission reduction measures. Doing this requires an economic model capable of tracing the various indirect economic interactions both within and between countries and sectors.

Modelling economic interactions in the future is difficult. But, again, recent experience points to certain factors that need to be taken into account. First, models must take into account the ability of people to substitute — between goods and services, and between energy sources. Second, models must account for the interaction between sectors within a country and for the interaction between countries themselves. Only with these interactions can the models account for the changing patterns of production, consumption and trade that have such an important influence on economic outcomes. Finally, the models need to capture both changes in the flows of goods and services between countries, and changes in flows of financial assets between countries.

This report

The model

This report uses the G-Cubed model of the world economy to present both carbon dioxide emission projections and economic outcomes under a ‘business as usual scenario’, and estimates of the economic effects of attempting to achieve carbon dioxide emission targets using different policy instruments.

The focus

The focus of the report is on carbon dioxide emissions from energy sources. Unless stated otherwise, references to 'emissions' should be interpreted as carbon dioxide emissions from an energy source.

The policies

The report considers three broad sets of policy instruments. The first, a 'carbon tax', is used to represent policies that attempt to achieve particular emissions targets by changing the relative price of carbon based fuels. A tax on carbon (or carbon dioxide) emissions makes carbon based fuels relatively more expensive, leading various energy users to switch energy sources. Under these policies, the level of tax required differs by country.

The second set of policy instruments is 'tradable emission permits'. Under these policies, countries are allocated a set number of permits to emit carbon dioxide. Permit trade is allowed between countries and the total quantity of permits is set to achieve a particular aggregate carbon dioxide emission target.

Third, the report considers a globally uniform tax scheme where all countries impose the same carbon tax to achieve an aggregate emissions target.

These three sets of instruments have different implications for the economic effect of carbon dioxide emissions targets. The purpose of this report is to explore and compare these implications and to derive lessons relevant to New Zealand's policy choices and stance in international negotiation.

Although we use a numerical model to examine these issues, the relevance of the model results is not in the literal numerical values but in the broad orders of magnitude, and in the relativities between different scenarios and different policy instruments.

Structure of the report

The report is structured as follows. Chapter 2 provides a brief overview of the G-Cubed model. Chapter 3 presents the 'business as usual' projections. Chapter 4 summarises the scenarios that are examined in subsequent chapters. Chapters 5 and 6 present the results of these scenarios. Chapter 7 provides selected analysis of the sensitivity of model results to particular settings. Chapter 8 provides concluding comments as well as qualifications relevant to these conclusions.

2 The G-Cubed multicountry model

Origins

In 1991, the United States Environmental Protection Agency, together with the Brookings Institution, funded the construction of a new multicountry model in order to project the possible path of global greenhouse gas emissions. The goal of this project was to also consider the consequences for the global economy of implementing policies to reduce the emissions of greenhouse gases. The resulting model, called G-Cubed, was an ambitious and unique approach that combined the macroeconomic and multisectoral schools of economic modelling into a model of the world economy.

The G-Cubed multicountry model is developed in McKibbin and Wilcoxen (1992) and extended in McKibbin and Wilcoxen (1995). It combines the approach taken in the MSG2 model developed by McKibbin and Sachs (1991) with the disaggregated, econometrically estimated, intertemporal general equilibrium model of the US economy by Jorgenson and Wilcoxen (1989).

Key features

G-Cubed is a world model with regional disaggregation and sectoral detail. Countries and regions are linked both temporally and intertemporally through trade and financial markets. G-Cubed contains sound short and long run macroeconomic foundations. It imposes intertemporal budget constraints on households, governments and nations (the latter through accumulations of foreign debt) through forward looking behaviour incorporated in consumption and investment decisions.

G-Cubed's sectoral detail permits analysis of environmental policies, which tend to have their largest effects on small segments of the economy. By integrating sectoral detail with the macroeconomic features of MSG2, G-Cubed can be used to consider the long run costs of alternative environmental regulations as well as considering the macroeconomic implications of these policies over time.

The response of monetary and fiscal authorities in different countries can have important effects in the short to medium run which, given the long lags in physical capital and other asset accumulation, can be a substantial period. Overall, the model is designed to provide a bridge between computable general equilibrium models and macroeconomic models by integrating the more desirable features of both approaches. In addition to the strong theoretical foundations, many of the key parameters in the model are econometrically estimated.

While still in the process of development, G-Cubed is already large. The version used in this report, which includes New Zealand, contains 6600 equations and over 140 intertemporal co-state variables.

Other key features of the version of the G-Cubed model used in this paper include:

- the specification of the demand and supply sides of industrial economies so that prices in all countries are determined through the interaction of demand and supply;
- the integration of real and financial markets of these economies;
- intertemporal accounting of stocks, and flows of real resources and financial assets;
- imposition of intertemporal budget constraints so that agents and countries cannot forever borrow or lend without undertaking the required resource transfers necessary to service outstanding liabilities;
- short run behaviour of a weighted average of neoclassical optimising behaviour and ad hoc 'liquidity constrained' behaviour;
- the real side of the model is disaggregated to allow for production and trade of multiple goods and services within and across economies;
- sector specific dynamics with adjustment costs to move physical capital between sectors;
- full short run and long run macroeconomic closure with macro and sectoral dynamics at an annual frequency around a long run Solow–Swan neoclassical growth model; and
- solved for a full rational expectations equilibrium at an annual frequency from 1990 to 2100.

Although the model is solved to 2100, for this report model data is only extracted for the period 1990 to 2020. In some cases estimates of post 2020 results are available, however, and these are quoted where appropriate.

Country detail

The version of the G-Cubed model used in this model consists of nine economic regions with full internal and external detail for:

- the United States;
- Japan;
- Australia;
- New Zealand;
- rest of the OECD;
- China;
- Eastern Europe and the former Soviet Union; and
- other developing countries.

In addition, a group called 'oil exporting developing countries' are included with external linkages only.

Sectoral detail

For each region, the model contains five energy sectors:

- electric utilities;
- gas utilities;
- petroleum refining;
- coal mining; and
- crude oil and gas extraction.

It also includes seven nonenergy sectors for each region:

- mining;
- agriculture, fishing and hunting;
- forestry and / or wood products;
- durable manufacturing;
- nondurable manufacturing;
- transportation; and
- services.

This disaggregation enables us to capture the sectoral differences in the impact of alternative environmental policies. The relationship between these sectors and other industrial classifications is set out in appendix A.

Is the sectoral detail appropriate?

There is a trade-off involved in choosing the same sectoral breakdown for all regions in the model. On the one hand, a single breakdown is essential to ensure consistency in production, consumption and trade flows across all regions in the model (it is very difficult to ensure trade flows are consistent if each country's production has a different breakdown).

The cost of this is that the breakdown chosen is a compromise and will not be ideal for every country. For example, some industries such as forestry are relatively more important for New Zealand than for other countries in the model.

Is anything important lost by not focusing in more detail on these sectors in New Zealand? Two points are important in this regard. First, G-Cubed is an economywide model, which means that it covers all economic activity in each country. Thus, the forestry sector and all its interactions with other sectors in the model are covered, although particular aspects of forestry cannot be separately identified.

Second, the main focus of G-Cubed is on the broad economywide effects and intercountry interactions that result from different abatement policies. These broad effects are all covered for all sectors of the model and the model appropriately calculates the macroeconomic implications. What the model does not allow (with its current sectoral detail) is a closer examination of outcomes for activities within a particular sector. This would be an important limitation if the focus of the analysis was on the impact on particular activities. But this is not the case. This report is concerned with broad economic interactions and with comparing the broad effects of different policies.

Given all this, the sectoral breakdown chosen for G-Cubed is appropriate for all regions in the model.

Data for New Zealand

A key aspect of G-Cubed is its integration of data from input–output tables with conventional macroeconomic data. The New Zealand data used in this study is from a range of sources. The input–output Table is the 1993 table supplied by Statistics New Zealand. Data for the coal industry was extracted from this table using shares from the input output tables for 1986-87. The macroeconomic data comes from range of sources including the December 1996 *OECD Economic Outlook* and IMF *Government Financial*

Statistics obtained through the International Economic Database at the Australian National University (ANU).

Data on carbon emissions and energy use are from the New Zealand Ministry of Commerce publications on *Energy Outlook* (February 1997) and *Energy Greenhouse Gas Emissions 1990–95* (May 1996). In addition, the elasticities of substitution in production and consumption are estimated from US time series and cross sectional data from 1947 through 1987.

Production structure

Chart 2.1 summarises the production structure of the G-Cubed model. Total supply of the output of sector *h* consists of both domestic production and imports. Total imports are in turn made up of imports from different countries.

For domestic production, each of the twelve sectors is represented by a single firm, which chooses its inputs and level of investment in order to maximise its stock market value subject to a multiple input production function and a vector of prices it takes to be exogenous. For each sector *h*, output (Q_h) is produced with inputs of capital (K_h), labour (L_h), energy (E_h), materials (M_h) and a sector specific resource (R_h). The nature of the sector specific resource varies across sectors. For example, in the coal industry it is reserves of coal, in agriculture and forestry and wood products it is land which is substitutable between these two sectors.

Firms can substitute between capital, labour, energy and materials. Within the energy and material inputs, firms can also substitute. For example, the energy input can be made up of electricity, gas, petroleum, coal or crude oil. Similarly, materials are in turn made up of mining through to services.

Chart 2.1 also illustrates the structure of energy production in the model. If sector *h* is the electricity industry, then that industry can produce its output (electricity) by selecting appropriate combinations of capital, labour, energy and materials. It can also substitute between the inputs that make up the energy nest (gas, petroleum, etc). Renewable fuels are embodied within the capital stock of the electricity sector. Thus, as the price of fossil fuels increases, the electricity sector will substitute towards capital.

Macroeconomics in G-Cubed

G-Cubed is unique in its treatment of macroeconomics. Money enters the model through a restriction that it is required for transactions. This introduces a meaningful difference between real and nominal variables, and allows for aggregate inflation. With some wage stickiness, this allows for Keynesian style business cycles. In addition, key relative prices such as real exchange rates and interest rates are determined through the standard national income accounting identity that GDP equals consumption plus investment plus government spending plus net exports. An alternative way of thinking of this constraint is that the current account balance of an economy is equal to the net saving of the private sector plus the net saving of the public sector. With endogenous saving and investment behaviour, and international financial flows the outcome for real exchange rates and interest rates are determined by this overall macroeconomic constraint.

G-Cubed and economic growth

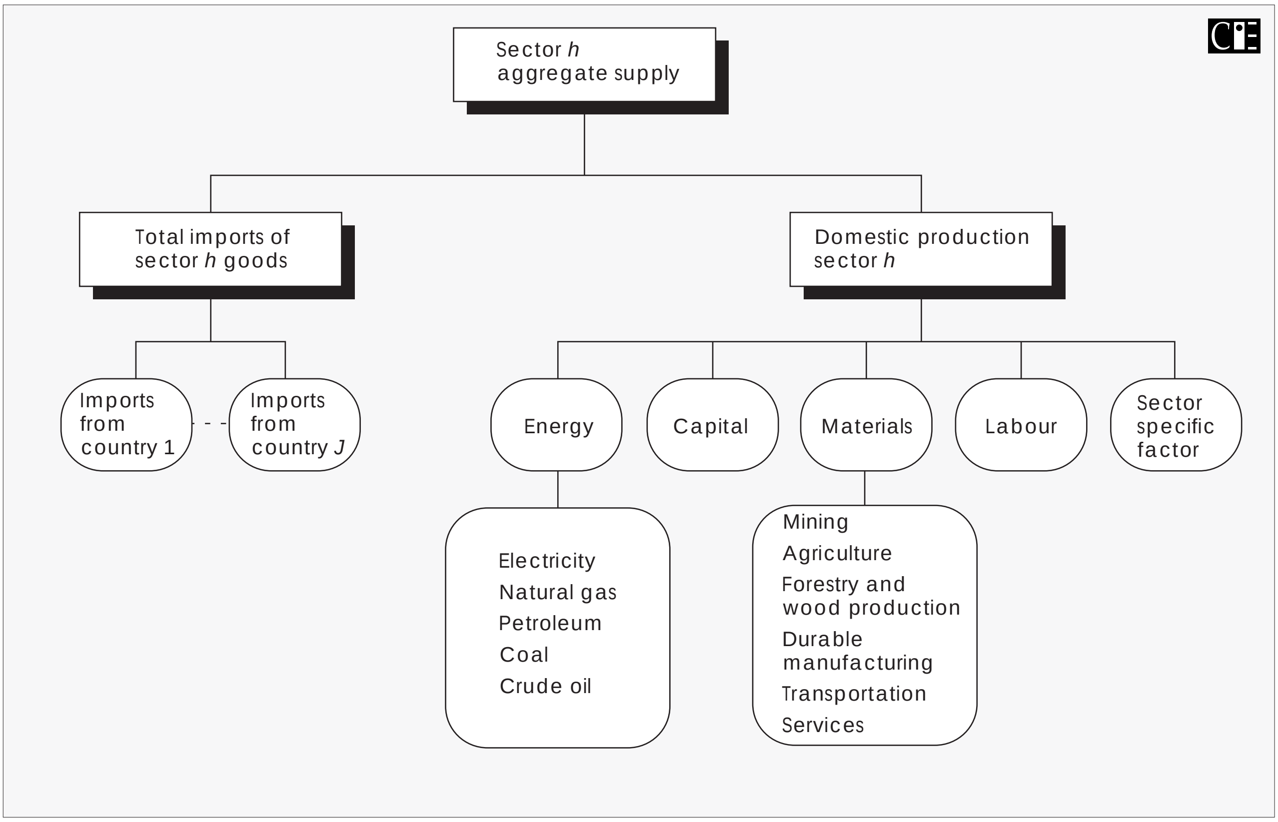
Underlying G-Cubed is a conventional neoclassical growth model. This means that in the model the rate of economic growth is determined by growth in the use of labour and capital as well as improvements in the productivity with which these factors are used. Productivity growth and growth in the labour force (ultimately determined by population growth) are determined outside the model, while growth in the capital stock is determined within the model.

This structure of the model implies that the long term growth rate of any economy is determined by factors outside the model. It does not follow from this, however, that various economic policies and shocks do not have any permanent effect in the model. Economic policies and shocks can permanently affect the *level* of economic activity. As a result of imposing a carbon tax, for example, the level of GDP will be permanently lower than it would otherwise have been, even if the long term growth rate remains unchanged.

Emissions in G-Cubed

G-Cubed focuses on CO_2 emissions from energy use — that is, the burning of fossil fuels for energy purposes. It does not account for nonenergy CO_2 emissions nor for non-CO_2 sources of greenhouse gases.

Chart 2.1 **Production structure of the G-Cubed model**



3 The 'business as usual' scenario

Projecting growth

The future path of carbon dioxide emissions depends on both the rate of future economic growth and the way in which that growth is achieved. While emissions depend on growth, there is not a simple relationship between GDP growth and growth in emissions.

A major task in projecting emissions growth, therefore, is appropriately projecting economic growth. A detailed discussion of the problems of projecting the world economy is given in Bagnoli, McKibbin and Wilcoxen (1996, 1997).

There are four sources of growth within an economy:

- increases in the supply of labour, capital, primary energy and other inputs;
- increases in the quality of these inputs,
- improvements in the way inputs are used (technical change);
- improvements in the way that inputs are allocated between industries.

For the whole world economy, a fifth source of growth is the reallocation of inputs between countries.

Since the G-Cubed model is based on a conventional growth model, some of these factors are endogenously determined and some are exogenously imposed as inputs into the model scenarios. The rates of technical change and of population growth are both exogenous to the model. The capital stock and short run supply of labour and other inputs are endogenously determined.

In this report all references to technical change and productivity growth refer technically to labour augmenting technical change, which is the assumed source of all technical change in the G-Cubed model.

Tax rates

Other important exogenous assumptions include tax rates on labour and capital income, taxes on carbon dioxide emissions and energy in general, taxes on imports, and government spending on goods and services.

Unless otherwise specified, government spending on each good is a fixed share of GDP and tax rates are held fixed (except a lump sum tax on households, which is varied over time to satisfy the governments' intertemporal budget constraint).

Resource inputs

In the simulations below, it is also assumed that primary resource inputs (reserves of coal crude oil and natural gas in the ground) have infinite supply elasticities rather than becoming scarce over the horizon of the simulation. Note that the production of coal and natural gas from these sectors do have upward sloping supply curves because of the fixed capital stock in these sectors. This assumption about global primary resource supplies is consistent with the assumption that world energy prices do not rise in real terms over the simulation period.

The Maui gas field

For New Zealand, the 'business as usual' scenario incorporates the depletion of the Maui gas field by 2005. This is incorporated in the model as a productivity decline in the gas sector. The effect of this is a decline in production, an increase in price and a subsequent reduction in demand.

This setting in 'business as usual' means that, in the simulations (reported in subsequent chapters), New Zealand has less scope to substitute from coal into gas as a result of the imposition of a carbon tax. Also, the 'business as usual' scenario does not incorporate imports of gas, and so the possibility of imports is excluded from the simulations. The model does, however, contain the possibility of increased gas production from fields other than Maui. Like other sectors, the production of gas depends upon prices and costs. If prices increase sufficiently, production will increase. In the case of gas, production requires exploration and development, but could be profitable depending upon the extent of changes in energy prices.

Productivity growth

A key input into the 'business as usual' scenario is the assumption about productivity growth at the sectoral level. We estimate this by using recent data trends as well as drawing on the literature on the economics of growth convergence.

Some growth literature (for example: Barro and Salai Martin, 1995; and Dowrick and Nguyen, 1989) suggests convergence between countries in income levels per capita or total factor productivity. We assume (following Dowrick and Nguyen, 1989 that convergence occurs in the technology used in production rather than in incomes. Further, we assume that convergence occurs at the sectoral rather than aggregate level, although aggregate convergence will also apply.

We assume that the United States economy is the leader in each sector and all other countries ‘catch up’ to the United States such that the gap closes at 2 per cent per year (which is consistent with a range of empirical evidence). Thus, the rate of technical change in a sector within New Zealand is the growth rate in the equivalent US sector plus 2 per cent of the gap between the initial level of technology in New Zealand and the initial level of technology in the United States. If a sector is close to the US in technology then the difference in the growth rate of technological change will be small. A sector that is only 50 per cent of the US level of technology will therefore experience much faster technical change.

We have measures of the initial level of technology for the United States (in 1990) but not for New Zealand. We thus assume that the average growth rate of GDP in the preceding five years, if consistent with the convergence hypothesis, implies a particular initial level of productivity in New Zealand relative to the United States.

It is important to note that this catch up model does not imply that all countries apply the same physical technologies. These will always vary between countries depending on their various resource endowments. The catch up model implies that productivity converges, where productivity is defined as a level of output for a given level of inputs.

In the ‘business as usual’ scenarios reported here, economywide New Zealand labour augmenting technical change is assumed to be 1.60 percent in 1990, 1.49 per cent by the year 2000, 1.4 per cent in 2010 and 1.33 per cent by the year 2020. However, the actual rate of technical change of each sector differs because we assume that the distribution of labour augmenting technical change between sectors in the US — to which New Zealand is converging — is the same as the historical average. Each of the sectoral growth rates in the US is weighted by that sector’s share in the economy such that the overall economywide labour augmenting technical change is 1 per cent per year. The rates of productivity growth for each sector are summarised in table 3.1.

Costs and benefits of this approach

This approach to estimating sectoral productivity growth is one of many approaches that could be adopted. The advantage with this approach is that it provides a well defined and consistent approach to estimating productivity growth for all countries in the model. It is, of course, possible that projections derived in this way will not necessarily reflect the historical experience of particular countries. There may also be special factors in particular countries that are missed by this approach. Discussions with experts in New Zealand, however, did not reveal any basis for alternative estimates for New Zealand.

Clearly, the sectoral productivity assumptions influence the results in the ‘business as usual’ scenario. However, without running a number of scenarios, each with different productivity assumptions, it is difficult to determine exactly how different assumptions will change the results. Further, it is difficult to determine how specific assumptions, such as those for agriculture, influence the final results without conducting a large number of additional simulations.

More important, however, is the fact that changes to the ‘business as usual’ scenarios will not necessarily change the model projections of the effect of particular emission targets or policies. Testing the importance of any particular assumption, while possible in principle, is time consuming in practice.

A more appropriate way to consider underlying model assumptions is to ask what changes in assumptions would be needed to change the qualitative insights from the model. This question is addressed in the final chapter of this report.

Energy efficiency assumptions

In addition to the productivity changes in table 3.1, energy efficiency in each sector is assumed to improve at 0.8 per cent each year. This assumption is made for consistency with the Energy Modelling Form of the International Panel on Climate Change (IPCC) and reflects the opinion of leading energy modellers.

Population projections

Population projections are based on annual interpolation of the World Bank’s population projections under its ‘standard fertility decline’ scenario.

For New Zealand, growth rates are 1.14 per cent in 1990 dropping to 0.49 per cent by 2020. Population projections are also summarised in table 3.1.

The ‘business as usual’ results

Using the above methodology, the model is solved from 1990 to 2070 given all exogenous assumptions and adjustments to all equations so that the model exactly replicates the 1990 database.

Key ‘business as usual’ results are presented in tables 3.2 to 3.4. The results include gross domestic product (GDP), private consumption, private investment, government spending, the trade balance, fiscal deficit, terms of trade and carbon dioxide emissions. They also include detailed results for gross output, user prices, employment, energy use for each sector and energy use by type of energy for transportation. All variables are in billions of New Zealand dollars in 1990 except for the terms of trade and prices, which are indexed to one in 1990; the level of carbon dioxide emissions which is in millions of metric tonnes; and interest rates which are in percentage points. The nominal exchange rate is expressed in NZ dollars per US dollar. The effective exchange rate is expressed as a log index to give a clear indication of how it changes over time.

Key ‘business as usual’ results are as follows.

- Carbon dioxide emissions increase from 24.42 million tonnes in 1990 to 40.29 million tonnes in 2020. This is a 65 per cent increase in emissions over the 30 year period.

Table 3.1 **Population growth and labour augmenting technical change projections**

	1990	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2005*	*2010*	*2015*	*2020*
	% pa	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**	**% pa**
Population growth	1.14	1	0.97	0.94	0.92	0.89	0.87	0.76	0.66	0.58	0.5
Sectoral labour augmenting technical change											
Electric utilities	3.66	3.52	3.50	3.48	3.45	3.43	3.41	3.30	3.20	3.11	3.03
Gas utilities	0.35	0.33	0.33	0.33	0.33	0.33	0.32	0.31	0.30	0.30	0.29
Petroleum refining	-2.17	-2.09	-2.07	-2.06	-2.05	-2.03	-2.02	-1.95	-1.90	-1.84	-1.80
Coal mining	-0.16	-0.16	-0.16	-0.15	-0.15	-0.15	-0.15	-0.15	-0.14	-0.14	-0.13
Crude oil and gas extract	-2.17	-2.09	-2.07	-2.05	-2.05	-2.03	-2.02	-1.95	-1.90	-1.84	-1.80
Mining	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Agriculture	3.39	3.27	3.25	3.22	3.20	3.18	3.16	3.06	2.97	2.89	2.81
Forestry	0.61	0.59	0.59	0.58	0.58	0.57	0.57	0.55	0.54	0.52	0.51
Durable manufacturing	1.14	1.10	1.09	1.09	1.08	1.07	1.06	1.03	1.00	0.97	0.95
Nondurable manufacturing	2.60	2.51	2.49	2.47	2.45	2.44	2.42	2.34	2.28	2.21	2.16
Transportation	2.13	2.05	2.04	2.02	2.01	2.00	1.98	1.92	1.86	1.81	1.77
Services	1.07	1.03	1.02	1.01	1.01	1.00	0.99	0.96	0.93	0.91	0.89

Source: G-Cubed model simulation.

Table 3.2 : **Projections for New Zealand 1990 to 2020** (simulation starts in 1990) 'Business as usual' scenario

		1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2005**	**2010**	**2015**	**2020**
GDP	(1990 NZ$b)	72.67	82.72	85.52	88.15	90.52	92.75	94.87	104.94	115.60	128.74	143.49
Consumption	(1990 NZ$b)	45.41	52.95	54.48	55.59	56.26	56.69	56.95	57.89	60.74	67.99	76.72
Investment	(1990 NZ$b)	14.14	17.87	17.86	17.89	17.92	17.95	18.00	18.56	19.82	21.76	23.81
Government spending	(1990 NZ$b)	15.80	15.89	16.32	16.75	17.17	17.61	18.06	20.57	23.43	26.76	30.49
Trade balance	(1990 NZ$b)	0.40	-0.51	0.44	1.59	2.92	4.35	5.80	12.39	16.66	17.95	18.93
Imports of G&S	(1990 NZ$b)	19.41	23.45	23.53	23.48	23.30	23.06	22.82	22.24	23.75	27.94	33.11
Exports of G&S	(1990 NZ$b)	19.81	22.94	23.97	25.07	26.22	27.41	28.61	34.63	40.40	45.89	52.04
Fiscal balance	(1990 NZ$b)	-1.14	1.56	1.86	2.14	2.39	2.61	2.79	3.27	3.49	3.78	3.98
Terms of trade (inverse of RER)	1990=1	1.00	0.94	0.98	1.01	1.06	1.10	1.13	1.28	1.35	1.35	1.36
Ten year interest rate	% pa	12.45	7.49	7.57	7.56	7.50	7.42	7.32	7.22	7.13	7.05	6.99
Short term interest rate	%pa	13.89	7.62	8.56	9.28	9.65	9.84	9.91	9.90	9.85	9.80	9.78
Nominal exchange rate	NZ$/US$	1.68	1.04	1.06	1.09	1.13	1.17	1.21	1.37	1.40	1.33	1.26
Nominal effective exchange rate	log index=0 in 1990	0.00	20.74	19.78	18.23	16.28	14.25	12.33	6.69	9.94	20.32	30.53
Inflation	% pa	6.05	2.28	2.36	2.47	2.57	2.66	2.72	2.88	2.57	2.47	2.51
Co2 emissions	mil tonnes	24.42	28.18	28.73	29.18	29.54	29.83	30.10	31.43	33.43	36.62	40.29
Share of fuels in primary energy supply:												
Coal		8.72	9.20	9.30	9.37	9.46	9.55	9.63	10.05	12.17	12.84	13.59
Oil and gas		56.56	57.60	57.65	57.64	57.41	57.23	57.01	55.57	48.43	47.32	45.90
Other		34.72	33.19	33.05	32.99	33.13	33.23	33.37	34.38	39.40	39.84	40.51
		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: G-Cubed model simulation

Table 3.3 **Sectoral Results for New Zealand** 'Business as usual' scenario

		1990	1995	1996	1997	1998	1999	2000	2005	2010	2015	2020
Output												
Electric utilities	(1990 NZ$b)	3.70	4.40	4.55	4.68	4.80	4.92	5.03	5.58	6.21	7.00	7.93
Gas utilities	(1990 NZ$b)	0.53	0.56	0.56	0.56	0.56	0.56	0.56	0.54	0.34	0.33	0.32
Petroleum refining	(1990 NZ$b)	3.73	4.44	4.54	4.63	4.64	4.64	4.62	4.50	4.21	4.19	4.11
Coal mining	(1990 NZ$b)	0.33	0.38	0.39	0.40	0.40	0.41	0.41	0.43	0.46	0.50	0.53
Crude oil & gas extract	(1990 NZ$b)	1.09	1.25	1.29	1.32	1.35	1.38	1.41	1.55	1.69	1.87	2.06
Mining	(1990 NZ$b)	0.27	0.33	0.33	0.34	0.34	0.35	0.35	0.38	0.41	0.45	0.49
Agriculture	(1990 NZ$b)	18.61	22.48	23.09	23.66	24.19	24.69	25.20	27.86	31.12	35.35	40.12
Forestry	(1990 NZ$b)	3.53	4.09	4.22	4.33	4.44	4.54	4.63	5.05	5.52	6.10	6.77
Durable manufacturing	(1990 NZ$b)	9.66	11.25	11.50	11.76	12.01	12.26	12.51	13.80	15.24	16.84	18.54
Nondurable manufacturing	(1990 NZ$b)	16.85	19.74	20.57	21.35	22.08	22.78	23.47	26.92	30.76	35.39	40.59
Transportation	(1990 NZ$b)	7.30	8.67	8.95	9.21	9.45	9.67	9.88	10.94	12.13	13.60	15.22
Services	(1990 NZ$b)	74.37	85.06	87.77	90.25	92.46	94.45	96.28	104.27	112.74	124.00	137.09
User price												
Electric utilities	1990=1	1.00	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.97	1.00	1.03
Gas utilities	1990=1	1.00	1.06	1.11	1.15	1.20	1.24	1.29	1.51	1.98	2.10	2.21
Petroleum refining	1990=1	1.00	0.98	1.00	1.02	1.07	1.11	1.15	1.36	1.58	1.73	1.88
Coal mining	1990=1	1.00	1.04	1.06	1.08	1.10	1.13	1.15	1.28	1.33	1.43	1.53
Crude oil & gas extract	1990=1	1.00	1.02	1.04	1.05	1.07	1.08	1.09	1.16	1.21	1.27	1.34
Mining	1990=1	1.00	1.03	1.04	1.06	1.08	1.09	1.11	1.21	1.30	1.38	1.45
Agriculture	1990=1	1.00	0.97	0.98	0.99	1.01	1.03	1.05	1.14	1.21	1.25	1.30
Forestry	1990=1	1.00	1.03	1.04	1.05	1.06	1.08	1.10	1.22	1.33	1.41	1.49
Durable manufacturing	1990=1	1.00	1.02	1.03	1.05	1.06	1.08	1.10	1.20	1.28	1.35	1.43
Nondurable manufacturing	1990=1	1.00	1.00	1.01	1.03	1.04	1.06	1.08	1.18	1.25	1.31	1.37
Transportation	1990=1	1.00	1.02	1.03	1.05	1.06	1.08	1.09	1.18	1.26	1.34	1.41
Services	1990=1	1.00	1.04	1.05	1.06	1.07	1.08	1.10	1.19	1.28	1.37	1.45

Continued

Table 3.3 **Sectoral Results for New Zealand** 'Business as usual' scenario *Continued*

		1990	1995	1996	1997	1998	1999	2000	2005	2010	2015	2020
Employment (in efficiency units)												
Electric utilities	1990=1	1.00	1.16	1.19	1.21	1.22	1.22	1.23	1.24	1.28	1.37	1.45
Gas utilities	1990=1	1.00	1.16	1.21	1.26	1.30	1.34	1.38	1.57	1.88	2.15	2.46
Petroleum refining	1990=1	1.00	1.28	1.33	1.38	1.42	1.46	1.50	1.72	1.95	2.27	2.62
Coal mining	1990=1	1.00	1.22	1.26	1.29	1.31	1.33	1.35	1.44	1.53	1.68	1.84
Crude oil & gas extract	1990=1	1.00	1.27	1.32	1.37	1.42	1.47	1.51	1.74	1.98	2.28	2.60
Mining	1990=1	1.00	1.28	1.31	1.34	1.36	1.38	1.40	1.52	1.69	1.90	2.11
Agriculture	1990=1	1.00	1.24	1.28	1.32	1.35	1.39	1.42	1.62	1.87	2.14	2.41
Forestry	1990=1	1.00	1.23	1.26	1.30	1.33	1.36	1.39	1.57	1.79	2.04	2.31
Durable manufacturing	1990=1	1.00	1.20	1.23	1.26	1.30	1.33	1.36	1.53	1.74	1.98	2.24
Nondurable manufacturing	1990=1	1.00	1.20	1.25	1.31	1.35	1.40	1.44	1.67	1.93	2.23	2.54
Transportation	1990=1	1.00	1.21	1.24	1.28	1.31	1.34	1.36	1.51	1.68	1.91	2.15
Services	1990=1	1.00	1.19	1.23	1.27	1.30	1.33	1.36	1.52	1.70	1.94	2.23
Exports												
Electric utilities	(1990 NZ$b)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas utilities	(1990 NZ$b)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum refining	(1990 NZ$b)	0.09	0.12	0.12	0.13	0.13	0.14	0.14	0.16	0.16	0.17	0.17
Coal mining	(1990 NZ$b)	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07
Crude oil & gas extract	(1990 NZ$b)	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04
Mining	(1990 NZ$b)	0.07	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.13	0.14
Agriculture	(1990 NZ$b)	1.52	1.74	1.82	1.90	1.98	2.07	2.15	2.57	2.96	3.31	3.69
Forestry	(1990 NZ$b)	0.32	0.35	0.38	0.40	0.43	0.45	0.47	0.58	0.68	0.76	0.85
Durable manufacturing	(1990 NZ$b)	1.97	2.35	2.47	2.60	2.73	2.86	3.00	3.66	4.23	4.72	5.25
Nondurable manufacturing	(1990 NZ$b)	10.18	11.38	11.97	12.62	13.30	14.01	14.73	18.33	21.78	25.04	28.71
Transportation	(1990 NZ$b)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Services	(1990 NZ$b)	5.62	6.60	6.79	6.99	7.19	7.41	7.62	8.74	9.93	11.18	12.59

Source: G-Cubed model simulation

Table 3.4 **Outcomes for Other Countries** 'Business as usual' scenario

		1990	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2005**	**2010**	**2015**	**2020**
USA	Emissions (in tonnes)	4994.00	5142.72	5212.26	5283.65	5356.73	5430.36	5505.68	5903.37	6336.98	6813.20	7342.99
	GDP US$b	5743.82	6206.90	6343.70	6482.87	6624.46	6768.41	6914.70	7681.38	8509.36	9407.31	10387.34
	Consumption	3839.28	4076.35	4165.30	4257.42	4352.47	4450.01	4550.14	5086.90	5684.38	6350.70	7099.39
Japan	Emissions (in tonnes)	1034.00	1467.87	1497.87	1522.60	1544.75	1564.45	1582.89	1665.54	1749.92	1846.54	1955.62
	GDP US$b	2976.29	3601.25	3721.28	3833.87	3944.32	4053.66	4162.27	4711.47	5309.46	5993.31	6784.55
	Consumption	172537	2297.35	2394.85	2484.22	2569.16	2650.80	2729.96	3109.33	3500.83	3938.58	4440.04
Australia	Emissions (in tonnes)	292.23	333.41	342.59	351.87	361.15	370.38	379.58	425.48	472.36	521.74	574.68
	GDP US$b	294.65	342.07	353.43	364.93	376.47	388.05	399.65	458.32	519.33	584.53	655.41
	Consumption	175.73	203.66	210.72	217.94	225.24	232.53	239.84	276.24	313.23	352.31	395.09
ROECD	Emissions (in tonnes)	3886.67	4117.96	4171.33	4226.46	4282.80	4339.90	4398.30	4711.48	5063.78	5460.69	5909.17
	GDP US$b	7532.23	8343.11	8514.18	8688.98	8866.69	9047.63	9231.51	10202.06	11266.28	12436.47	13727.48
	Consumption	4432.33	4867.45	4963.25	5062.20	5163.76	5267.61	5373.86	5945.69	6594.01	7332.11	8176.40
China	Emissions (in tonnes)	2262.33	2687.63	2773.20	2860.98	2950.23	3040.74	3132.51	3609.73	4115.77	4647.68	5201.84
	GDP US$b	505.73	631.41	658.94	687.63	717.38	748.20	780.07	956.06	1161.68	1399.82	1673.42
	Consumption	187.59	285.75	306.19	327.44	349.38	371.94	395.13	520.25	660.33	815.05	984.03
Other LDCs	Emissions (in tonnes)	2874.67	3423.64	3543.29	3665.65	3789.99	3915.23	4042.16	4699.24	5394.42	6132.98	6919.48
	GDP US$b	1446.35	1825.54	1910.46	1998.48	2089.38	2183.22	2279.82	2805.57	3407.24	4095.45	4882.53
	Consumption	873.94	1103.30	1158.38	1215.75	1275.06	1336.02	1398.48	1730.66	2092.98	2486.13	2912.56
EEFSU	Emissions (in tonnes)	4377.81	3185.01	3027.98	2862.91	2683.23	2670.45	2636.79	2602.41	2677.49	2796.86	2947.09
	GDP US$b	867.63	949.01	961.92	973.86	984.35	1008.67	1032.33	1170.65	1336.12	1526.43	1742.77
	Consumption	350.06	347.37	349.89	352.02	353.50	367.96	381.16	460.83	559.22	672.74	801.13

Source: G-Cubed model simulation

- GDP increases from $72.67 billion in 1990 to $143.49 billion (both in 1990 prices) in 2020. This is a 97.5 per cent increase over the period.
- These two results suggest a declining ratio of carbon dioxide emissions to GDP over time. This results from the assumed energy efficiency improvements, the compositional change within the economy and the different rates of labour augmenting technical change assumed for each sector.

The projected level of carbon dioxide emission is the most important aspect of the ‘business as usual’ scenario. The level of emissions in the future determines the magnitude of the abatement task (for any particular target) and hence the costs of achieving that target.

As noted above, the ‘business as usual’ scenario also includes projections of a number of other economic variables. The results presented in table 3.2, for example, show a steady improvement in New Zealand’s trade balance along with a currency depreciation from 1995.

The improvement in the trade balance is a result of two broad effects. The first is New Zealand’s fiscal adjustment, which is modelled from 1991. The increase in government saving that this implies leads to an improvement in the balance of trade (the balance of trade is determined by the balance between saving and investment in each country).

Second, New Zealand’s foreign debt is captured in the model and this debt must be serviced. Agents in the model know this and adjust their behaviour accordingly. This also leads to an improvement in the balance of trade to service the foreign debt.

Together, these assumptions imply a rapid improvement in New Zealand’s trade balance.

This adjustment should not be interpreted as a literal forecast, but as one macroeconomic scenario consistent with the projections of emissions. It is possible for the macroeconomic scenario to change without changing the emission projection.

4 The scenarios

Table 4.1 sets out the various scenarios analysed in this report. They fall into four broad types — those involving carbon taxes, those involving international tradable permits, those with uniform carbon taxes and those with some combination of these.

The layout of table 4.1 is designed to show the way in which various scenarios can be compared with each other. For example, comparing scenarios A, B, C, D and E will show the effects of different abatement targets. Comparing scenarios B and F, or D and G will show the effect of using international emission trading rather than a carbon tax. Comparing scenario H with F, or I with H or F will show the effect of a permit scheme versus a uniform tax scheme or a mixed scheme.

For ease of presentation, graphs in subsequent chapters will use shorthand notation to refer to the scenarios. For example, scenario A will be referred to as A: 1990 levels by 2005.

Table 4.1 **Summary of key scenarios**

Targets individual country emission	*Targets aggregate Annex I emissions*		
Carbon tax	***International emission permit trading***	***Uniform carbon tax***	***Uniform tax and international permit trading***
A Stabilisation of CO_2 emissions to 1990 levels by 2005			
B Stabilisation of CO_2 emissions to 1990 levels by 2010	**F** Stabilisation of CO_2 emissions to 1990 levels by 2010 using tradable permits introduced in January 1999	**H** Stabilisation of CO_2 emissions to 1990 levels by 2010 using uniform carbon tax in all Annex I countries from January 1999	**I** Stabilisation of CO_2 emissions to 1990 levels by 2010 using a uniform carbon tax from Jan 1999 to December 2004 then a permit system from January 2005
C Reduction of CO_2 emissions to 5 per cent below 1990 by 2010			
D Reduction of CO_2 emissions to 10 per cent below 1990 levels by 2010	**G** Reduction of CO_2 emissions to 10 per cent below 1990 levels by 2010 using tradable permits introduced in Jan 1999		
E NZ CO_2 emissions reduced to 20 per cent above 1990 levels by 2010. Other regions as for scenario B			
J As for scenario B excluding Australia			

The analysis for this report also includes sensitivity analysis around scenario B. This sensitivity analysis relates to revenue recycling and the value of specific model parameters.

Two alternative assumptions on revenue recycling for New Zealand are considered. In the first, the revenue from the carbon tax is used to reduce the petroleum excise tax with remaining revenue used to reduce personal and company income taxes. In the second, the revenue from the carbon tax is used to reduce personal and company income taxes alone.

Separate sensitivity analysis also involves halving:

- the elasticities of substitution in final consumption between energy sources (in each country); and
- the elasticities of substitution between all final consumer products (in all countries)

5 Results: carbon tax scenarios

Emissions under each scenario

Chart 5.1 summarises emissions for each Annex I region, and the world, under each scenario. Chart 5.2 summarises emissions for non-Annex I countries. (EEFSU are included in this latter group as they do not need to do any abatement under the scenarios.) Note that in chart 5.1 the kink in New Zealand's 'business as usual' emission path is a result of the depletion of the Maui gas field.

Chart 5.1 shows the magnitude of the abatement task under each scenario. For New Zealand, the most stringent target is under scenario D, with the least stringent under scenario E.

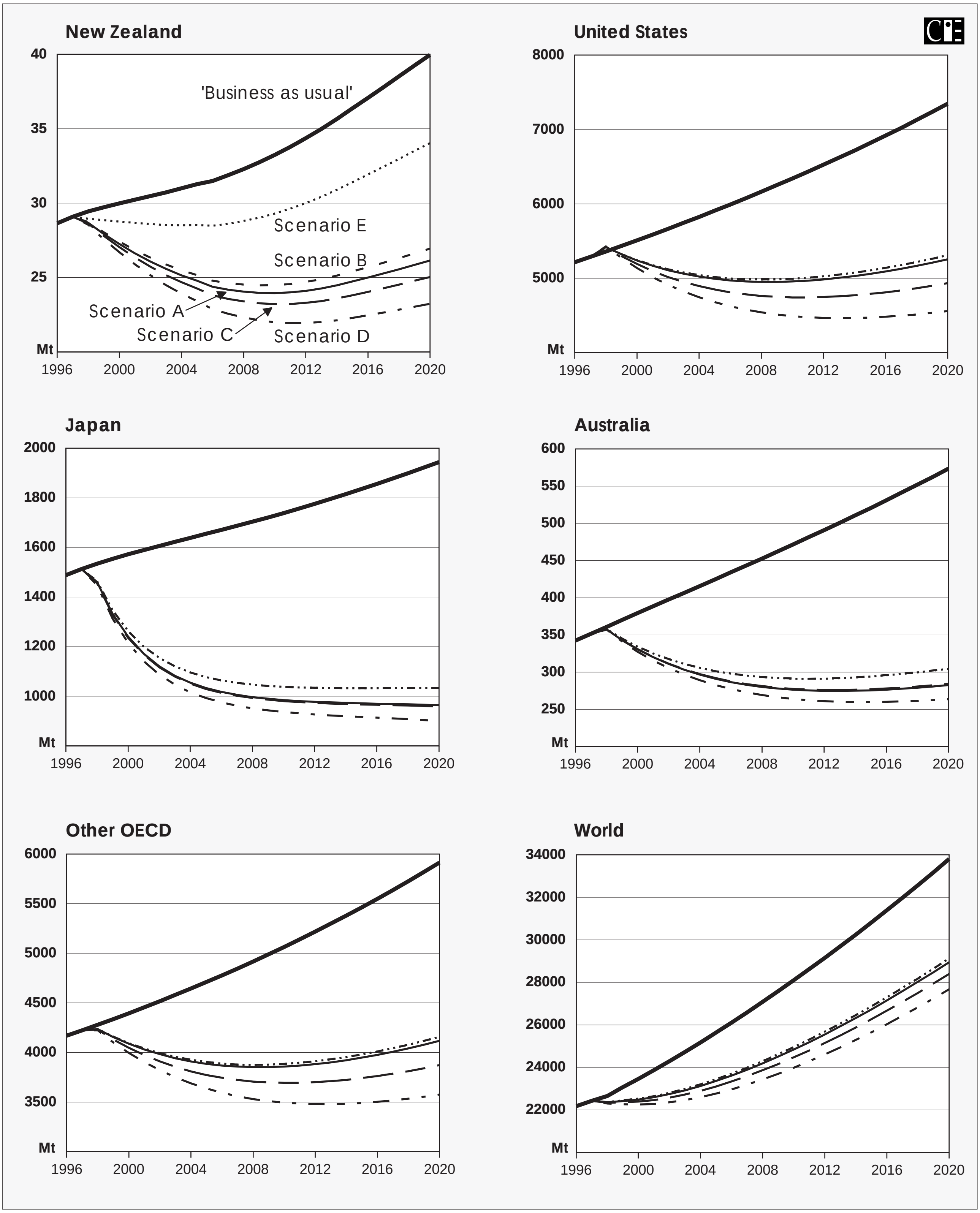
A number of important points emerge from these results.

First, it is interesting to note that emissions are not precisely targeted in each of these scenarios — they tend to drift up again after hitting the initial target in 2005 or 2010. This results from the way the carbon tax is implemented in the model. The tax is chosen to smoothly increase over time in order to hit target emissions at the target date (2005 or 2010). However, it is not possible to maintain a smooth tax profile and hit a rigid emission target for the years after the target date. This illustrates an important point: if targets are hard to hit in a model, they are going to be even harder to hit in the real world. Hitting targets is an iterative process. But an iterative process in the real world is likely to make for unpredictable policy.

Second, under scenarios A to D the biggest abatement task (in terms of the percentage reduction in emissions relative to 'business as usual' required in the target year) is faced by Australia, followed by Japan, New Zealand, other OECD and the US. This has implications for the relative costs of abatement between countries as discussed below.

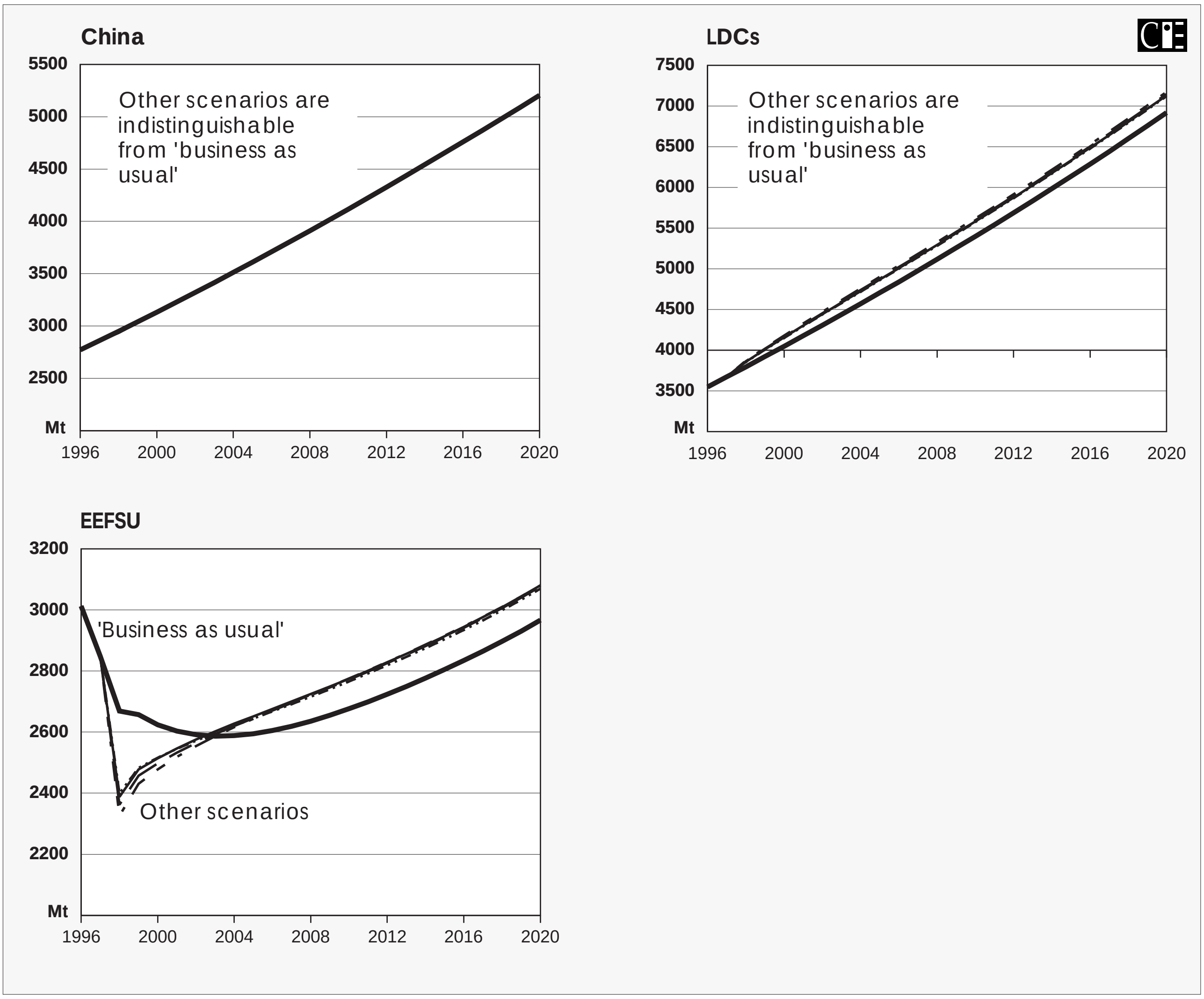
Third, chart 5.2 illustrates that, for most of the scenarios, carbon dioxide emissions by the LDCs and Eastern Europe and the Former Soviet Union (EEFSU) actually increase by around 4 per cent in 2020 in each case. Chinese emissions barely change from the 'business as usual' scenario. This means that 'leakage' (defined as the percentage increase in emissions in non abating countries resulting from the actions of abating countries) is low

Chart 5.1 **Carbon dioxide emissions by country under each scenario**



Data source: G-Cubed model simulations.

Chart 5.2 **Carbon dioxide emissions**



Data source: G-Cubed model simulations.

in these simulations. These simulations do not allow a direct calculation of 'leakage' from New Zealand (this would require a simulation in which only New Zealand abates). While total Annex I leakage is low, it is not possible to determine what proportion of this comes from New Zealand. Another issue is the extent of movement of emissions from one Annex I country to another. While the model cannot determine this movement, the large capital inflow to the United States (see below) suggests that firms or industries may contract (or close) in some Annex I countries and expand in the United States, taking advantage of a lower carbon tax. Relocation of investment to other countries may also take place. Given the size of New Zealand's carbon tax relative to other countries (see below), this form of Annex I to Annex I 'leakage' may not necessarily be low, although the decision to move offshore is likely to be determined by a range of factors, not just one.

Finally, Annex I country abatement has a limited effect on world carbon dioxide emissions. For example, scenario A applied to the whole world would imply an 18 per cent reduction in emissions below ‘business as usual’ in 2005. However, Annex I abatement only results in global emissions 8 per cent below ‘business as usual’, less than half what is required. Similarly, scenario D applied to the world would imply that emissions should be 44 per cent below ‘business as usual’ by 2020. Annex I abatement only results in emissions 18 per cent below ‘business as usual’.

Note that in these each of the simulation scenarios, EEFSU, although an Annex I region, does not need to do any abatement because throughout the relevant simulation period, as its carbon dioxide emissions are below 1990 levels.

The carbon tax to achieve the targets

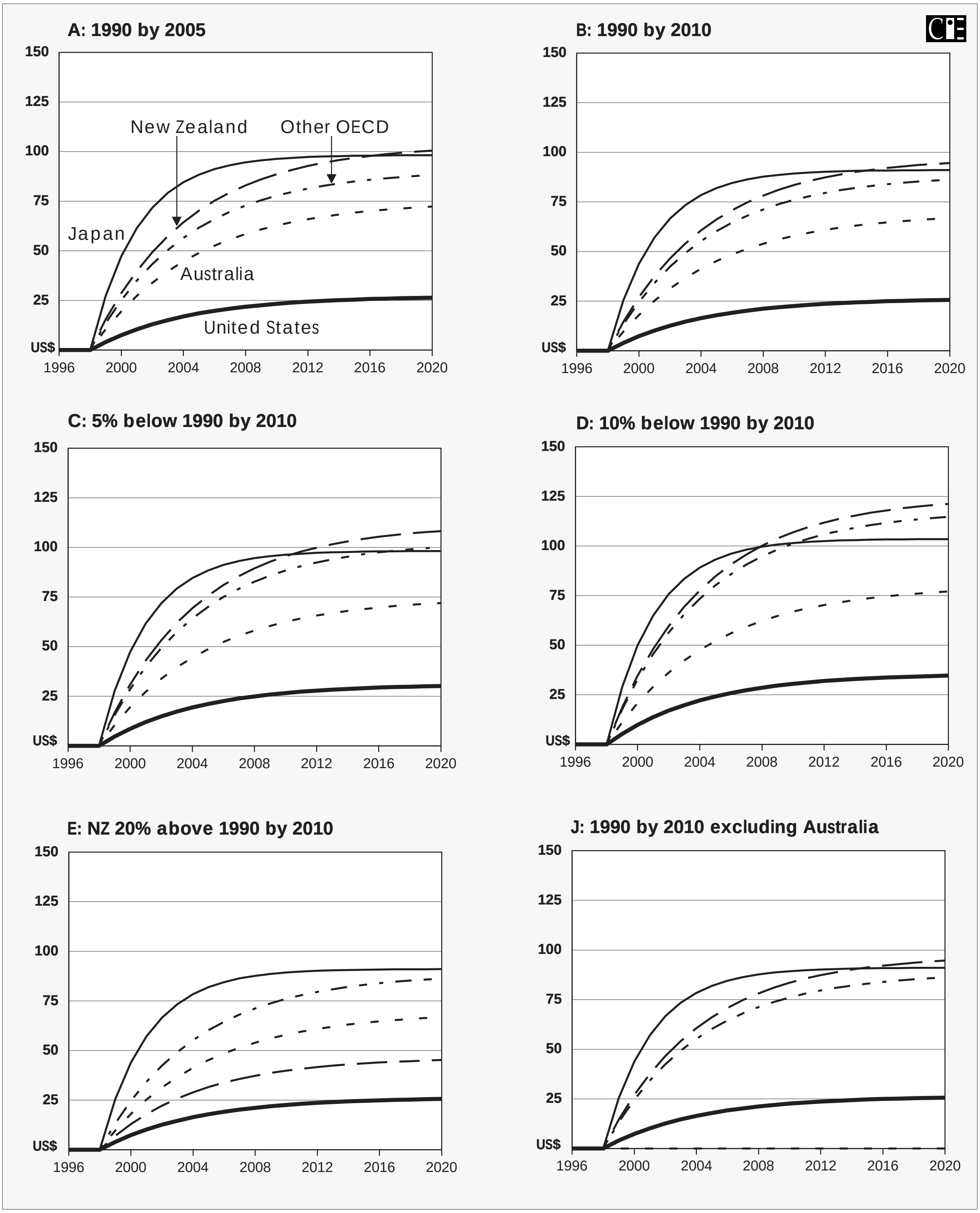
Chart 5.3 summarises the carbon tax required in each abating country to achieve the emission targets set out in each scenario.

The smooth profile of these taxes for each country is determined by assumption. The taxes are introduced in 1999 and then increased at a decreasing rate to achieve the target. This profile is one of a number of possible profiles and is chosen because of the ease with which it can be implemented. It is not in any sense an optimal path for the tax.

The chart shows that for most of the scenarios, the highest taxes are for Japan and New Zealand, followed closely by other OECD, then Australia. The exception is scenario E, where New Zealand has a low carbon tax. The United States has the lowest carbon tax in all scenarios.

The tax in each country summarises the marginal cost of abatement for that country. The fact that the taxes are different between countries indicates that marginal costs of abatement differ between countries. There are, therefore, potential gains from trading in abatement. That is, countries with higher marginal abatement costs would be willing to pay for abatement to take place in countries with lower marginal abatement costs. This suggests that there will be efficiency gains in a policy that allows different amounts of abatement in different countries, so that the marginal abatement cost is the same in all countries.

Chart 5.3 **Carbon tax for stabilisation by scenario** US$ per tonne of carbon



Data source: G-Cubed model simulations.

Marginal abatement costs are higher in New Zealand and Japan because first, 'business as usual' emission growth is higher than for other countries leading to a larger abatement task (except in Scenario E for New Zealand) and second there are fewer energy substitution possibilities. New Zealand is already non fossil fuel energy intensive. For example, most electricity is produced from renewable sources which makes it hard to substitute further away from carbon based fuels. Further New Zealand, unlike Australia, is limited in the extent to which it can expand gas usage.

Effects on GDP

Charts 5.4 and 5.5 summarise the changes in GDP for abating and non abating countries under each scenario. These changes are expressed as a percentage deviation from 'business as usual'.

A number of points emerge from these results.

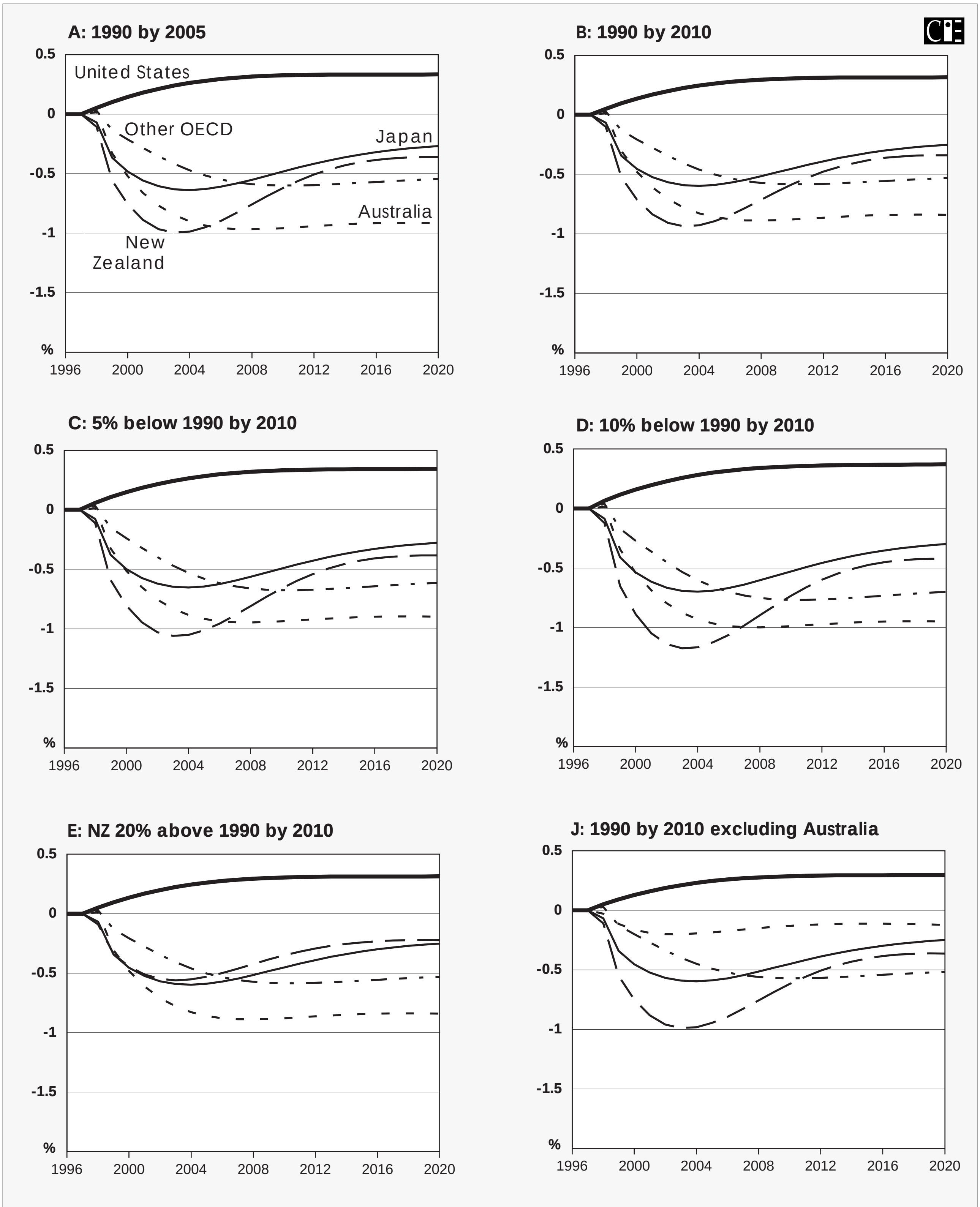
First, GDP falls in all abating countries except the US. (Note that the effect on GDP starts in 1998, one year before the implementation of the tax, this is because of the behaviour for forward looking agents in the model.) GDP falls in most cases because the carbon tax raises the price of energy and hence reduces aggregate production. While there is substitution away from energy towards other inputs, this takes time. In particular it is costly and difficult to change the capital stock in each industry (although the phasing of the tax minimises this cost).

As well as substitution between inputs within countries, there is also a reallocation of production between countries which takes place through the movement of financial capital between countries. Capital moves out of the abating countries to those that are not abating. However, because these are small developing countries, they cannot absorb the full capital flows. This means that capital must move between abating countries. In particular, it moves from high marginal abatement cost countries to those with lower abatement costs. Thus, capital moves into the US. Indeed, as it has a large capital stock, the US can easily absorb the capital that moves from other abating countries.

This results in an increase in GDP in the US.

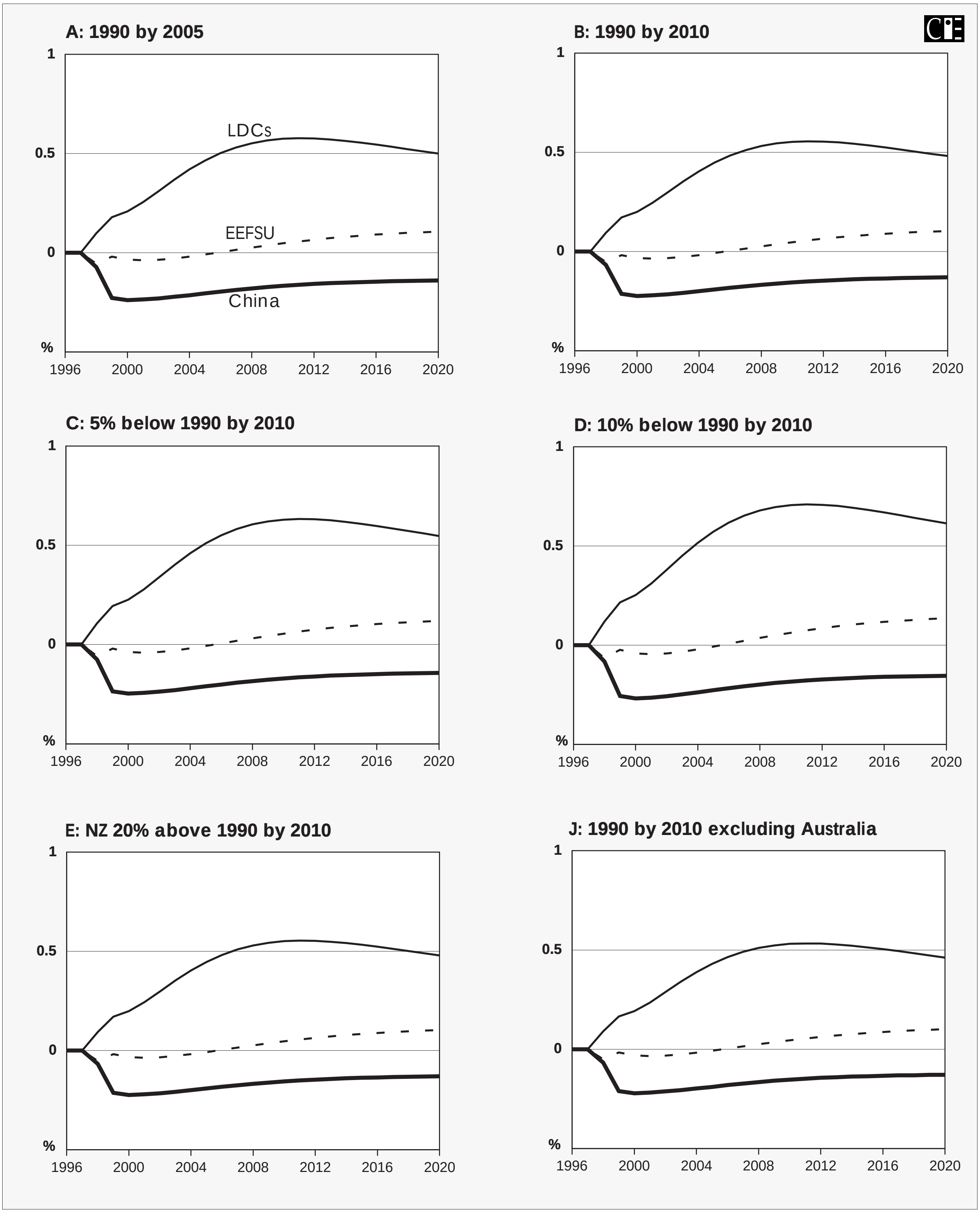
Second, for New Zealand (and to a lesser extent Japan), there is a larger decline in GDP in early years than in later years. This is because of the time it takes the economy to adjust to the initial taxes. The larger the tax, the

Chart 5.4 **Change in GDP by scenario** Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

Chart 5.5 **Change in GDP by scenario** Per cent relative to 'business as usual' *Continued*



Data source: G-Cubed model simulations.

harder the short run adjustment. The GDP loss is smaller in the long run because by then more adjustment, including substitution in production, can take place.

Third, there are number of interacting effects on GDP in the non abating countries. Reduced demand in abating countries reduces the demand for imports from non abating countries. Enhancing this effect is an appreciation of the exchange rates of non abating countries as a result of capital inflow. Working against this demand effect is the fact that the non abating countries obtain a cost advantage over countries that abate, resulting in increased exports. Over all, GDP increases in the LDCs and EEFSU, but declines in China.

Effects on real consumption

Charts 5.6 and 5.7 summarise changes in real consumption under each scenario.

Consumption in the model is determined by a combination of expected future income and current income and the prices of goods that consumers buy. Here income refers to income of households (after tax) and not GDP, which is a measure of production.

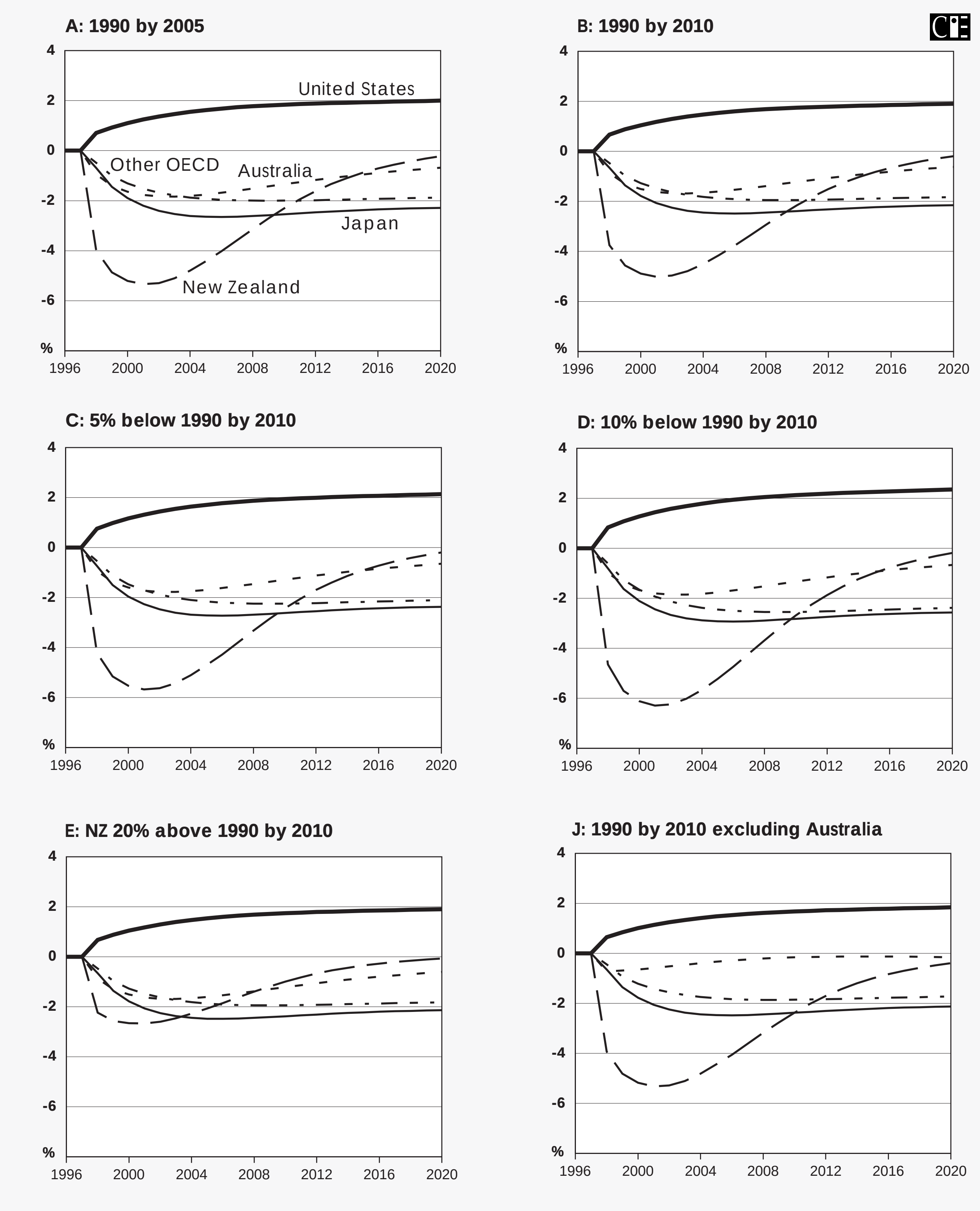
The introduction of a carbon tax leads to changes in returns to labour and capital as a result of reduced production in the economy. In particular, wages fall and in most cases returns to capital fall. Thus income to households falls. At the same time, the price of energy intensive goods increases, further reducing real consumption of these products.

Consumption falls by more than GDP both because income falls by more than GDP and because of the relative price effects – the same consumption bundle is now more expensive.

Although in most countries real consumption declines, this is not the case in the US. In the US returns to capital and labour both increase and so consumption increases.

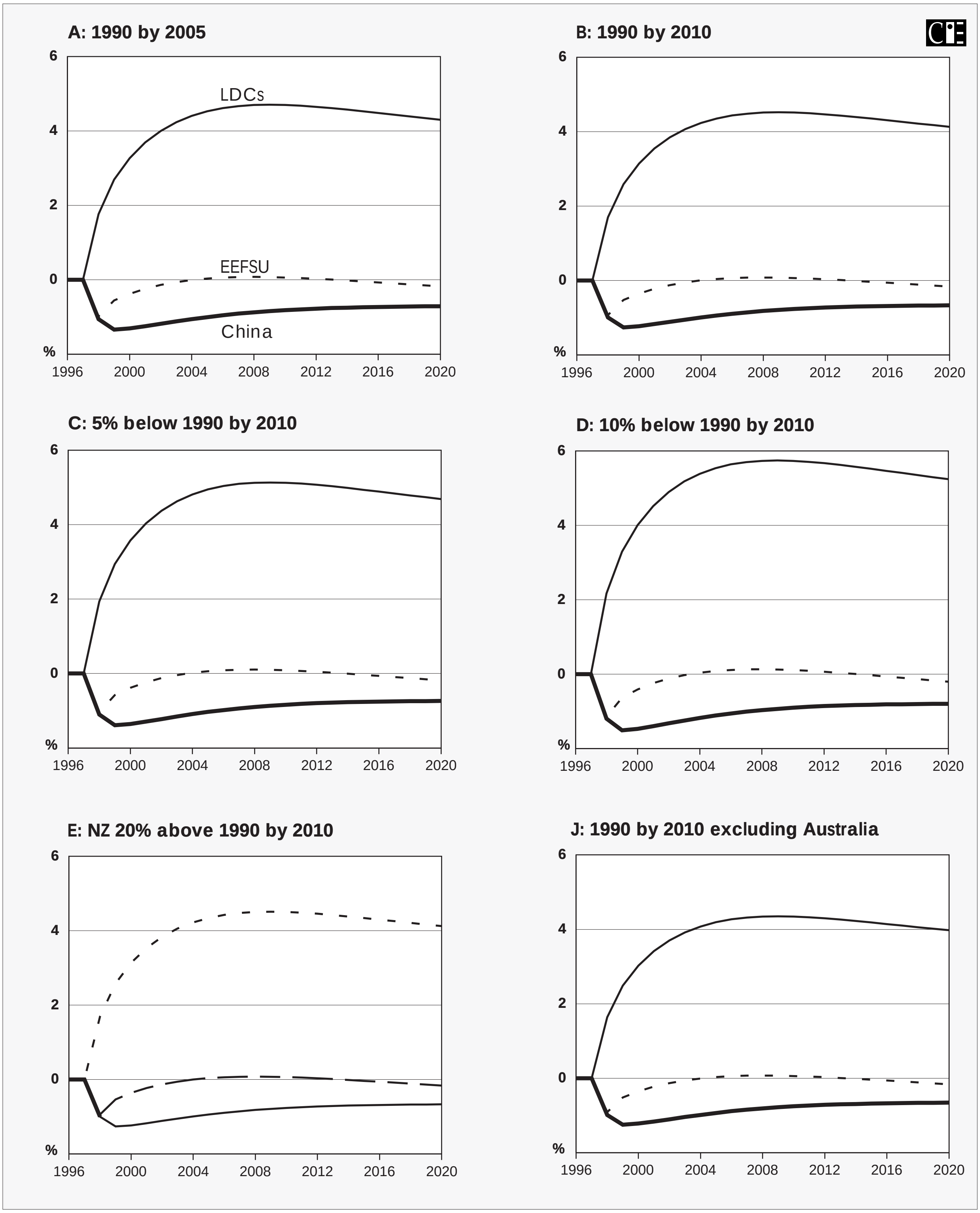
It is interesting to note that in chart 5.6 New Zealand’s consumption path has quite a different shape to that of other countries. This is the result of a number of factors including: the size of the tax in New Zealand; the timing of the tax; and the costs of adjustment to the tax. The result indicates that compared with other countries, it is relatively more difficult for New Zealand to adjust to the tax (which is larger than that for other countries) in

Chart 5.6 **Change in real consumption by scenario** Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

Chart 5.7 **Change in real consumption by scenario** Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

the short term. Higher adjustment costs mean that more resources must be devoted to the process of adjustment, leaving less for consumption.

This result itself depends on the time profile of the tax. Recall that this time profile has been set to smoothly increase by assumption and is not in any way an optimal tax profile. Changing the profile of the tax will change the profile of the consumption results. Indeed, it may be possible to find the 'optimal' tax profile that minimises the costs of adjustment and so smooths New Zealand's consumption profile.

Detailed results for New Zealand

Broad results

Chart 5.8 summarises key sectoral results for scenarios B, D and E. In each case, the biggest output losses are in the energy related sectors. Within the other sectors, losses are fairly evenly spread.

Chart 5.9 summarises the changes in the composition of fuels under scenarios B, D and E. In each case, the share of oil and gas and coal declines relative to 'business as usual'.

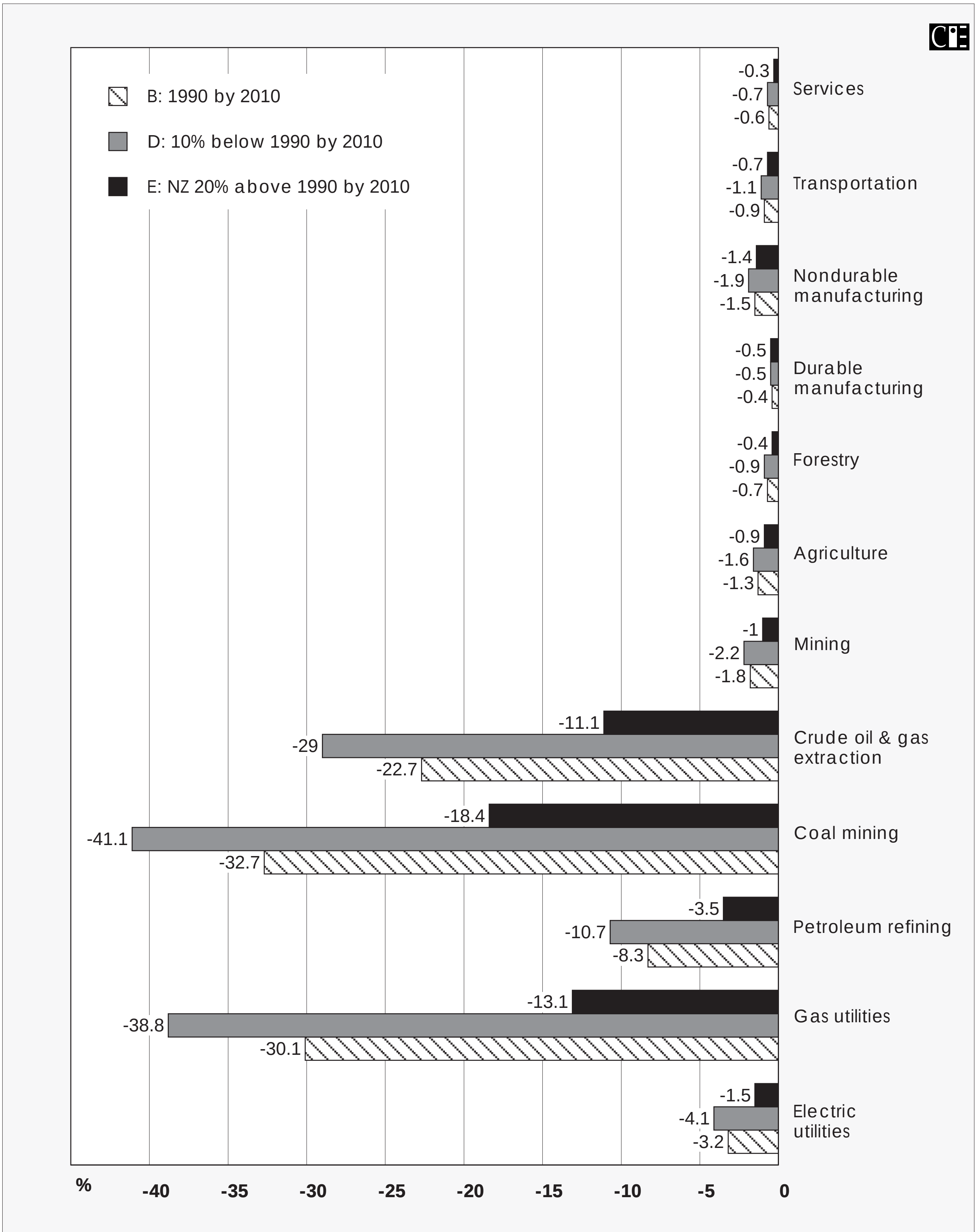
Employment effects

Chart 5.10 summarises the effects of each scenario on real wages and employment.

In the G-Cubed model, labour market effects of policy changes emerge through both changes in employment and changes in real wages. In the short run, employment changes in response to policy changes because over this time frame, real wages are slow to adjust. Over the long term, however, employment returns to 'business as usual' as changes in real wages take place.

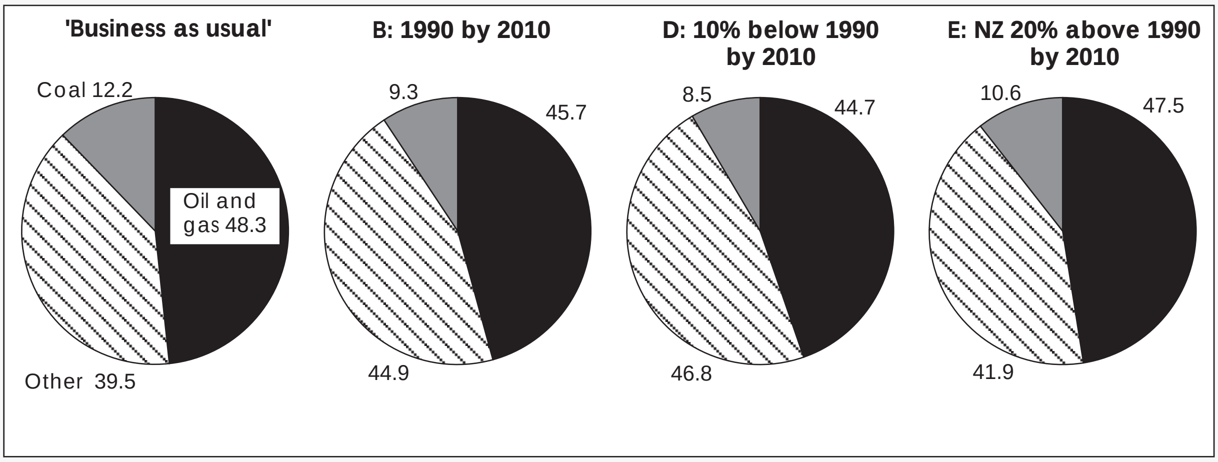
This pattern of results can be seen in chart 5.10. Initially aggregate employment falls under each scenario, however over time, employment returns to around the 'business as usual' level. Note that by 2020, the labour market has not fully adjusted and employment has not returned exactly to 'business as usual'. It is slightly above 'business as usual' because of a slight overshooting of real wages. While wages remain permanently below 'business as usual' over the long term, they adjust slightly after 2020

Chart 5.8 **Changes in output by sector in 2010** Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

Chart 5.9 **Composition of fuel in 2010**



Data source: G-Cubed model simulations.

so that after 2020 (by around 2030) employment returns to 'business as usual' levels.

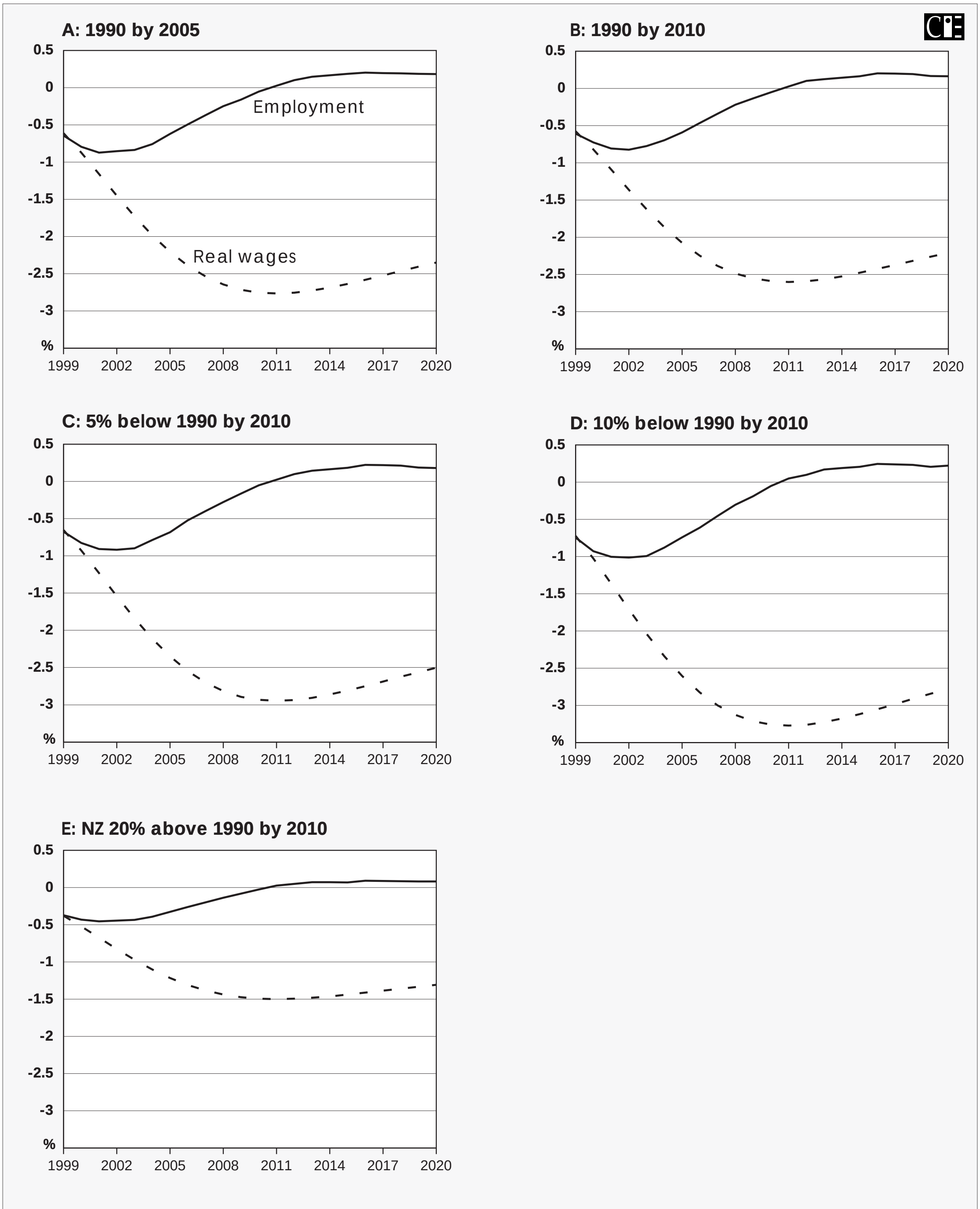
Under each scenario, real wages remain between 2 and 3 per cent below 'business as usual' over the long term. The exception is scenario E where wages remain 1.5 per cent below 'business as usual'.

Relationship between scenarios

The relative magnitude of results between scenarios is determined by the relative size of the carbon tax under each scenario. Indeed, in the G-Cubed model the results are approximately linear with respect to the size of the carbon tax — a doubling of the tax means a doubling of the GDP loss (in percentage terms), for example. While this relationship may not be exactly linear in the real world, the relative magnitude of effects between scenarios will depend on the relative magnitude of the carbon taxes between scenarios.

Thus, the key model mechanisms operating in each of the carbon tax scenarios are the same; it is only the order of magnitude that varies. The discussion that follows focuses on the mechanisms for the first two scenarios and then broadly compares the orders of magnitude for the other scenarios.

Chart 5.10 **Changes in New Zealand employment and real wages** Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

Scenario A: emissions to 1990 levels by 2005

Table B.1 (in appendix B) summarises the simulation results for this scenario. It presents results in terms of percentage deviation from the 'business as usual' scenario. Exceptions to this are the interest rates and the inflation rate, which are expressed as percentage point deviations from 'business as usual'. Note that in the tables, the nominal exchange rate is defined so that a positive percentage change is a depreciation. The terms of trade is defined as the price of imports over the price of exports, so a positive percentage change is a worsening of the terms of trade.

A target of 1990 emissions by 2005 means that emissions in 2005 must be 22 per cent below 'business as usual' levels, and 39 per cent below 'business as usual' by 2020. Achieving this target requires a New Zealand carbon tax of NZ$26 per tonne of carbon in 1999, increasing to NZ$169 per tonne of carbon in 2020. Expressed per tonne of carbon dioxide, these taxes are NZ$7 and NZ$45 respectively.

The introduction of the carbon tax reduces GDP below 'business as usual' levels. GDP is 0.76 per cent below 'business as usual' in 2000, 0.95 per cent below 'business as usual' in 2005 and is around 0.36 per cent below 'business as usual' in 2020.

The carbon tax increases costs throughout the economy, with the raw price of coal, oil and gas increasing by around 35 per cent in 2010. This leads to an increase in the price of electricity and gas to users of 2 and 6 per cent respectively.

The increased costs lead to reduced output, with the greatest reductions in the coal, oil and gas industries (including gas utilities) where output is reduced by between 32 and 50 per cent in 2020. The output of the gas sector declines, despite gas having lower emissions than other fuels, because of the pattern of substitution in the energy sector. This sector tends to use more of its 'capital stock' and less of fossil fuels in response to the carbon tax. In the G-Cubed model, the capital stock of the energy sector embodies the various alternative and renewable fuels. Given their initial high shares in New Zealand, and given the closure of the Maui gas field, it is easier to substitute into renewable fuels than it is to substitute to gas.

The next biggest losses are in nondurable manufacturing (1.5 per cent in 2020) and mining (2.1 per cent).

The pattern of employment changes is similar, but not identical, to that for output. The greatest employment losses (in percentage terms relative to 'business as usual') are for coal, oil and gas, and gas and electric utilities.

Some industries, however, experience an increase in employment. Employment increases in agriculture and forestry in all years of the simulation. Employment increases in durable and nondurable manufacturing in the early years of the simulation. This increase in employment comes about through a substitution of labour for capital in these industries. This is a result of both an increase in the price of capital goods (as a result of the carbon tax) and a reduction in the real wages faced by those industries as the labour market adjusts to the carbon tax.

The New Zealand dollar depreciates following the introduction of the tax, although the magnitude of this depreciation declines through time. This depreciation assists the trade balance in early years — although, by 2020, the improvement in the trade balance is very small. The depreciation results from a decline in long term interest rates relative to the rest of the world, which encourages an outflow of capital. Simultaneously, the trade balance improves, both as a result of the depreciation and to allow the capital outflow.

Long term interest rates decline because of the reduction in the marginal product of capital resulting from the imposition of the carbon tax. Because New Zealand has a higher marginal cost of abatement than other countries, capital is encouraged to flow out of New Zealand.

The depreciation of the currency means that exports of some industries increase following the imposition of the carbon tax, particularly in the early years of the simulation. Given that depreciation is the same for all industries, the size of the export increase for particular industries is determined by the extent to which industry costs are raised by the carbon tax and the extent to which the prices of competing exports are raised by the tax imposed in other abating countries. The largest initial export increases (in percentage terms relative to 'business as usual') are for agriculture, forestry and nondurable manufacturing.

By 2010, the depreciation is not sufficient to offset the cost increase from the carbon tax and so all exports decline relative to 'business as usual'.

These results indicate that the carbon tax has a number of effects on the 'competitiveness' of the New Zealand economy. On the one hand, the New Zealand currency depreciates as a result of a capital outflow. This leads to an improvement in the balance of trade (although the extent of this improvement declines over time). The composition of this improvement is determined by relative prices — in particular, the change in relative industry costs in New Zealand as a result of tax as well as the change in relative industry costs between countries, determined by the magnitude of the carbon tax imposed in different countries, and their different abilities to respond to it.

Scenario B: emissions to 1990 levels by 2010

Table B.2 summarises the results for this scenario.

A target of 1990 emissions by 2010 means that emissions in 2010 must be 27 per cent below 'business as usual' levels. This requires a tax of NZ$25 per tonne of carbon in 1999, increasing to NZ$159 per tonne of carbon in 2020.

In 2020, the tax in this scenario is around 6 per cent lower than that required for scenario A. Other results reflect this, with all changes being lower in magnitude than for scenario A. GDP is reduced below 'business as usual' by: 0.71 per cent in 2000, 0.89 per cent in 2005 and 0.34 per cent in 2020. The loss in 2020 is 6 per cent lower than that for scenario A, illustrating the linearity of the results with respect to the size of the carbon tax.

The carbon tax increases costs throughout the economy, with the raw price of coal, oil and gas increasing by 33 per cent, and the user price of electricity and gas increasing by 2 and 5 per cent respectively.

The increased costs lead to reduced output. The greatest output losses are in coal, oil and gas (including gas utilities) where output is reduced by between 29 and 48 per cent. Outside the energy sector, the greatest output losses (in percentage terms relative to 'business as usual') are in electric utilities, mining, agriculture and durable and nondurable manufacturing.

Despite these output reductions, changes in real wages results in an increase in employment in some sectors, although over the long term aggregate employment returns to 'business as usual' levels. While employment declines in the energy related sectors, it increases in agriculture and forestry, and in most years in durable and nondurable manufacturing.

As in scenario A, the carbon tax results in a reduction in interest rates and a capital outflow as a result of a reduction in the marginal product of capital. This is associated with a currency depreciation and an improvement in the balance of trade. The magnitude of each of these is smaller under scenario B than under scenario A, reflecting the lower tax under scenario B. As before, the improvement in the balance of trade is not sufficient to offset the reduction in consumption and investment, so GDP declines.

Scenario C: emissions to 5 per cent below 1990 levels by 2010

Table B.3 summarises the results for this scenario.

The target under this scenario requires that emissions in 2010 must be 31 per cent below ‘business as usual’ levels and emissions in 2020 must be 42 per cent below ‘business as usual’. This requires a tax of NZ$28 per tonne of carbon in 1999, increasing to NZ$182 per tonne of carbon in 2020. In 2020, this tax is 8 per cent higher than that for scenario A and 14 per cent higher than that for scenario B.

In this scenario, GDP declines (relative to ‘business as usual’) by 0.8 per cent in 2000, 1.01 per cent in 2005 and 0.38 per cent in 2020. The magnitude of this decline relative to scenarios A and B reflects the linearity of model results with respect to the size of the carbon tax.

The carbon tax increases costs throughout the economy, with the price of coal, oil and gas increasing by around 40 per cent, and the user price of electricity and gas increasing by 3 and 6 per cent respectively. The increased costs lead to reduced output. The greatest output losses (in percentage terms relative to ‘business as usual’) are in coal, oil and gas (including gas utilities), where output is reduced by between 34 and 55 per cent. Outside the energy sector, the greatest output losses are in electric utilities, mining, agriculture and durable and nondurable manufacturing.

As in scenarios A and B, changes in real wages lead to an increase in employment in some sectors (including agriculture, forestry and durable and nondurable manufacturing), although in the long term there is no change in aggregate employment (relative to ‘business as usual’), but a permanent reduction in real wages.

As in scenarios A and B, the carbon tax results in a reduction in interest rates and a capital outflow (which is associated with a depreciation and an improvement in the balance of trade). The magnitude of this effect is generally greater in scenario C.

Scenario D: emissions to 10 per cent below 1990 levels by 2010

Table B.4 summarises the results for this scenario.

This target requires that emissions in 2010 must be 34 per cent below ‘business as usual’ and 45 per cent below ‘business as usual’ by 2020. This requires a tax of NZ$31 per tonne of carbon in 1999, increasing to NZ$203. in 2020. This is the highest tax rate of all the carbon tax scenarios, leading to the highest magnitude effects.

GDP declines (relative to ‘business as usual’) by 0.89 per cent in 2000, 1.12 per cent in 2005 and 0.42 per cent in 2020.

As in the other scenarios, costs throughout the economy increase, with the price of coal, oil and gas increasing by 42 per cent, and the user price of electricity and gas increasing by 3 and 7 per cent respectively.

The resulting output losses are greatest in coal, oil and gas (including gas utilities) where output is reduced by between 38 and 61.5 per cent (in 2020). Nondurable manufacturing output declines by between 1.3 and 1.8 per cent, and agriculture and forestry output declines by 1.3 and 0.6 percent respectively (in 2020).

Although employment in most sectors declines, the reduction in real wages leads to an increase in employment in some sectors. Employment in agriculture and forestry increases in all years, while employment in durable and nondurable manufacturing increases in most years. Over the long term there is no change in aggregate employment, but a permanent reduction in real wages.

As in scenarios A, B and C, the carbon tax results in a reduction in interest rates and a capital outflow (which is associated with a depreciation and an improvement in the balance of trade). The magnitude of each of these is greater under scenario D, reflecting the higher tax under this scenario. The improvement in the balance of trade (which declines over time) is not sufficient to offset the reduction in consumption and investment, (which declines over time) so GDP declines.

Scenario E: emissions to 20 per cent above 1990 levels by 2010

Table B.5 summarises results for this scenario.

Under this scenario, New Zealand’s abatement target is lower than that for any other abating region. For New Zealand, carbon dioxide emissions need to be 12 per cent below ‘business as usual’ by 2010 (this is slightly less than half as stringent than the target under scenario B). The target for this scenario requires a carbon tax of NZ$12 per tonne in 1999, increasing to NZ$76 per tonne in 2020. By 2020 this is roughly half the carbon tax as under scenario B.

The various results for this scenario reflect this less stringent target and lower carbon tax. GDP declines by 0.44 per cent (relative to ‘business as usual’) in 2000, by 0.53 per cent in 2005 and by 0.22 per cent in 2020.

The price rises in the economy are lower than under the other scenarios, with the raw price of coal, oil and gas increasing by 15 per cent and the user price of electricity and gas increasing by 1 and 2 per cent respectively.

Output losses are also correspondingly lower, with an output loss in coal, oil and gas (including gas utilities) of between 15 and 22 per cent.

As in other scenarios, the reduction in real wages leads to an increase in employment in agriculture and forestry. Over the long term there is no change in aggregate employment, but a permanent reduction in real wages.

The interest rate reduction and capital outflow is also lower, resulting in a smaller depreciation and a smaller improvement in the balance of trade.

Scenario J: excluding Australia from abatement

Table B.6 summarises the results for this scenario.

For New Zealand, the abatement target and carbon tax is the same as for scenario B. The tax starts at NZ$25 in 1990 and increases to NZ$159 by 2020 while this means that the changes in New Zealand's domestic prices are the same as for scenario B, the macroeconomic and other results are different, however, because of differences in relative prices between regions.

When Australia does not abate, the capital outflow from New Zealand is larger, as is the reduction in investment, GDP and consumption. The same is true for other countries. For example, under this scenario the US has a smaller increase in GDP than under scenario B. This is because Australia is able to maintain some of the capital that went to the US under scenario B.

GDP declines by 0.75 per cent (relative to 'business as usual') in 2000, by 0.95 per cent in 2005 and by 0.36 per cent in 2020.

The output losses are greatest in coal, oil and gas (including gas utilities) where output declines by between 29.4 and 49.2 percent. Manufacturing output declines by up to 0.7 per cent for durable manufacturing and 1.29 per cent for nondurable manufacturing. Agriculture and forecasting output declines by 1 per cent and 0.5 per cent (in 2020) respectively.

Although employment in most sectors declines, the reduction in real wages leads to an increase in employment in some sectors. Employment in agriculture and forestry increases in all years, while employment in durable and nondurable manufacturing increases in most years. Over the long term there is no change in aggregate employment, but a permanent reduction in real wages.

6 Results: permit trading and uniform tax scenarios

This chapter reports results for scenarios F, G, H and I. Each of these scenarios involves either internationally tradable emissions permits, uniform carbon taxes or some combination of these. As outlined in table 4.1, scenarios F, H and I should be compared with scenario B, while scenario G should be compared with scenario D.

Modelling tradable emission permits in G-Cubed

The value of permits bought and sold by each country enters the model explicitly as a wealth transfer through the current account in each country. Changes in the value of wealth also appear in the private wealth holdings of citizens. The purchase of permits by a country means that, at some point in the future, exports must be greater than imports by the amount of the permit in order to pay for the permit (plus any interest payments on foreign debt, depending on when permits are paid for). This feature defines the key difference between G-Cubed and other models that treat permit trading.

A permit trading simulation involves the following broad steps.

- First, specify the total emissions target for all countries within the trading system. For scenario F this is 1990 levels by 2010. For scenario G this is 10 per cent below 1990 levels by 2010.
- Second, find the uniform carbon tax that will achieve this target (given this uniform tax, different countries will undertake different amounts of abatement).
- Third, specify the initial allocation of permits for each country. For the simulations presented here, the initial allocation is determined by each country's share of gross emissions in 1990.

Given this, each country will want to trade emissions permits depending upon their emissions with the uniform tax, their initial allocation of permits and the marginal costs of abatement versus the price of permits. Thus, if a country does not have enough permits for its requirements and the price of permits is lower than the marginal cost of abatement, then that country will buy some permits. The value of those permits is equal to the uniform carbon tax times the quantity.

Once this first round of permit trade takes place, there will be transfers of wealth through the current accounts of different countries and hence changes in the patterns of exports and imports to pay for permit trade. This will lead to changes in emission paths and so the original uniform carbon tax will no longer achieve the given target. This must then be recalculated and the value of permits trade recalculated and so on.

Hence, by an iterative process, the model calculates permits trade, value of permits and wealth transfers that are all consistent with the emissions target. The final value of all these will most likely be quite different to the initial value set up in the first interaction.

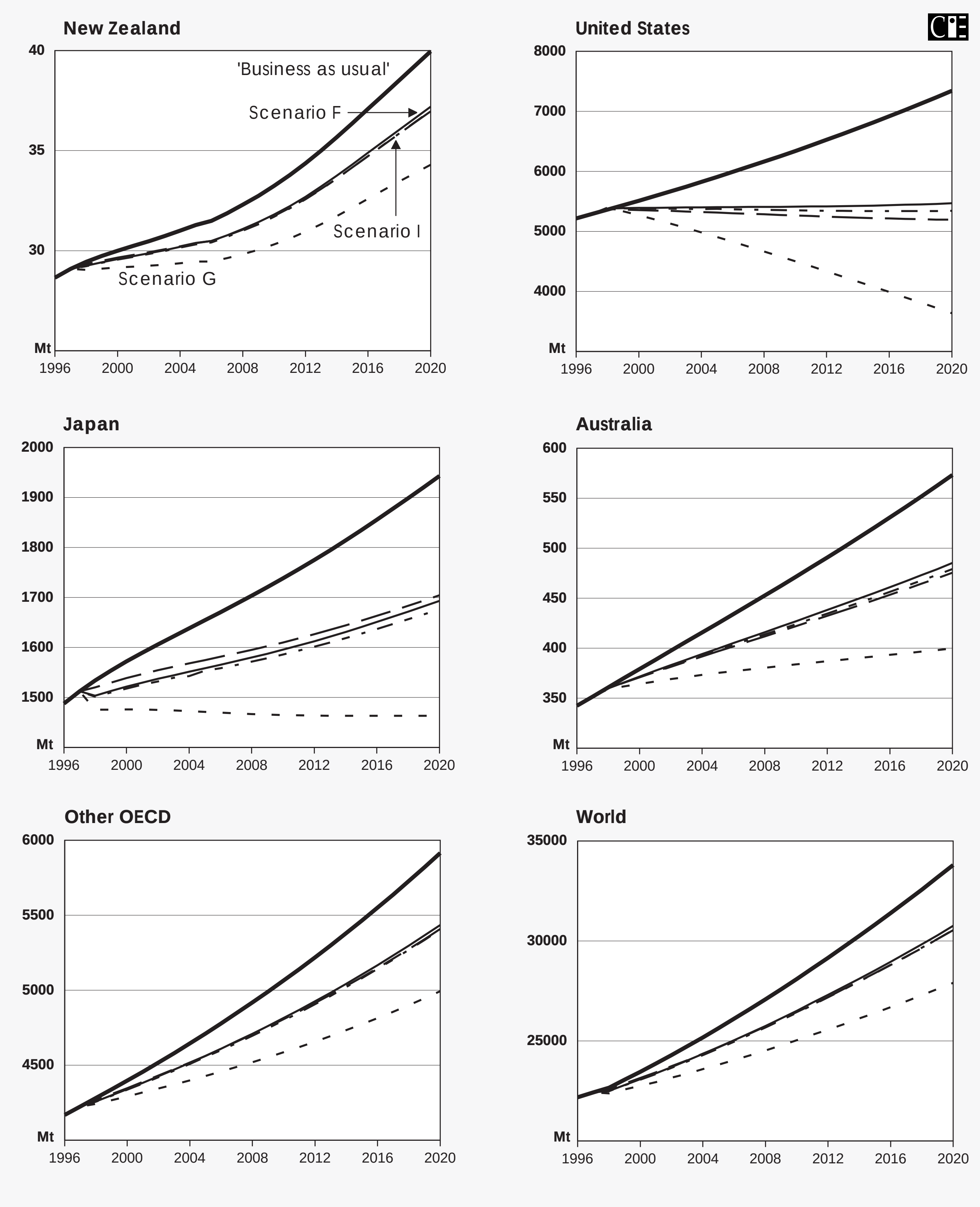
It is worth noting that permit trading in a dynamic model has quite different implications to permit trading in a static model. In a dynamic model the pattern of emissions changes over time and so the weighted average marginal abatement cost (and hence the price of permits) changes over time. Whereas in a static model it may be possible to find an initial allocation that removes the need for any trade of permits (and hence all the associated wealth transfers). This is considerably more difficult in a dynamic model, which indicates it is likely to be impossible in practice.

Differences in emission targets

The key difference between these scenarios and the carbon tax scenarios is that, for the permit trading and uniform tax scenarios, the emission targets refer to total Annex I emissions, while under the carbon tax scenarios the targets refer to each Annex I country. This means that, under the permit trading and uniform tax scenarios, the abatement by each region will differ.

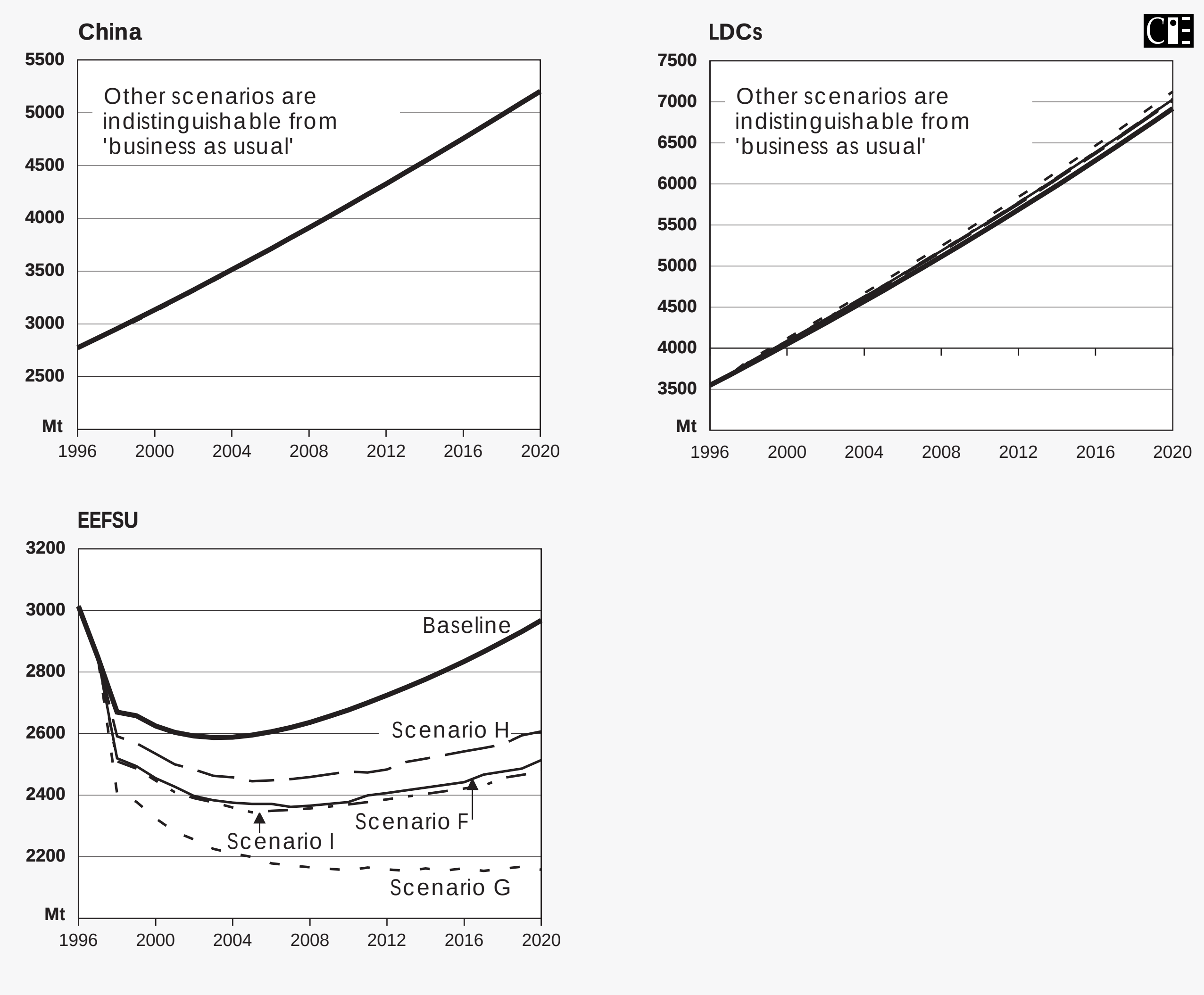
This is illustrated in charts 6.1, 6.2 and 6.3. The differences between the permit trading and carbon tax scenarios are clearest in chart 6.3, which shows the percentage change in emissions relative to ‘business as usual’ in 2020 (although 2020 is used as the year of comparison here, the patterns of changes are the same in other years). Under scenarios F, H and I, each Annex I region (except EEFSU), does less abatement than under scenario B, and New Zealand does the least abatement of all regions. It is also the case that total abatement under scenarios F, H and I is less than total abatement under scenario B. This is because under scenario B, EEFSU does not need to do any abatement as its emissions remain below 1990 levels throughout the ‘business as usual’ scenario. However, EEFSU is included in the permit scheme. This effectively lowers the total abatement required under the permit scheme.

Chart 6.1 **Carbon dioxide emissions by country** Emission trading scenarios



Data source: G-Cubed model simulations.

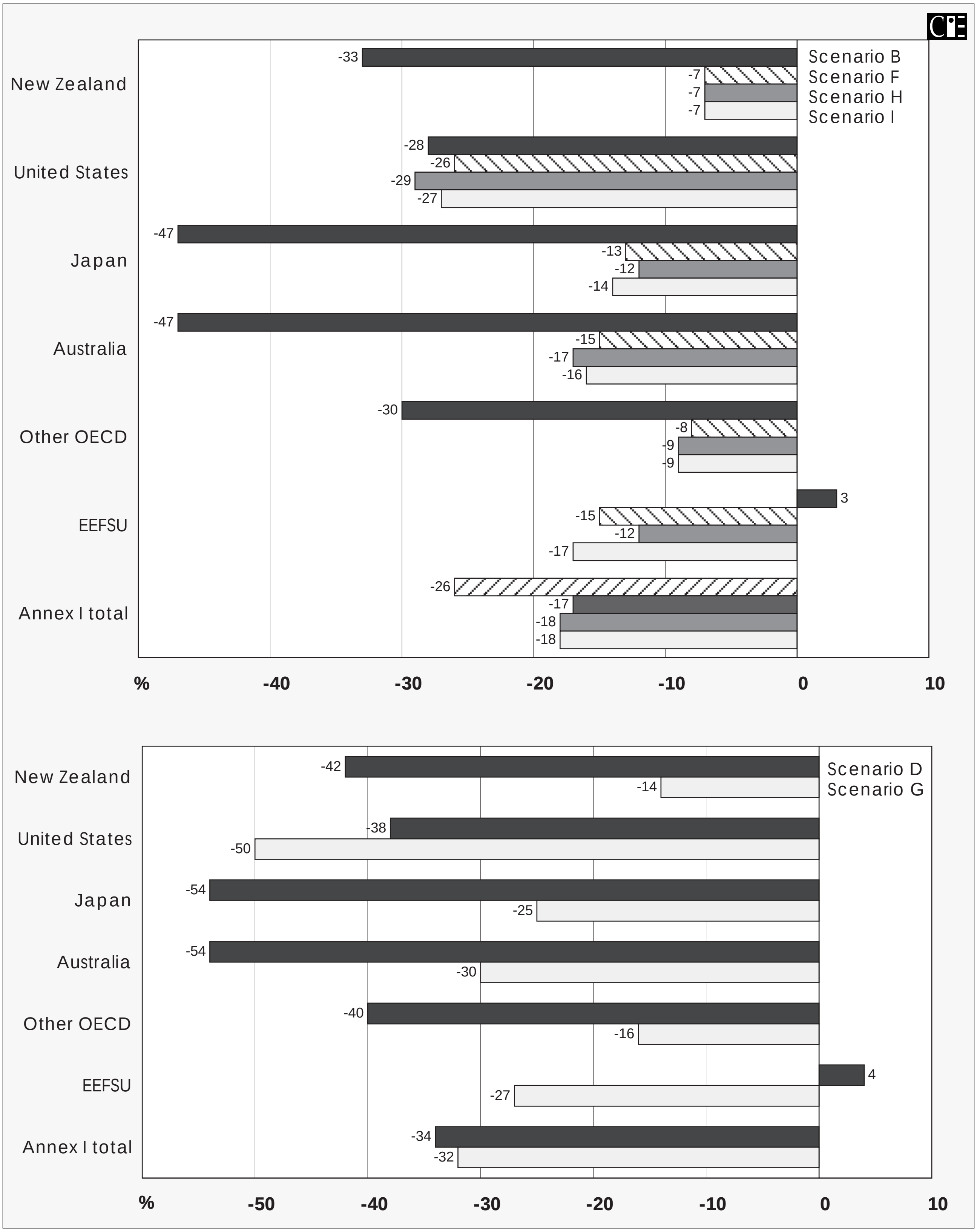
Chart 6.2 **Carbon dioxide emissions for nonabating countries**



Data source: G-Cubed model simulations.

Comparing scenarios D and G makes the differences between country targets and total Annex I targets clear. In this case, the total amount of abatement for all Annex I is approximately the same in both cases (it is not the same because of the effect of including EEFSU in the permit scheme). However, the distribution of abatement is considerably different. Under scenario G, the least abatement is done by New Zealand (in percentage terms relative to the 'business as usual' scenario), followed by other OECD, Japan and then Australia. The United States does the most abatement. This pattern of abatement follows the pattern of the marginal cost of abatement as reflected in the carbon tax rates for scenario D (see chart 5.3). The regions with the highest marginal cost of abatement do the least abating, and those with the highest marginal cost do the most.

Chart 6.3 **Patterns of abatement** Change in emissions relative to 'business as usual' in 2020



Data source: G-Cubed model simulations.

Although EEFSU does not need to do any abating under the targets for scenario D, it in fact has a low marginal cost of abatement. Because it is allocated permits, it is profitable for EEFSU to do some abating and sell the permits.

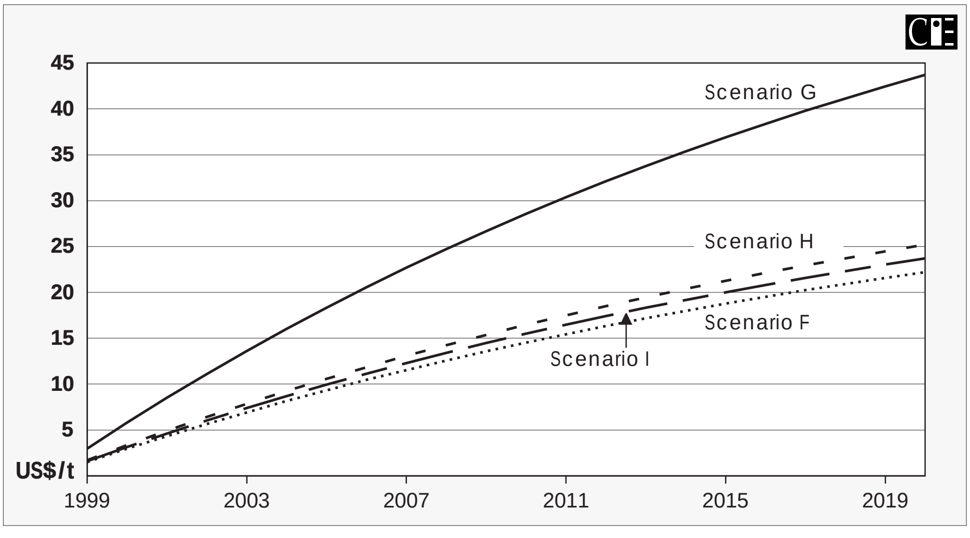
Differences in tax rates

The key mechanism that drives the differences in abatement between countries relates to the fact that scenarios F, G, H and I all involve a uniform tax across countries. For the emission trading scenarios, this tax is in fact the permit price in each year. These taxes and prices are shown in chart 6.4. The same tax imposed on different economies, each with different substitution possibilities, will result in different levels of abatement. Combined with this is the fact that countries with low marginal abatement costs can effectively make money by selling permits and abating.

The various economic effects of scenarios F to I result from the magnitudes of the uniform tax (or permit price). For most countries, the uniform tax or permit price is lower than the country specific taxes under scenarios B or D. For New Zealand, the permit price in scenario F (in 2020) is 77 per cent lower than the corresponding carbon tax in scenario B. Also for New Zealand, the permit price for in scenario G is 64 per cent lower than the corresponding carbon tax in scenario D.

For the United States, permit prices are actually higher than the carbon taxes, which is why the United States sells permits and does abatement.

Chart 6.4 **Uniform tax and permit price**



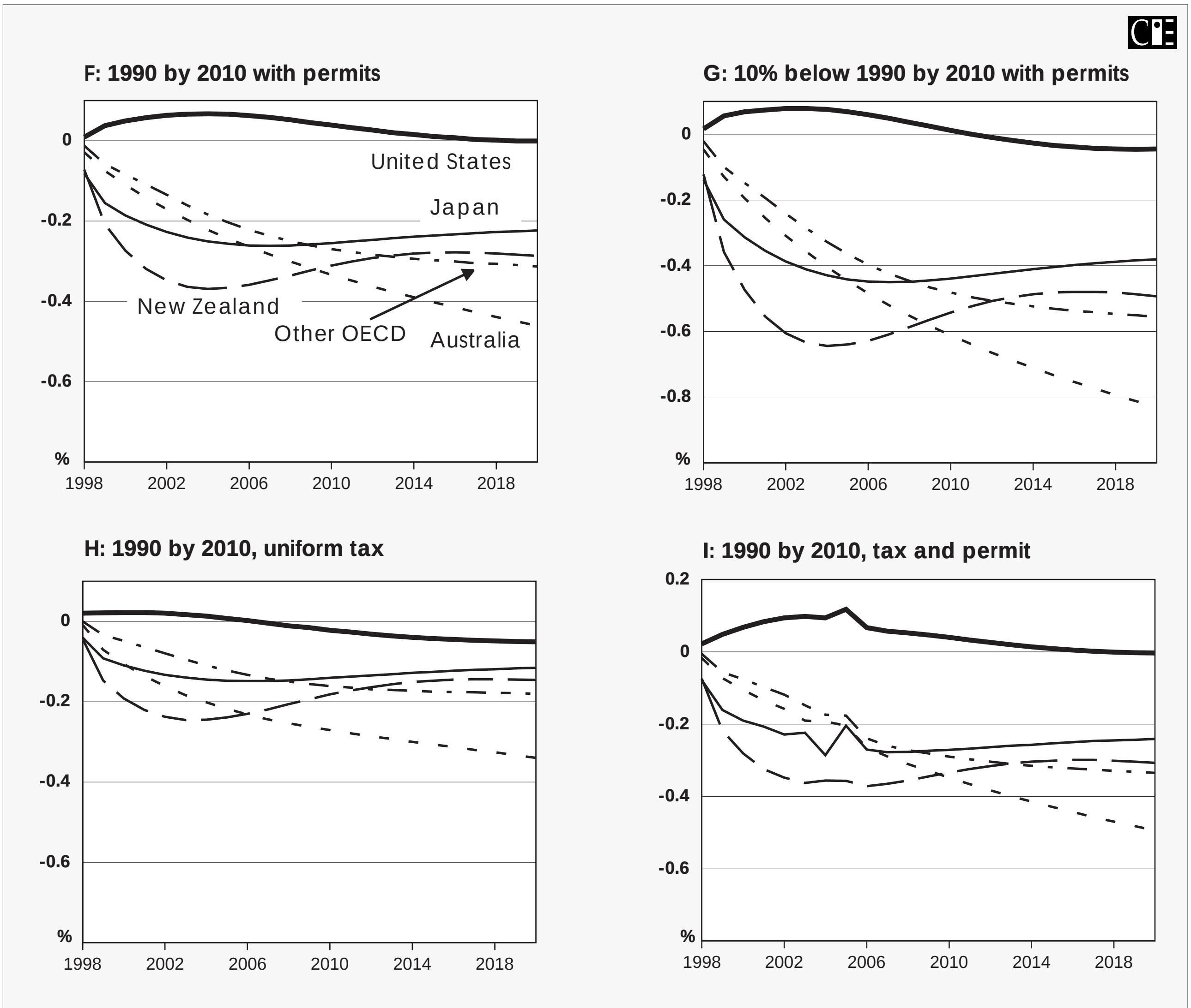
Data source: G-Cubed model simulations.

Effects on GDP

Charts 6.5 and 6.6 summarise the changes in GDP for each region for scenarios F to I.

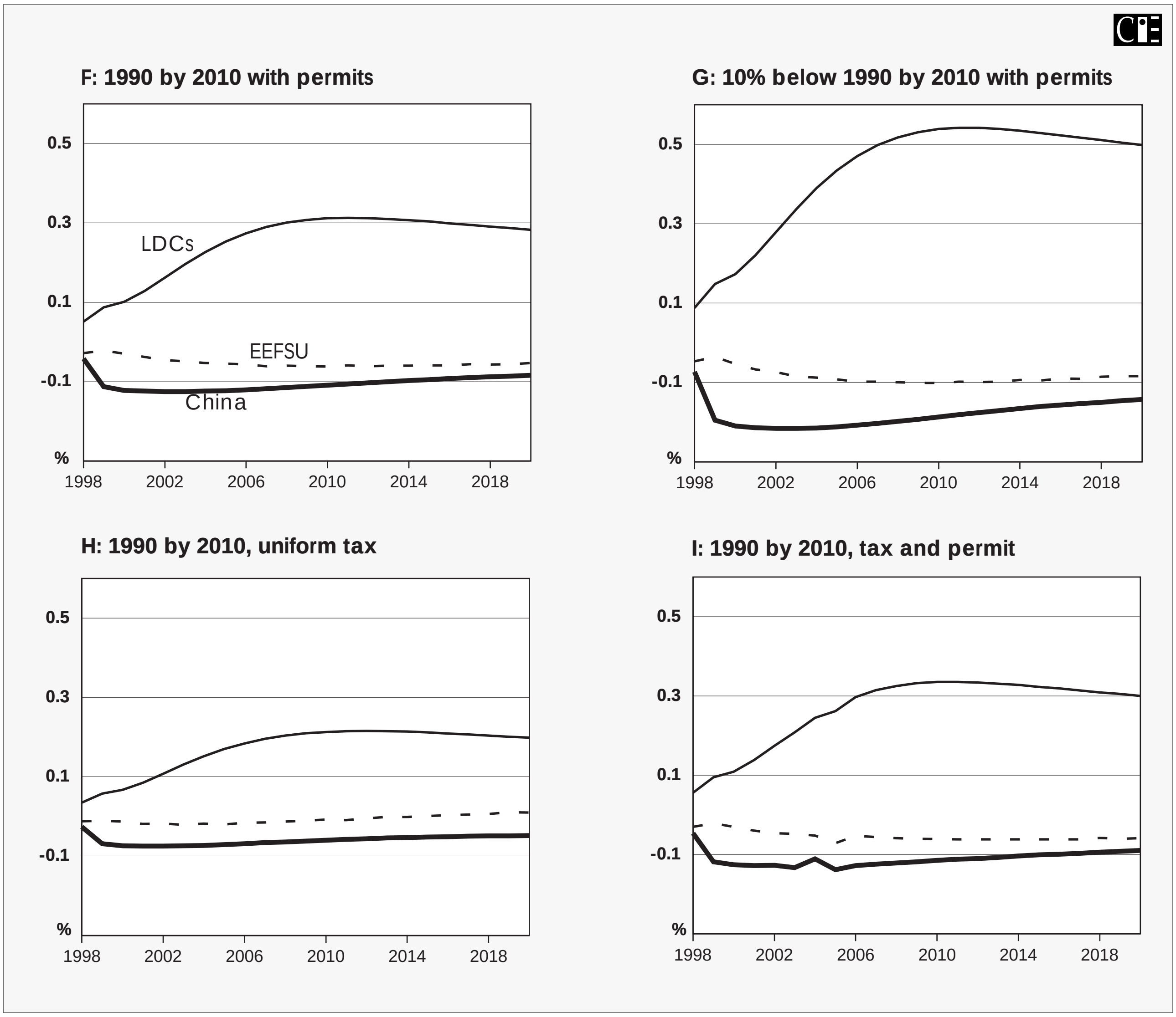
For each of the Annex I countries (except the US and EEFSU), the losses in GDP are smaller under the permit trading scenarios than the losses under the corresponding carbon tax scenarios. (As before, the effects start in 1998.) As noted above, this is a result of the lower carbon tax rate in the permit trading scenarios. For New Zealand, the uniform carbon tax leads to a lower GDP loss than does permit trading or the mix of permit trading and uniform tax (that is, comparing scenarios F, H and I to scenario B). This is because New Zealand gets to keep the revenue under a uniform carbon tax.

Chart 6.5 **Change in GDP for emission trading scenarios**



Data source: G-Cubed model simulations.

Chart 6.6 **Change in GDP for emission trading scenarios** *Continued*



Data source: G-Cubed model simulations.

For the US, the gains in GDP are smaller under the permit trading scenarios than under the individual country carbon tax scenarios. This is because the US does not attract the same capital inflow as under the carbon tax scenarios. US GDP declines under the uniform carbon tax scenario.

China experiences a slightly smaller loss in GDP under the permit trading scenarios, while the LDCs experience a smaller gain in GDP under permit trading than under the individual country carbon tax scenarios.

Scenario I is a mix of a tax regime and a permit trading system. The change from one system to the other in 2005 leads to an expected change in wealth, which in the case of Japan and the United States, leads to a short term over adjustment in GDP. This over adjustment is temporary and, after 2006, GDP returns to its original path.

A similar over adjustment occurs in real consumption for most countries. Again, this is due to the expectation effects of the change from a uniform tax to a permit scheme. As for GDP, this effect is temporary.

Effects on real consumption

Charts 6.7 and 6.8 summarise the changes in real consumption for each region for scenarios F to I. In the long term, New Zealand's real consumption declines by between 0.3 and 0.7 per cent. Losses in the short term are greater, however, between 1.7 and 2.8 per cent.

Real consumption is determined as described in chapter 5. For the Annex I countries, the losses in consumption are smaller under permit trading than under the carbon tax scenarios. The exceptions are the United States and EEFSU. For New Zealand, the real consumption losses are considerably lower under permit trading, with the best outcome under a uniform carbon tax.

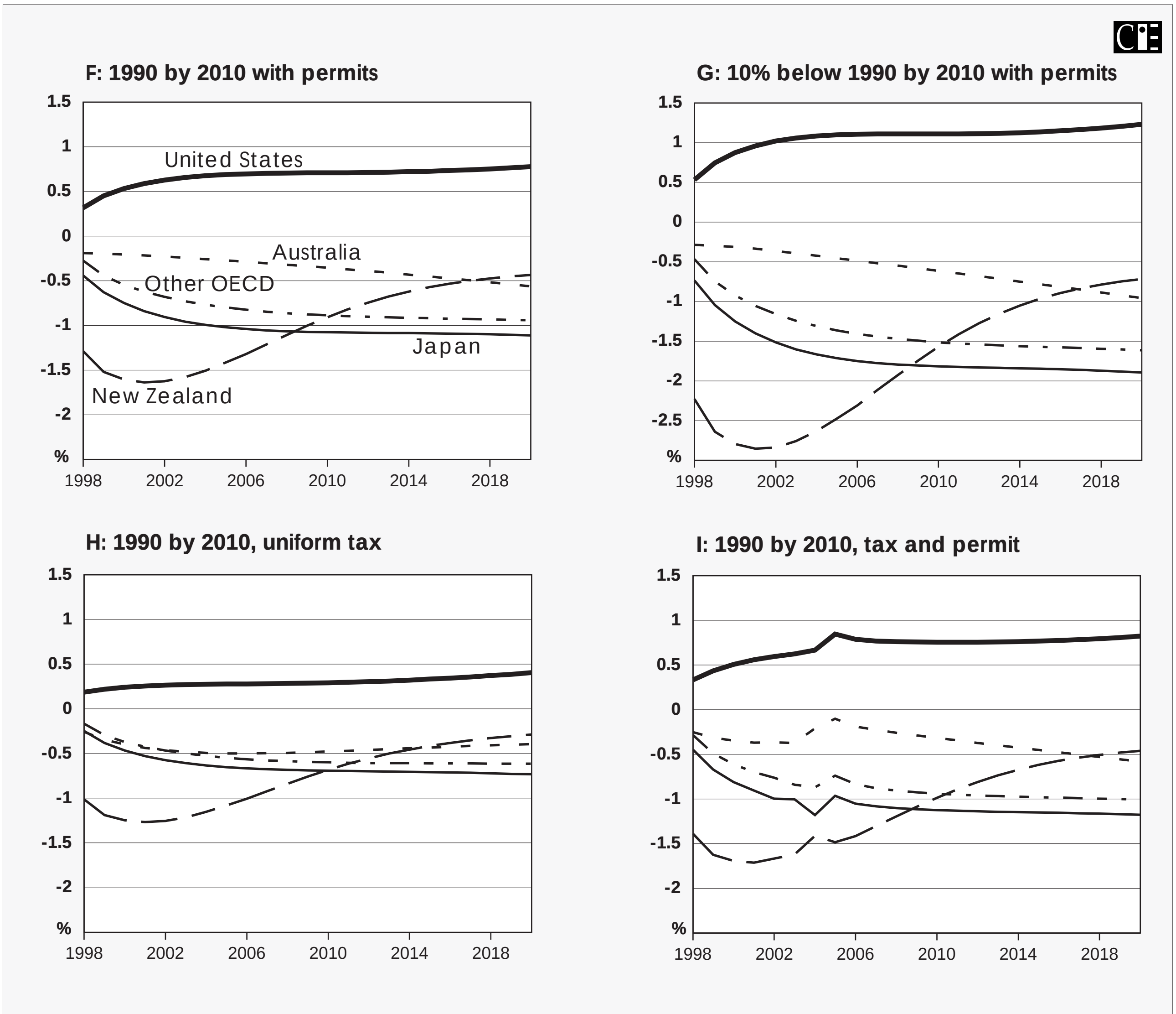
For scenario I, there is a similar effect on real consumption as there was for GDP at the time of the change from the uniform tax to the permit system. There is a temporary over adjustment in real consumption as a result of the expectation effects of the change in policy.

New Zealand employment and real wages

Chart 6.9 summarises changes in employment and real wages for New Zealand. As in the case of the carbon tax scenarios, the long term labour market effects come through a reduction in real wages. This reduction is considerably lower for the emission trading and uniform tax scenarios that for the corresponding individual country carbon tax scenarios.

In chart 6.9 employment has not finally returned to 'business as usual' level by 2020, but remains slightly below it. In contrast to the results for the individual country carbon tax scenarios, in this case there is not an over adjustment of real wages (because of the lower tax or permit price) and so employment does not move above 'business as usual'. Real wages adjust slightly after 2020 to return employment to 'business as usual levels' after 2020 (by around 2030).

Chart 6.7 **Change in real consumption by scenario**



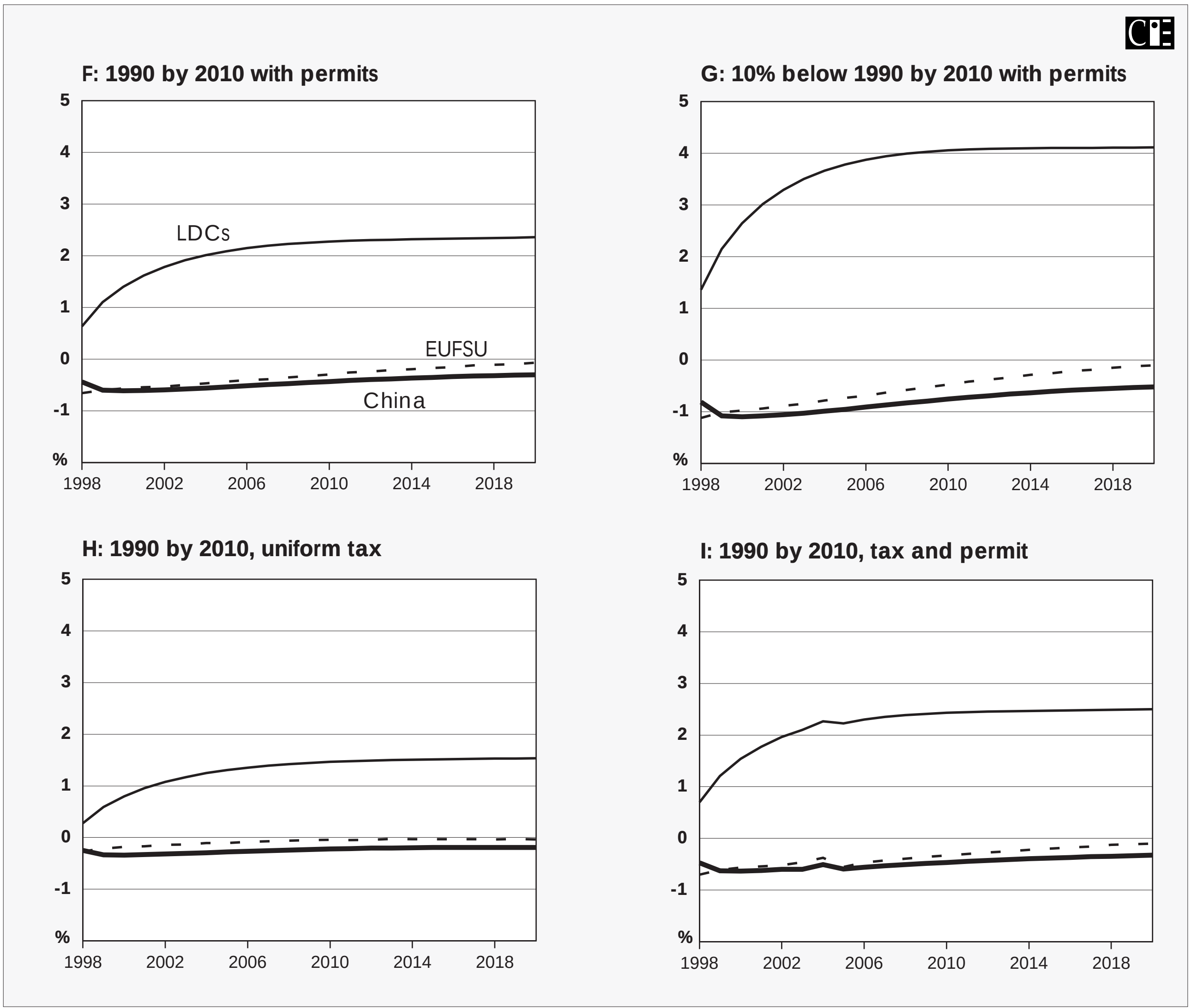
Data source: G-Cubed model simulations.

Other results for New Zealand

Tables C.1 to C.4 (in Appendix C) summarise a range of results for New Zealand for scenarios F to I.

In each case, the magnitude of the results is smaller than under the corresponding individual country carbon tax scenario. For example, the magnitude of the effects for scenarios F, H and I are smaller than those for scenario B. This is because the taxes involved (or the permit price in the case of scenarios F and I) are lower than the tax under scenario B.

Chart 6.8 **Changes in real consumption** Relative to 'business as usual'

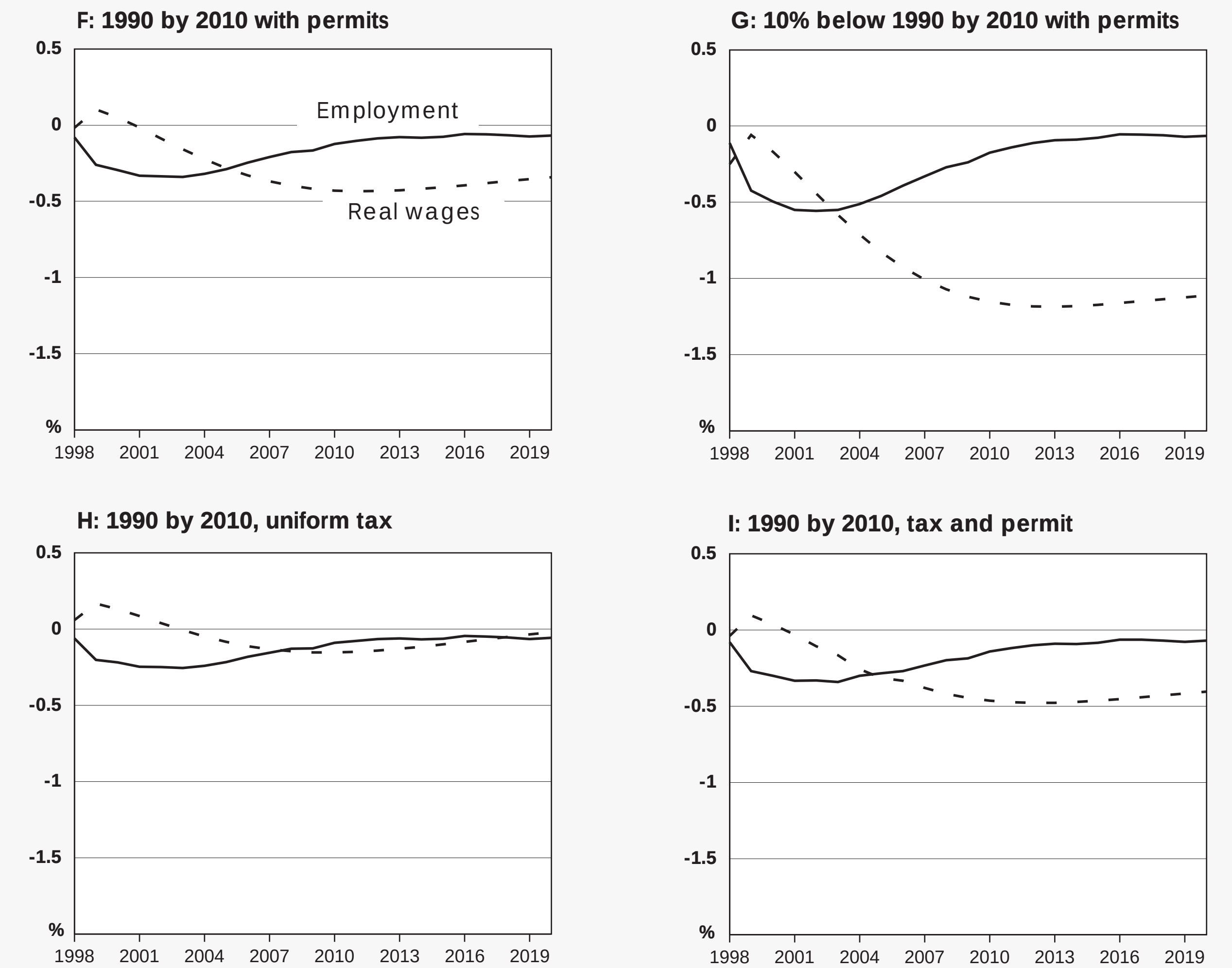


Data source: G-Cubed model simulations.

The taxes, or permit price, are similar for scenarios F, H and I. This means that the results are broadly similar. An important difference, however, is that, under scenario H, New Zealand gets to keep the revenue from the carbon tax. This is in contrast to scenario F, where domestic resources must be spent to purchase permits from other countries. Thus, while the permit price and taxes are similar (the tax is, in fact, marginally higher under scenario H), the GDP and consumption losses are smaller under scenario H than under scenario F.

Reduction in the output of the primary energy industries is slightly greater in scenario H than in scenario F, but the output reduction in the other sectors is smaller.

Chart 6.9 **Changes in employment and real wages for New Zealand** Relative to 'business as usual'



Data source: G-Cubed model simulations.

The effects of scenario G are smaller than those of the corresponding individual country carbon tax scenario (D). This is because the permit price is less than the carbon tax. The key mechanisms operating in scenario G are the same as for scenario D.

7 Sensitivity analysis

This chapter reports selected sensitivity analysis with the G-Cubed model. The sensitivities are undertaken relative to core scenario B.

Approach

Our approach to sensitivity analysis is as follows. First, the appropriate elasticity or revenue recycling assumption is changed and, where necessary (in the case of elasticities), the 'business as usual' scenario is recalculated. We then impose on the new model the tax rates in each year and in each country that were used in the original scenario B. Thus, the only thing that changes between scenario B and the relevant sensitivity scenario is the elasticity or the way in which the revenue is recycled. By comparing the responsiveness of the original and the modified models, we can make judgements about the importance of the changed parameter or revenue recycling assumption.

We compare the responsiveness of the models with alternative parameters or recycling setting by examining two ratios:

- the GDP change per unit of tax; and
- the change in emissions per unit of tax.

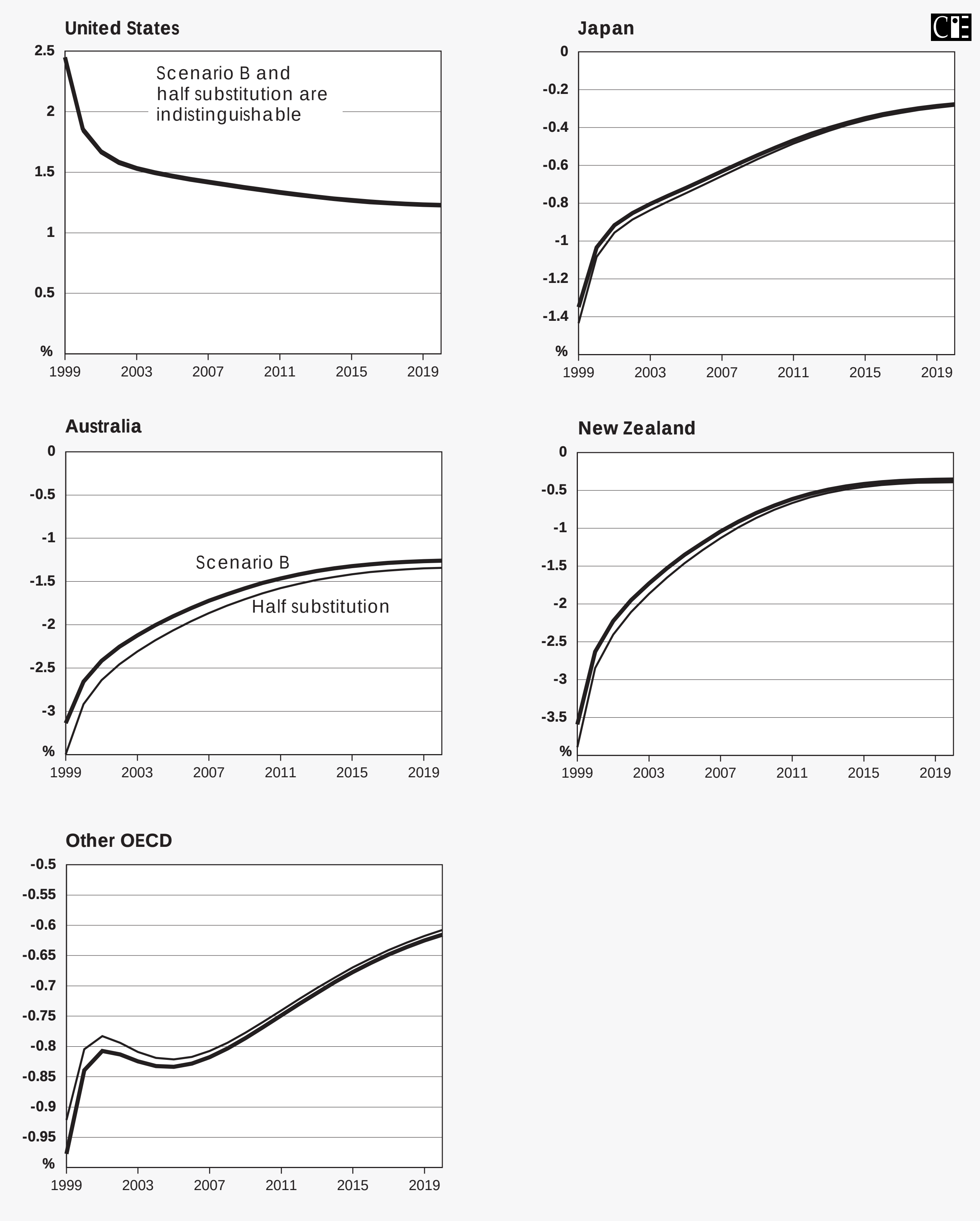
Comparing these ratios between the original model and the modified model indicates the marginal cost of abatement in the different models and hence the sensitivity of results to the selected parameters or settings.

Halving consumer substitution between energy sources

This sensitivity test involves halving final consumers' elasticity of substitution between energy sources in each region. Chart 7.1 summarises the GDP change per unit of tax for the core scenario B and the same scenario in which the consumer elasticity of substitution between energy sources is halved. Chart 7.2 summarises the change in emissions per unit of tax under the core scenario B and the scenario with the halved elasticity.

The most notable result is that the two sets of ratios are almost identical. While there are some detectable differences (in the case of New Zealand),

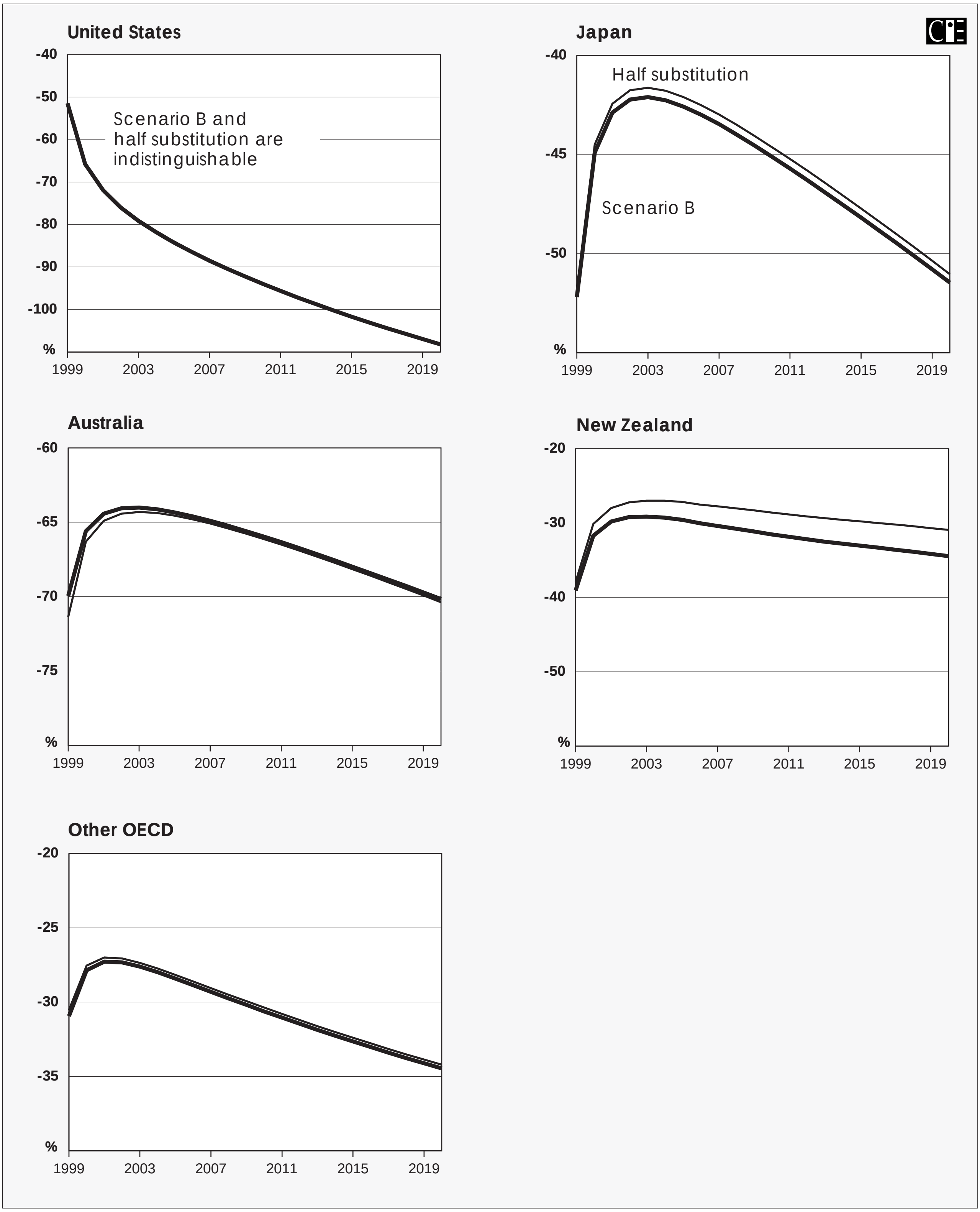
Chart 7.1 **GDP change per unit of tax**[a] Standard versus half consumer substitution elasticity between energy sources



[a] Defined as the percentage change in real GDP relative to the 'business as usual' scenario divided by the carbon tax in US cents per tonne.

Data source: G-Cubed model simulations.

Chart 7.2 **Change in emissions per unit of tax**[a] Standard versus half consumer substitution elasticity between energy sources



[a] Defined as the percentage change in emissions relative to 'business as usual' scenario divided by the carbon tax in US cents per tonne.

Data source: G-Cubed model simulations.

the differences are very small (for New Zealand the difference in the change in emissions per unit of tax is less than 0.04 percentage points per US$1 tax). This indicates that the marginal cost of abatement is unchanged with this change in parameters. This in turn implies that the key results from the analysis will also be unchanged.

Halving substitution between consumer goods

This sensitivity involves halving the final consumers' elasticity of substitution between consumer goods. Charts 7.3 and 7.4 summarise the GDP change per unit of tax and the change in emissions per unit of tax for the base scenario B and the scenario with half the substitution elasticity.

Again, the ratios for the alternative settings are mostly indistinguishable, indicating that the parameter change does not alter the marginal costs of abatement.

Implications

This sensitivity analysis indicates that changes in the magnitude of either set of final consumption elasticities (between energy sources and between consumer goods) does not significantly change the key model results. This indicates that these parameters are not important in determining the global effects of changes in carbon taxes. This result is not surprising given that the elasticities are relatively low.

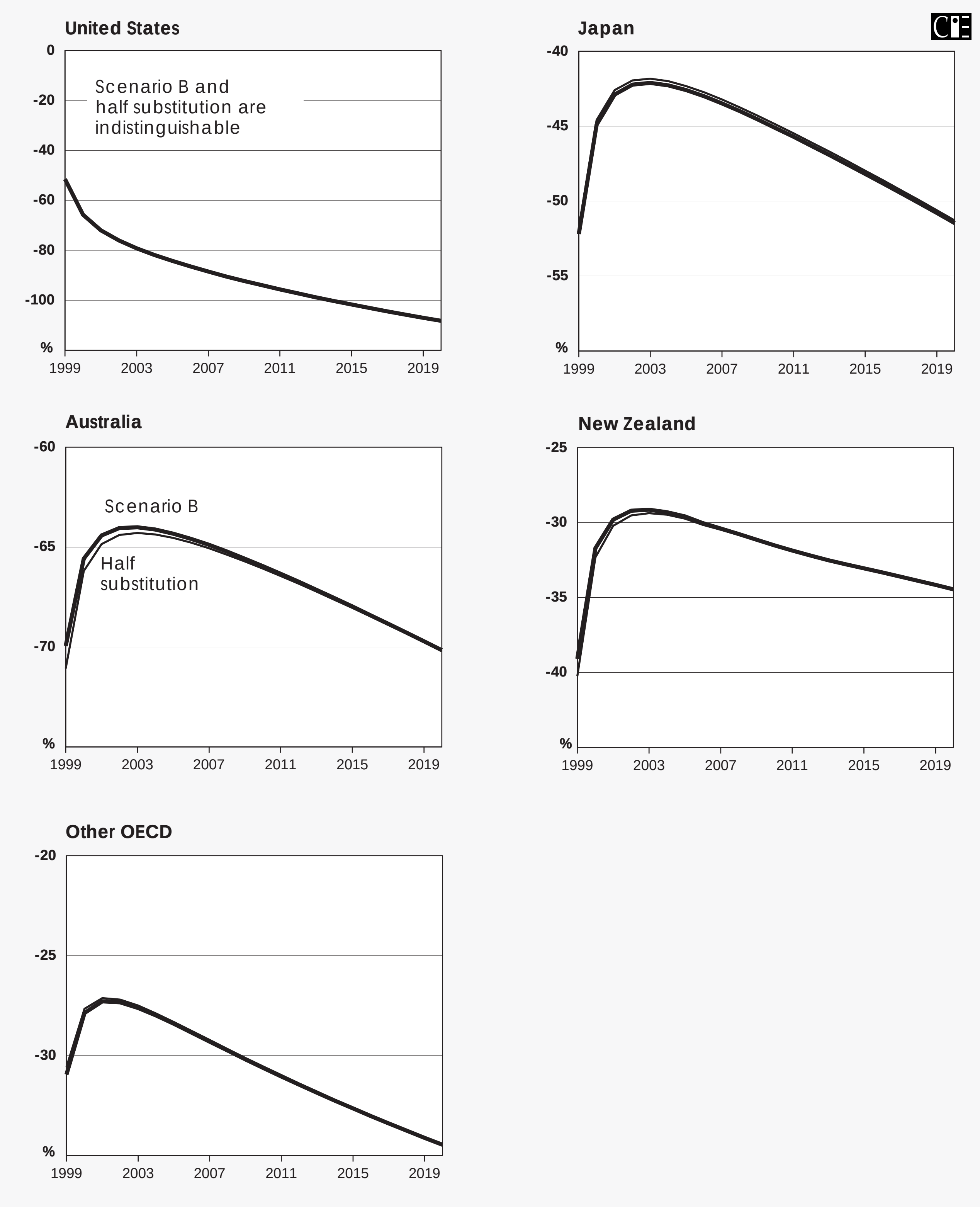
There may, of course, be other parameters (such as intermediate users' substitution between energy sources) that do have an effect on model outcomes, however this requires broader sensitivity analysis beyond the scope of this report.

Alternative revenue recycling assumption for New Zealand

Chart 7.5 compares the GDP change and emissions change per unit of tax for three scenarios:

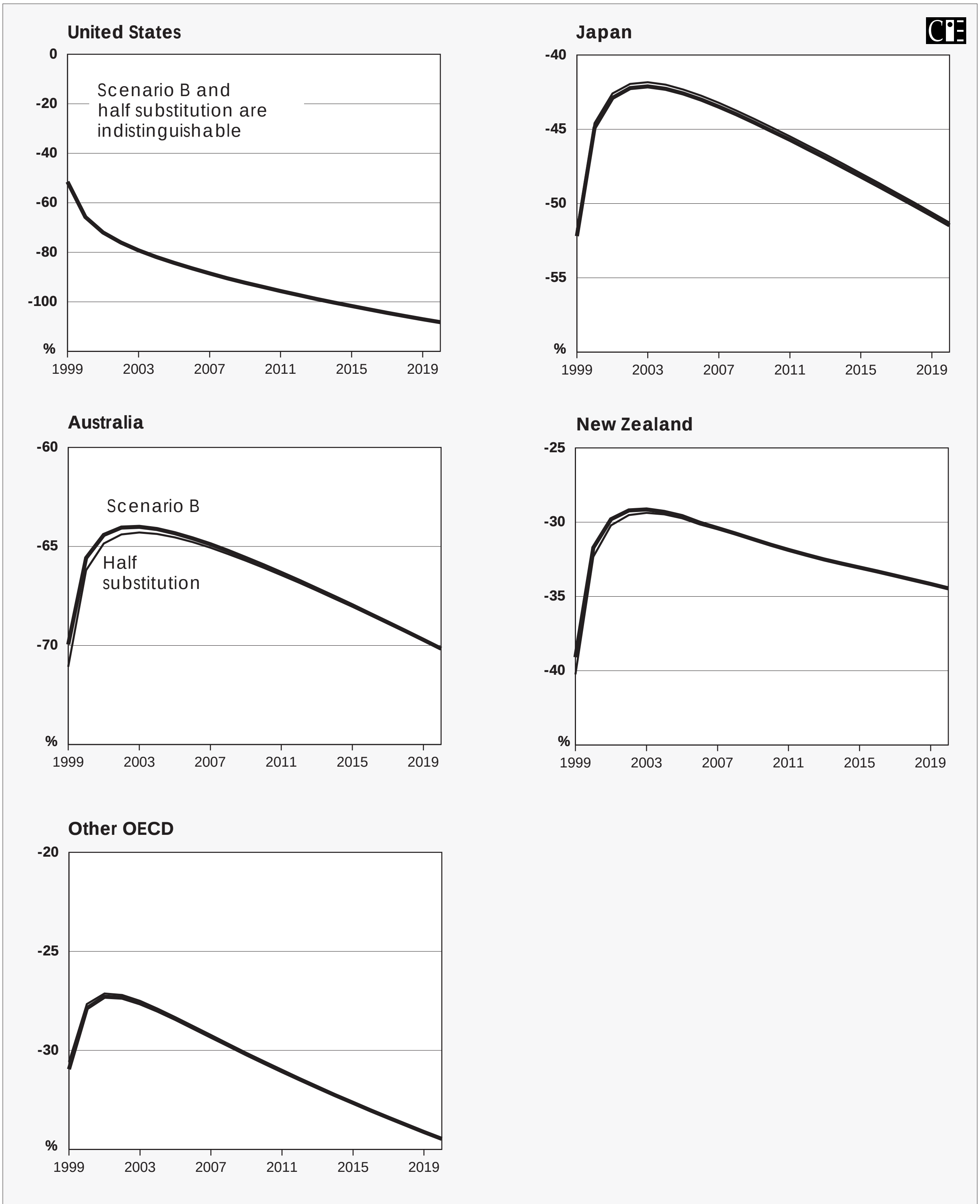
- scenario B;
- scenario B taxes with the revenue used first to reduce the petroleum excise and, subsequently, income taxes; and
- scenario B taxes with the revenue used to reduce personal and company income tax only.

Chart 7.3 **GDP change per unit of tax**[a] Standard versus half substitution elasticity between consumer goods



[a] Defined as the percentage change in real GDP relative to the 'business as usual' scenario divided by the carbon tax in US cents per tonne.
Data source: G-Cubed model simulations.

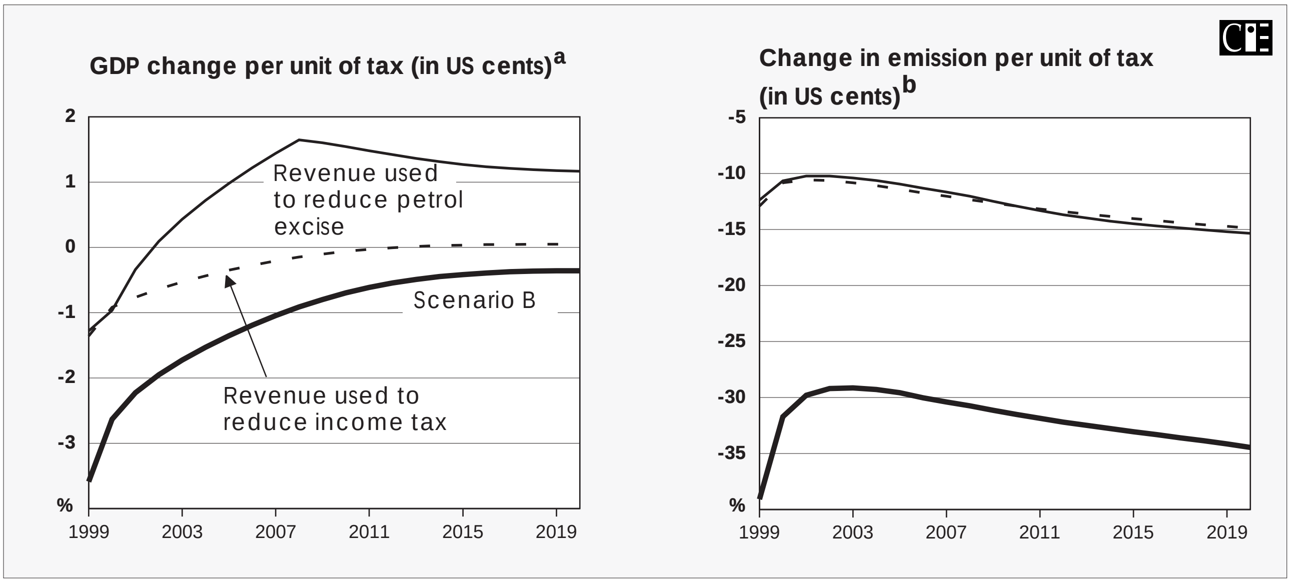
Chart 7.4 **Change in emissions per unit of tax**[a] Standard versus half substitution elasticity between consumer goods



[a] Defined as the percentage change in emissions relative to 'business as usual' scenario divided by the carbon tax in US cents per tonne.

Data source: G-Cubed model simulations.

Chart 7.5 **Comparison of revenue recycling results for New Zealand**



[a] Defined as the percentage change in real GDP relative to the 'business as usual' scenario divided by the carbon tax in US cents per tonne.
[b] Defined as the percentage change in emissions relative to 'business as usual' scenario divided by the carbon tax in US cents per tonne.

Data source: G-Cubed model simulations.

In this case, the ratios are significantly different between the alternate settings.

Both the tax recycling assumptions result in lower abatement per unit of carbon tax. This means that stabilisation requires a higher carbon tax under the alternative settings than under the scenario B.

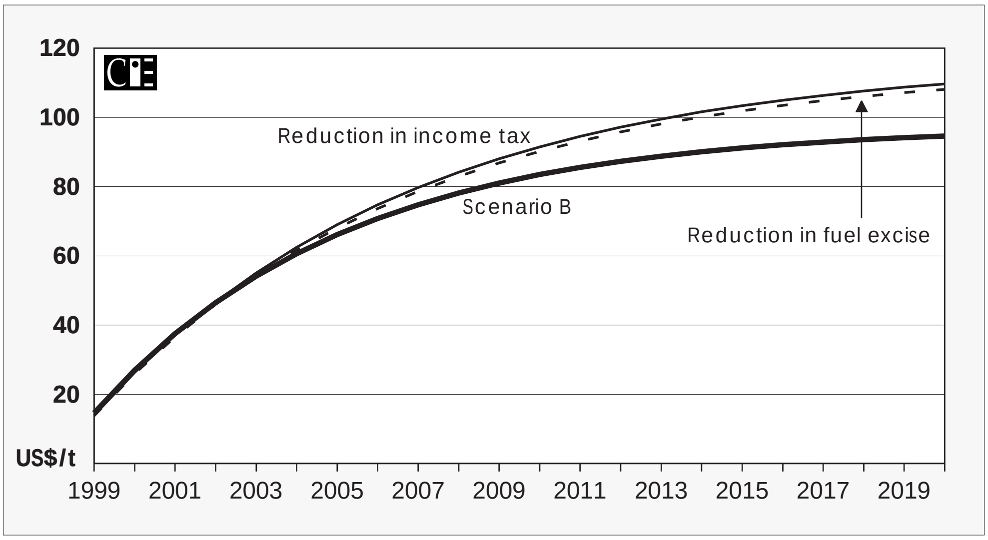
At the same time, the alternative recycling assumptions lead to a lower GDP loss per unit of tax (or a GDP gain in the case of the revenue used to reduce the petroleum excise). This implies that the carbon tax with reduced excise or lower income tax creates a more efficient tax system than the carbon tax with the higher excise or income tax.

A closer look at revenue recycling

Given the magnitude of the sensitivity to the revenue recycling assumptions, it is worth looking closer at the effects of stabilisation (as per scenario B) given alternative revenue uses.

Chart 7.6 sets out the carbon tax required for stabilisation under the alternative revenue assumptions. In each case the tax required is higher

Chart 7.6 **Carbon tax under alternative revenue recycling assumptions**



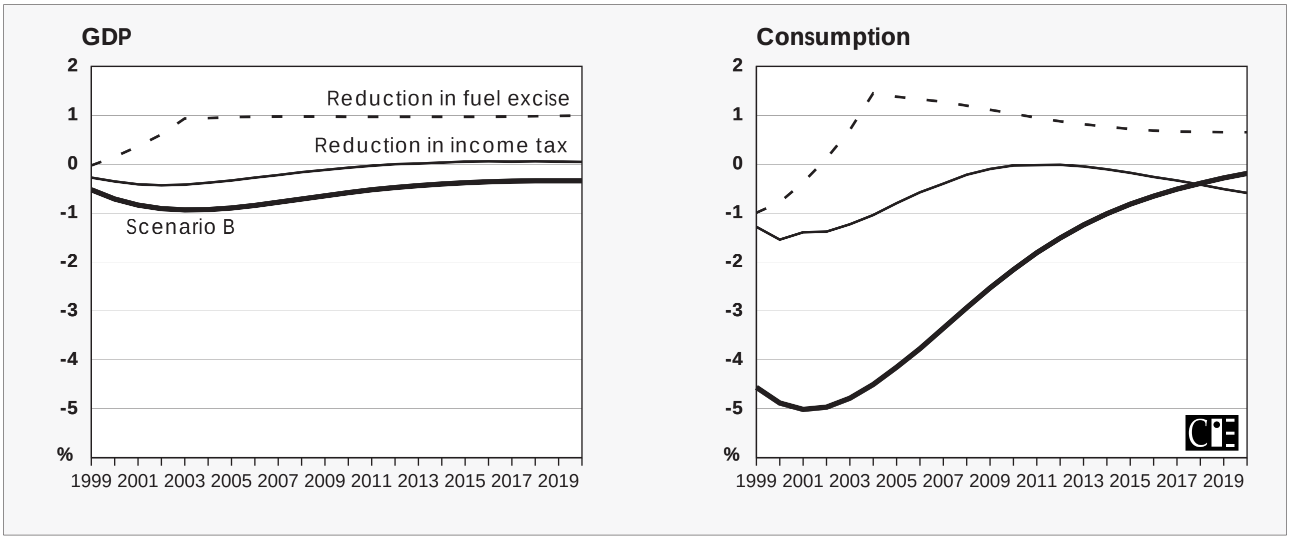
Data source: G-Cubed model simulations.

than in core scenario B. This is because the revenue recycling encourages higher production, offsetting to some extent the higher carbon tax.

Chart 7.7 sets out the effects of stabilisation on GDP and real consumption under the alternative revenue use assumptions.

The profile and magnitude of the GDP and consumption changes under the revenue recycling scenarios differ significantly to that under core scenario B. This is due to a combination of effects.

Chart 7.7 **Change in GDP and real consumption under alternative revenue recycling assumption**
Per cent relative to 'business as usual'



Data source: G-Cubed model simulations.

In the G-Cubed model, a reduction in petroleum excises is beneficial to the economy, leading to an increase in GDP and real consumption. Cuts in income and company tax rates are also beneficial. In the case of the cut in the company tax rate, this leads to an increase in investment and capital inflow, increasing both production and future consumption. The cut in personal taxes leads to an initial increase in consumption, although over the longer term this is not maintained.

The final outcome (chart 7.7) is a result of the interaction of these different effects, with the effect of the carbon tax itself.

The key finding is that, if the revenue from the carbon tax is used to reduce other taxes, it is possible to achieve economic gains from this. In some cases these gains can offset the effects of the carbon tax itself.

These results should be treated with some caution, however, for two reasons. First, the version of G-Cubed developed for this report (including New Zealand) has not been specifically set up for detailed tax analysis for the New Zealand economy. While the results presented here indicate likely direction, they should not be interpreted as specific policy recommendations.

Second, these results are conditional on the fact that only New Zealand uses the carbon tax revenue for other than deficit reduction. The results would be quite different if all countries were to use alternative revenue recycling in the same way as New Zealand. For example, when only New Zealand reduces company tax rates, it is able to attract additional investment without increasing interest rates. However, if other countries reduce taxes on capital, they will also attract investment — leading to an increase in global interest rates which will reduce New Zealand's ability to attract capital at the same cost.

The global implications of alternative revenue recycling measures are an important issue, but are beyond the scope of this report.

8 Implications and conclusions

The analysis of abatement scenarios undertaken in this report illustrates a number of important points.

Different countries have different marginal costs of abatement because of their different growth rates and different structures of energy use. New Zealand has one of the highest marginal costs of abatement, mostly because the New Zealand economy is not fossil fuel intensive. This makes it harder to achieve particular abatement targets. This high marginal abatement cost means that achieving a particular target requires a high carbon tax, which leads to larger GDP losses for New Zealand than for other countries. This is also associated with a capital outflow, a depreciation of the New Zealand dollar and a reduction in long term interest rates.

It is important to note that a carbon tax is a proxy for many other possible policy instruments. Achieving a particular abatement target will require an increase in the price of carbon fuels relative to the price of other energy sources. Whether this is achieved through a tax or sets of quantitative controls, it will have similar effects on the economy.

The high marginal abatement costs in New Zealand result from the projected path of emissions in the ‘business as usual’ scenario and the current and projected structure of energy use in the economy. Both of these will be sensitive to various model settings. However, it is unlikely that any changes in model settings will result in New Zealand having a low marginal cost of abatement.

New Zealand’s high marginal cost of abatement means that it is not in its economic interest to join an agreement that involves uniform country targets. This does not mean that New Zealand should argue for special treatment, only that it should argue for more economically efficient abatement policies. In this way, global economic costs can be minimised while still meeting global abatement targets.

The losses to New Zealand are significantly reduced under an emission permit trading system. Under such a system the average permit price is lower than the carbon tax so New Zealand can afford to do less abatement and still be better off. Under an Annex I permit trading system, most abatement is undertaken by the US and EEFSU, countries with the lowest marginal abatement costs.

Similar results to a permit system emerge from a global uniform tax system. The main difference is that countries get to keep the tax revenue under the uniform tax system whereas they must transfer payments across borders (depending on the initial allocation of permits) under a permit system.

Note that the model analysis undertaken here does not account for the administrative and compliance costs of an international emission trading scheme. These are likely to be large, probably larger than any associated with a uniform tax scheme. This suggests the superiority of a global uniform carbon tax scheme. The possible workings of such a scheme are set out in McKibbin and Wilcoxen (1997).

Sensitivity analysis with the model suggests that, while consumer substitution parameters (between energy sources and between goods) do not affect the pattern of results, revenue recycling assumptions are crucial. If revenue from the carbon tax is used to reduce other taxes, it is possible that this will reduce existing distortions in the tax system. This will mean lower economic costs associated with particular abatement targets.

Qualifications

All model results should, of course, be treated with caution. The underlying parameter values and model structure are approximations to a complex reality. Changes to parameter values and structure will change the numerical value of the model results, but not necessarily change the qualitative insights obtained from the model. What is important are the aspects of the model that determine the pattern of results and lead to the general conclusions.

The conclusions about New Zealand's high marginal cost of abatement relative to other countries depends upon the projected emissions in the 'business as usual' scenario for all countries and on the ability of the New Zealand economy to substitute to lower emitting fuel sources, compared with the same substitution for other countries. That this latter substitution is difficult for New Zealand in turn depends on the composition of fuel usage under 'business as usual' and the substitution parameters in the model.

The conclusion about New Zealand's relatively high marginal cost of abatement could be reversed if:

- other countries had considerably higher emission growth (relative to the stabilisation target year) than under the current 'business as usual' scenario; or
- the substitution possibilities in other countries were in fact significantly less than those for New Zealand.

While such a reversal is possible, it is unlikely given reasonable assumptions about other countries.

The conclusion relating to the benefit to New Zealand of an emission trading scheme or a uniform international tax scheme depends on New Zealand having a relatively high marginal cost of abatement and on at least some other countries having lower costs of abatement. This requirement is likely to be met.

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Appendix A G-Cubed sectoral detail

Table A.1 **Relationship between G-Cubed and SIC and SITC sectors**

G-Cubed Sector		***SIC Code***		***SITC Code***	
1	Electric utilities	491	Electric services	351	Electric current
2	Gas utilities	492	Gas production and distribution	341.31	Liquefied propane and butane
				341.5	Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons
3	Petroleum refining	29	Petroleum refining and related industries	334	Petroleum products, refined
				335	Residual petroleum products
4	Coal mining	12	Coal mining	32	Coal, coke and briquettes
5	Crude oil and gas extraction	13	Oil and gas extraction	333	Petroleum oils and oils obtained from bituminous oils, crude
				341.39	Liquefied gaseous hydrocarbons, n.e.s.
				341.4	Petroleum gases and other gaseous hydrocarbons, n.e.s. in the gaseous state
6	Mining	10	Metal mining	28	Metalliferous ores and metal scrap
		14	Mining and quarrying of nonmetallic	27	Crude fertilisers, and crude minerals, (excluding coal, petroleum and precious stones) except 271.1
7	Agriculture	01	Agricultural production-crops	121	Tobacco, unmanufactured; tobacco refuse
				29	Crude animal and vegetable materials, n.e.s.
				05	Vegetables and fruit
				22	Oil seeds and oleaginous fruits
				022.3	Milk and cream, fresh (including skimmed milk, buttermilk, sour milk, sour cream, whey, kephir, and yoghurt), not concentrated or sweetened
				061.1	Sugar, beet and cane, raw, solid
				071.11	Coffee, not roasted
				025.1	Eggs, birds', and egg yolks, fresh, dried or otherwise preserved, in shell
				04	Cereals and cereal preparations, excluding 046,047,048
		02	Agricultural production-livestock and animal specialties	00	Live animals chiefly for food
		07	Agricultural services	034.1	Fish, fresh (alive or dead) or chilled (excluding fillets)
		09	Fishing, hunting, and trapping		
8	Forestry and wood products	08	Forestry	232	Natural rubber latex, natural rubber and similar natural gums
		24	Lumber (part of 24)	24	Cork and wood
				63	Cork and wood manufactures (excluding furniture)
9	Durable manufacturing	24	Wood products (part of 24), except furniture	6	Manufactured goods classified chiefly by material, excluding 61,62,63,64,65
		33	Primary metal industries		
		34	Fabricated metal products, except machinery and transportation equipment		
		25	Furniture and fixtures	8	Miscellaneous manufactured articles, excluding 83,84,85
		32	Stone, clay, glass, and concrete products		
		35	Industrial and commercial machinery and computer equipment	7	Machinery and transport equipment

Continued

Table A.1 **Relationship between G-Cubed and SIC and SITC sectors** *Continued*

G-Cubed Sector	*SIC Code*		*SITC Code*	
	36	Electronic and other electrical equipment and components, except computer equipment		
	38	Measuring, analysing, and controlling instruments; photographic, medical and optical goods; watches and clocks		
	37	Transportation equipment		
	39	Miscellaneous manufacturing industries	951.0	Armoured fighting vehicles, arms of war and ammunition parts of arms, n.e.s.
10 Non-durable manufacturing	20	Food and kindred products	0	Food and live animals, excluding all 0's in 1
			11	Beverages
			4	Animal and vegetable oils, fats and waxes, excluding 43
			21	Hides, skins and fur skins, raw
			046	Meal and flour of wheat and flour of meslin
			047	Other cereal meals and flours
			048	Cereal preparations and preparations of flour or starch of fruits or vegetables
	21	Tobacco products	122	Tobacco, manufactured
	22	Textile mill products	26	Textile - fibres (other than wool tops) and their wastes (not manufactured into yarn or fabric)
			65	Textile yarn, fabrics, made-up articles, n.e.s., and related products
	23	Apparel and other finished products made	83	Travel goods, handbags and similar containers from fabrics and similar materials
			84	Articles of apparel and clothing accessories
	26	Paper and allied products	64	Paper, paperboard and articles of paper pulp, of paper or of paperboard
	27	Printing, publishing, and allied industries	25	Pulp and waste paper
	28	Chemicals and allied products	43	Animal or vegetable fats and oils, processed; waxes of animal or vegetable origin; inedible mixtures or preparations of animal or vegetable fats and oils, n.e.s.
			5	Chemicals and related products, n.e.s.
	30	Rubber and miscellaneous plastics products	62	Rubber manufactures, n.e.s.
			233	Synthetic rubber latex; synthetic rubber and reclaimed rubber; waste and scrap of unhardened rubber
			85	Footwear
	31	Leather and leather products	61	Leather, leather manufactures, n.e.s. and dressed fur skins
11 Transportation	40	Railroad transportation		
	41	Local and suburban transit and interurban highway passenger transportation		
	42	Motor freight transportation and warehousing		
	44	Water transportation		
	45	Transportation by air		
	46	Pipelines, except natural gas		
	47	Transportation services		
12 Services				

Source: G-Cubed model .

Appendix B Detailed result for carbon tax simulations

Table B.1 **Scenario A** Percentage change relative to 'business as usual'

	2000	*2005*	*2010*	*2015*	*2020*
GDP	-0.76	-0.95	-0.62	-0.40	-0.36
Consumption	-5.21	-4.42	-2.31	-0.89	-0.22
Investment	-2.19	-1.41	-0.88	-0.72	-0.76
Government spending	-0.70	-0.92	-1.13	-1.29	-1.40
Trade balance	2.59	1.92	1.07	0.55	0.24
Imports of G&S	-9.34	-8.55	-6.11	-4.30	-3.31
Exports of G&S	2.24	0.35	-0.77	-1.29	-1.56
Fiscal balance	-0.36	7.55	18.89	31.24	45.02
Terms of trade (inverse of RER)	5.36	2.67	0.85	-0.02	-0.49
Ten year interest rate	-0.64	-0.63	-0.61	-0.58	-0.54
Short term interest rate	-0.31	-0.50	-0.63	-0.70	-0.74
Nominal exchange rate	23.95	18.05	14.44	13.49	13.26
Nominal effective exchange rate	-7.50	-4.94	-1.61	-0.03	0.71
Inflation	0.06	-0.03	-0.04	-0.02	-0.01
Sectoral output					
Electric utilities	-2.05	-3.22	-3.43	-3.45	-3.46
Gas utilities	-5.61	-13.65	-31.87	-40.99	-50.62
Petroleum refining	-3.69	-6.69	-8.89	-10.56	-12.53
Coal mining	-12.26	-27.96	-34.78	-39.37	-43.11
Crude oil & gas extract	-5.72	-16.65	-24.12	-28.75	-31.62
Mining	-1.62	-1.95	-1.90	-1.95	-2.09
Agriculture	-1.87	-1.78	-1.38	-1.17	-1.11
Forestry	-0.83	-1.07	-0.76	-0.55	-0.54
Durable manufacturing	-0.30	-0.38	-0.44	-0.58	-0.77
Nondurable manufacturing	-1.02	-1.66	-1.56	-1.48	-1.51
Transportation	-1.21	-1.29	-0.92	-0.72	-0.69
Services	-1.20	-1.32	-0.63	-0.09	0.16
Sectoral employment					
Electric utilities	-2.96	-2.67	-1.50	-1.07	-1.18
Gas utilities	-1.62	-2.89	-3.08	-3.42	-3.79
Petroleum refining	-1.59	-1.77	-1.40	-1.29	-1.36
Coal mining	-12.92	-28.47	-35.70	-39.06	-41.90
Crude oil & gas extract	-8.45	-19.97	-24.88	-26.88	-27.91
Mining	-0.94	-0.69	-0.34	-0.52	-0.92
Agriculture	1.32	2.11	2.52	2.35	2.00
Forestry	0.47	1.17	1.59	1.48	1.19
Durable manufacturing	0.14	0.26	0.25	0.05	-0.22
Nondurable manufacturing	0.47	0.21	0.38	0.24	-0.06
Transportation	-0.95	-0.63	-0.07	0.06	-0.04
Services	-1.22	-0.98	-0.17	0.29	0.42
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-1.34	-4.03	-6.39	-8.22	-9.91
Coal mining	-18.84	-36.64	-40.20	-44.25	-48.33
Crude oil & gas extract	-2.01	-11.60	-17.78	-21.72	-23.87
Mining	0.31	-0.25	-0.79	-1.12	-1.39
Agriculture	2.57	0.68	-0.41	-0.90	-1.17
Forestry	4.29	2.01	0.75	0.21	-0.11
Durable manufacturing	2.56	0.66	-0.68	-1.36	-1.77
Nondurable manufacturing	3.41	0.84	-0.61	-1.24	-1.57
Transportation	na	na	na	na	na
Services	0.29	-0.14	-0.44	-0.59	-0.67

Table B.2 **Scenario B** Percentage change relative to 'business as usual'

	2000	2005	2010	2015	2020
GDP	-0.71	-0.89	-0.58	-0.38	-0.34
Consumption	-4.89	-4.15	-2.16	-0.82	-0.19
Investment	-2.05	-1.32	-0.82	-0.67	-0.70
Government spending	-0.66	-0.87	-1.06	-1.22	-1.32
Trade balance	2.43	1.80	0.99	0.51	0.21
Imports of G&S	-8.77	-8.04	-5.74	-4.04	-3.12
Exports of G&S	2.09	0.31	-0.75	-1.23	-1.49
Fiscal balance	-0.32	7.13	17.83	29.47	42.45
Terms of trade (inverse of RER)	4.98	2.46	0.75	-0.07	-0.51
Ten year interest rate	-0.60	-0.60	-0.58	-0.55	-0.51
Short term interest rate	-0.29	-0.47	-0.59	-0.66	-0.69
Nominal exchange rate	22.55	17.01	13.62	12.75	12.56
Nominal effective exchange rate	-6.98	-4.56	-1.43	0.05	0.74
Inflation	0.06	-0.03	-0.04	-0.02	-0.01
Sectoral output					
Electric utilities	-1.93	-3.03	-3.23	-3.25	-3.26
Gas utilities	-5.31	-12.88	-30.05	-38.64	-47.71
Petroleum refining	-3.44	-6.28	-8.35	-9.93	-11.79
Coal mining	-11.51	-26.26	-32.68	-37.00	-40.51
Crude oil & gas extract	-5.38	-15.67	-22.71	-27.06	-29.77
Mining	-1.52	-1.83	-1.78	-1.82	-1.96
Agriculture	-1.76	-1.68	-1.30	-1.10	-1.05
Forestry	-0.77	-1.00	-0.70	-0.51	-0.50
Durable manufacturing	-0.28	-0.36	-0.42	-0.55	-0.73
Nondurable manufacturing	-0.97	-1.58	-1.48	-1.41	-1.44
Transportation	-1.14	-1.22	-0.87	-0.68	-0.65
Services	-1.13	-1.24	-0.59	-0.08	0.15
Sectoral employment					
Electric utilities	-2.78	-2.51	-1.41	-1.00	-1.11
Gas utilities	-1.57	-2.75	-2.93	-3.24	-3.58
Petroleum refining	-1.48	-1.66	-1.31	-1.21	-1.28
Coal mining	-12.13	-26.74	-33.54	-36.71	-39.39
Crude oil & gas extract	-7.93	-18.79	-23.41	-25.30	-26.27
Mining	-0.87	-0.65	-0.32	-0.49	-0.87
Agriculture	1.25	1.99	2.38	2.21	1.88
Forestry	0.45	1.10	1.50	1.39	1.12
Durable manufacturing	0.13	0.24	0.23	0.04	-0.21
Nondurable manufacturing	0.43	0.18	0.34	0.20	-0.08
Transportation	-0.89	-0.60	-0.07	0.06	-0.04
Services	-1.14	-0.92	-0.16	0.27	0.40
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-1.25	-3.79	-6.03	-7.78	-9.39
Coal mining	-17.47	-33.98	-37.30	-41.07	-44.87
Crude oil & gas extract	-1.71	-10.55	-16.31	-19.97	-21.98
Mining	0.32	-0.21	-0.72	-1.04	-1.29
Agriculture	2.41	0.64	-0.39	-0.86	-1.12
Forestry	4.08	1.93	0.74	0.22	-0.08
Durable manufacturing	2.40	0.60	-0.65	-1.31	-1.69
Nondurable manufacturing	3.18	0.76	-0.61	-1.20	-1.51
Transportation	na	na	na	na	na
Services	0.26	-0.14	-0.42	-0.56	-0.64

Table B.3 **Scenario C** Percentage change relative to ‘business as usual’

	2000	2005	2010	2015	2020
GDP	-0.80	-1.01	-0.66	-0.43	-0.38
Consumption	-5.53	-4.70	-2.43	-0.91	-0.19
Investment	-2.31	-1.49	-0.92	-0.74	-0.78
Government spending	-0.74	-0.99	-1.21	-1.39	-1.50
Trade balance	2.75	2.04	1.12	0.57	0.23
Imports of G&S	-9.91	-9.09	-6.46	-4.53	-3.48
Exports of G&S	2.37	0.37	-0.83	-1.39	-1.69
Fiscal balance	-0.31	8.24	20.49	33.82	48.69
Terms of trade (inverse of RER)	5.59	2.73	0.78	-0.15	-0.66
Ten year interest rate	-0.68	-0.68	-0.65	-0.62	-0.58
Short term interest rate	-0.33	-0.53	-0.67	-0.75	-0.79
Nominal exchange rate	25.22	18.98	15.17	14.19	14.01
Nominal effective exchange rate	-7.87	-5.11	-1.54	0.15	0.93
Inflation	0.07	-0.04	-0.05	-0.02	-0.01
Sectoral output					
Electric utilities	-2.20	-3.45	-3.69	-3.71	-3.73
Gas utilities	-6.09	-14.80	-34.51	-44.35	-54.75
Petroleum refining	-3.89	-7.16	-9.54	-11.37	-13.51
Coal mining	-12.99	-29.73	-37.04	-41.95	-45.95
Crude oil & gas extract	-6.13	-17.89	-25.93	-30.91	-34.00
Mining	-1.70	-2.06	-2.01	-2.06	-2.22
Agriculture	-1.99	-1.90	-1.47	-1.24	-1.18
Forestry	-0.85	-1.11	-0.78	-0.57	-0.55
Durable manufacturing	-0.30	-0.39	-0.46	-0.62	-0.82
Nondurable manufacturing	-1.11	-1.79	-1.68	-1.59	-1.63
Transportation	-1.28	-1.37	-0.98	-0.76	-0.73
Services	-1.28	-1.40	-0.67	-0.08	0.18
Sectoral employment					
Electric utilities	-3.15	-2.87	-1.62	-1.15	-1.28
Gas utilities	-1.85	-3.21	-3.40	-3.75	-4.13
Petroleum refining	-1.67	-1.90	-1.51	-1.40	-1.48
Coal mining	-13.69	-30.28	-38.02	-41.64	-44.69
Crude oil & gas extract	-9.04	-21.44	-26.72	-28.89	-30.00
Mining	-0.97	-0.73	-0.36	-0.56	-0.99
Agriculture	1.41	2.25	2.69	2.50	2.12
Forestry	0.52	1.25	1.70	1.58	1.27
Durable manufacturing	0.17	0.29	0.27	0.05	-0.24
Nondurable manufacturing	0.47	0.20	0.38	0.23	-0.10
Transportation	-1.00	-0.67	-0.07	0.07	-0.04
Services	-1.29	-1.04	-0.18	0.31	0.45
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-1.30	-4.22	-6.81	-8.84	-10.71
Coal mining	-18.65	-36.47	-40.13	-44.24	-48.38
Crude oil & gas extract	-1.32	-10.76	-17.11	-21.18	-23.42
Mining	0.45	-0.14	-0.73	-1.10	-1.40
Agriculture	2.73	0.74	-0.43	-0.96	-1.26
Forestry	4.71	2.28	0.90	0.29	-0.06
Durable manufacturing	2.77	0.74	-0.71	-1.46	-1.90
Nondurable manufacturing	3.57	0.86	-0.69	-1.37	-1.72
Transportation	na	na	na	na	na
Services	0.31	-0.14	-0.47	-0.63	-0.72

Table B.4 **Scenario D** Percentage change relative to 'business as usual'

	2000	2005	2010	2015	2020
GDP	-0.89	-1.12	-0.73	-0.47	-0.42
Consumption	-6.12	-5.22	-2.69	-0.99	-0.19
Investment	-2.54	-1.65	-1.01	-0.81	-0.85
Government spending	-0.83	-1.10	-1.35	-1.56	-1.68
Trade balance	3.04	2.26	1.24	0.62	0.24
Imports of G&S	-10.97	-10.07	-7.13	-4.98	-3.82
Exports of G&S	2.62	0.42	-0.92	-1.55	-1.88
Fiscal balance	-0.27	9.32	23.05	37.99	54.66
Terms of trade (inverse of RER)	6.14	2.96	0.78	-0.26	-0.81
Ten year interest rate	-0.76	-0.76	-0.73	-0.69	-0.65
Short term interest rate	-0.37	-0.59	-0.74	-0.84	-0.88
Nominal exchange rate	27.69	20.79	16.58	15.52	15.35
Nominal effective exchange rate	-8.66	-5.58	-1.60	0.28	1.14
Inflation	0.07	-0.04	-0.05	-0.03	-0.01
Sectoral output					
Electric utilities	-2.44	-3.86	-4.12	-4.15	-4.17
Gas utilities	-6.85	-16.64	-38.77	-49.80	-61.45
Petroleum refining	-4.30	-7.98	-10.67	-12.72	-15.14
Coal mining	-14.37	-32.95	-41.10	-46.58	-51.04
Crude oil & gas extract	-6.85	-20.00	-28.99	-34.56	-38.03
Mining	-1.87	-2.28	-2.22	-2.28	-2.45
Agriculture	-2.20	-2.11	-1.63	-1.37	-1.31
Forestry	-0.93	-1.22	-0.86	-0.62	-0.60
Durable manufacturing	-0.32	-0.42	-0.50	-0.68	-0.91
Nondurable manufacturing	-1.25	-1.99	-1.87	-1.77	-1.81
Transportation	-1.41	-1.51	-1.08	-0.84	-0.80
Services	-1.41	-1.55	-0.74	-0.09	0.21
Sectoral employment					
Electric utilities	-3.50	-3.20	-1.81	-1.29	-1.44
Gas utilities	-2.12	-3.66	-3.86	-4.24	-4.67
Petroleum refining	-1.85	-2.12	-1.70	-1.58	-1.67
Coal mining	-15.14	-33.57	-42.21	-46.25	-49.66
Crude oil & gas extract	-10.08	-23.95	-29.87	-32.30	-33.54
Mining	-1.06	-0.80	-0.40	-0.63	-1.11
Agriculture	1.57	2.49	2.98	2.77	2.35
Forestry	0.58	1.40	1.89	1.75	1.41
Durable manufacturing	0.20	0.33	0.31	0.06	-0.26
Nondurable manufacturing	0.50	0.21	0.41	0.24	-0.12
Transportation	-1.11	-0.74	-0.08	0.08	-0.04
Services	-1.43	-1.16	-0.19	0.35	0.51
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-1.35	-4.64	-7.57	-9.88	-12.00
Coal mining	-19.46	-38.28	-42.21	-46.61	-51.02
Crude oil & gas extract	-0.97	-11.03	-17.97	-22.41	-24.87
Mining	0.59	-0.06	-0.73	-1.15	-1.49
Agriculture	3.03	0.84	-0.46	-1.06	-1.40
Forestry	5.32	2.61	1.05	0.37	-0.03
Durable manufacturing	3.12	0.86	-0.76	-1.61	-2.11
Nondurable manufacturing	3.92	0.93	-0.79	-1.55	-1.93
Transportation	na	na	na	na	na
Services	0.35	-0.15	-0.51	-0.69	-0.80

Table B.5 **Scenario E** Percentage change relative to 'business as usual'

	2000	*2005*	*2010*	*2015*	*2020*
GDP	-0.44	-0.53	-0.35	-0.24	-0.22
Consumption	-2.66	-2.07	-0.99	-0.35	-0.07
Investment	-1.21	-0.65	-0.40	-0.35	-0.38
Government spending	-0.49	-0.58	-0.68	-0.76	-0.81
Trade balance	1.31	0.84	0.41	0.19	0.07
Imports of G&S	-5.19	-4.81	-3.80	-3.03	-2.58
Exports of G&S	0.77	-0.52	-1.12	-1.35	-1.46
Fiscal balance	-0.48	2.94	7.97	13.45	19.52
Terms of trade (inverse of RER)	2.36	1.08	0.31	-0.03	-0.21
Ten year interest rate	-0.35	-0.35	-0.34	-0.33	-0.31
Short term interest rate	-0.17	-0.27	-0.33	-0.37	-0.39
Nominal exchange rate	17.79	14.20	12.39	12.35	12.66
Nominal effective exchange rate	-3.17	-1.66	-0.21	0.37	0.62
Inflation	0.03	-0.02	-0.02	-0.01	0.00
Sectoral output					
Electric utilities	-1.03	-1.48	-1.53	-1.53	-1.54
Gas utilities	-2.59	-5.63	-13.05	-16.85	-20.88
Petroleum refining	-1.53	-2.63	-3.47	-4.16	-4.98
Coal mining	-6.91	-15.06	-18.39	-20.64	-22.51
Crude oil & gas extract	-2.62	-7.65	-11.09	-13.22	-14.54
Mining	-0.89	-1.03	-1.02	-1.05	-1.13
Agriculture	-1.15	-1.12	-0.94	-0.86	-0.84
Forestry	-0.48	-0.59	-0.42	-0.32	-0.31
Durable manufacturing	-0.36	-0.42	-0.45	-0.52	-0.61
Nondurable manufacturing	-0.74	-1.31	-1.35	-1.33	-1.35
Transportation	-0.74	-0.83	-0.68	-0.59	-0.59
Services	-0.65	-0.68	-0.31	-0.04	0.07
Sectoral employment					
Electric utilities	-1.50	-1.20	-0.57	-0.37	-0.44
Gas utilities	-0.99	-1.24	-1.15	-1.23	-1.37
Petroleum refining	-0.64	-0.56	-0.31	-0.25	-0.28
Coal mining	-7.32	-15.34	-18.84	-20.42	-21.81
Crude oil & gas extract	-3.91	-9.35	-11.60	-12.51	-12.99
Mining	-0.54	-0.34	-0.15	-0.23	-0.41
Agriculture	0.94	1.35	1.56	1.48	1.32
Forestry	0.29	0.69	0.93	0.88	0.76
Durable manufacturing	-0.12	-0.06	-0.05	-0.14	-0.26
Nondurable manufacturing	0.13	-0.24	-0.22	-0.29	-0.43
Transportation	-0.63	-0.50	-0.23	-0.16	-0.22
Services	-0.65	-0.48	-0.05	0.17	0.23
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-2.02	-3.29	-4.43	-5.36	-6.29
Coal mining	-20.15	-36.35	-38.99	-42.38	-45.93
Crude oil & gas extract	-5.98	-15.54	-20.26	-23.12	-24.58
Mining	-0.50	-0.80	-1.03	-1.18	-1.33
Agriculture	1.25	-0.06	-0.66	-0.89	-1.01
Forestry	2.02	0.77	0.26	0.10	0.03
Durable manufacturing	0.47	-0.65	-1.27	-1.56	-1.72
Nondurable manufacturing	1.57	-0.22	-1.04	-1.34	-1.46
Transportation	na	na	na	na	na
Services	-0.17	-0.44	-0.56	-0.61	-0.64

Table B.6 **Scenario J** Percentage change relative to 'business as usual'

	2000	*2005*	*2010*	*2015*	*2020*
GDP	-0.75	-0.95	-0.62	-0.40	-0.36
Consumption	-5.17	-4.44	-2.37	-1.00	-0.39
Investment	-2.35	-1.59	-1.02	-0.83	-0.86
Government spending	-0.67	-0.87	-1.05	-1.21	-1.30
Trade balance	2.78	2.05	1.17	0.66	0.38
Imports of G&S	-9.15	-8.24	-5.74	-4.00	-3.11
Exports of G&S	2.42	0.64	-0.47	-0.99	-1.25
Fiscal balance	-0.60	6.61	17.03	28.28	40.56
Terms of trade (inverse of RER)	5.48	2.61	0.69	-0.21	-0.67
Ten year interest rate	-0.61	-0.60	-0.58	-0.54	-0.50
Short term interest rate	-0.32	-0.50	-0.62	-0.69	-0.71
Nominal exchange rate	23.17	17.32	13.86	13.14	13.18
Nominal effective exchange rate	-57.45	-61.88	-14.81	-0.63	1.75
Inflation	0.06	-0.03	-0.04	-0.02	-0.01
Secoral output					
Electric utilities	-2.03	-3.17	-3.36	-3.37	-3.38
Gas utilities	-5.63	-13.58	-31.33	-40.03	-49.22
Petroleum refining	-3.71	-6.73	-8.92	-10.60	-12.59
Coal mining	-11.59	-26.32	-32.69	-36.98	-40.49
Crude oil & gas extract	-5.37	-15.52	-22.42	-26.69	-29.35
Mining	-1.62	-1.89	-1.81	-1.84	-1.97
Agriculture	-1.84	-1.72	-1.30	-1.08	-1.02
Forestry	-0.76	-0.95	-0.64	-0.45	-0.46
Durable manufacturing	-0.26	-0.31	-0.37	-0.51	-0.70
Nondurable manufacturing	-0.94	-1.48	-1.34	-1.26	-1.29
Transportation	-1.18	-1.23	-0.85	-0.64	-0.60
Services	-1.20	-1.34	-0.68	-0.15	0.09
Sectoral employment					
Electric utilities	-2.94	-2.63	-1.43	-1.00	-1.12
Gas utilities	-1.62	-2.89	-3.05	-3.34	-3.68
Petroleum refining	-1.61	-1.88	-1.56	-1.48	-1.58
Coal mining	-12.20	-26.82	-33.60	-36.80	-39.54
Crude oil & gas extract	-7.77	-18.36	-22.87	-24.74	-25.72
Mining	-0.94	-0.63	-0.25	-0.42	-0.81
Agriculture	1.28	2.08	2.49	2.31	1.97
Forestry	0.52	1.24	1.65	1.52	1.22
Durable manufacturing	0.18	0.33	0.33	0.12	-0.15
Nondurable manufacturing	0.55	0.38	0.57	0.43	0.13
Transportation	-0.92	-0.57	0.00	0.14	0.04
Services	-1.22	-1.00	-0.21	0.24	0.36
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-0.41	-2.63	-4.86	-6.65	-8.29
Coal mining	-17.16	-34.00	-37.61	-41.65	-45.71
Crude oil & gas extract	7.79	8.99	6.83	5.17	4.09
Mining	0.44	-0.05	-0.54	-0.84	-1.07
Agriculture	2.73	0.96	-0.13	-0.63	-0.91
Forestry	4.99	2.80	1.39	0.70	0.27
Durable manufacturing	3.03	1.16	-0.24	-0.98	-1.41
Nondurable manufacturing	3.56	1.13	-0.30	-0.92	-1.23
Transportation	na	na	na	na	na
Services	0.31	-0.10	-0.39	-0.53	-0.59

Table B.7 **Carbon tax by scenario** US dollars per tonne

	1999	2000	2005	2010	2015	2020
Scenario A						
United States	4.07	7.53	18.44	23.27	25.42	26.37
Japan	27.50	47.30	88.36	96.31	97.85	98.14
Australia	10.50	19.53	48.91	62.72	69.23	72.28
New Zealand	15.50	28.68	70.21	88.64	96.81	100.44
Other OECD	13.60	25.16	61.60	77.77	84.94	88.13
Scenario B						
United States	3.95	7.31	17.89	22.59	24.67	25.60
Japan	25.50	43.86	81.94	89.30	90.73	91.01
Australia	9.70	18.04	45.18	57.95	63.95	66.78
New Zealand	14.60	27.01	66.13	83.49	91.19	94.61
Other OECD	13.30	24.61	60.24	76.05	83.07	86.18
Scenario C						
United States	4.65	8.60	21.06	26.59	29.04	30.13
Japan	27.50	47.30	88.36	96.31	97.85	98.14
Australia	10.45	19.44	48.67	62.43	68.90	71.94
New Zealand	16.70	30.90	75.64	95.50	104.31	108.22
Other OECD	15.45	28.58	69.98	88.35	96.50	100.12
Scenario D						
United States	5.35	9.90	24.23	30.59	33.42	34.67
Japan	29.00	49.88	93.18	101.56	103.18	103.5
Australia	11.20	20.83	52.17	66.91	73.84	77.10
New Zealand	18.70	34.60	84.70	106.93	116.80	121.18
Other OECD	17.70	32.75	80.17	101.22	110.55	114.70
Scenario E						
United States	3.95	7.31	17.89	22.59	24.67	25.60
Japan	25.50	43.86	81.94	89.30	90.73	91.01
Australia	9.70	18.04	45.18	57.95	63.95	66.78
New Zealand	6.97	12.89	31.57	39.86	43.53	45.17
Other OECD	13.30	24.61	60.24	76.05	83.07	86.18
Scenario J						
United States	3.95	7.31	17.89	22.59	24.67	25.60
Japan	25.5	43.86	81.94	89.30	90.73	91.01
Australia	0.00	0.00	0.00	0.00	0.00	0.00
New Zealand	14.60	27.01	66.13	83.49	91.19	94.61
Other OECD	13.30	24.61	60.24	76.05	83.07	86.18

Appendix C Detailed results for emission trading and uniform tax scenarios

Table C.1 **Scenario F** Percentage change relative to 'business as usual'

	2000	2005	2010	2015	2020
GDP	-0.27	-0.37	-0.31	-0.28	-0.29
Consumption	-1.60	-1.42	-0.91	-0.57	-0.43
Investment	-1.22	-1.13	-1.01	-1.00	-1.06
Government spending	-0.25	-0.25	-0.30	-0.36	-0.41
Trade balance	0.92	0.70	0.46	0.34	0.30
Imports of G&S	-3.25	-3.01	-2.41	-2.00	-1.83
Exports of G&S	0.62	0.08	-0.27	-0.47	-0.59
Fiscal balance	-1.64	-2.57	-2.77	-2.56	-2.23
Terms of trade (inverse of RER)	1.69	0.82	0.30	0.07	-0.04
Ten year interest rate	-0.14	-0.13	-0.12	-0.10	-0.09
Short term interest rate	-0.13	-0.16	-0.18	-0.18	-0.17
Nominal exchange rate	9.48	7.35	6.41	6.61	7.19
Nominal effective exchange rate	-17.99	-19.67	-5.68	-0.94	-0.03
Inflation	0.04	0.00	0.00	0.00	0.00
Sectoral output					
Electric utilities	-0.56	-0.78	-0.86	-0.94	-1.04
Gas utilities	-1.27	-2.44	-5.94	-8.49	-11.64
Petroleum refining	-0.83	-1.21	-1.60	-2.08	-2.78
Coal mining	-1.67	-4.01	-5.92	-7.87	-9.81
Crude oil & gas extract	-0.71	-2.31	-3.96	-5.51	-6.90
Mining	-0.61	-0.69	-0.72	-0.81	-0.92
Agriculture	-0.75	-0.73	-0.64	-0.62	-0.64
Forestry	-0.30	-0.43	-0.39	-0.39	-0.43
Durable manufacturing	-0.31	-0.42	-0.49	-0.59	-0.69
Nondurable manufacturing	-0.42	-0.58	-0.59	-0.62	-0.68
Transportation	-0.44	-0.49	-0.43	-0.42	-0.44
Services	-0.41	-0.51	-0.37	-0.25	-0.19
Sectoral employment					
Electric utilities	-0.88	-0.66	-0.29	-0.17	-0.22
Gas utilities	-0.51	-0.63	-0.62	-0.72	-0.87
Petroleum refining	-0.36	-0.27	-0.14	-0.12	-0.17
Coal mining	-1.59	-3.76	-5.71	-7.46	-9.21
Crude oil & gas extract	-0.83	-2.58	-3.97	-5.12	-6.11
Mining	-0.40	-0.21	-0.06	-0.11	-0.22
Agriculture	0.49	0.77	0.95	0.96	0.93
Forestry	0.15	0.37	0.52	0.52	0.47
Durable manufacturing	-0.17	-0.18	-0.20	-0.27	-0.35
Nondurable manufacturing	0.11	0.11	0.18	0.13	0.05
Transportation	-0.36	-0.26	-0.11	-0.07	-0.10
Services	-0.41	-0.37	-0.17	-0.04	0.00
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-0.78	-1.51	-2.29	-3.11	-4.03
Coal mining	-1.40	-4.50	-6.90	-9.45	-11.97
Crude oil & gas extract	0.09	-2.56	-4.87	-6.93	-8.63
Mining	-0.24	-0.42	-0.62	-0.76	-0.88
Agriculture	0.91	0.40	0.06	-0.14	-0.27
Forestry	1.83	0.99	0.50	0.24	0.05
Durable manufacturing	0.62	-0.04	-0.51	-0.80	-1.00
Nondurable manufacturing	1.04	0.34	-0.10	-0.34	-0.47
Transportation	na	na	na	na	na
Services	-0.05	-0.19	-0.29	-0.34	-0.37

Table C.2 **Scenario G** Percentage change relative to ‘business as usual’

	2000	*2005*	*2010*	*2015*	*2020*
GDP	-0.47	-0.64	-0.54	-0.48	-0.49
Consumption	-2.79	-2.47	-1.57	-0.96	-0.72
Investment	-2.10	-1.93	-1.68	-1.63	-1.71
Government spending	-0.43	-0.45	-0.54	-0.66	-0.76
Trade balance	1.60	1.21	0.79	0.57	0.48
Imports of G&S	-5.63	-5.23	-4.19	-3.48	-3.19
Exports of G&S	1.09	0.13	-0.51	-0.88	-1.10
Fiscal balance	-2.84	-4.39	-4.51	-3.75	-2.63
Terms of trade (inverse of RER)	2.95	1.46	0.55	0.14	-0.06
Ten year interest rate	-0.24	-0.23	-0.20	-0.18	-0.15
Short term interest rate	-0.21	-0.27	-0.30	-0.31	-0.30
Nominal exchange rate	15.97	12.29	10.62	10.95	12.00
Nominal effective exchange rate	-31.42	-34.40	-9.75	-1.51	0.02
Inflation	0.07	0.00	-0.01	0.00	0.01
Sectoral output					
Electric utilities	-0.98	-1.40	-1.58	-1.74	-1.93
Gas utilities	-2.27	-4.53	-11.25	-16.18	-22.28
Petroleum refining	-1.47	-2.24	-3.02	-3.99	-5.34
Coal mining	-3.11	-7.73	-11.53	-15.36	-19.18
Crude oil & gas extract	-1.36	-4.51	-7.76	-10.78	-13.51
Mining	-1.06	-1.22	-1.28	-1.44	-1.65
Agriculture	-1.30	-1.26	-1.11	-1.07	-1.11
Forestry	-0.52	-0.75	-0.68	-0.66	-0.73
Durable manufacturing	-0.52	-0.71	-0.83	-0.99	-1.15
Nondurable manufacturing	-0.74	-1.03	-1.07	-1.15	-1.26
Transportation	-0.76	-0.85	-0.76	-0.73	-0.77
Services	-0.71	-0.88	-0.63	-0.40	-0.30
Sectoral employment					
Electric utilities	-1.53	-1.19	-0.56	-0.37	-0.47
Gas utilities	-0.91	-1.15	-1.16	-1.38	-1.66
Petroleum refining	-0.64	-0.51	-0.29	-0.27	-0.37
Coal mining	-3.00	-7.35	-11.26	-14.73	-18.17
Crude oil & gas extract	-1.65	-5.13	-7.89	-10.16	-12.11
Mining	-0.70	-0.39	-0.15	-0.23	-0.44
Agriculture	0.83	1.32	1.64	1.67	1.62
Forestry	0.26	0.65	0.92	0.92	0.84
Durable manufacturing	-0.29	-0.31	-0.33	-0.44	-0.57
Nondurable manufacturing	0.19	0.17	0.26	0.17	0.02
Transportation	-0.62	-0.45	-0.19	-0.13	-0.17
Services	-0.70	-0.65	-0.28	-0.06	0.02
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-1.22	-2.54	-3.99	-5.48	-7.15
Coal mining	-2.60	-8.57	-13.22	-18.15	-23.04
Crude oil & gas extract	0.03	-5.08	-9.53	-13.48	-16.73
Mining	-0.35	-0.69	-1.05	-1.31	-1.50
Agriculture	1.58	0.68	0.04	-0.33	-0.57
Forestry	3.21	1.73	0.85	0.39	0.09
Durable manufacturing	1.13	-0.04	-0.88	-1.38	-1.70
Nondurable manufacturing	1.79	0.54	-0.26	-0.70	-0.95
Transportation	na	na	na	na	na
Services	-0.07	-0.31	-0.49	-0.57	-0.62

Table C.3 **Scenario H** Percentage change relative to 'business as usual'

	2000	2005	2010	2015	2020
GDP	-0.19	-0.24	-0.18	-0.15	-0.15
Consumption	-1.25	-1.08	-0.68	-0.41	-0.29
Investment	-0.69	-0.48	-0.32	-0.26	-0.27
Government spending	-0.17	-0.19	-0.25	-0.32	-0.37
Trade balance	0.68	0.50	0.33	0.23	0.19
Imports of G&S	-2.39	-2.19	-1.77	-1.48	-1.34
Exports of G&S	0.48	0.05	-0.23	-0.39	-0.49
Fiscal balance	-0.71	0.23	2.29	5.01	8.39
Terms of trade (inverse of RER)	1.30	0.65	0.29	0.15	0.07
Ten year interest rate	-0.13	-0.12	-0.12	-0.11	-0.10
Short term interest rate	-0.09	-0.12	-0.14	-0.14	-0.14
Nominal exchange rate	6.12	4.57	3.96	4.18	4.68
Nominal effective exchange rate	-13.51	-14.54	-4.43	-0.94	-0.21
Inflation	0.02	0.00	-0.01	0.00	0.00
Sectoral output					
Electric utilities	-0.43	-0.63	-0.73	-0.82	-0.91
Gas utilities	-1.01	-2.23	-5.80	-8.50	-11.80
Petroleum refining	-0.72	-1.13	-1.61	-2.17	-2.91
Coal mining	-1.59	-4.24	-6.48	-8.71	-10.90
Crude oil & gas extract	-0.75	-2.53	-4.38	-6.10	-7.65
Mining	-0.41	-0.45	-0.47	-0.53	-0.62
Agriculture	-0.51	-0.48	-0.41	-0.39	-0.40
Forestry	-0.22	-0.27	-0.21	-0.18	-0.19
Durable manufacturing	-0.14	-0.16	-0.17	-0.21	-0.26
Nondurable manufacturing	-0.31	-0.45	-0.48	-0.52	-0.57
Transportation	-0.31	-0.34	-0.29	-0.27	-0.28
Services	-0.30	-0.34	-0.21	-0.10	-0.04
Sectoral employment					
Electric utilities	-0.68	-0.55	-0.33	-0.29	-0.38
Gas utilities	-0.34	-0.50	-0.57	-0.71	-0.88
Petroleum refining	-0.32	-0.27	-0.20	-0.21	-0.27
Coal mining	-1.57	-4.16	-6.54	-8.61	-10.62
Crude oil & gas extract	-1.00	-3.02	-4.65	-5.98	-7.11
Mining	-0.23	-0.10	-0.03	-0.10	-0.23
Agriculture	0.36	0.57	0.68	0.67	0.63
Forestry	0.12	0.31	0.41	0.41	0.37
Durable manufacturing	-0.04	0.01	0.02	-0.02	-0.07
Nondurable manufacturing	0.07	0.04	0.05	-0.02	-0.10
Transportation	-0.25	-0.17	-0.07	-0.05	-0.08
Services	-0.30	-0.25	-0.09	0.01	0.05
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-0.52	-1.16	-1.79	-2.43	-3.16
Coal mining	-1.20	-4.51	-7.08	-9.82	-12.56
Crude oil & gas extract	-0.69	-3.43	-5.67	-7.66	-9.29
Mining	-0.01	-0.14	-0.29	-0.39	-0.48
Agriculture	0.64	0.22	-0.06	-0.23	-0.35
Forestry	1.17	0.59	0.29	0.16	0.08
Durable manufacturing	0.51	0.05	-0.27	-0.44	-0.55
Nondurable manufacturing	0.76	0.18	-0.18	-0.38	-0.50
Transportation	na	na	na	na	na
Services	0.02	-0.09	-0.16	-0.19	-0.21

Table C.4 **Scenario I** Percentage change relative to 'business as usual'

	2000	2005	2010	2015	2020
GDP	-0.28	-0.36	-0.33	-0.30	-0.31
Consumption	-1.69	-1.48	-0.99	-0.62	-0.46
Investment	-1.11	-1.35	-1.11	-1.07	-1.13
Government spending	-0.27	-0.26	-0.32	-0.38	-0.44
Trade balance	0.95	0.79	0.51	0.37	0.31
Imports of G&S	-3.37	-3.28	-2.60	-2.13	-1.94
Exports of G&S	0.62	0.17	-0.27	-0.50	-0.63
Fiscal balance	-1.19	-1.98	-2.29	-2.13	-1.82
Terms of trade (inverse of RER)	1.72	0.94	0.35	0.08	-0.05
Ten year interest rate	-0.16	-0.14	-0.13	-0.11	-0.09
Short term interest rate	-0.15	-0.20	-0.22	-0.27	-0.20
Nominal exchange rate	9.80	7.86	6.80	7.00	7.62
Nominal effective exchange rate	-18.26	-22.43	-6.40	-1.04	-0.02
Inflation	0.03	0.06	0.00	0.00	0.00
Sectoral output					
Electric utilities	-0.58	-0.80	-0.91	-1.01	-1.11
Gas utilities	-1.34	-2.56	-6.34	-9.05	-12.41
Petroleum refining	-0.87	-1.27	-1.70	-2.22	-2.95
Coal mining	-1.77	-4.24	-6.33	-8.40	-10.47
Crude oil & gas extract	-0.75	-2.43	-4.22	-5.87	-7.36
Mining	-0.59	-0.74	-0.77	-0.86	-0.98
Agriculture	-0.76	-0.78	-0.69	-0.66	-0.68
Forestry	-0.29	-0.43	-0.43	-0.42	-0.46
Durable manufacturing	-0.26	-0.46	-0.53	-0.63	-0.73
Nondurable manufacturing	-0.46	-0.56	-0.63	-0.67	-0.73
Transportation	-0.46	-0.50	-0.46	-0.45	-0.47
Services	-0.43	-0.51	-0.40	-0.27	-0.21
Sectoral employment					
Electric utilities	-0.92	-0.68	-0.35	-0.20	-0.24
Gas utilities	-0.55	-0.64	-0.68	-0.78	-0.93
Petroleum refining	-0.38	-0.27	-0.16	-0.14	-0.18
Coal mining	-1.69	-3.99	-6.13	-7.97	-9.82
Crude oil & gas extract	-0.89	-2.73	-4.24	-5.47	-6.53
Mining	-0.36	-0.25	-0.11	-0.13	-0.24
Agriculture	0.54	0.81	0.98	1.01	0.99
Forestry	0.20	0.38	0.53	0.55	0.50
Durable manufacturing	-0.12	-0.22	-0.23	-0.29	-0.38
Nondurable manufacturing	0.09	0.19	0.17	0.13	0.05
Transportation	-0.38	-0.25	-0.13	-0.08	-0.10
Services	-0.42	-0.37	-0.19	-0.05	0.00
Sectoral exports					
Electric utilities	na	na	na	na	na
Gas utilities	na	na	na	na	na
Petroleum refining	-0.89	-1.42	-2.37	-3.26	-4.26
Coal mining	-1.52	-4.70	-7.34	-10.06	-12.75
Crude oil & gas extract	-0.10	-2.52	-5.11	-7.34	-9.17
Mining	-0.21	-0.40	-0.65	-0.81	-0.93
Agriculture	0.92	0.51	0.08	-0.14	-0.29
Forestry	1.90	1.16	0.57	0.27	0.06
Durable manufacturing	0.66	0.01	-0.52	-0.84	-1.05
Nondurable manufacturing	1.04	0.45	-0.10	-0.36	-0.51
Transportation	na	na	na	na	na
Services	-0.07	-0.17	-0.30	-0.36	-0.39

Table C.5 **Carbon taxes under emission trading and uniform tax scenarios**

	Scenario F	Scenario G	Scenario H	Scenario I
	US/t	US/t	US/t	US/t
	0.00	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00
1999	1.50	2.95	1.70	1.60
2000	2.94	5.78	3.33	3.14
2001	4.32	8.50	4.90	4.61
2002	5.65	11.11	6.40	6.03
2003	6.92	13.62	7.85	7.39
2004	8.15	16.02	9.23	8.69
2005	9.32	18.33	10.56	9.94
2006	10.45	20.55	11.84	11.14
2007	11.53	22.68	13.07	12.30
2008	12.57	24.72	14.24	13.41
2009	13.57	26.68	15.37	14.47
2010	14.52	28.56	16.46	15.49
2011	15.44	30.37	17.50	16.47
2012	16.32	32.11	18.50	17.41
2013	17.17	33.77	19.46	18.32
2014	17.98	35.37	20.38	19.18
2015	18.77	36.91	21.27	20.02
2016	19.51	38.38	22.12	20.82
2017	20.23	39.79	22.93	21.58
2018	20.92	41.15	23.71	22.32
2019	21.59	42.46	24.47	23.03
2020	22.22	43.71	25.19	23.71