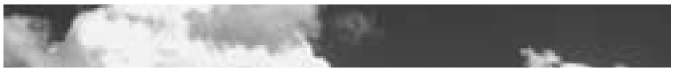
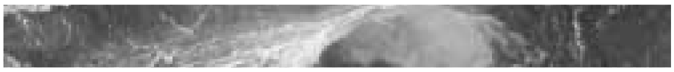
THE ECONOMIC IMPACT
of INTERNATIONAL
CLIMATE CHANGE POLICY





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Foreword

The purpose in this report is to contribute to international climate change policy development by providing an assessment of the effectiveness, equity and efficiency of alternative proposals to mitigate carbon dioxide emissions from fossil fuel combustion in Annex I countries. This study is part of a broader ongoing program of climate change policy analysis at ABARE based on model developments being conducted under the GIGABARE project.

BRIAN FISHER
Executive Director

June 1997

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Glossary

ABARE	Australian Bureau of Agricultural and Resource Economics
Abatement	Reduction of greenhouse gas emissions below business-as-usual levels
Annex I	Countries which have committed to emission abatement under Article 4.2(a) and (b) of the Framework Convention on Climate Change as listed in Annex I of the Convention; generally developed countries and countries undergoing the process of transition to a market economy
Anthropogenic	Resulting from human activities — anthropogenic emissions are greenhouse gases attributable to human activities
AOSIS	Alliance of Small Island States
ASEAN	Association of South East Asian Nations — for modelling purposes ASEAN includes Malaysia, the Philippines, Thailand and Indonesia, and excludes Brunei, Vietnam and Singapore
Atmospheric concentration	A measure of the amount of greenhouse gases (in this case) present in the world's atmosphere, per unit volume
Berlin Mandate	The decision of the first Conference of the Parties, dealing with the review of adequacy of commitments of Article 4, paragraph 2 (a) and (b), of the Framework Convention on Climate Change, including establishing a process for negotiation of a protocol or another legal instrument to apply to Annex I Parties for the period beyond 2000

Business-as-usual	A MEGABARE simulation in which policies designed to limit the growth of carbon dioxide emissions are not imposed on the model
Carbon dioxide	The principal anthropogenic greenhouse gas — the focus of this report is on energy related carbon dioxide emissions
Carbon leakage	Displacement of carbon dioxide emitting activities from countries with abatement policies to countries without abatement policies (one focus of this report is on leakage from Annex I countries to non-Annex I countries)
Carbon dioxide tax	Excise tax on fossil fuels, proportional to the carbon dioxide content of each fuel and assumed in this study to be levied at the point of fossil fuel combustion
EE	Eastern Europe – comprises Bulgaria, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia
Emissions intensity	Defined in this study as emissions per dollar of aggregate output
EPA	Environmental Protection Agency
European Union (15)	Austria, Belgium, Denmark, Finland, France, Germany, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden and the United Kingdom
EFTA	European Free Trade Association – comprises Norway, Switzerland and Iceland
Externality	An externality exists whenever the welfare of some agent depends directly on the agent's activities and on activities under the control of some other agent. An externality can be positive or negative
FCCC	United Nations Framework Convention on Climate Change

GDP	Gross domestic product — a measure of the aggregate output of a country
GNE	Gross national expenditure — comprises the sum of aggregate consumption, aggregate investment and aggregate government expenditure
Greenhouse gas	Any gas in the atmosphere that absorbs and re-emits infrared radiation — major greenhouse gases include water vapour, carbon dioxide, methane and nitrous oxides
GREEN model	The OECD's general equilibrium environmental model
GTAP	A comparative static general equilibrium model of the world economy developed at Purdue University
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Joint implementation	Realisation of reduction of emissions by one party (investor) on the territory of another (see also activities implemented jointly)
Less stringent scenario	Defined in the study for modelling purposes as a scenario where Annex I countries reduce their carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and further reduce emissions to 10 per cent below 1990 levels by 2020
Marginal emission abatement cost	The cost of reducing emissions by one further unit
MEGABARE	ABARE's dynamic general equilibrium model of the world economy
Methane	A significant greenhouse gas — important anthropogenic sources are energy production, enteric fermentation and paddy fields

More stringent scenario	Defined in the study for modelling purposes as a scenario where Annex I countries stabilise their carbon dioxide emissions from fossil fuel combustion at 15 per cent below 1990 levels by 2010 and hold emissions at those levels in the period to 2020
Non-Annex I	Developing country Parties not listed in Annexes to the Framework Convention on Climate Change
OECD	Organisation for Economic Cooperation and Development
Property rights	Refers to a bundle of entitlements defining an owner's rights, privileges, and limitations for the use of a resource
Radiative forcing	Process by which radiation from the sun is absorbed and scattered by the earth's atmosphere. Radiative forcing disturbs the balance between incoming and outgoing radiation, and the climate responds to re-establish the radiative balance by either warming or cooling the surface of the earth
Rest of the world	Group of regions used for modelling in MEGABARE — comprises all regions except those identified individually
Sink	Repository for greenhouse gases which are removed from the earth's atmosphere and absorbed and stored permanently or semi-permanently — major carbon sinks are oceans, soils and vegetation
Terms of trade	The ratio of aggregate export prices (weighted by the corresponding export shares) to aggregate import prices (weighted by the corresponding import shares) for a given country or region
Tradable emission quotas	Rights to emit greenhouse gases that are tradable

Summary

December in Kyoto is a crucial time for international climate change policy

The ultimate aim of the Berlin Mandate arising from the first Conference of the Parties to the United Nations Framework Convention on Climate Change was to negotiate greenhouse gas emission reduction objectives and policies for Annex I countries for the period beyond 2000. The deadline for an agreement on these objectives and policies is the third Conference of the Parties to the Convention to be held in Kyoto in December 1997. At this stage, however, the nature of any possible outcome from Kyoto remains very difficult to predict as many Parties are still developing their proposals for international greenhouse gas emission limitation strategies.

Analysing the economic impacts of reducing emissions

The purpose in this report is to contribute analytical input to the international climate change policy development process by providing an assessment of the economic impacts of policies to reduce carbon dioxide emissions from fossil fuel combustion in Annex I countries over the period to 2020. The assessment is based on using the MEGABARE model of the world economy to analyse alternative emission abatement policy scenarios.

To date, much of the discussion on emission abatement has focused on the adoption of uniform emission reductions across Annex I countries. More recently, the potential role of tradable emission quota schemes in reducing the costs associated with emission abatement has become more prominent in the international climate change negotiations. Both uniform emission reduction regimes and tradable quota schemes are analysed and compared in this report.

The assessment encompasses the production, expenditure and trade impacts of the emission abatement policies on developed and developing economies. It should be noted that no attempt is made to address the broader issue of assessing the overall costs of climate change itself compared with the costs of mitigation and adaptation.

Business-as-usual emissions growth

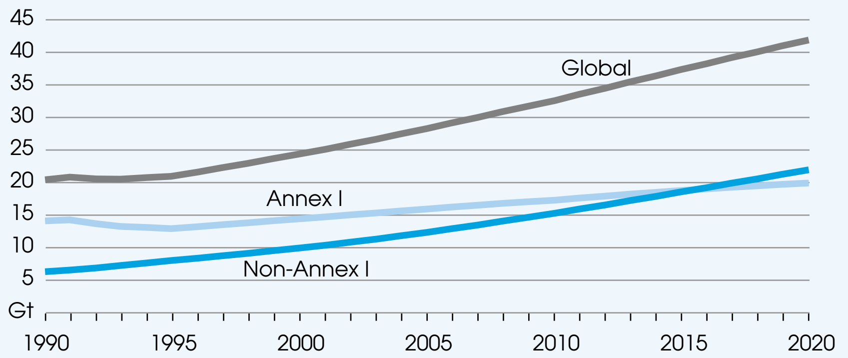
Under the business-as-usual scenario, global carbon dioxide emissions from fossil fuel combustion are projected to double over the period 1990 to 2020 (figure A) . This growth will be driven to a large extent in the future by emissions growth in non-Annex I regions. Owing to their rapid projected growth, annual emissions from non-Annex I regions are projected to overtake Annex I emissions by 2016. By 2020 these regions are projected to be responsible for 52 per cent of global emissions, compared with their 1990 share of around 30 per cent.

Among the Annex I countries high emissions growth rates (table A) are correlated with:

- high projected population growth rates, leading to increased energy demands;
- high current levels of dependence on energy sources other than fossil fuels such as hydroelectricity and nuclear power, both of which are expected to be disadvantaged compared with fossil fuel based electricity generation in the future; and
- a comparative advantage in emission intensive activities such as minerals processing.

The rapid growth in non-Annex I emissions is principally due to their relatively high projected rates of economic growth and increasing levels of industrialisation that, together, contribute to increased demand for fossil fuels.

A **Carbon dioxide emissions from fossil fuel combustion**
Business-as-usual



A Projected annual average growth in emissions, population, output and emissions per person, 1990–2020: Annex I regions, business-as-usual

	Emissions	Population a	Output (GDP)	Emissions per person
	%	%	%	%
Australia	1.63	0.94	2.31	0.68
New Zealand	2.20	0.34	2.43	1.86
United States	1.38	0.36	2.13	1.03
Canada	1.28	0.85	1.83	0.43
Japan	1.16	–0.07	2.52	1.22
European Union	1.12	–0.24	2.01	1.36
EFTA	1.10	–0.08	1.47	1.18
Former Soviet Union and Eastern Europe	0.85	0.22	1.34	0.63
Annex I average	1.34	0.29	2.01	1.05

a In Bos et al. 1992 and Urban and Trueblood 1990, population projections are presented which are generally higher than the population growth projected by MEGABARE. This can largely be attributed to the fact that neither of these other studies calculates population endogenously and they therefore do not take into account the full effects of any income changes on the population growth rate.

The implications of uniform emission abatement policies

A uniform targets approach to emission abatement requires each Annex I country to reduce its emissions to levels based on a uniform base period such as 1990. This contrasts with a differentiated targets approach, under which countries' individual economic and trade circumstances would be taken into account when their targets are set.

To illustrate the economic consequences of uniform emission abatement strategies, two alternative international climate change policies were simulated using MEGABARE:

- ***less stringent scenario***: Annex I countries reduce their carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and further reduce emissions to 10 per cent below 1990 levels by 2020; and

- ***more stringent scenario***: Annex I countries stabilise their carbon dioxide emissions from fossil fuel combustion at 15 per cent below 1990 levels by 2010 and hold emissions at those levels in the period to 2020.

Neither simulation requires developing countries to restrict their emissions growth. This assumption is based on the requirement in the Berlin Mandate that the current round of negotiations will not require developing countries to take additional measures to reduce their emissions at this time.

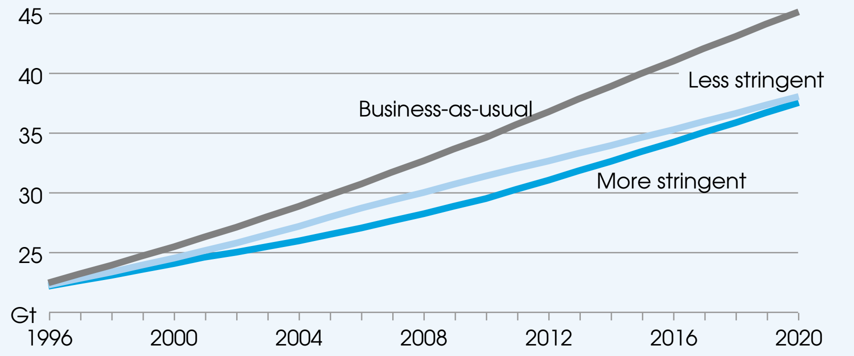
Impact on emissions

The results in figure B show that the more stringent emission reduction leads to moderately greater reductions in global emissions relative to business-as-usual than the less stringent emission reduction over the medium term. However, over the longer term the difference between the impacts of the more and less stringent policies becomes increasingly small.

There are two reasons for this result. First, the share of Annex I emissions in global emissions is projected to decline, implying that emission reductions in Annex I regions alone will have an increasingly small impact on global emissions. Second, emission abatement action in Annex I countries is projected to encourage increased fossil fuel use and emissions in non-Annex I countries as fossil fuel intensive industries relocate to non-Annex I regions, where emission abatement targets do not apply. This process, known as 'carbon leakage', is projected to offset the impacts of emission reductions in Annex I countries on global emissions by around 12 per cent in the less stringent scenario at 2020 and 14 per cent in the more stringent scenario. This means that for every million tonnes reduction in emissions achieved by Annex I regions, emissions in non-Annex I regions rise by between 120 000 tonnes and 140 000 tonnes.

The limited impact of the assumed policies on global emissions highlights the need for all countries to become involved in emission abatement over

B **Global carbon dioxide emissions from fossil fuel combustion under uniform emission reduction scenarios**



the longer term if any significant and sustained reduction to global emissions is to be achieved.

Global economic impacts

The emission reductions are estimated to impose losses in real gross national expenditure in both Annex I and non-Annex I regions (table B). At a global level, gross expenditure and output are projected to be around 0.8 per cent below business-as-usual levels by 2020 under the less stringent scrnario and 1.1 per cent below business-as-usual under the more stringent scenario.

B Change in GNE at 2020 relative to business-as-usual due to emission reductions in Annex I regions

	Less stringent	More stringent
	%	%
Annex I	–1.0	–1.5
Non-Annex I	–0.5	–0.2
Global	–0.8	–1.1

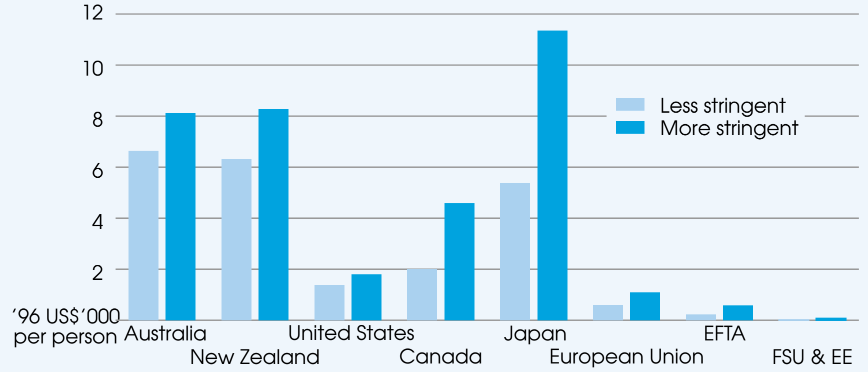
Source: MEGABARE projections.

Annex I impacts

Owing to significant differences in economic structures and trading patterns, uniform emission abatement targets do not lead to uniform economic costs between Annex I regions (figure C). For example, the projected economic costs for Australia, Norway, New Zealand and Japan are many times higher than those projected for the other Annex I regions. The magnitude of the burden increases for the more ambitious emission abatement target. Japan experiences high costs because Japanese industries have already taken major steps to improve energy efficiency and reduce fossil fuel use. Further action to reduce emissions by significant amounts in Japan would imply further structural adjustment to the Japanese economy, carrying large costs. In the case of Australia, which supplies large shares of the world's coal and processed minerals processes, emission abatement activities would entail major structural adjustment in industry, with high economic costs.

At a sectoral level, there are significant reductions in the outputs of coal, oil and gas as Annex I countries shift away from fossil fuel use to meet their

C Net present value of GNE losses due to uniform emission reduction, 2000–2020 Annex I regions



emission abatement targets. Coal, which is the most emission intensive fuel experiences the largest output fall, followed by gas and oil (table C).

Significant declines in output are also experienced in the chemical, rubber and plastics and iron and steel industries of most countries. Nonferrous metals production in Australia, which is based on coal fired power generation, also experiences a significant output fall.

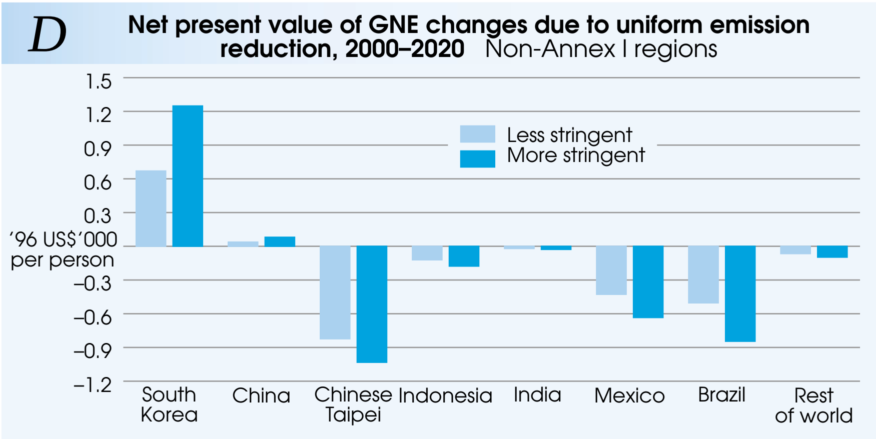
Non-Annex I impacts

A key factor driving economic growth in non-Annex I countries is the increased integration of non-Annex I countries into the global economy through trade and investment linkages. These linkages are likely to be affected when Annex I countries undertake emission abatement, with consequent economic impacts.

C Change in global primary energy use at 2020 relative to business-as-usual due to emission reductions in Annex I regions

	Less stringent scenario	More stringent scenario
	%	%
Coal	–41.0	–41.8
Oil	–5.9	–6.3
Gas	–26.6	–30.3

Source: MEGABARE projections.



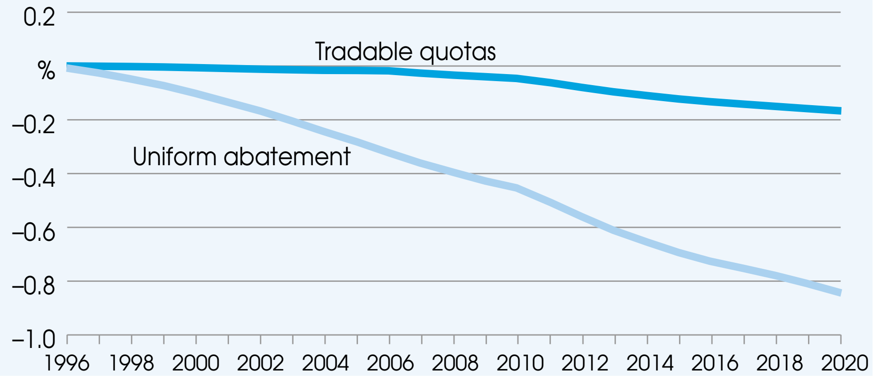
Among the non-Annex I regions, South Korea and China are projected to experience economic benefits under both emission reduction scenarios as these countries benefit from the phenomenon of carbon leakage or, more particularly, from their increased competitiveness in emission intensive production processes relative to Annex I countries (figure D).

The remaining non-Annex I regions are projected to experience economic costs due to adverse trade and investment outcomes. For example, Mexico and Indonesia export fossil fuels to Annex I regions and therefore experience a decline in export demand for these commodities. Further, the declining world price of these commodities contributes to a decline in export earnings. These countries also import fossil fuel intensive manufactures from Annex I regions, the prices of which rise due to the emission abatement efforts in Annex I regions. These price increases are passed on to consumers in Mexico and Indonesia, further contributing to the economic costs experienced by them.

Least cost approaches and tradable emission quota schemes

Strategies that impose smaller economic costs on the international community, and which lead to outcomes that are perceived to involve a more equitable sharing of these costs are much more likely to lead to effective global efforts to limit emissions than strategies that impose high and unequal costs on countries. A tradable quota scheme has the potential to allow carbon dioxide emissions to be reduced by the same amount as uniform abatement policies but at a lower cost to the international community (figure E).

E Change in global GNE over time relative to business-as-usual under grandfathered tradable quotas and uniform abatement

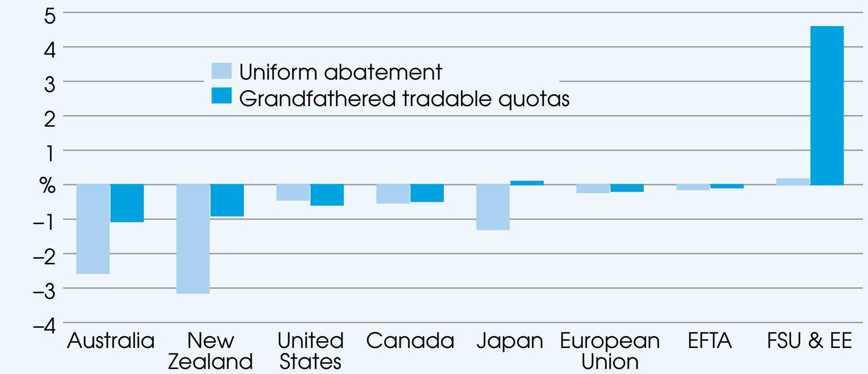


The process of trade leads to greater emission abatement in low cost locations such as the Former Soviet Union and Eastern Europe than would have been the case under the uniform targets approach. This region receives a substantial compensation for undertaking the emission reductions in the form of revenue from emission permits sold to other regions.

While trading reduces the global costs of emission abatement, the costs do not fall evenly among Annex I countries. The results in figure F show the percentage changes in GNE at 2010 when countries' emission are allocated on the basis of historical emission levels (also known as grandfathering).

The results in figure F indicate that, compared with the uniform targets result, countries such as Japan and New Zealand (where marginal abatement costs

F Change in GNE at 2010 relative to business-as-usual under uniform abatement and grandfathered tradable quotas



are projected to be the highest under uniform targets) experience the greatest benefit from the shift to grandfathered tradable quotas. Australia, on the other hand, continues to experience trade related losses owing to reduced demand for its coal exports and, as a result, it continues to experience a greater GNE loss than the other Annex I regions relative to business-as-usual.

A key result is that the United States experiences a greater loss in GNE under the grandfathered approach than under the uniform targets approach. This occurs for two reasons. First, the United States does not experience as great a reduction in marginal emission abatement costs from the move to tradable quotas as do countries such as Japan and New Zealand. As a result, the gains to fossil fuel using industries in the United States are not as great those for industries in many other Annex I regions. Second, the significant reduction in marginal emission abatement costs in other Annex I regions relative to that for the United States reduces the competitiveness of US industry compared to the situation it faced with uniform targets. Consequently, the terms of trade (or the rate at which US exports can be exchanged for imports) decline relative to the uniform targets outcome. This leads to a substantial trade related loss in GNE for the United States that outweighs the relatively small benefits from reduced marginal emission abatement costs.

Kyoto in December

In the very long term the United Nations Framework Convention on Climate Change will be judged to have been effective if a balance has been achieved between the net damages from climate change itself and the economic costs imposed as a result of emission abatement and adaptation. One of the necessary conditions for such a balance is that major emitters are part of an agreement to reduce greenhouse gases. This type of participation will be encouraged only if emission abatement actions undertaken by signatories are equitable and least cost.

A demand for simplicity by some parties to the convention has led them to insist on uniform abatement targets that lead to an inequitable allocation of economic costs among Annex I countries. Such an approach does not lay the long term foundation for an agreement that will be implemented whole-heartedly, that will provide a mechanism for signing on developing countries to undertake future commitments, or that will form the basis for introduction of innovative new policies such as tradable emissions quotas.

An emission trading scheme has the potential to be the least cost approach to meeting the challenge of reducing emissions at the international level. The initial allocation of emission permits could be used to compensate countries (at least to some extent) for the costs of meeting emission abatement targets. This will serve to encourage participation in the international emission abatement process.

1

Introduction

Widespread concerns about the potential risks of global warming motivated over 150 countries to become Parties to the United Nations Framework Convention on Climate Change. The Convention came into force in March 1994 with the aim of stabilising the atmospheric concentration of greenhouse gases at a level that would prevent 'dangerous human interference with the climate system' (United Nations 1992).

A fundamental result of the Berlin Mandate, agreed at the first Conference of the Parties to the Framework Convention in 1995, was the commencement of negotiations to establish greenhouse gas emission reduction objectives and policies for Annex I countries for the period beyond 2000 (see box 1). The deadline for an agreement on these objectives and policies is the third Conference of the Parties to the Convention in Kyoto, Japan, in December 1997. However, the nature of any possible outcome from Kyoto remains highly unclear as many countries are yet to provide the details of their proposals for international greenhouse gas emission limitation strategies.

As alternative proposals for international emission abatement are developed and refined in the lead up to the third Conference of the Parties, three key factors will influence attitudes toward them:

- the *effectiveness* of the proposals in terms of their potential impact on global greenhouse gas emissions;
- the *equity* of the distribution of the economic costs likely to be associated with proposed levels of emission abatement; and
- the cost effectiveness or *efficiency* of the emission reduction strategies.

The purpose in this report is to contribute to international climate change policy development by providing an assessment of these three aspects of the climate change debate. This will be done by assessing the economic impacts of alternative policies for the reduction of carbon dioxide emissions from fossil fuel combustion in Annex I countries.

The policy scenarios analysed include uniform or flat rate emission reduction regimes, under which countries are required to reduce their

Box 1: **Annex I Parties and the Berlin Mandate**

Parties to the Framework Convention can be categorised into two groups, Annex I and non-Annex I Parties. The Annex I group consists of OECD economies (with the exception of South Korea and Mexico) and the economies in transition (the Former Soviet Union and Eastern European countries). Non-Annex I countries are generally characterised as developing economies.

A key outcome of the first conference of the Parties to the Framework Convention held in Berlin in 1995 was agreement on a mandate for further negotiations aimed at elaborating policies and setting quantified greenhouse gas emissions limitation and reduction objectives (QELROs) for Annex I Parties. Specific aims of the negotiations leading up to third Conference of the Parties taking place under the auspices of the Ad Hoc Group on the Berlin Mandate include:

- to strengthen the commitments in Article 4.2(a) and (b) of the Framework Convention for Parties included in Annex I; for example, in relation to emission abatement;
- to consider ... the coordination among Annex I Parties, as appropriate, of relevant economic and administrative instruments;
- to provide a review mechanism to evaluate the appropriateness of set quantified limitation and reduction objectives in light of new scientific evidence and or compliance difficulties.

The Berlin Mandate outcome will not require non-Annex I countries to take on new commitments to reduce greenhouse gas emissions beyond 2000, although it requires all Parties to reaffirm their existing commitments and advance their implementation.[1]

emissions to a level based on a uniform historical period, and tradable quotas schemes, under which the right (or a permit) to emit carbon dioxide from fossil fuel combustion may be traded between emitters of carbon dioxide within and across the countries participating in the schemes.

The assessment encompasses the production, expenditure and trade impacts of the alternative emission abatement policies on developed and developing economies in the period 2000 to 2020. No attempt is made in this report to address the broader issue of assessing the overall costs of climate change itself compared with the costs of mitigation and adaptation. This subject is covered in the ‘environmental impact assessment’ literature (see, for

1 Report of the Conference of the Parties on its first session, held at Berlin from 28 March to 7 April 1995. Part two: Action taken by the Conference of the Parties at its first session, Addendum, FCCC/CP/1995/7/Add.1.

example, Weyant 1994; Weyant et al. 1995; Reilly 1997). Also, only policies to abate carbon dioxide from fossil fuel combustion are considered in this report. At this stage, data constraints prevent analysis of policies affecting emissions of carbon dioxide from non-fossil fuel sources, other greenhouse gases, and greenhouse gas sinks. A brief qualitative description of the potential implications of climate change and the role carbon dioxide and other greenhouse gases play in global warming is contained in box 2.

The analysis presented in this report is based on applications of the MEGABARE model of the world economy (ABARE 1996). MEGABARE is a multicommodity, multiregion, dynamic, computable general equilibrium model designed to conduct research on issues facing the global economy, including the impacts of climate change policy (see, for example, ABARE and DFAT 1995; Brown et al. 1997). The model documentation, together with some working papers that illustrate further model developments, can be found on ABARE's web site at www.abare.gov.au

Box 2: **The enhanced greenhouse effect**

It is argued that increases in greenhouse gas concentrations since pre-industrial times (since about 1750) have tended to warm the earth's surface and to produce other changes of climate. By 1992, the atmospheric concentrations of greenhouse gases, such as, carbon dioxide, methane and nitrous oxide had risen significantly – by about 30 per cent, 145 per cent and 15 per cent respectively (IPCC 1995b). These trends can be attributed largely to human activities, mostly fossil fuel use, land use change and agriculture (IPCC 1995a).

Carbon dioxide contributes 70 per cent of the total cumulative anthropogenic (human induced) contribution of the major greenhouse gases to changes in radiative forcing (a measure of global warming) since pre-industrial times. The contribution of methane is 21 per cent, halocarbons (controlled by the Montreal Protocol) about 6 per cent, and nitrous oxide 4 per cent. These estimates are based on direct radiative forcing for each gas resulting from increases in atmospheric concentrations (IPCC 1994).

Uncertainty over the projected extent of global warming continues to present problems of sequential decision making for policy makers (Working Group III 1995). The Second Scientific Assessment produced by the IPCC (1995a) has revised the 1992 forecasts on the extent of global warming downward. The IPCC (1995a) now predicts a rise in mean surface air temperatures of between 1.0˚C and 3.5˚C within 100 years or so and a rise in the global mean sea level of between 15 centimetres and 95 centimetres (IPCC 1995a). However, some of the scientific community assert that climate data only support a more moderate prediction of climate change of between 1.0˚C and 1.5˚C (Michaels and Knappenberger 1996).

International policy context

At the sixth negotiating meeting of the Ad Hoc Group on the Berlin Mandate, held in March 1997, a number of countries tabled proposals aimed at defining the structure and broad content of an international protocol for the limitation of greenhouse gas emissions in Annex I countries. While the various proposals differ in scope and emphasis, they indicate that three major issues will shape the outcome of the Kyoto Conference of the Parties.

1. The magnitude and timing of quantitative emission limitation and reduction objectives (QELROs)

One aim of the Berlin Mandate is to strengthen commitments under Article 4.2 of the Framework Convention relating to an implicit goal for Annex I Parties to reduce their greenhouse gas emissions to 1990 levels by 2000. (The Berlin Mandate applies only to gases not covered by the Montreal Protocol to limit ozone depleting substances.) While it is unlikely that many Annex I Parties will achieve this goal (Sturgiss 1995) a number of Parties have called for emission reductions to levels well below 1990 levels to be achieved in the period 2000 to 2020. For example, the European Union has advocated a uniform 15 per cent reduction in greenhouse gas emissions from 1990 levels by 2010. This is a weaker position than that of the Alliance of Small Island States (AOSIS), which is proposing a 20 per cent reduction in greenhouse gas emissions below 1990 levels in Annex I countries by 2005.[2]

2. The use of emission trading regimes to reduce the Annex I costs of meeting a given QELRO for developed countries

The majority of proposals heard at the sixth meeting of the Ad Hoc Group supported the potential use of emission trading among Annex I Parties as a cost effective abatement strategy. In essence, under an emission trading scheme, the quantitative emission limitation and reduction objective (QELRO) assigned to each Party would be treated as a permit to emit greenhouse gases that can be traded among emitters. Various Parties have noted that the actual cost effectiveness of such a scheme will depend on the costs of the institutional structures needed to administer the program[3]. Further, the equitable allocation of abatement costs under a tradable quota scheme will depend on the initial allocation of QELROs among Annex I countries.

2 Framework Compilation of proposals from parties for the Elements of a Protocol or Another Legal Instrument Item 3 of the provisional agenda, Note by the Chairman, Ad Hoc Group on the Berlin Mandate Sixth session Bonn, 3–7 March 1997, FCCC/AGBM/1997/2, 31 January 1997.

3. Whether developed countries' QELROs should be differentiated in order to share more equally the likely costs of achieving a given aggregate developed country QELRO

In contrast to a uniform rate QELRO approach, a 'differentiated QELRO' approach has been advocated by a number of the Parties to the negotiations. The differentiated approach takes account of the different economic and trade circumstances facing each Party when setting the QELRO to be assigned to that Party. Alternative differentiation schemes have been proposed by a number of countries including Australia, France, Japan and Norway. The European Union is in favour of using differentiated QELROs for burden sharing between its member nations. The approach outlined in the Australian proposal to the Convention is based on the principle that QELROs should be negotiated among Parties so as to ensure that each Annex I Party bears the same percentage economic loss per person from efforts to achieve the aggregate Annex I emission abatement objective.

In addition to these three issues, efforts to resolve several more critical issues will play an important role in determining the outcome of negotiations. These include: the legal force to be applied to commitments undertaken as a result of the Berlin Mandate negotiations; the role of alternative policies and measures for reducing emissions in Annex I countries and whether they should be uniformly applied or chosen from a uniform set across Parties; the range of greenhouse gases and greenhouse gas sources and sinks to be covered by new commitments; the elaboration of commitments made by non-Annex I Parties under the Framework Convention; and the role that non-Annex I Parties might play in future emission abatement strategies, including their participation in efforts to reduce emissions jointly with Annex I Parties (joint implementation).

Countries' attitudes to the various issues that are likely to determine the outcome of the Berlin Mandate negotiations will be influenced in large measure by their national circumstances. However, the development of attitudes will also be shaped by new scientific information on the nature and extent of any climate change problem and by information emerging from analytical work on the various policy related climate change issues facing international decision makers.

3 Report of the Ad Hoc Group on the Berlin Mandate on the Work of its Sixth Session, Bonn, 3–7 March 1997, Addendum, Proposals for a Protocol or Another Legal Instrument, Negotiating text by the Chairman, FCCC/AGBM/1997/3/Add.1.

2

Analytical framework

Given the all pervasive use of fossil fuels in the global economy, policies designed to constrain carbon dioxide emissions from fossil fuel use will affect almost every aspect of economic activity. Computable general equilibrium models of the world economy such as MEGABARE are able to capture the impacts of such significant policy shifts on large numbers of economic variables. These include the prices of consumer goods and inputs to production, sectoral and regional output, trade and investment flows and, ultimately, national incomes and expenditure levels in Annex I and non-Annex I countries.

MEGABARE incorporates the fact that different fossil fuels release different amounts of carbon dioxide. This means that the projected emission level for a region in a given period is a function of the mix and quantity of fossil fuel consumption in that region in that period. Alternative emission abatement policies can be analysed by modelling the impact of restrictions on emissions growth on economic variables.

Because MEGABARE is an intertemporal model the impacts of emission abatement can be traced over time and alternative timetables for the implementation of emission abatement policies can be assessed.

A number of other global general equilibrium models have been developed and used extensively to analyse climate change policies. These include ERM (Edmonds and Reilly 1983), GREEN (Burniaux et al. 1991), WEDGE (Industry Commission 1991), Whalley and Wigle (1991), Global 2100 (MR) (Manne and Richels 1992), G-Cubed (McKibbin and Wilcoxen 1992) CRTM (Rutherford 1993), Second Generation Model (Edmonds et al. 1995), EPPA (Yang et al. 1996) and the International Impact Assessment Model (Bernstein, Montgomery and Rutherford 1996) .

Regional and sectoral disaggregation

At its most disaggregated level, MEGABARE consists of equations and data that describe the production, consumption, trade and investment behaviour of representative producers and consumers in 30 regions across 41 sectoral groupings. The database used to simulate the impacts of the various emission abatement policies in this report has been aggregated to the 16 commodity groups and 18 regions presented in table 1. This particular aggregation was chosen:

- to allow focus on the links between fossil fuel industries, energy intensive sectors and other parts of the economy and to enable a comprehensive analysis of the impacts of emission abatement policies on a broad range of key sectors in each economy; and
- to enable a comprehensive assessment of the international competitiveness and trade impacts of Annex I emission abatement on both Annex I and non-Annex I countries.

Results from the MEGABARE model can be broken down to obtain a broad estimate of the possible impact of Annex I emission abatement policies on countries contained within the more aggregated MEGABARE regions. Such a breakdown has been conducted for Norway (in the European Free Trade Association). A breakdown of results for countries in the European Union will be provided in a report to follow the publication of this study.

1 Regions and sectors included in MEGABARE simulations

	Regions		Sectors
1	Australia	1	Coal
2	New Zealand	2	Oil
3	United States	3	Gas
4	Canada	4	Other minerals
5	Japan	5	Petroleum and coal products
6	European Union (15)	6	Chemicals, rubber and plastics
7	EFTA **a**	7	Nonmetallic mineral products
8	South Korea	8	Primary iron and steel
9	China	9	Primary nonferrous metals
10	Chinese Taipei	10	Fabricated metal products
11	Indonesia	11	Electricity, gas and water
12	Rest of ASEAN **b**	12	Agriculture
13	India	13	Processed agricultural products
14	Mexico	14	Capital goods
15	Brazil	15	Manufacturing
16	Rest of America	16	Services
17	Former Soviet Union and Eastern Europe		
18	Rest of the world		

a Comprises Norway, Switzerland and Iceland. **b** Comprises Malaysia, the Philippines, Singapore and Thailand.

Fuel switching and technological change

The carbon substitution possibilities available to an economy and the costs of implementing them will have a major influence on the economic consequences of any given emission abatement policy. In this regard, a key feature of the MEGABARE model is the unique ‘technology bundle’ approach to modelling fuel substitution possibilities. In MEGABARE electricity can be generated from coal, oil, gas, nuclear, hydro or renewable based technologies, while iron and steel can be produced using blast furnace or electric arc technologies.

Explicit modelling of the alternative methods of production available to them enables the electricity and iron and steel industries to substitute between technologies in response to relative price changes or restrictions on input use including the use of fossil fuels. A more detailed description of this approach to modelling fuel substitution and its advantages over commonly used alternatives is found in Appendix A.

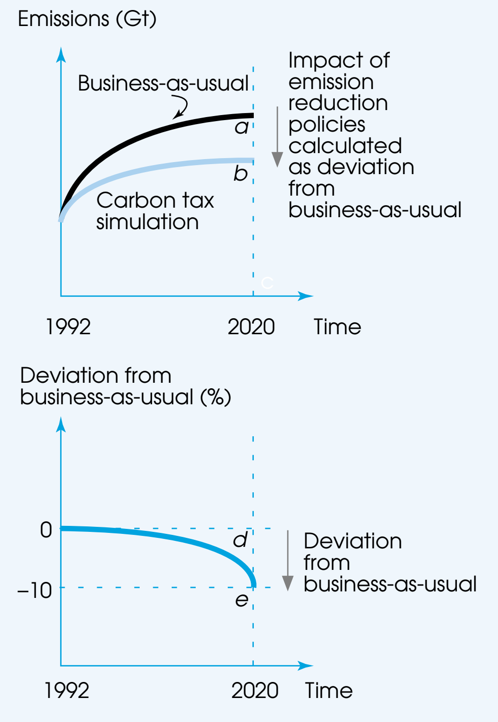
Substantial improvements in energy efficiency at no additional cost to firms are assumed to take place in the MEGABARE business-as-usual case. However, firms are assumed not to be able to accelerate their levels of innovation or induce technological change at a faster pace than is allowed under business-as-usual conditions in order to reduce the costs of emission abatement to them. For example, increased restrictions on fossil fuel use associated with an emission abatement policy could motivate firms to seek innovative ways to economise on the use of fossil fuels at a faster rate than is allowed for in the business-as-usual case. The possibility of such price responsive innovation and its implications for the cost of emission abatement are explored in Appendix B.

Policy impacts and business-as-usual

Emission abatement policies will induce resource shifts with economy wide consequences which can be traced using MEGABARE. More specifically, under different emission abatement scenarios MEGABARE calculates an equilibrium solution in which the supply of each factor input (land, labour and capital) and the output from each sector in each region equals the global demand for it. This is known as a ‘market clearing’ equilibrium. The different policy scenarios analysed using the model will be consistent with different equilibrium income levels in each region and with different equilibrium output prices, production and consumption levels and import and export levels for each type of commodity and factor input in each region.

A MEGABARE business-as-usual scenario provides a benchmark against which to measure the influences of a policy change. The projections are based on a 'no policy' scenario in which governments do not implement policies to reduce carbon dioxide emissions. The impacts of emission abatement policies on economic variables can be interpreted as deviations from the business-as-usual scenario.

1 Deviation from business-as-usual in a MEGABARE simulation



For example, the influence of an emission reduction policy on emission growth can be isolated by comparing emission growth in the policy simulation against emission growth in the business-as-usual scenario, as illustrated in figure 1. To provide a numerical example, consider that business-as-usual emissions at 2020 were projected to be 100 Mt (point *a* on the top graph). Following the introduction of an emission reduction policy, emissions at 2020 were projected to be 90 Mt (point *b* on the top graph). This corresponds to the 10 per cent reduction in emissions from business-as-usual reported in the bottom graph of figure 1. Hence the effect of the emission reduction policy is to reduce emission levels by 10 per cent compared with the business-as-usual projection for 2020.

3

Business-as-usual projections

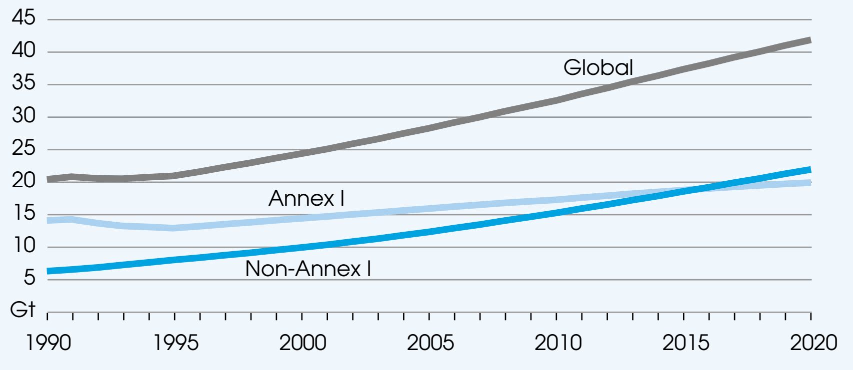
In this chapter MEGABARE business-as-usual projections for carbon dioxide emissions from Annex I and non-Annex I regions over the period 1990–2020 are presented. It is important to note that the business-as-usual scenario is not a prediction of future carbon dioxide emissions. Future emissions growth will be influenced by energy policies that are currently being either implemented or negotiated. The business-as-usual scenario abstracts from such policy developments.

Broad regional emissions growth and driving forces

Figure 2 shows projected global carbon dioxide emissions from fossil fuel combustion over the period 1990–2020. Global emissions are projected to double over the period 1990 to 2020. This growth will be driven to a large extent in the future by emissions growth in non-Annex I regions. Emissions are projected to rise at an average rate of 1.34 per cent a year in Annex I regions, while emissions from non-Annex I regions are projected to rise by 3.96 per cent a year.

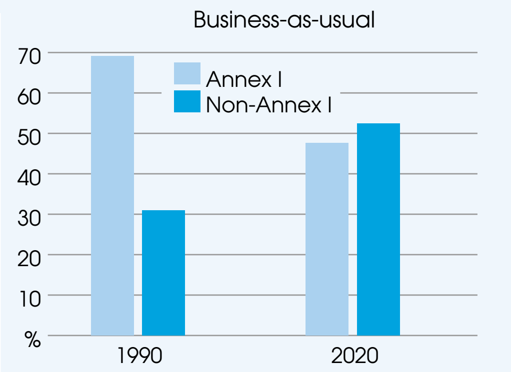
In 1990, Annex I regions contributed 69 per cent of global carbon dioxide emissions from fossil fuel combustion; the remaining 31 per cent were contributed by non-Annex I countries. However, owing to their projected

2 **Carbon dioxide emissions from fossil fuel combustion**
Business-as-usual



rapid growth, by 2016 non-Annex I emissions overtake Annex I emissions and, in 2020, Annex I regions are projected to contribute only 48 per cent of global emissions, while non-Annex I regions are projected to contribute 52 per cent in a business-as-usual setting (figure 3). This result is important in the context of present international negotiations on climate change, which are primarily focused on the obligations of Annex I countries to reduce carbon dioxide emissions.

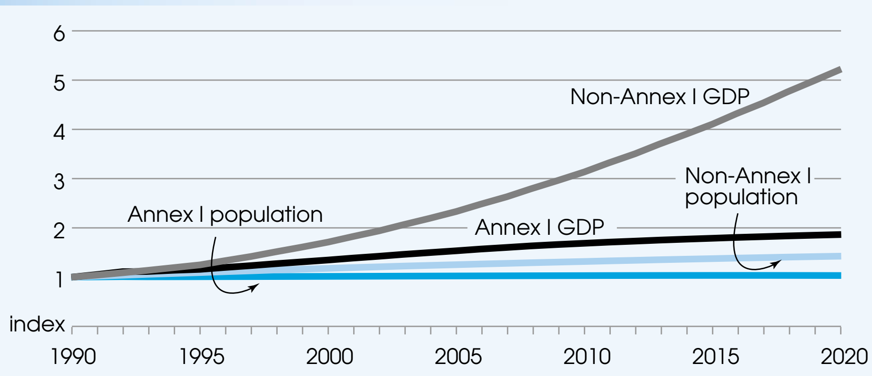
3 Contributions to global CO_2 emissions from fossil fuel combustion



The strong projected emissions growth from non-Annex I regions is largely a result of the strong business-as-usual output and population growth expected in those regions and the consequent growth in demand for fossil fuels as inputs to production (see Curtotti et al. 1997). Projected business-as-usual growth in population and gross domestic product in the Annex I and non-Annex I regions are shown in figure 4, highlighting the differences in growth patterns between the two regions.

In MEGABARE population growth is determined endogenously, with income and migration rates being taken into account. Countries with higher

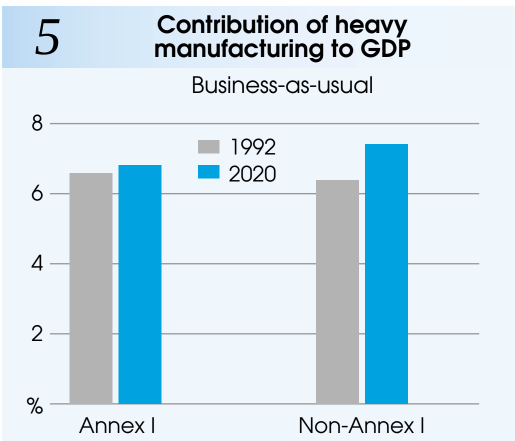
4 Population and GDP growth



levels of per person income tend to have lower birth rates, indicating a negative relationship between income levels and population growth. In general, Annex I regions have relatively high incomes and thus are projected to have lower population growth rates, while non-Annex I regions can be expected to have relatively high population growth rates. In MEGABARE the projected output growth of a region is positively related to population growth and, as a result, the relatively rapid expected growth in population in non-Annex I regions implies relatively fast growth in final demand. Population growth in non-Annex I regions contributes to the projected rapid growth in output, fossil fuel use and carbon dioxide emissions.

A second feature to note is that because non-Annex I regions have low starting levels of per person output relative to most developed countries they will also have a higher projected per person growth rate. This is because it is assumed in MEGABARE that countries with low per person incomes will have substantial scope to 'catch up' to the technological base and productive capacity of developed countries. The assumed scope for technological catch up leads to faster output growth in non-Annex I regions. However, the technological catch up also provides non-Annex I regions with a relatively rapid increase in energy efficiency from their current base of low energy efficiency on average. This effect partially offsets the influence of economic growth on emissions.

Another key difference between the regions is that the Annex I countries are already at an advanced stage of industrialisation while most non-Annex I countries are only now beginning to industrialise and show strong growth in industrial, emission intensive sectors. The current and projected shares of gross domestic product attributable to emission intensive industrial activities in Annex I and non-Annex I regions are shown in figure 5. It can be seen that over time, the share of emission intensive production increases in non-Annex I regions as their production structures become less oriented toward agriculture and more toward industrial outputs.



The share of emission intensive sectors in Annex I countries also rises, but to a much smaller extent as income growth from high starting levels leads to an increase in the share of the relatively less emissions intensive services sector in GDP.

Annex I regions

The projected emission levels for Annex I regions are provided in table 2. The projections for growth in emissions, population, output and emissions per person for each of the Annex I countries are presented in table 3. Projections for emissions growth per person are generally highest in regions in which fossil fuels contribute a relatively smaller share to total energy use. This is because it is expected that the shares of non-fossil fuel energy sources, such as nuclear power and hydroelectricity, will decline over time.

A number of factors contribute to Australia's relatively high growth in emissions, including a high rate of population growth, continued strong reliance on fossil fuels (particularly coal) in electricity generation, and strong projected growth in exports from the energy intensive industries of iron and steel and nonferrous metals. The relatively high population growth rate is related to assumed levels of migration significantly above the Annex I average.

New Zealand is projected to show stronger growth in emissions than Australia. New Zealand relies heavily on hydroelectricity and the

2 Projected carbon dioxide emissions from fossil fuel combustion: Annex I regions, business-as-usual

	1990 a	**2000**	**2010**	**2020**
	Mt	Mt	Mt	Mt
Australia	266	329	370	431
New Zealand	24	33	40	45
United States	4 935	5 593	6 511	7 454
Canada	419	471	537	612
Japan	1 080	1 210	1 414	1 525
European Union	2 812	3 404	3 727	3 930
EFTA	97	120	127	135
Former Soviet Union and Eastern Europe	4 493	3 273	4 570	5 797
Total of Annex I regions	14 126	14 433	17 296	19 929

a Figures from the World Resources Institute 1996-97 Database Diskette.

3 Projected annual average growth in emissions, population, output and emissions per person, 1990–2020: Annex I regions, business-as-usual

	Emissions	Population a	Output (GDP)	Emissions per person
	%	%	%	%
Australia	1.63	0.94	2.31	0.68
New Zealand	2.20	0.34	2.43	1.86
United States	1.38	0.36	2.13	1.03
Canada	1.28	0.85	1.83	0.43
Japan	1.16	–0.07	2.52	1.22
European Union	1.12	–0.24	2.01	1.36
EFTA	1.10	–0.08	1.47	1.18
Former Soviet Union and Eastern Europe	0.85	0.22	1.34	0.63
Annex I average	1.34	0.29	2.01	1.05

a In Bos et al. 1992 and Urban and Trueblood 1990, population projections are presented which are generally higher than the population growth projected by MEGABARE. This can largely be attributed to the fact that neither of these other studies calculates population endogenously and they therefore do not take into account the full effects of any income changes on the population growth rate.

opportunities for future hydro projects are limited (IEA 1996). Thus, increases in New Zealand’s energy use will need to rely more on fossil fuel intensive energy sources. The explanation for Canada’s high projected annual emissions growth lies largely in its high projected population growth rate.

For Eastern Europe and the Former Soviet Union, projected emission levels remain lower than 1990 levels until 2010, after which they rise rapidly due to projected strong economic growth, as these economies continue to emerge from the period of economic decline experienced during the 1990s.

The projected annual average growth in emissions from the European Union is low at 1.12 per cent, primarily due to projected population growth being negative. This takes no account of any future changes in membership of the European Union and therefore does not include emission reductions likely to be achieved through restructuring in the formerly centrally planned economies of central Europe (IPCC 1995a). Japan and the European Free Trade Association are also projected to experience a decline in their populations and low emissions growth for the period 1990–2020.

Emission projections from MEGABARE are broadly comparable with those obtained in other studies. In table 4, the emissions projected with

4 Projected annual average change in emissions, 1990–2020: Selected Annex I regions, business-as-usual

	MEGABARE	GREEN	European Commission	DRI/McGraw Hill
	%	%	%	%
Australia	1.6	na	na	1.5
United States	1.4	1.1	0.8	0.8
Japan	1.2	1.2	0.7	0.7
European Union	1.1	0.7	0.5	1.2 **a**
Former Soviet Union and Eastern Europe	0.9	1.9	-0.1	na

a This figure is the sum of the figures for Germany, France, Italy, the United Kingdom, Sweden, Spain, the Netherlands and Greece. **na** Not available.

MEGABARE are compared with those obtained by DRI/McGraw Hill (1992), the European Commission (1996) and the GREEN model (Nicoletti and Oliveira-Martins 1993).

The projections in table 4 differ between the studies presented, with MEGABARE projecting slightly larger average annual changes in emissions. However, the country rankings mostly remain the same among the studies, indicating that the different levels of emissions are mainly due to differing assumptions about growth rates. The one exception is for the Former Soviet Union and Eastern Europe, where the projections differ widely among the studies, with European Commission projecting a decline in emissions for the region.

This difference is likely to be because the MEGABARE estimate includes projections for Eastern European countries, which are generally expected to experience a more rapid increase in emissions than the countries of the Former Soviet Union. Also, Nicoletti and Oliveira-Martins (1993) note that the GREEN simulation may overstate the growth in emissions from the Former Soviet Union.

Non-Annex I regions

MEGABARE projects significant emission increases from all of the non-Annex I regions from 1990 until 2020, as shown in table 5. Projections for growth in emissions, population, output and emissions per person are presented in table 6 to illustrate the forces driving the emissions projections.

5 Projected carbon dioxide emissions from fossil fuel combustion: Non-Annex I regions, business-as-usual

	1990	2000	2010	2020
	Mt	Mt	Mt	Mt
South Korea	241	413	542	628
China	2 421	4 235	6 221	8 680
Chinese Taipei	74	118	148	157
Indonesia	155	270	414	603
Rest of ASEAN **a**	230	419	644	913
India	675	1 075	1 683	2 470
Mexico	325	391	605	831
Brazil	202	305	475	666
Rest of America	448	674	1 062	1 547
Rest of the world	1 554	2 048	3 500	5 452
Total of non-Annex I regions	6 325	9 948	15 294	21 947

a Association of South-East Asian Nations.

Brazil and the Rest of America both show large annual average increases in emissions, 4.06 per cent and 4.22 per cent respectively, mainly due to their high projected output growth. Cost related restrictions on growth in Brazilian hydro capacity imply that energy demands will need to be met by increasing use of fossil fuels. As a result, the growth in Brazilian emissions is projected to be relatively high.

6 Projected annual average growth in emissions, population, output and emissions per person, 1990–2020: Non-Annex I regions, business-as-usual

	Emissions	Population	Output (GDP)	Emissions per person
	%	%	%	%
South Korea	3.24	0.28	4.62	2.97
China	4.35	0.86	6.37	3.49
Chinese Taipei	2.55	0.05	3.93	2.50
Indonesia	4.62	1.09	6.47	3.53
Rest of ASEAN **a**	4.70	1.05	6.69	3.65
India	4.42	1.13	5.37	3.29
Mexico	3.18	1.29	5.56	1.89
Brazil	4.06	1.08	4.74	2.98
Rest of America	4.22	1.29	6.56	2.93
Rest of the world	4.27	1.62	5.64	2.65
Non-Annex I average	3.96	0.97	5.60	2.99

a Association of South-East Asian Nations.

7 Projected annual average change in emissions, 1990–2020: Selected non-Annex I regions, business-as-usual

	MEGABARE	GREEN	European Commission	DRI/McGraw Hill
	%	%	%	%
China	4.4	4.3	2.2	na
India	4.4	4.3	na	na

na Not available.

There is no uniform trend among Asian countries (many of which are at significantly different development stages) with a range in increases of emissions of 2.55 per cent for Chinese Taipei to 4.70 per cent for the Rest of ASEAN. Significant emissions growth is also projected for India owing to its expected rapid output growth rate and an increasing share of emission intensive industries (as opposed to agriculture) in the structure of its gross domestic product over the projection period.

Table 7 shows that the estimates for China's emissions growth vary considerably among different modelling studies. The European Commission projects a much smaller annual average growth in emissions for China, at only 2.2 per cent, compared with the 4.4 per cent projected by MEGABARE and the 4.3 per cent projected by GREEN. The European Commission's projection for output growth in China is 6.9 per cent a year, which is higher than MEGABARE's projected 6.4 per cent a year. This implies that the European Commission is likely to be expecting a higher rate of energy efficiency improvement or more rapid structural change away from energy intensive activities than is projected with MEGABARE. In this context, Levine and Price (1997) point out that it is unlikely that China (and other countries) will be able to sustain the policy driven level of energy efficiency improvement experienced during the 1980s into the next century.

4

Global impacts of uniform emission reductions

An assessment of the impacts of uniform emission reduction targets at a broad global level is provided in this chapter. A uniform targets approach to achieving emission reductions requires each Annex I country to reduce its emissions to levels based on a uniform base period such as 1990. This contrasts with a differentiated targets approach under which countries' individual economic and trade circumstances would be taken into account when their quantitative emission limitation and reduction objectives (QELROs) are set.

For illustrative purposes two alternative uniform emission abatement scenarios have been selected for analysis of their economic impacts:

- ***less stringent scenario:*** Annex I countries reduce their carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and further reduce emissions to 10 per cent below 1990 levels by 2020; and

- ***more stringent scenario:*** Annex I countries stabilise their carbon dioxide emissions from fossil fuel combustion at 15 per cent below 1990 levels by 2010 and hold emissions at those levels in the period to 2020.

The first scenario is based on a ten year delay in achieving the implicit commitment in Article 4.2 of the Framework Convention that Annex I Parties aim to reduce their emissions to 1990 levels by 2000. The further 10 per cent reduction beyond 2010 represents a strengthening of the emission abatement commitment implied in Article 4.2. The second scenario represents a policy similar to that proposed by the European Union Parties at the international climate change negotiations held in Bonn in March 1997. Developing countries are not required to restrict their emissions growth in either scenario. This assumption is based on the requirement that the outcome of the Berlin Mandate negotiations will not require developing countries to take additional measures to reduce their emissions.

It is assumed that in achieving the emission reductions, governments adopt policy instruments that impose the smallest possible cost on their economies. A discussion of efficient approaches to reducing carbon dioxide emissions within a country is presented in chapter 11 of the Intergovernmental Panel on Climate Change's Second Assessment Report of Working Group III, IPCC (1995a). If, in practice, least cost approaches are not adopted, then economic costs to a given Annex I region would be higher than those reported in this study.

In MEGABARE, least cost modelling of emission abatement involves imposing a tax on emissions of carbon dioxide in each period for which emission restrictions apply. The tax raises the costs associated with carbon dioxide emission intensive activities and encourages a shift of resources into less emission intensive activities, thereby reducing emissions.

Revenue from the tax is assumed to be returned to the economy in a lump sum fashion. In practice, changing the way in which revenue is returned to the economy can alter estimates of the implications of emission abatement. For example, some analysts have shown that using the revenue from a carbon tax to reduce government budget deficits or to replace highly inefficient taxes can confer some benefits on an economy (see, for example, McDougall and Dixon 1996). Critics of such conclusions, including de Mooij (1996), point out that estimates of such benefits are highly sensitive to the type of models used for the analysis and the underlying assumptions. Further, the changes in income distribution implied by the shift in revenue base can render the reform of highly inefficient taxes using environmentally based taxes politically infeasible. In addition, such alternative approaches to the treatment of carbon tax revenue do not permit the impacts of emission abatement to be separated from the impacts of taxation or budgetary reforms and they can provide a distorted picture of the impacts of emission abatement on economies.

A carbon tax is representative of the broad class of economic instruments that could be used by governments to reduce emissions, including nationally based tradable emission quota schemes. In the context of the MEGABARE simulations the carbon tax associated with achieving a given level of emission abatement can also be interpreted as the unit price of nationally traded emission quotas (Hinchy et al. 1993). In more general terms the carbon tax can be interpreted as the marginal cost to the economy associated with any least cost policy or set of policies designed to achieve a given level of emission abatement.

Impacts of policies on emissions

Annex I emissions

Reducing Annex I emissions to 10 per cent below 1990 levels by 2020 (the ‘less stringent’ of the two scenarios examined in this study) implies an emission reduction relative to business-as-usual emissions in this region of around 38 per cent by 2020 (table 8). Reducing Annex I regions’ emissions to 15 per cent below 1990 levels by 2010 and holding them fixed in the period to 2020 (the ‘more stringent’ scenario) requires a reduction in Annex I emissions of 41.6 per cent compared with the business-as-usual level by 2020.

Non-Annex I emissions and carbon leakage

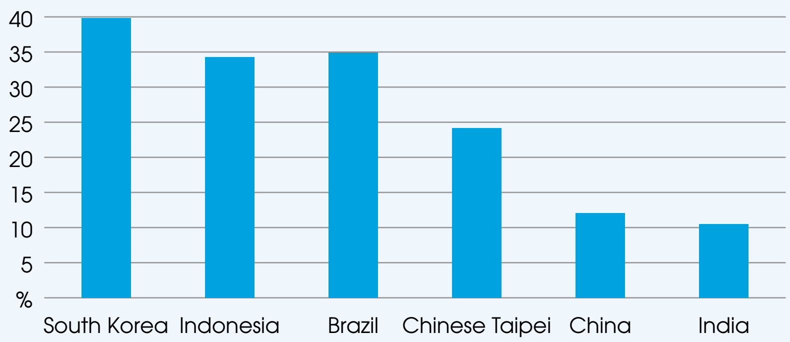
Carbon dioxide emissions from non-Annex I countries are projected to rise by over 4 per cent relative to business-as-usual in both simulations. This phenomenon is known as ‘carbon leakage’. Carbon leakage is the partial off-setting of emission abatement achieved in Annex I countries by increases in emissions from non-Annex I countries. In the simulations, Annex I countries impose policies to reduce fossil fuel usage to reduce emissions. These policies increase production costs in fossil fuel intensive industries such as iron, steel and nonferrous metals production in Annex I countries. As a result, non-Annex I countries obtain a competitive advantage over Annex I countries in fossil fuel intensive products. In response, there is a partial shift in emission intensive industries from Annex I to non-Annex I countries. For example, figure 6 shows the projected significant increases in iron and steel production in selected non-Annex I countries as a result of the less stringent emission abatement action undertaken in Annex I countries.

8 Change in CO_2 emissions at 2020 relative to business-as-usual due to emission reductions in Annex I regions

	Less stringent scenario	More stringent scenario
	%	%
Annex I	–38.2	–41.6
Non-Annex I	4.2	5.1
Global	–15.7	–16.8

Source: MEGABARE projections.

6 Change in iron and steel output at 2020 relative to business-as-usual
Non-Annex I regions, less stringent scenario



The partial shift in emission intensive production toward non-Annex I countries leads to an increase in their emissions and, therefore, carbon leakage. In effect, emission abatement actions undertaken in Annex I countries encourage non-Annex I countries to increase their carbon dioxide emissions above business-as-usual levels.

The results presented in table 8 imply a carbon leakage rate[4] of 12.5 per cent at 2020 under the less stringent scenario and 13.9 per cent under the more stringent scenario. This implies that for every million tonnes reduction in carbon dioxide emissions in Annex I countries, carbon dioxide emissions from non-Annex I countries are projected to rise by between 125 000 and 139 000 tonnes, respectively. In previous studies using MEGABARE that involved emission abatement in OECD countries only (Brown et al. 1997), the estimated rate of carbon leakage at 2020 was a higher 24 per cent. In those studies, however, a significant proportion of the increase in non-OECD emissions was estimated to occur in the Former Soviet Union and Eastern Europe. In the current analysis, emissions growth in these regions is constrained, thereby preventing carbon leakage in their direction.

It should be noted that different analysts' estimates of carbon leakage rates vary greatly. For example, carbon leakage rates estimated by Martin et al. (1992) based on results from the GREEN model are close to zero at 2020. However, Pezzey (1992) estimated carbon leakage rates of 70 per cent based on results from the Whalley-Wigle model. Manne and Oliveiria-Martins

4 The carbon leakage rate is calculated as the emissions increase projected for non-Annex countries in megatonnes (Mt), divided by the emissions reductions in Annex I countries (Mt), multiplied by -

(1994) estimated a carbon leakage rate of 35 per cent from the 12RT model. The carbon leakage estimates of around 12 per cent from MEGABARE that are reported in this study lie between the extreme estimates from other models. However, care should be taken in comparing carbon leakage estimates between models or even between simulations using the same model for a number of reasons.

First, each model uses different regional aggregation and carbon leakage estimates are sensitive to which regions are included in the emission abatement action. This is particularly important because the MEGABARE simulations reported here consider emission reductions from the Former Soviet Union and Eastern Europe while many other models exclude these regions from abatement actions.

Second, the carbon leakage rate estimated by each model depends, to an extent, on the assumed sectoral aggregation. It is expected that greater sectoral detail, particularly in fossil fuel intensive products, would provide greater substitution possibilities and, therefore, larger carbon leakage estimates. MEGABARE contains a greater degree of sectoral detail than most models. It is reasonable to expect that the carbon leakage rates estimated by MEGABARE would be higher than those estimated by models with relatively less sectoral detail, particularly in fossil fuel intensive manufactures.

Third, each of the models mentioned is based on different assumptions about trade and investment flows. The carbon leakage estimates from MEGABARE can be expected to be higher than those generated from models that do not capture the potentially significant scope for capital and trade flows in response to changes in relative competitiveness between Annex I and non-Annex I regions.

Global fossil fuel use and emission reductions

Changes in global emissions shown in table 8 are associated with reductions in the global use of fossil fuels, which in turn are driven by reduced use in Annex I countries. Projected changes in the world’s use of oil, gas and coal are shown in table 9. Global coal use is projected to decline by 41 per cent relative to business-as-usual in the less stringent scenario. The significant decline in coal use can be attributed largely to greater substitution away from coal use in electricity production than for less carbon intensive energy sources such as oil and gas. The projected decline in global oil use is less

9 Change in global primary energy use at 2020 relative to business-as-usual due to emission reductions in Annex I regions

	Less stringent scenario	More stringent scenario
	%	%
Coal	–41.0	–41.8
Oil	–5.9	–6.3
Gas	–26.6	–30.3

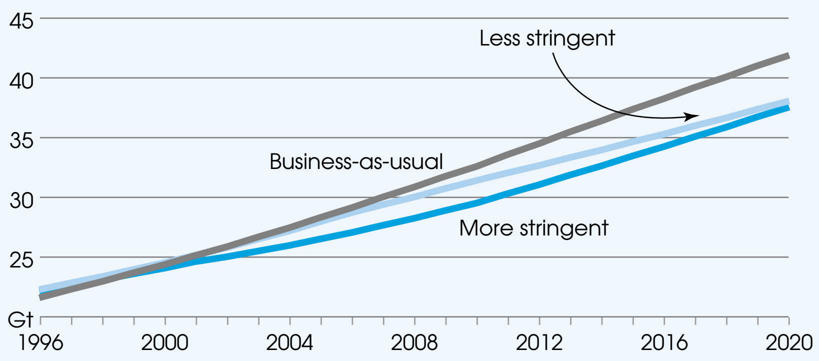
Source: MEGABARE projections.

than that for coal and gas, mainly because oil products are used extensively in the transport sector, where substitution possibilities are more limited than in the power generation sector where coal and gas are used extensively.

The results presented in figure 7 show that the more stringent emission reduction scenario leads to moderately greater reductions in global emissions over the medium term (that is, by 2010). However, over the longer term, carbon leakage to non-Annex I countries, coupled with the declining Annex I share of global emissions, reduces the difference between the impacts of the more and less stringent Annex I actions on global emissions.

Under the less stringent emission abatement scenario, global carbon dioxide emissions are projected to fall by 15.7 per cent, or 7.1 Gt, relative to business-as-usual at 2020. The more stringent emission reduction scenario is projected to lead to a decline in emissions of 16.8 per cent, or 7.6 Gt, relative

7 Global carbon dioxide emissions from fossil fuel combustion under uniform emission reduction scenarios



to business-as-usual. The limited impact of the assumed policies on global emissions highlights the need for all countries to become involved in emission abatement if any significant and sustained reduction in global emissions is to be achieved.

Impacts of policies on economies

The assumed emission reductions are estimated to impose losses in real gross national expenditure (GNE) (see box 3) on Annex I and non-Annex I regions (table 10). Global losses in GNE (and gross domestic product) at 2020 relative to business-as-usual are projected to increase from 0.8 per cent of GNE under the less stringent emissions reduction target to 1.1 per cent under the more stringent emission reduction objective.

10 Change in GNE at 2020 relative to business-as-usual due to emission reductions in Annex I regions

	Less stringent scenario	More stringent scenario
	%	%
Annex I	–1.0	–1.5
Non-Annex I	–0.5	–0.2
Global	–0.8	–1.1

Source: MEGABARE projections.

While comparison of estimated economic losses obtained from different models is difficult, the overall magnitude of the economic loss projected by MEGABARE is close to those obtained in other studies. For example, the MEGABARE results can be compared with results from some well known global models.[5] These models estimated gross domestic product losses for the OECD (that is, Annex I countries excluding the Former Soviet Union and Eastern Europe) countries from stabilising carbon dioxide emissions at 1990 levels of between 0.3 per cent and 0.5 per cent at 2020. In these studies, the emission abatement targets imposed on countries were less stringent than the scenarios presented in this study.

5 Includes GREEN (Burniaux et al. 1991), Global 2100 (MR) (Manne and Richels 1992), ERM (Edmonds and Reilly 1983), CRTM (Rutherford 1993) and McKibbin and Pearce (1996), in which the results applied to emission stabilisation at 1990 levels by 2005.

Box 3: **Gross national expenditure as an aggregated measure of economic outcomes**

In much of the literature on greenhouse policy gross domestic product (GDP) or gross national product (GNP) are used as aggregate measures of economic impacts (or in more technical terms 'economic welfare') due to the wide familiarity with these concepts.

In the context of an intertemporal model of a closed stationary economy, it can be shown that gross national product can serve as an appropriate indicator of economic welfare (Beltratti 1996). Gross national product is the sum of consumption and investment. Consumption measures current welfare while investment indicates the future consumption stream possible. Complications arise if allowance is made for international trade, technical progress, exhaustible resources and environmental quality (Vellinga and Withagen 1996).

In modelling a world with international trade, gross national product is frequently used as a measure of national welfare. However, it is arguable that gross national expenditure (GNE) may be a better proxy measure of the welfare impact of a policy change under some conditions. The relationship between the two concepts is given by

GNE = GDP + Imports – Exports – Foreign income transfers

and GNE is defined directly as

GNE = Private consumption + Investment + Government expenditure

The main advantage of gross national expenditure is that it better captures the impact of changes in the current account on consumption and investment possibilities. Thus, if two countries had the same gross domestic product, the one with the greater surplus of imports over exports and foreign income (a higher gross national expenditure) would be able to support a higher level of consumption, investment and government expenditure in that period.

In many simulations with the MEGABARE model, the change in equivalent variation of a representative consumer has been significantly more highly correlated with the change in gross national expenditure per person than the change in gross domestic product per person. Such a result supports the view that at least for the types of policy changes considered, gross national expenditure is a better proxy economic welfare measure than gross domestic product or gross national product.

The key source of economic loss in Annex I countries is an increase in industrial production costs and consumer prices as assumed emission restrictions force producers and consumers in Annex I countries to move away from carbon intensive fossil fuel use into more costly alternatives. The increased costs to industry tend to dampen economic activity. The resulting decline in demand for labour and capital reduces real returns to capital and labour (defined as the gains in output associated with adding an extra unit of capital and labour, respectively, to the economy), in turn, leading to reduced income and economic losses.

The impacts of Annex I policies on international trade can be very significant for both Annex I and non-Annex I economies. For example, both Annex I and non-Annex I fossil fuel exporters can be expected to experience a decline in demand and prices for their fossil fuel exports. Also, Annex I countries with significant exports of fossil fuel intensive products (such as iron and steel, or aluminium in the case of Australia) could face a reduction in export demand as these industries begin to relocate to developing countries to take advantage of increased price competitiveness. While, on average, Annex I exporters of fossil fuel intensive products lose competitiveness, non-Annex I exporters of these products experience gains in competitiveness, leading to carbon leakage and contributing positively to GNE changes in non-Annex I countries.

Trade related economic losses can also arise because the increased costs of production in Annex I countries (resulting from their efforts to restrict emissions) are passed on to consumers of Annex I products, including those in developing countries. For example, the prices of capital goods sold by Japan to all countries, including non-Annex I countries, rise with the imposition of emission abatement policies in Japan. All other things being equal, countries with significant imports of emission intensive products from Annex I countries can be expected to experience more significant economic losses than countries with less significant imports of those products.

The trade related impacts of Annex I emission abatement on a country will depend on two factors. The first factor is the extent to which a country is able to purchase more imports from its national income. A decline in a country's international purchasing power from national income will contribute to a trade related loss in GNE. The second factor affecting trade impacts experienced by a country is the change in its ability to buy imports with a unit of exports, as measured by its terms of trade. A decline in a country's terms of trade represents a devaluation of its export returns, contributing to a trade related loss in GNE.

A key feature of the MEGABARE results is that under certain policy simulations, trade effects lead to economic losses in a number of non-Annex

I countries even though they do not take any direct action to reduce their emissions. In table 10 non-Annex I countries are projected to experience a loss of 0.5 per cent of gross national expenditure at 2020 under the less stringent policy. Under the more stringent policy, non-Annex I countries are projected to experience a smaller 0.2 per cent decline in gross national expenditure by 2020 as the beneficial impacts of carbon leakage become more significant than under the less stringent emission reduction scenario.

The figures in table 10 represent average outcomes across broad regional groupings. However, within groupings there are substantial differences in outcomes owing to differences in economic structures and trading patterns. The magnitude and sources of these differences in Annex I regions and non-Annex I regions are explored in the following two chapters.

5

Economic impacts on Annex I regions

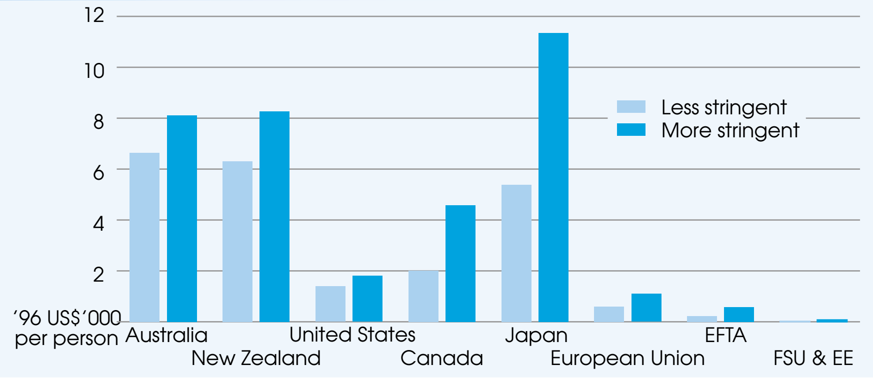
An assessment of the economic impacts of uniform emission reduction targets in each Annex I region is provided in this chapter. Differences in aggregate economic costs incurred in Annex I regions as a result of adopting uniform emission reduction targets are identified and impacts on key industries and sectors in each region are examined.

The detailed explanation of results focuses on the impacts of the less stringent emission abatement policies at 2010. In general, the pattern of these results is reflected in results for other time periods and also under the more stringent scenario. Cases for which this correspondence does not hold are highlighted.

Differences in economic impacts

The economic losses incurred by Annex I countries under the more stringent and less stringent emission reduction scenarios are shown in figure 8. These losses are presented as the sum of the net present values of per person changes to gross national expenditure incurred in each year of the simulation period. A discount rate of 5 per cent is assumed. The net present valuation explicitly incorporates the time value of money and allows comparison of economic costs incurred in one period relative to those experienced in another period. Also, calculating the net present value on a per person basis

8 **Net present value of GNE losses due to uniform emission reduction, 2000–2020** Annex I regions

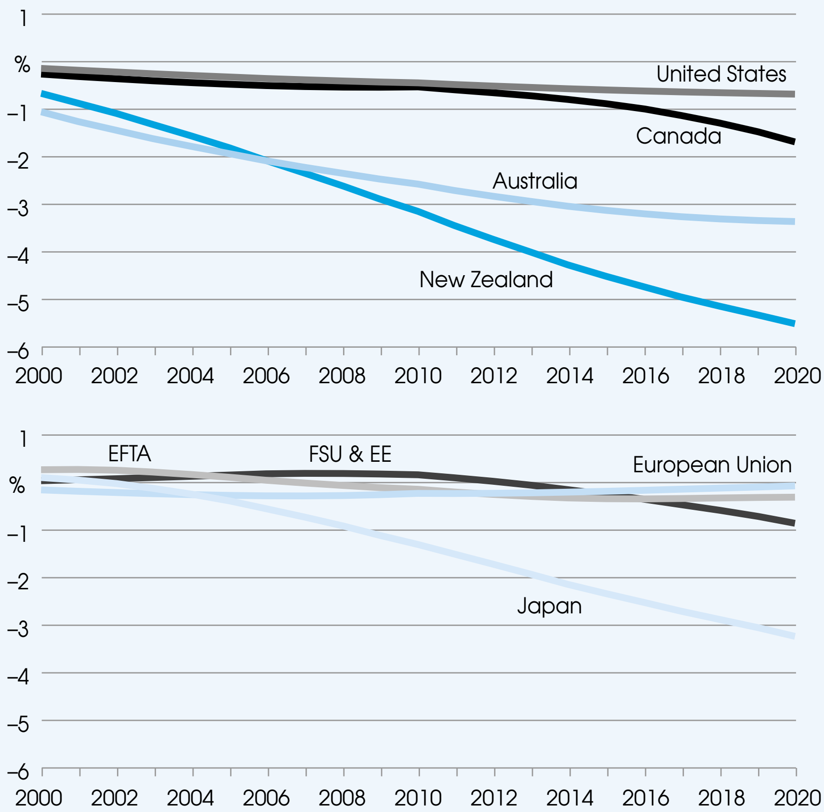


allows a comparison of the projected economic costs across different regions.

The net present value can be regarded as an estimate of the 'one off' cost of the Annex I emission reduction policies to different regions. The use of such one off payments to express estimates of the costs associated with achieving given environmental outcomes is supported by many recent examples in the contingent valuation literature (for example, see Carson et al. 1995).

The results presented in figure 8 show that GNE losses are projected to vary significantly between Annex I regions. For example, the projected costs for Australia, New Zealand and Japan are many times higher than those projected for the other Annex I regions. For all regions, projected costs are higher under the more stringent scenario.

9 Change in GNE over time relative to business-as-usual
Annex I regions, less stringent scenario



Different emission abatement actions can be expected to differ in their impacts over time. The time paths of GNE changes for the Annex I regions under the less stringent emission reduction scenario are shown in figure 9. In most Annex I regions annual GNE costs are projected to increase over time. For example, under the less stringent emission reduction scenario, the annual loss to Japan is projected to more than double between 2010 and 2020, from 1.3 per cent to 3.2 per cent of GNE relative to the business-as-usual case. Over the same period the loss to Canada increases from 0.5 per cent to 1.7 per cent of GNE.

In contrast to the other Annex I regions, the European Union exhibits decreasing GNE costs over time. This is principally the result of a growing competitive advantage over other Annex I countries in the production of some energy intensive products. These effects are explained later in this chapter.

Within regions there are likely to be significant differences in the economic costs faced by constituent countries. For example, within the European Free Trade Association, losses to Norway would include the significant negative effects of reduced income from oil production. A breakdown of impacts on Norway, including substantial projected reductions in aggregate output, is provided in Appendix C.

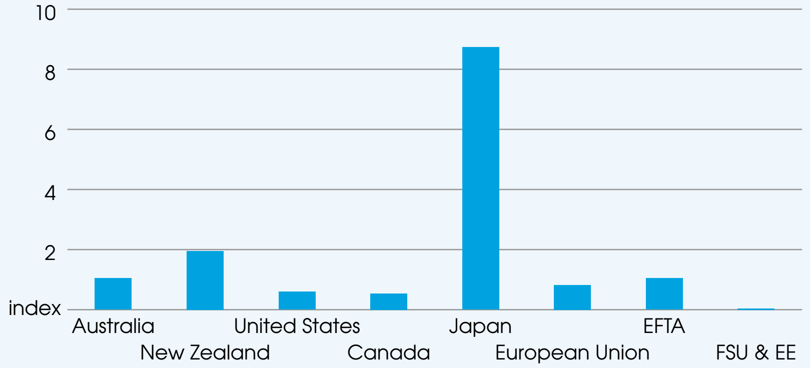
As noted in the previous chapter, the effects on GNE of emission restrictions in Annex I economies arise from two sources. First is the effect of the policies on production in various industries and therefore on GDP. The second source is the effect of the policies on the ability of a country to benefit from trade. The nature and magnitude of these impacts on different Annex I regions will depend on their economic structures and trading patterns. The production and trade impacts of Annex I abatement policies are discussed in detail in the following sections.

Impacts on production

Marginal costs of abatement

The production impacts of achieving a given emission reduction in Annex I regions will depend to a large extent on the size of the penalty that is needed to be put in place to discourage emission generation. The marginal cost of emission abatement is a measure of this penalty[6] (see chapter 2).

10 Marginal cost of abatement at 2010
Annex I regions, less stringent scenario



Marginal emission abatement costs under the less stringent scenario at 2010 are shown in figure 10. In this figure, the marginal emission abatement costs have been normalised so that the average marginal abatement cost across Annex I countries (weighted according to 1990 emission levels) is set equal to 1. This means, for example, that the projected marginal abatement costs for Australia and EFTA are approximately equal to the Annex I average, while the projected marginal abatement cost for Japan is about eight times the Annex I average.

The size of the marginal abatement cost for each Annex I region depends on two main factors:

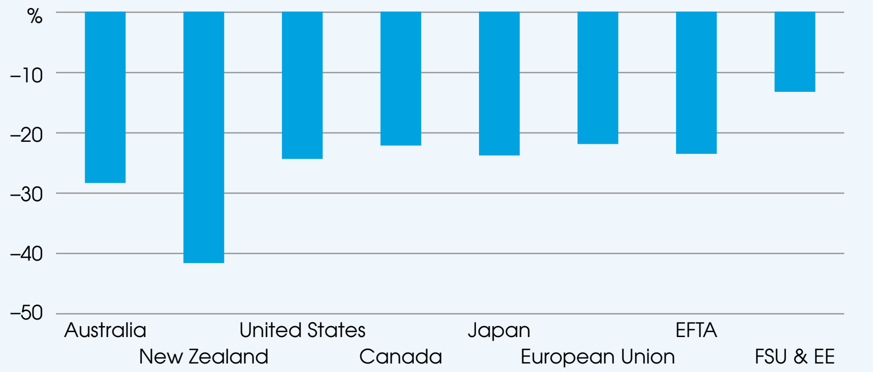
- the magnitude of the emission reduction required; and
- the cost of fossil fuel alternatives.

Magnitude of the emission reduction

As an emission abatement target is increased, low cost options to reduce emissions become more scarce. As a result, the penalty for generating emissions must be increased in order to force firms and consumers to adopt alternatives to emission intensive fossil fuels. This implies that marginal emission abatement costs will tend to be higher for countries with higher emission abatement targets.

6 In this report the term ‘marginal cost of emission abatement’ refers to the level of marginal cost associated with a given emission abatement action. The functional relationship between marginal costs and emission abatement is termed the ‘marginal abatement cost curve’.

11 **Change in carbon dioxide emissions at 2010 relative to business-as-usual** Annex I regions, less stringent scenario



Estimates of the required emission abatement for each Annex I region are presented in figure 11. Countries with relatively high business-as-usual emissions growth such as Australia and New Zealand are required to achieve relatively large emission reductions to meet their emission abatement objectives under the uniform targets approach. This contributes to their high marginal cost of emission abatement.

Under the less stringent emission reduction scenario the Former Soviet Union and Eastern Europe grouping is not required to undertake emission reductions until after 2007 as their emissions are not projected to increase above 1990 levels until that year. This is reflected in the results presented in figure 11 by the relatively small emission reduction requirement for this region. It should be noted, however, that by 2020, with the significant growth in emissions from the Former Soviet Union and Eastern Europe, this region will be required to reduce emissions to more than 40 per cent below business-as-usual levels. This compares with the estimated 30 per cent reduction for the United States in the same year.

The cost of fossil fuel alternatives

While emission abatement targets are closely related to marginal abatement costs, the extent and expense of possible alternatives to carbon intensive production processes are also important determinants of marginal and, ultimately, total emission abatement costs.

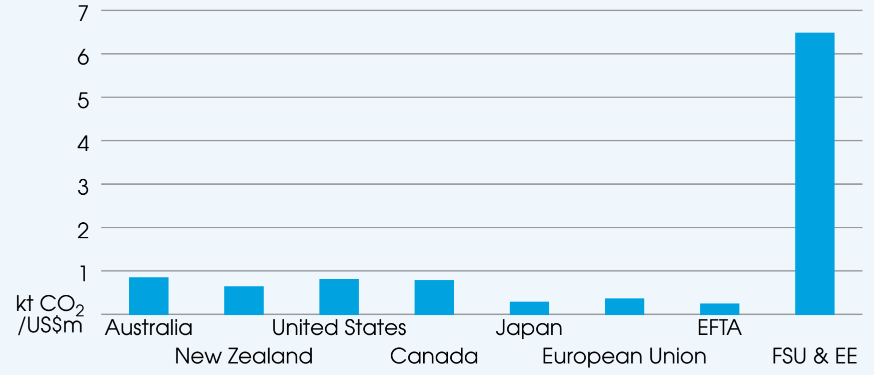
A region that can substitute readily into less emission intensive fuel sources would be expected to incur a relatively low marginal abatement cost and experience lower economic costs than a region with limited, or more expensive, substitution possibilities, all other things being equal.

Substitution possibilities can be limited if a region uses technologies that are relatively less emission intensive. In this case the region is said to have limited *technical* possibilities for substitution. For example, a country that is heavily reliant on hydroelectricity or nuclear power will not have significant scope to achieve low cost emission reductions in the electricity sector. This would imply a need to reduce emissions in the transport and industrial sectors, where substitution possibilities tend to be more limited and where higher penalties or marginal emission abatement costs would need to be imposed to encourage emission reductions.

Technical substitution possibilities are likely to be especially limited in Japan which has achieved significant reductions in fossil fuel use over the past twenty-five years in most sectors of its economy. As a result, low cost options to reduce fossil fuel use that might have existed are likely to have been exhausted in the past and, therefore, Japan will need to impose substantial penalties on emitters in order to achieve further emission reductions. This will be reflected by a relatively high marginal cost of emission abatement.

In contrast with Japan, the production structure in the Former Soviet Union and Eastern Europe relies heavily on carbon dioxide intensive inputs (figure 12). This region is likely to have significant low cost opportunities to reduce emissions and, therefore, is unlikely to need to impose substantial penalties on emitters in order to achieve emission reductions in future years. For the

12 Emission intensity of aggregate output in Annex I regions, 1995



United States and Canada, relatively high emission intensity contributes to their relatively low projected marginal costs of abatement at 2010.

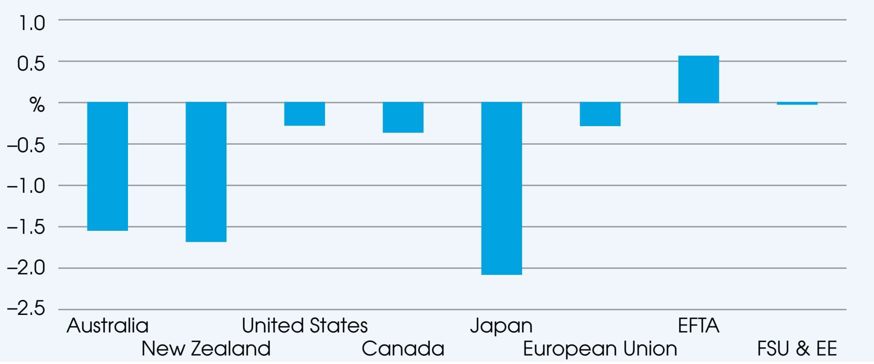
Substitution possibilities for a region can also be expensive if alternative less emission intensive fuels are more costly than the more emission intensive fuel source already in place. In this case the region is said to have limited *economic* possibilities for substitution. For example, Australia has vast reserves of coal that have a distinct price advantage over other potentially less emission intensive fuels, such as natural gas and renewables in electricity generation, given existing capital structures. The penalty for emitting carbon dioxide in this region must rise significantly in order to make coal a less attractive input than other fuel sources and thus for substitution to occur.

GDP and sectoral impacts

A high marginal cost of emission abatement will translate into increases in production costs for industries that use fossil fuels. The increased costs will tend to reduce production relative to business-as-usual in most industries and especially in those industries that use fossil fuels most intensively. These include industries such as electricity generation (in some countries), iron and steel and chemicals, rubber and plastics.

There will also be effects on industries that use electricity, such as nonferrous metals. These effects occur because any increases in the costs of electricity production associated with emission abatement are passed on to electricity users.

13 **Change in aggregate output at 2010 relative to business-as-usual** Annex I regions, less stringent scenario



Emission abatement policies also affect the production of fossil fuels by increasing the costs associated with using fossil fuels in Annex I regions, leading to reduced world demand for coal, gas and oil (see chapter 4). This reduced demand will lead to reductions in fossil fuel output in Annex I regions, contributing to reductions in their gross domestic product.

Estimates of changes to aggregate output associated with the less stringent emission abatement policy are shown in figure 13. In general, regions with relatively low marginal emission abatement costs experience a smaller projected increase in production costs than regions with higher marginal emission abatement costs. As a result, fossil fuel using industries in low marginal cost regions will experience smaller reductions in competitiveness and output (on average) than in regions such as Australia, New Zealand and Japan, where the impacts of uniform emission abatement on gross domestic product are projected to be more significant. Aggregate output in EFTA rises, owing to increases in the outputs of a range of energy intensive products. These products receive a substantial competitive advantage over similar products in other Annex I regions because of the relatively low level of reliance on fossil fuels in their production.

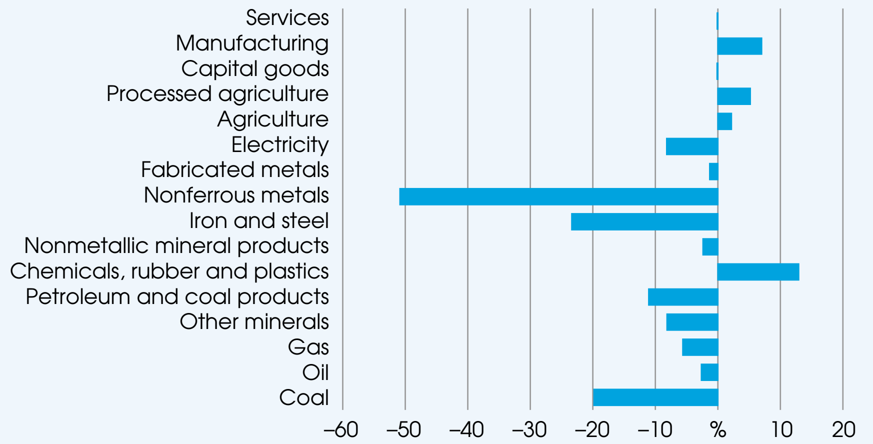
Reductions in fossil fuel outputs have the most significant impacts on gross domestic product in Australia and Norway (see Appendix C), where fossil fuel production is a more significant contributor to gross domestic product than in the other regions.

A more detailed picture of the implications of the emission abatement policies for production in different Annex I regions is provided in figures 14–21 and a detailed discussion of fuel switching in electricity generation is provided in Appendix D

Australian sectoral output

For Australia the most significant output reduction takes place in the nonferrous metals industry (figure 14). This industry (mainly aluminium) uses electricity very intensively and, in Australia, the majority of electricity is generated in coal fired power stations (see appendix D). As a result, the high marginal cost of abatement for Australia (see figure 10) is passed on to nonferrous metals producers through significant increases in electricity charges. This cost increase reduces the competitiveness of the Australian nonferrous metals industry (compared with nonferrous metals industries in

14 **Change in Australian sectoral output at 2010 relative to business-as-usual** Less stringent scenario



other regions where electricity generation is less dependent on fossil fuels), leading to a decline in output from this industry.

Australia's coal output is projected to decline significantly relative to business-as-usual. This is due mainly to a projected reduction in Australian coal exports to other Annex I countries, such as Japan, which reduce coal use with the adoption of emission abatement policies. The impact of reduced demand by Annex I regions on Australian coal exports is ameliorated to some extent by increased demand for coal by some non-Annex I regions (particularly in Asia). This occurs through the carbon leakage effect (see chapter 4).

Output for the Australian chemicals, rubber and plastic sector is projected to increase by around 13 per cent relative to business-as-usual at 2010. The Australian chemicals, rubber and plastic sector is relatively less emission intensive than the chemicals, rubber and plastic sectors in other Annex I countries. The adoption of emission abatement actions throughout Annex I regions therefore provides the Australian chemicals, rubber and plastic industry with a competitive advantage, leading to a projected increase in its exports and output.

Australian manufacturing, agricultural and processed agricultural production is projected to rise relative to business-as-usual. These sectors absorb labour and capital resources released from the mining and fossil fuel intensive manufacturing sectors.

New Zealand sectoral output

In New Zealand, iron and steel, nonferrous metals and chemicals, rubber and plastic output are all projected to decrease as a result of the emission abatement action (figure 15). However, the extent of the reduction in iron and steel production is ameliorated to some extent due to the significant projected potential for New Zealand to adopt electric arc production technologies which are significantly less emission intensive than blast furnace technologies.

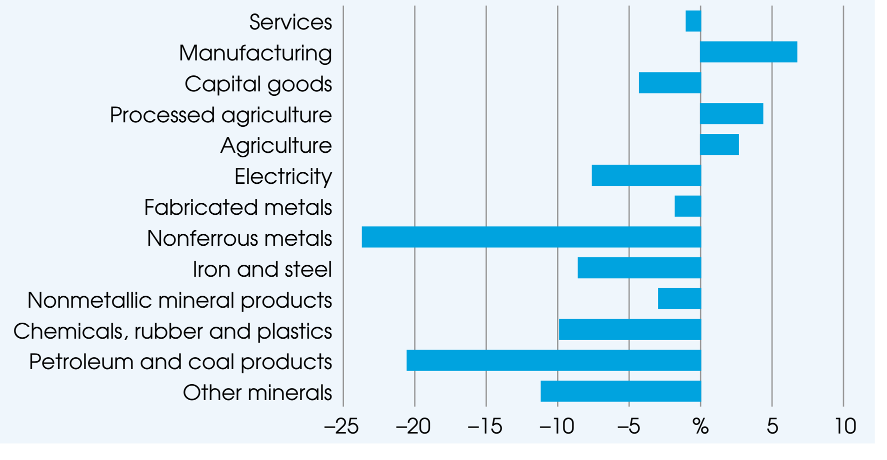
There is a projected increase in the manufacturing, agricultural and processed agricultural industries as, over time, they absorb labour and capital resources released from energy intensive production.

US sectoral output

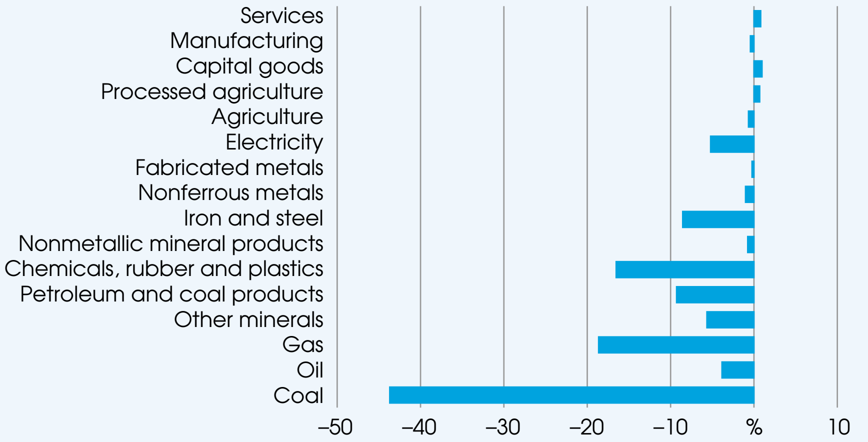
The sectoral effects of the less stringent emission abatement action for the United States are presented in figure 16. The output of each of the fossil fuel intensive sectors in the United States is projected to decline relative to business-as-usual at 2010. This includes a relatively significant decline in iron and steel, and chemicals, rubber and plastic production.

Coal, oil and gas production in the United States is also projected to decline significantly relative to business-as-usual. This is due to a decline in the domestic demand for fossil fuels as emission abatement policies discourage their use.

15 **Change in New Zealand sectoral output at 2010 relative to business-as-usual** Less stringent scenario



16 Change in US sectoral output at 2010 relative to business-as-usual Less stringent scenario



Output in the services sector is projected to increase relative to business-as-usual by a small amount as it absorbs labour resources released from the energy intensive and manufacturing sectors. However, it is important to note that the services sector accounts for over half the US economy. Therefore, even small increases in projected output in this sector have distinct positive effects on aggregate output.

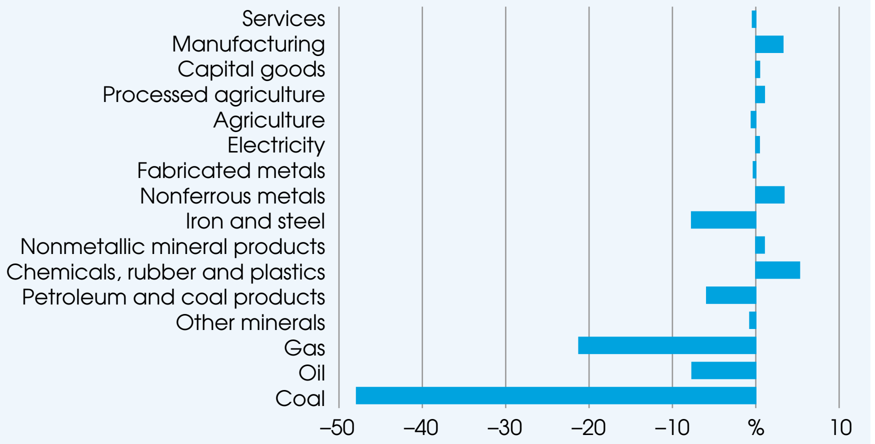
Canadian sectoral output

The sectoral effects of the less stringent emission abatement action for Canada are presented in figure 17. The output of the chemicals, rubber and plastic and iron and steel industries in Canada are projected to decline relative to business-as-usual at 2010.

Coal, oil and gas production in Canada are also projected to decline significantly relative to business-as-usual as the Annex I emission abatement action reduces world demand for these products. However, electricity output is projected to rise. This is due to the projected expansion of Canadian exports of hydroelectricity and other renewables based power to the United States as US electricity costs rise relatively significantly owing to US emission abatement action.

The emission abatement action is projected to have a small positive effect on Canadian nonferrous metals production. Canada uses hydro power to generate a significant proportion of its electricity. As such, costs to the

17 **Change in Canadian sectoral output at 2010 relative to business-as-usual** Less stringent scenario



Canadian nonferrous metals industry are not affected significantly by the emission abatement action. As a result this industry gains a competitive advantage relative to nonferrous metals industries in other Annex I countries.

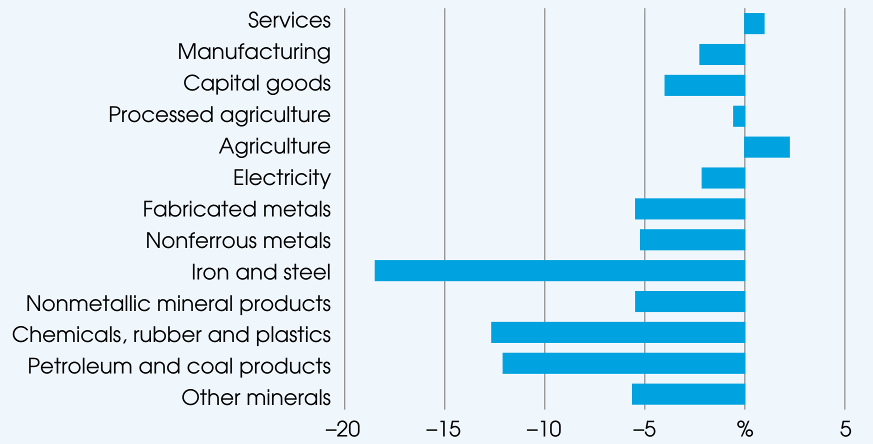
Canadian manufacturing and processed agricultural production are also projected to rise relative to business-as-usual. As in Australia, these sectors absorb labour and capital resources released from the mining and fossil fuel intensive manufacturing sectors over time.

Japanese sectoral output

Japanese output of iron and steel is projected to fall significantly relative to business-as-usual projections (figure 18). There are also large reductions in the outputs of a range of fossil fuel intensive sectors including nonferrous metals, and chemicals, rubber and plastic.

Importantly, there is a large reduction in less fossil fuel intensive manufacturing output relative to business-as-usual in Japan. Owing to the magnitude of the Japanese marginal cost of abatement, the Japanese manufacturing sector experiences a major loss in competitiveness compared with manufacturing sectors in other Annex I regions and in non-Annex I regions such as China, South Korea and Chinese Taipei that are not undertaking abatement actions.

18 **Change in Japanese sectoral output at 2010 relative to business-as-usual** Less stringent scenario

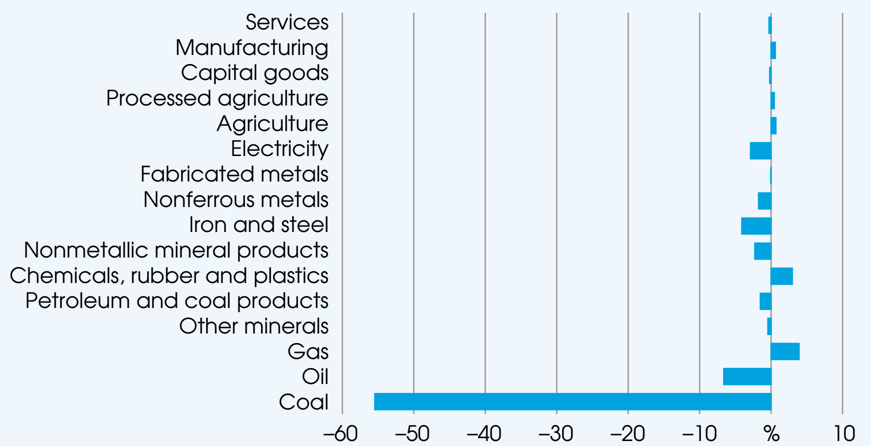


Labour resources released from the more energy intensive sectors are absorbed in the services and agricultural sectors.

EU sectoral output

The sectoral effects of the less stringent emission abatement action for the European Union are presented in figure 19. Production of iron and steel and nonferrous metals are estimated to fall relative to business-as-usual as the uniform emission target leads to a reduction in competitiveness for those industries.

19 **Change in EU sectoral output at 2010 relative to business-as-usual** Less stringent scenario



However, EU production of chemicals, rubber and plastics projected to increase by around 2.9 per cent relative to business-as-usual at 2010. The chemicals, rubber and plastic sector in the European Union is relatively less emission intensive than the chemicals, rubber and plastic sectors in other Annex I countries. The adoption of emission abatement actions throughout Annex I regions therefore provides the European Union's chemicals, rubber and plastic sector with a competitive advantage, leading to a projected increase in output. This is a significant result that benefits the European Union at an increasing rate over the period of the simulation as this sector earns over 10 per cent of that region's export revenue.

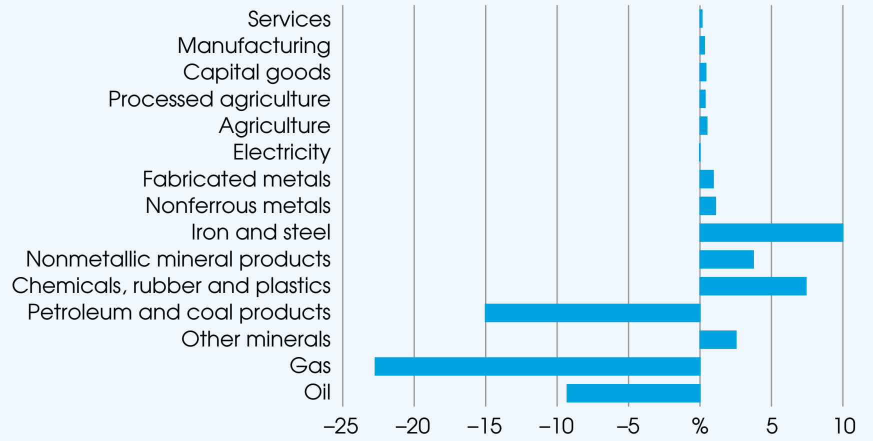
Coal and oil production in the European Union are projected to decline relative to business-as-usual at 2010. However, gas output is projected to rise slightly. The gas industry in the European Union benefits from substitution toward it in electricity production. Further, some natural gas is used in the production of chemicals, rubber and plastic and therefore experiences an increase in demand as a consequence of emission abatement actions in Annex I regions. The reduction in coal output, although large, does not contribute significantly to the loss in gross domestic product for the European Union. This is because a large proportion of coal produced in the European Union is heavily subsidised. A move of resources out of coal production into more efficient uses can confer some benefit on the economy.

EFTA sectoral output

The sectoral effects of the less stringent emission abatement action for the European Free Trade Association are presented in figure 20. The output of chemicals, rubber and plastic, iron and steel and nonferrous metals are projected to increase relative to business-as-usual at 2020. These sectors are relatively less emission intensive than in most other Annex I countries, resulting in projected increases in exports and output. In particular, the increase in iron and steel production is aided by the significant projected scope for EFTA countries to adopt electric arc technologies. The expansion of output in these sectors contributes significantly to EFTA's increase in gross domestic product compared with business-as-usual.

Oil and gas production in the European Free Trade Association are projected to decline significantly relative to business-as-usual, in line with reductions in world demand for these fuels (see chapter 4). In particular, a projected increase in gas exports to the European Union relative to business-as-usual is more than offset by reduced exports to other destinations and a fall in

20 **Change in EFTA sectoral output at 2010 relative to business-as-usual** Less stringent scenario



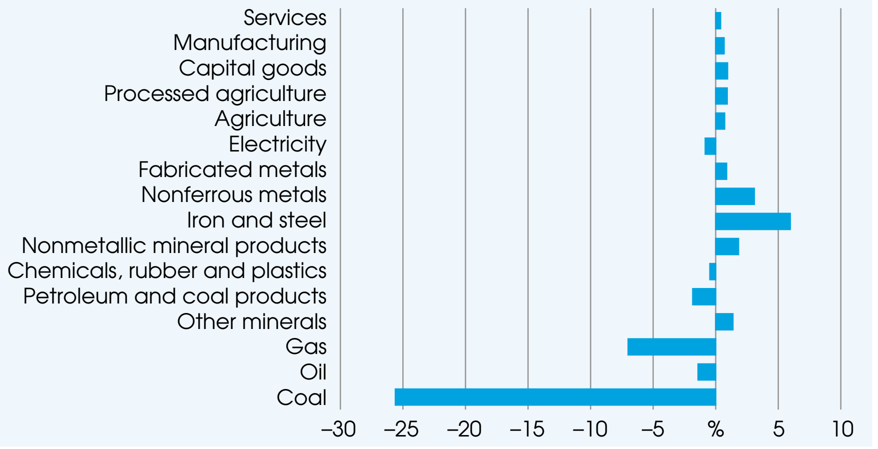
domestic use (see appendix D). These reductions will affect Norway most significantly owing to its heavy reliance on these industries for exports and their contribution to total gross domestic product (see appendix C).

Eastern Europe and FSU sectoral output

The sectoral effects of the less stringent emission abatement action for the Former Soviet Union and Eastern Europe are presented in figure 21. When considering these sectoral results it is important to take into account that the marginal abatement cost projected for this region is the lowest among Annex I regions. This allows the Eastern Europe and Former Soviet Union grouping to gain a competitive advantage over other Annex I regions in the production of a range of products, including nonferrous metals and iron and steel. This is despite the projection that energy to output conversion rates in this region will remain below levels in Annex I countries over the projection period.

Fossil fuel output in the Former Soviet Union and Eastern Europe is projected to decline relative to business-as-usual at 2010 as world demand falls. There is, however, considerable absorption of labour and capital resources released from fossil fuel and some fossil fuel intensive production activities into the services, manufacturing, agricultural and processed agricultural sectors, which leads to increased output relative to business-as-usual.

21 **Change in FSU and Eastern Europe sectoral output at 2010 relative to business-as-usual** Less stringent scenario



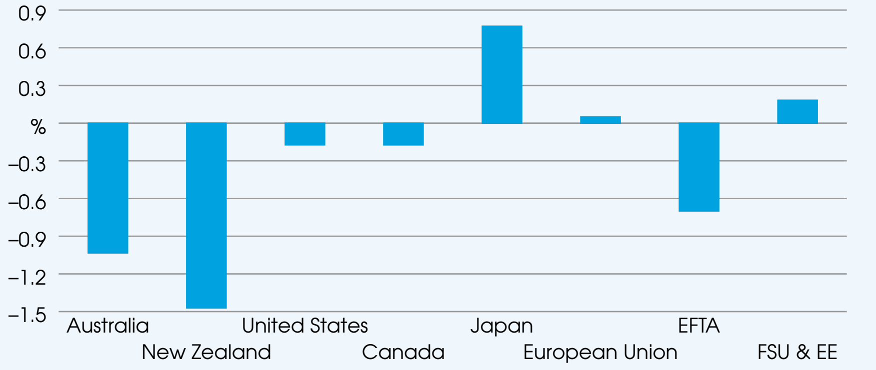
Trade related impacts of emission abatement

While the GDP losses shown in figure 13 are closely correlated with the GNE costs associated with the uniform emission abatement targets, there are differences that relate to the impacts of emission abatement on the capacity of an economy to benefit from trade (see chapter 4). The contribution of the trade related impact to the change in GNE is the difference between percentage change in real GNE and percentage change in real GDP relative to business-as-usual. The contributions of the trade related impacts under the two scenarios at 2010 are shown in figure 22. A positive number indicates that trade related impacts have made a positive contribution to the GNE change while a negative number implies an adverse trade effect. Negative trade effects are large for Australia, New Zealand and the European Free Trade Association.

The direction of the trade related impact on GNE depends on two key factors. First, changes to income and import prices will affect the ability of a region to purchase imports on international markets. An indicator of the affordability of imports is the ratio of income to import prices. A fall in this measure relative to business-as-usual will contribute to a reduction in a region's ability to purchase imports. All other things being equal, this will lead to a trade related loss in GNE.

The second factor affecting the direction of the trade related impact on GNE is the rate at which exports can be exchanged for imported goods. This is

22 **Trade related change in GNE at 2010 relative to business-as-usual** Annex I regions, less stringent scenario



measured as the ratio of export prices to import prices for a region and is known as the 'terms of trade'. A decrease in the terms of trade is, in effect, a devaluation of the unit value of exported commodities and will lead to a trade related loss in GNE, all other things being equal.

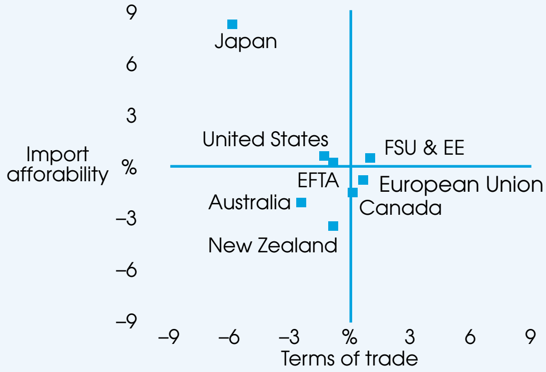
In figure 23, the changes in import affordability and the terms of trade under the less stringent scenario at 2010 have been plotted against each other. Australia and New Zealand face reductions in import affordability and terms of trade (lower left hand quadrant of figure 23), leading unambiguously to trade related losses in 2010 under the less stringent scenario.

Australia's reliance on fossil fuel and fossil fuel intensive exports means national and international emission abatement policies will lead to a relatively more significant decline in export revenues, and hence national income. This reduces Australia's capacity to purchase imports. Also, declines in fossil fuel export prices contribute to the reduced purchasing power of Australian exports.

New Zealand imports most of its fossil fuel intensive manufactures. The import prices of these manufactures from countries such as Japan rise owing to increased costs associated with emission abatement in those countries. This rise in import prices, combined with a fall in the purchasing power of exports leads to a trade related loss for New Zealand.

For the European Union, the positive trade impacts on GNE arise due to a growing competitive advantage and income from the chemicals, rubber and plastic sector.

23 Change in import affordability and terms of trade at 2010 relative to business-as-usual Annex I regions, less stringent scenario



In Canada's case there is a small increase in import affordability principally as a result of increased export revenues from renewables based electricity exports to the United States and increased nonferrous metals production. However, the terms of trade decline owing to an increase in import prices and reductions in the export prices of petroleum and coal products. On balance the terms of trade decline dominates the small improvement in import affordability, leading to an overall trade related loss in GNE.

Trade related losses in EFTA are also closely related to falls in export returns and fossil fuels for Norway. For the United States an improvement in its terms of trade results from an improvement in the competitiveness of some of its industries over Annex I competitors. This gain occurs because the US marginal abatement cost does not rise to the same extent as that for other Annex I countries such as Japan. On balance, however, the reduction in import affordability resulting from reduced overall levels of income leads to a small trade related loss in GNE.

The Eastern European and Former Soviet Union grouping receives an unambiguous trade related improvement as both the terms of trade and affordability of imports rise. Increases in import affordability are driven by increased income from exports of energy intensive products owing to the gain in competitiveness in these sectors experienced by the region (see previous section). At the same time, falls in fossil fuel export prices are offset by increased prices for exports of energy intensive products leading to improved terms of trade.

6

Economic impacts on non-Annex I regions

A key factor driving economic growth in non-Annex I countries is the increased integration of those countries into the global economy through trade and investment linkages. These linkages are likely to be affected when Annex I countries undertake emission abatement with consequent impacts on their gross national expenditure. The effects of emission abatement undertaken in Annex I regions on non-Annex I regions are examined in this chapter.

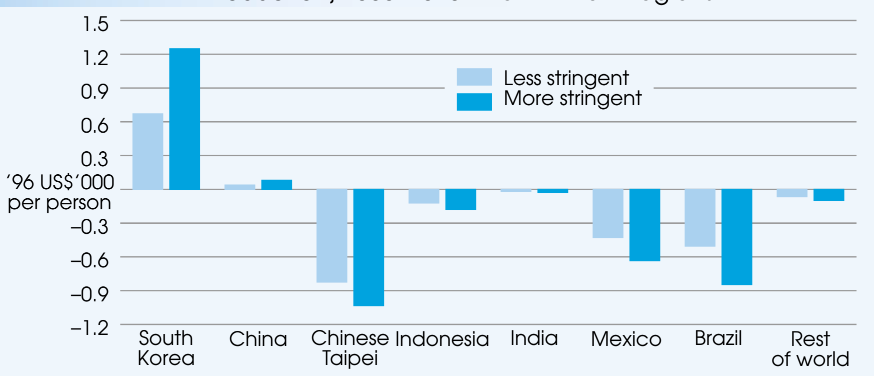
As in chapter 5, the detailed explanation of results focuses on the impacts of the less stringent emission policies at 2010.

The economic costs and benefits

A summary of the economic costs for non-Annex I countries is presented in figure 24. South Korea and China are projected to experience economic benefits under both emission reduction scenarios while other non-Annex I regions are projected to experience economic costs. It should be noted that the pattern of results from the rest of ASEAN region is similar to that for Indonesia.

Impacts on trade and investment are key determinants of the economic impacts of Annex I abatement policies on non-Annex I regions. There are four ways in which Annex I emission abatement policies affect non-Annex I countries adversely.

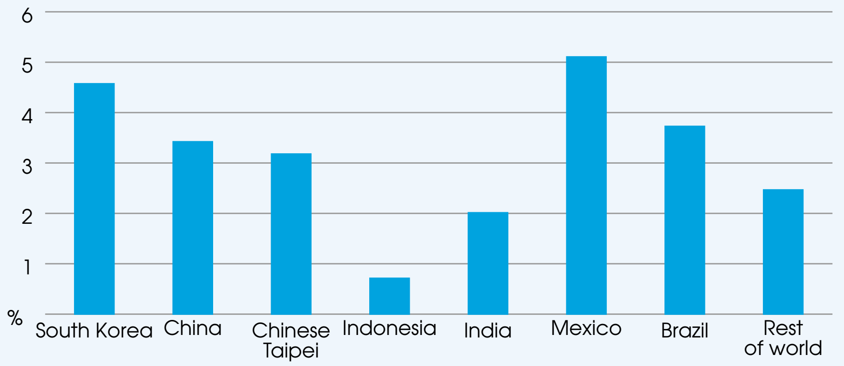
24 **Net present value of GNE changes due to uniform emission reduction, 2000–2020** Non-Annex I regions



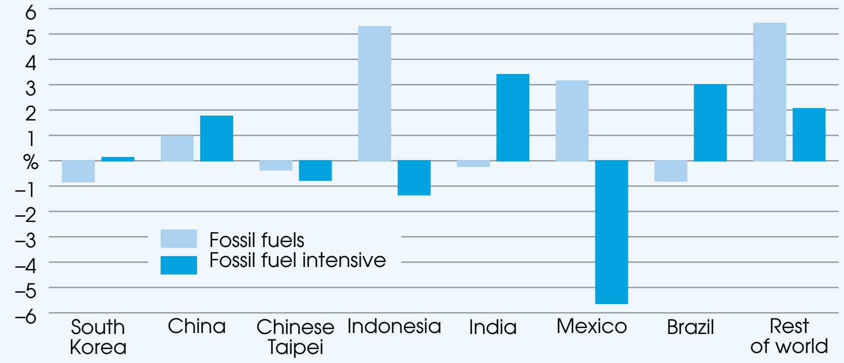
- First, the increased costs of production in Annex I countries (resulting from their efforts to restrict emissions) are passed on to consumers of Annex I products, including those in non-Annex I regions. For example, the price of Japanese iron and steel sold to Indonesia rises, resulting in an adverse economic impact on Indonesian industry and consumers.
- Second, fossil fuel exporters among the non-Annex I countries face a reduction in export demand from Annex I countries, as demand by these countries for fossil fuels declines. This contributes negatively to total output, with adverse implications for income and expenditure.
- Third, exporters in non-Annex I regions face an overall decline in export demand as income growth in Annex I regions declines as a result of emission abatement actions, again with adverse implications for income and expenditure.
- Finally, many non-Annex I regions rely heavily on capital from Annex I regions to fund their investment. Given the adverse economic impacts of emission abatement on Annex I regions (discussed earlier) the total amount of funds available globally for investment is likely to shrink resulting in adverse economic impacts in non-Annex I regions.

On the positive side, importers of fossil fuel in non-Annex I regions will benefit from the fall in the world prices of fossil fuels. Further, developing countries are likely to benefit from the phenomenon of carbon leakage or, more particularly, from their increased competitiveness in emissions intensive production processes relative to Annex I countries. In this context it is important to note that emission levels are projected to increase above business-as-usual levels in all non-Annex I regions (figure 25), reflecting a

25 **Change in emissions at 2010 relative to business-as-usual**
Non-Annex I regions, less stringent scenario



26 Net exports from non-Annex I regions to Annex I regions as a percentage of total exports, 1992



shift in fossil fuel intensive industrial production from Annex I to non-Annex I regions.

For non-Annex I regions the nature and extent of trade linkages with Annex I regions are important determinants of the economic impacts of emission abatement on them. A summary of the net trade in fossil fuels and fossil fuel intensive products between non-Annex I and Annex I regions from the base data is presented in figure 26.

South Korea exhibits a pattern of trade with Annex I regions that is likely to result in economic benefits when Annex I regions undertake emission abatement. South Korea is a net exporter of fossil fuel intensive products (mainly iron and steel) to Annex I regions. When Annex I regions undertake emission abatement, South Korean producers gain a competitive advantage in these markets. The increase in exports of fossil fuel intensive manufactures to Annex I regions, coupled with the rising world price of these products, contributes to an increase in South Korea’s export earnings. Lower import prices of fossil fuels benefit South Korean consumers and further contribute to the increased competitiveness of South Korea’s fossil fuel intensive production sector.

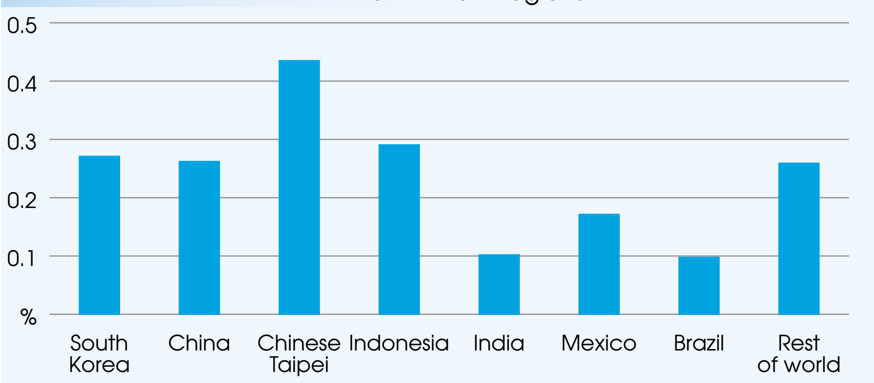
Countries such as Mexico and Indonesia are projected to experience GNE losses from emission abatement undertaken in Annex I regions. These regions exhibit a trade pattern with Annex I regions that is the reverse of that of South Korea. Mexico and Indonesia export fossil fuels to Annex I regions and therefore experience a decline in export demand for these commodities. Further, the declining world price of these commodities contributes to a decline in export earnings. These countries are also net importers of fossil fuel intensive manufactures from Annex I regions, the prices of which rise due to the emission abatement efforts in Annex I regions. These price increases are passed on to consumers in Mexico and Indonesia, further contributing to the economic costs experienced by them.

China is projected to experience a GNE gain from emission abatement undertaken in Annex I regions. It is a net exporter of both fossil fuels and fossil fuel intensive products to Annex I regions. In China's case, the small negative impacts of reduced fossil fuel exports to Annex I regions are more than offset by the positive impacts of increased exports of fossil fuel intensive products to Annex I regions.

The Rest of the world region, like China, is a net exporter of both fossil fuels and fossil fuel intensive products to Annex I regions. The Rest of the world includes the OPEC countries, which export oil to Annex I regions, and South Africa which is a major exporter of coal. The net exports of fossil fuels are a more significant component of this region's trade structure than the net exports of fossil fuel intensive products. In this case, the negative economic impacts of reduced fossil fuel exports to Annex I countries outweigh the positive impact from increased fossil fuel intensive products under carbon leakage resulting in a loss in GNE.

India and Brazil exhibit the same basic trade patterns as South Korea and would be expected to experience an economic benefit from emission abatement in Annex I regions. However, an overriding factor in determining the extent of the economic impact of emission reductions in Annex I

27 **Exports as a percentage of GDP, 1992**
Non-Annex I regions



countries on non-Annex I regions is the extent to which trade contributes to economic activity. In these two regions, exports contribute around 10 per cent of GDP as opposed to South Korea where exports contribute around 28 per cent of GDP (figure 27). For Brazil and India the positive trade effects are outweighed by the negative investment effects. First, the availability of capital is reduced as income in Annex I countries falls. Second, India and Brazil face increased import prices for capital goods, such as machinery and transport equipment from Annex I countries, the purchases of which are key factors in promoting growth in these developing countries.

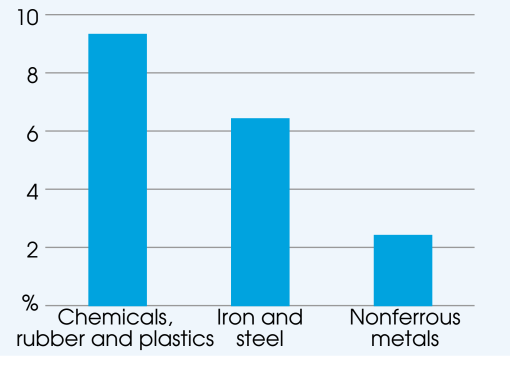
Impacts on production

The implementation of emission abatement policies by Annex I countries is projected to affect sectoral production in non-Annex I countries. These production changes are in response to increased world prices for fossil fuel intensive commodities and lower prices for fossil fuels as a result of Annex I countries shifting production away from fossil fuel intensive goods to meet emission targets. The impacts on sectoral output reveal a more detailed picture of the implications of the emission abatement policies for economic costs and benefits in different non-Annex I regions.

Fossil fuel intensive industries

Production of fossil fuel intensive manufactures in non-Annex I countries is likely to increase as the world price of fossil fuel intensive products increases (figure 28). The increases in world prices for these products are also correlated with their emission intensity at the global level. Of the fossil fuel intensive products considered, the price of chemicals, rubber and plastic is projected to increase the most relative to business-as-usual. This implies that the relocation of chemicals, rubber and plastic production from Annex I to non-Annex I regions is a major source of carbon leakage.

28 **Change in world prices of fossil fuel intensive products at 2010 relative to business-as-usual** Less stringent scenario

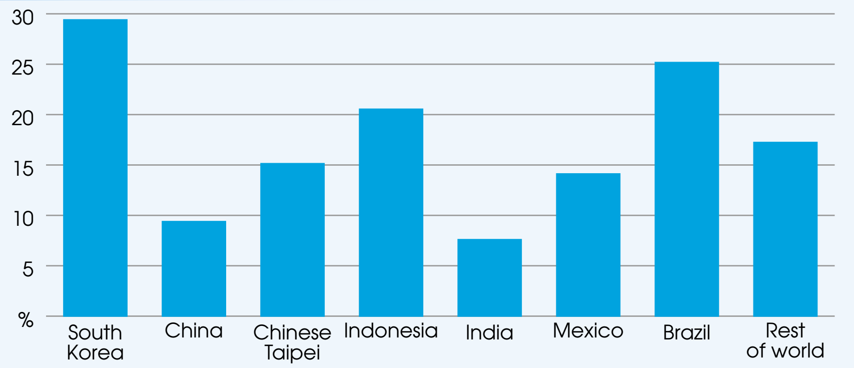


At the regional level, changes in output of fossil fuel intensive products in non-Annex I regions depend mainly on two related factors: first, the export orientation of fossil fuel intensive production of a particular non-Annex I region, and second, the extent to which fossil fuel intensive manufacturers in that non-Annex I region are competing with Annex I manufacturers.

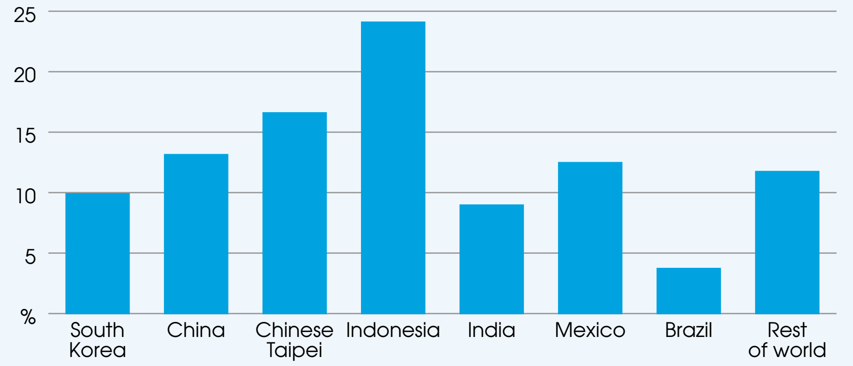
This is illustrated most clearly for iron and steel production which is projected to increase in all the non-Annex I regions as a result of emission abatement action undertaken in Annex I regions (figure 29). The largest increase is projected to be in South Korea (29.4 per cent relative to business-as-usual at 2010). This is because South Korea is a significant net exporter of iron and steel and has sufficient capital infrastructure in place to take advantage of the increased export demand. South Korean iron and steel producers compete with Japanese producers in many export markets. For example, one-third of iron and steel exports from South Korea are destined for Japan. As Japan undertakes emission abatement, South Korean iron and steel products gain a competitive advantage over Japanese production. As a result, there is an increase in the demand for, and price of, South Korean iron and steel in Japan, contributing to a large increase in output with positive effects on South Korean gross domestic product, income and expenditure.

The projected increases in output of the chemicals, rubber and plastic sector are presented in figure 30. Indonesia is projected to increase production of chemicals, rubber and plastic by 24.0 per cent as, mainly Japanese, consumers substitute toward the relatively less expensive Indonesian product. On the other hand, in Brazil, a relatively low export orientation results in output of chemicals, rubber and plastic increasing by only 3.7 per cent.

29 **Change in iron and steel output at 2010 relative to business-as-usual** Non-Annex I regions, less stringent scenario

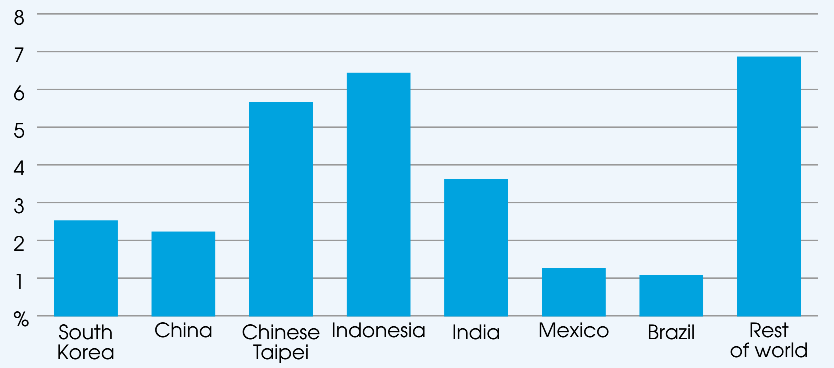


30 **Change in chemicals, rubber and plastics output at 2010 relative to business-as-usual** Non-Annex I regions, less stringent scenario



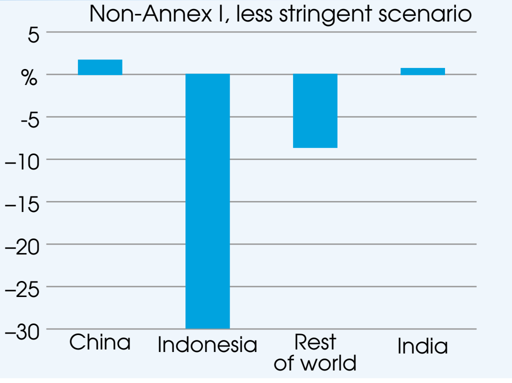
Production of nonferrous metals in non-Annex I regions is also expected to increase as Annex I regions reduce emissions (figure 31). Output of nonferrous metals is projected to increase in Indonesia, Chinese Taipei and China by 6.4 per cent, 5.7 per cent and 2.2 per cent respectively relative to business-as-usual. Differences in projected output increases reflect differences in trading patterns. For instance, Indonesia and Chinese Taipei export nonferrous metals to Japan, where a competitive advantage is gained over the domestically produced Japanese product and nonferrous metals from Annex I countries such as Australia. China exports 83 per cent of nonferrous metals to non-Annex I countries, and as a result it does not gain a significant competitive advantage over outputs produced in its export markets. Consequently, the projected increase in nonferrous metal output is lower for China than for Indonesia and Chinese Taipei.

31 **Change in nonferrous metals output at 2010 relative to business-as-usual** Non-Annex I regions, less stringent scenario



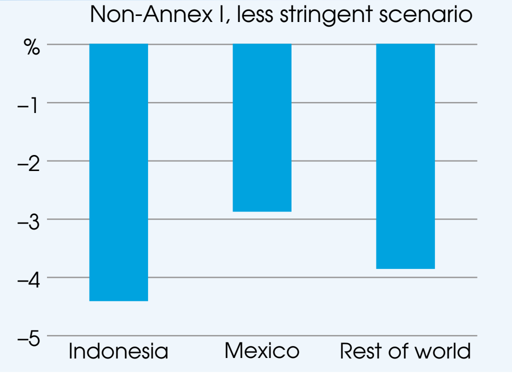
Fossil fuels

32 Change in coal output at 2010 relative to business-as-usual



Examples of the changes to coal production are shown for four major non-Annex I producers — India, China, Indonesia and the Rest of the world. Indonesia and the Rest of the world (which includes South Africa) export coal mainly to Annex I countries. These regions experience a decline in export demand but domestic demand for coal, from the iron and steel sector, for example, is projected to rise in response to higher production. The net result of these countervailing influences is a projected decline in coal output in Indonesia and the Rest of the world of 29.9 per cent and 8.6 per cent respectively relative to business-as-usual at 2010 (figure 32).

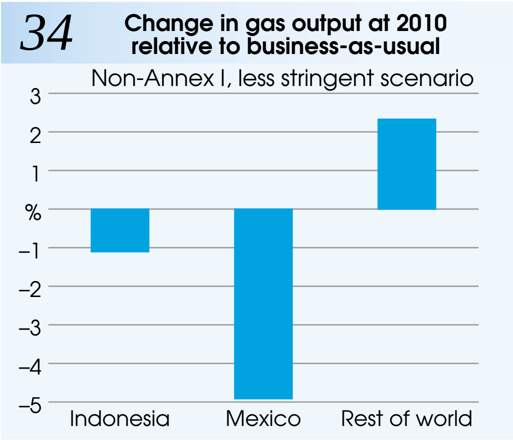
33 Change in oil output at 2010 relative to business-as-usual



A significant proportion of Indian and Chinese coal is of low quality and is not traded. As fossil fuel intensive industries expand in India and China, demand for coal increases. This results in a projected increase in Indian and Chinese coal output of 0.7 and 1.7 per cent respectively relative to business-as-usual at 2010.

Exporters of oil to Annex I regions such as Mexico, Indonesia and the Rest of the world are projected to experience a decline in export demand and output (figure 33).

A large proportion of gas exports from Indonesia, Mexico and Rest of the world go to Annex I countries. However, the Rest of the world is projected to experience an increase in gas production because of an increase in export demand from the European Union and increased domestic demand in



response to carbon leakage effects (figure 34). Unlike most other Annex I countries, the European Union is projected to increase its imports of gas to generate electricity (see appendix D). Indonesia and Mexico do not export gas to the European Union. Rather, gas exports from these regions are projected to be destined for Annex I regions that are reducing their gas demand, such as, Japan and the United States. Consequently, gas output in Indonesia and Mexico is projected to fall by 1.1 per cent and 4.9 per cent relative to business-as-usual at 2010.

The majority of non-Annex I regions are projected to experience economic costs when Annex I countries act to abate emissions. These economic costs would be likely to increase if non-Annex I countries were to undertake emission abatement themselves. A tradable quotas scheme, with the initial allocation of quota designed to ameliorate the impacts of participation in emission abatement activities, would encourage non-Annex I countries to join an international emission abatement action. Issues relating to tradable quotas and the potential for initial quota allocations to affect the attractiveness of entry to the international emission abatement process are discussed in the following chapter.

7

Tradable quotas

During the past decade solutions to environmental problems requiring government regulation have tended to move away from prescriptive policies toward market based solutions. A tradable quota scheme is a market based instrument which can be designed to reduce greenhouse gas emissions cost effectively. The potential for cost savings under a tradable quota scheme compared with uniform emission abatement policies is explored in this chapter. The impact on Annex I and non-Annex I regions of adopting a tradable quotas scheme to achieve emission abatement targets is estimated. The analysis in this chapter also highlights how the initial allocation of quotas affects the distribution of economic costs between Annex I countries.

Tradable quotas have been used to control a number of environmental problems including water allocation, overfishing, and sulphur dioxide emissions. A tradable quota regime addresses environmental externalities by allocating property rights in the form of a quota over the externality, in this case, greenhouse gas emission. The concept of allocating property rights over production externalities was introduced by Coase (1960) and later developed into an emissions trading approach to address pollution control by Dales (1968), Baumol and Oates (1971) and Montgomery (1972). Emissions trading has been recognised as a potentially superior policy instrument to domestic stabilisation policies to address greenhouse gas emissions on the grounds of cost minimisation, environmental certainty and international equity (Tietenberg 1985; Grubb 1989; Bertram, Stephens and Wallace 1990; Hinchy and Fisher 1991; and Fisher et al. 1996).

In a tradable quota system, an environmental goal is set determining the number of quotas to be issued and emitters are required to hold a certificate or quota for each unit of emissions (Mullins and Baron 1997). If participants have quotas they cannot use profitably, they can sell them to other participants who need extra quotas to cover excess emissions requirements (above their limit). Through trading, a market price for the quota emerges, equal to the marginal cost of pollution reduction in the regions included in the trading regime. Schemes where it may be possible to ‘bank’ unused quotas for future use have also been proposed.

Under a greenhouse gas emissions trading system, an initial allocation of emission quotas would have to be negotiated among the international community. Countries would then allocate these quotas domestically and they could be traded both domestically and internationally.

Potential benefits of a tradable quota scheme

Cost minimisation

Strategies that impose smaller economic costs on the international community, and which lead to outcomes that are perceived to involve a more equitable sharing of these costs, are much more likely to lead to effective global efforts to limit emissions than strategies that impose high costs on almost all countries (ABARE and DFAT 1995). A tradable quota scheme has the potential to allow carbon dioxide emissions to be reduced by the same amount as uniform abatement policies, but at lower cost to the international community.

The cost of reducing emissions varies greatly between countries. Therefore, the total cost of emission abatement to the global community depends on where emission reductions take place. Under a uniform abatement approach, countries fulfil emission targets by undertaking all emission reductions domestically regardless of cost. Under a tradable quota approach, the process of trade would lead to increased abatement in countries where initial abatement costs are low and reduced abatement in countries where initial abatement costs are high. This would reduce the total cost of compliance for a given emissions target as emission reductions would be transferred from countries with high costs of abatement (prior to emissions trade) to countries with lower costs of abatement (prior to emissions trade). A tradable quota scheme is well suited to addressing the climate change problem as greenhouse gases tend to be relatively well mixed in the atmosphere, making it unimportant where the emission reduction takes place.

The total cost of abatement is minimised from a global perspective when the incremental (marginal) costs of emission abatement across emission sources are equalised. Under a quota scheme, a profit maximising emission source will reduce emissions to the point where it would be indifferent between incurring the costs required to reduce its emissions by a further unit (its marginal emission abatement cost) and paying the price for a quota for the right to emit an additional unit. Similar behaviour by all emitters will ensure that the marginal costs of emission abatement across all sources are equated with the price of a quota. Thus, a tradable quota scheme provides a market based method of minimising the total costs of abatement. But, there are a number of factors which could constrain the cost effectiveness of a tradable quota scheme. These are discussed in a later section.

Environmental certainty

Assuming that monitoring and enforcement prevent any unauthorised emissions, a tradable quota scheme can provide certainty in achieving an environmental objective as the number of quotas issued is equal to the abatement target. Under a taxation approach, authorities will not know exactly what emitters' marginal costs of reducing emissions are, so some experimentation will be needed to find the level at which a tax must be set to produce a given level of emission reduction (Hinchy, Thorpe and Fisher 1993). The advantage of using taxation to control emission levels is that the costs of complying to an abatement target can be calculated, whereas the cost of complying under a tradable quotas scheme depends on the quota price which emerges through trade.

Under full certainty of the costs and benefits of meeting an abatement target the same cost minimising result could be achieved by an optimally selected tax as under a tradable quota scheme. However, given the scientific and economic uncertainty surrounding the climate change problem, these costs and benefits are uncertain. Under these conditions of uncertainty the appropriate choice of instrument will depend on the steepness of the marginal benefits and cost curves and the correlation between uncertainty about benefits and costs (Weitzman 1974; Stavins 1996). If the policy goal is to meet a particular emission target, then tradable quotas or an equivalent quantity based instrument will be preferred, insofar as they can guarantee that the emission target is met (Fisher et al. 1996).

International equity

An emission quota is an asset (assuming that the overall quota on emissions represents a binding commitment) and so the initial allocation of quotas has the potential to redistribute wealth between and within countries. It is therefore possible to meet various equity goals by altering the initial allocation of quotas. Allocation issues, including those related to fairness and redistribution of wealth, are often considered to be the most controversial part of an emission trading system (Mullins and Baron 1997).

Quotas could be allocated to meet the equity goals of Annex I countries and non-Annex I countries and many possible allocation rules have been proposed. Annex I countries face different costs of abatement and differ in their contribution to the atmospheric concentration of greenhouse gases. The initial allocation of quotas could be made to reflect these differences in cost and contribution (Hanslow, Hinchy and Fisher 1996). Quotas could also be used in the future to compensate non-Annex I countries for their efforts in emissions abatement. Although non-Annex I countries have made no commitment under the FCCC to reduce emissions, they could be encouraged to undertake emission abatement in the future through a tradable quota scheme. Non-Annex I (developing) countries could receive side payments in the form of an excess allocation of quotas, compensating them for their actions in emissions abatement. The sale of excess quotas could lead to a balance of payments surplus, allowing non-Annex I countries to increase imports and expenditure.

It has been argued that this reallocation of quotas could result in non-Annex I countries suffering a loss in the competitiveness of traditional exports due to an appreciation of their exchange rates (McKibbin and Wilcoxen 1997). On the other hand, Hinchy and Fisher (1997), note that the basic issue is whether a country gains from these side payments rather than whether its export pattern changes.

Risk management

The scientific uncertainty surrounding the climate change problem means that the magnitude of future abatement commitments needed to address the problem is also uncertain. This uncertainty confers some degree of risk upon industries producing emissions and industries involved in the development of emission reducing technologies. A tradable quota scheme can be used to address the problem of risk as it can stimulate the development of a futures market in emission quotas (Epstein and Gupta 1990; Hinchy, Thorpe and Fisher 1993; Fisher et al. 1996). Forward or futures markets for emission quotas could be used as a risk management tool as they provide an avenue for spreading risks, hedging and collecting future price estimates (Fisher, Hinchy and Thorpe 1996; Laffont and Tirole 1996) and increase the incentive to invest in developing abatement technology.

The risk involved in investing in emission producing industries could be spread between asset holders and speculators in a futures market. A futures market would provide hedging opportunities by allowing companies which need to plan for future emission reductions to lock into a price for the emission quotas now and by allowing technology development companies access to hedge against research failure. The futures price of an emission quota could reduce uncertainty and risk by providing a summary statistic of expectations about directions in public policy and progress in developing emissions reducing technology. The possibility of a futures market in greenhouse emission quotas is highlighted by the establishment of a futures market in sulphur dioxide emissions permits on the Chicago Futures Exchange.

Limitations of a tradable quota scheme

The aim of a tradable quotas scheme is to establish a trading market in greenhouse gas emissions. How cost effectively tradable quotas can reduce emissions will depend on the level of confidence in the market, the structure and size of the market and the magnitude of market transaction costs.

Market confidence

Fundamental to the establishment of a tradable quotas scheme is confidence in the economic value of an emissions quota. Establishing confidence would require the adoption of an international emission target and domestic compliance procedures to ensure that countries shares of this target, net of any trade in permits, are realised. Without emission limits or strict compliance mechanisms in place there would be no incentive to trade. Monitoring and enforcement procedures would have to be designed to hold the probability of violating emission restrictions at a level which does not undermine the market value of quotas. The need for tradable quotas to be enforceable is one of the most important characteristics of property rights (Thampapillai 1991).

Structure and size of the market

The competitiveness and size of a tradable quotas market will influence the cost effectiveness and equity of the scheme. In a competitive market, where no participant has the ability to influence prices, regardless of the initial allocation of quotas, the outcome will be cost minimising.

When some participants have significant market power they may be able to influence the price of a quota in the short term. Market power could arise in the form of a few large buyers of emission quotas, a few large sellers of quotas, or a few participants that dominate the market through the size of their quotas holdings (Mullins and Baron 1997). Hahn (1984) demonstrates that in a market where one or more participants have significant market power, the market is unlikely to be efficient. Hinchy and Fisher (1991) show that under some non-competitive situations, a tradable quotas scheme could actually produce an economic loss. These caveats do not hold only under situations of market power in the quota market. The cost minimising properties of a greenhouse gas emission quota scheme are also reduced when emitters hold significant power in product markets (Malueg 1990).

In non-competitive markets, the initial allocation of quotas can have major equity implications (van Egteren and Weber 1996). If international negotiations were to allocate quotas on an historical basis, it is likely that certain countries would have significant market power in the tradable quota scheme. Therefore, it is important that market competitiveness is secured either through a distribution of the initial allocation of quotas or by rules governing the size and number of participants in the quota market. The efficiency loss due to market imperfections may tend to increase the greater the difference between the initial and final allocation of quotas after trade (Westskog 1996).

One way to curb the market power of larger countries would be to require that emission sources of a given size within such countries, rather than the countries themselves, trade in the international market (ABARE and DFAT 1995). The aim would be to ensure that there are a sufficiently large number of emission sources competing for quotas to approach the competitive outcome. Emission sources from a given country operating in the quota market may attempt to collude to exercise market power. Given that the difficulty of colluding increases with the number of parties involved, the solution would be to ensure that a sufficiently large number of emission sources operate in the market for the larger countries. Of course, such a solution would apply only if a tradable quota scheme operated at both the international and domestic level.

Transaction costs

Transaction costs in a tradable quotas market are costs incurred by market participants in buying and selling quotas and the costs to the international community in establishing and monitoring a tradable quota market. The magnitude of these costs will affect the cost effectiveness of a quota scheme.

The types of transaction costs incurred in a quota system include the costs of finding partners to trade, the costs of negotiating a trading agreement, approval costs and the insurance costs associated with the uncertainty of completing a trade (Mullins and Baron 1997). Costs incurred from monitoring, verifying emission abatement and costs of enforcing non-compliance penalties will be present regardless of which policy instrument is used to address the climate change problem.

Many of these transaction costs could be minimised through the establishment of private quota exchange markets or by an international agency established under the FCCC (Stewart, Weiner and Sands 1996). Private sector exchanges, brokers and traders could be developed, reducing these costs substantially as they benefit from economies of scale in the collection of information and trading

Evidence from other schemes

To date there has been more experience with domestic quota schemes than international tradable quota schemes. Although international trade in ozone depleting substance permits has taken place under the Montreal Protocol, trading has been very limited.[7] The most elaborate domestic trading scheme to date is the sulphur dioxide allowance trading program in the United States (box 4). Even though the Environmental Protection Agency auctions a reserve of sulphur dioxide emissions each year, the market for sulphur dioxide has been quite illiquid with turnover at about 10 per cent of total stock. Market illiquidity has been a characteristic of domestic quota schemes in general, with less trade in quotas occurring than would be expected in a competitive market. Nevertheless, the overall assessment is that these schemes usually have resulted in substantial cost savings over a purely regulatory approach (Harper 1994).

Under an international trading system, it would be expected that market liquidity would improve as more participants in the quota market would increase the number of trades. This increased number of market participants may increase the size of transaction costs. However, increased market participation may also produce scale economies in the provision of a central information and trading agency, partially offsetting these costs.

Unlike domestic schemes, an international trading scheme would have to be established and operated under international law. Although this would require agreement over new international laws, Stewart, Wiener and Sands

7 Between 1989 and 1995 about 40 trades were made between United States companies and companies in other countries (Mullins and Baron 1997).

Box 4: **Sulphur dioxide trading in the United States**

To address the problem of acid rain in the United States, a limit was placed on the sulphur dioxide emissions[8] of electricity generating utilities in order to achieve a 10 million ton a year reduction in sulphur dioxide emissions from 1980 levels by the year 2000 (Joskow and Schmalensee 1996). To facilitate this goal, a system of tradable emission allowances was introduced. Allowances are equivalent to one ton of sulphur dioxide and can be used for the year of issue or future years. The allocation of allowances is based on the utilities historical fuel consumption and a specific emissions rate (Environmental Protection Agency 1997a). However, there has been a differentiated allocation of extra allowances to address the special circumstances of particular utilities (Joskow and Schmalensee 1996).These allowances may be bought and sold between electricity utilities, brokers and environmental groups. Electricity utilities trade in order to reduce the costs of current and future abatement, brokers speculate on allowance prices and environmental groups trade to accelerate the abatement process by retiring allowances early. Allowances may be banked for use in the future but they cannot be borrowed from future time periods. At the end of the trading year, the Environmental Protection Agency reconciles actual emissions with utility holdings of allowances to emit and there are strong penalties for noncompliance.

The scheme is being phased in to cover sulphur dioxide emissions from all electricity utilities. Phase I (1995–1999) caps the emissions of the 261 dirtiest electricity generating units[9] and Phase II, which begins in the year 2000, applies to all generating units. At the end of 1995, the first year of the scheme, the sulphur dioxide emissions of Phase I affected utilities were 5.3 million tons, a 5.4 million ton reduction from 1985 levels. Further, sulphur dioxide emissions were reduced by almost 40 per cent below the required level of 8.7 million tons (Environmental Protection Agency 1997b). While tradable allowances have increased flexibility for utilities in deciding where and when to take emissions abatement and have reduced transaction costs of compliance, other factors have influenced the magnitude of the emissions reduction. In particular, it has been argued that the main factor in explaining sulphur dioxide reductions has been the deregulation of railways in the United States, making low sulphur coal more cost effective to use in electricity generation (Ellerman and Montero 1996). This unforeseen cost change has resulted in the overestimation of business-as-usual sulphur emissions and therefore an overestimation of the cost associated with achieving the emissions target, explaining why allowance prices are less than predicted.[10]

8 The dominant precursor of acid rain in the United States is sulphur dioxide from coalfired, and to a much smaller extent, oil fired power plants (Joskow and Schmalensee 1996).

9 The scheme is limited to US electricity utilities only. In 1985 electric utilities accounted for about 70 per cent of US sulphur dioxide emissions (Joskow and Schmalensee 1996).

10 Early studies estimated the price of an allowance to be around $300/ton -$500/ton, but at the first annual auction of permits, it cleared at a price of $131 (Ellerman and Montero 1996) and in January 1997 an allowance cleared for $66.05 (EPA 1997b).

(1996) argue that these legal issues can in principle be resolved in a satisfactory manner and do not represent a material impediment to establishing a successful pilot trading system. Moving to an international tradable quota scheme for greenhouse gas emissions raises further issues regarding the design of the scheme, the timetable under which it operates and its coverage of emission sources.

Institutional design and the phasing in of a global tradable quota scheme

If a tradable quota scheme is adopted by the international community it would have to be phased in. In the beginning it is likely that only carbon dioxide emissions from fossil fuel combustion would be traded as these emissions are easy to measure and verify at least in Annex I countries. It has proven more difficult to accurately measure other emissions such as methane, nitrous oxide and non-fossil fuel sources of carbon dioxide and to measure the impact sinks have in sequestering these emissions. As more accurate quantitative data become available and more experience is gained under a restricted tradable quotas scheme, trade in all greenhouse gases could take place.

It is also likely that to begin with, market participation will be limited to Annex I countries, as they have committed to emission abatement and already have detailed greenhouse gas inventories in place and are able to measure emissions (and emissions reductions) quite accurately. In contrast, non-Annex I countries have made no such commitment to reduce emissions and do not have such inventories in place. As non-Annex I emissions become easier to monitor and verify and more experience is gained under a restricted tradable quotas scheme it is likely that such a scheme could be extended to include trade with non-Annex I countries.

Cost savings would be maximised under a global scheme as the cost of abatement is much lower in non-Annex I countries, than in Annex I countries (ABARE and DFAT 1995). As previously mentioned, non-Annex I countries could be encouraged to join the scheme through side payments transferred through an appropriately large initial allocation of quotas.

Simulation results

The impacts of using a tradable quota scheme to meet given Annex I emission abatement targets are assessed in this section. For this purpose, two simulations have been selected for analysis:

- ***grandfathered tradable quotas***: The Annex I region reduces its carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and further reduces emissions to 10 per cent below 1990 levels by 2020 using a tradable quotas scheme. The initial allocation of quotas for each region is based on its historical level of emissions, in this case 1990 levels at 2010 and 10 per cent below at 2020; and

- ***differentiated tradable quotas***: The Annex I region reduces its carbon dioxide emissions from fossil fuel combustion to 1990 levels by 2010 and further reduces emissions to 10 per cent below 1990 levels by 2020 using a tradable quotas scheme. The initial allocation of quotas is differentiated to produce an equal percentage loss in gross national expenditure for all Annex I regions as a result of the abatement effort.

As in other simulations presented in this report, the tradable quota simulation does not require developing regions to restrict their emissions growth. It is assumed that there are no impediments to competitive trade in the emission permits.

The results from these simulations are compared with the results obtained for the less stringent uniform abatement stabilisation policy discussed in chapters four, five and six.

Grandfathered tradable quotas

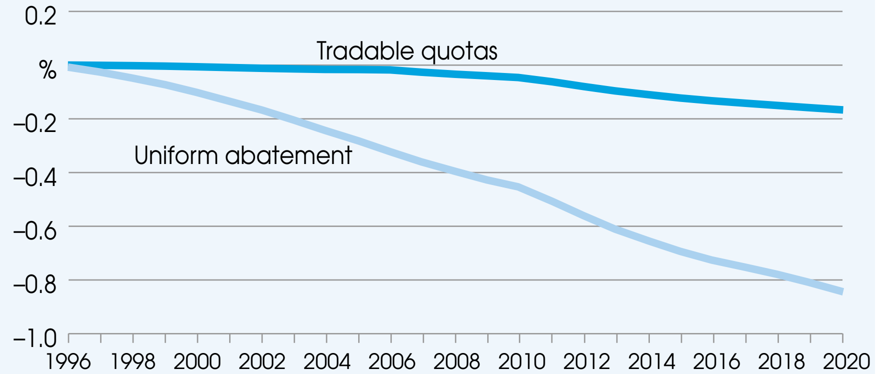
Global impacts

Global GNE declines under both tradable quotas[11] and uniform abatement (figure 35). However, the loss in GNE is substantially less under the tradable quotas scheme than under a policy of uniform abatement. By 2010, global GNE falls by 0.45 per cent relative to business-as-usual under uniform abatement (the less stringent case), whereas GNE falls by only 0.04 per cent relative to business-as-usual under tradable quotas.

Under a uniform abatement strategy, regions are required to achieve the entirety of emission reduction targets domestically, regardless of the abatement cost differentials which exist between regions. In contrast, the use of tradable quotas allows emission reductions to take place in the least cost

11 This tradable quotas scenario assumes a grandfathered allocation of quotas. The initial allocation will affect the distribution of these costs, not the total cost of abatement. Consequently, the estimates shown in figure 35 also hold for the differentiated tradable quotas scheme.

35 **Change in global GNE over time relative to business-as-usual under grandfathered tradable quotas and uniform abatement**

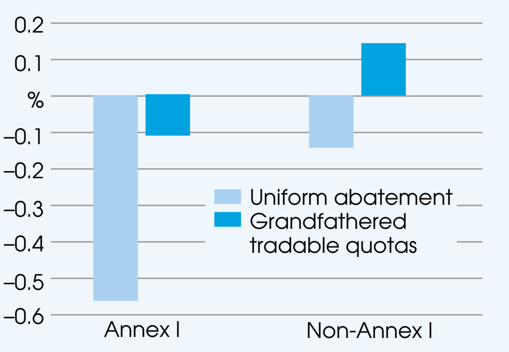


locations. This is projected to confer substantial benefit on the global economy relative to the uniform abatement approach.

Regional impacts

Under a policy of uniform abatement, both Annex I and non-Annex I regions experience a decline in aggregate GNE relative to business-as-usual (figure 36). However, under a tradable quota scheme Annex I regions' aggregate GNE falls by less than it does under uniform abatement and non-Annex I regions' aggregate GNE increases relative to business-as-usual. For non-Annex I regions this occurs for three reasons. First, a tradable quota scheme reduces the cost of achieving emission reductions, increasing aggregate Annex I income relative to uniform abatement levels. This reduces the fall in demand for non-Annex I exports.

36 **Change in regional GNE at 2010 relative to business-as-usual under grandfathered tradable quotas and uniform abatement**



Second, the rise in import prices faced by many non-Annex I regions is smaller under the tradable quota scheme than under the uniform targets approach. This is because countries such as Japan, with significant export links with non-Annex I countries, experience a large reduction in

11	Change in CO_2 emissions at 2010 relative to business-as-usual due to uniform stabilisation and tradable quotas

	Uniform stabilisation	Tradable quotas
	%	%
Annex I	–20.1	–20.1
Non-Annex I	2.7	1.1
Global	–9.3	–10.0

Source: MEGABARE projections.

marginal emission abatement costs under the tradable quotas approach (discussed later in this section). As a result, production costs in these countries do not rise as significantly as they would under a uniform emission abatement scheme and hence the prices of the products they sell on international markets rise by less (on average) than they would under a tradable quotas scheme.

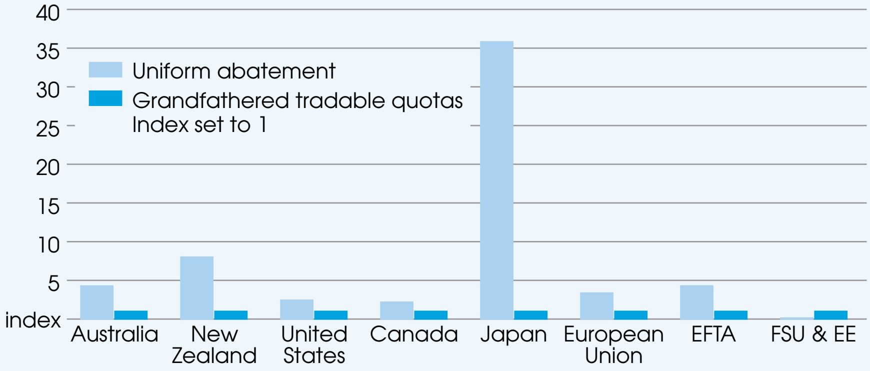
Third, many non-Annex I regions continue to experience gains from carbon leakage, although not as high as those experienced under the uniform targets approach (see chapter 4 for a discussion of carbon leakage). The results presented in table 11 imply a carbon leakage rate of 5.1 per cent by 2010 under tradable quotas and 12.1 per cent under uniform abatement. Carbon leakage is lower under the tradable quotas scheme because the reduced costs of achieving the emission target in Annex I regions results in less of their emission intensive production being transferred to non-Annex I regions than under the uniform emission abatement approach.

Finally, it should be noted that while non-Annex I countries gain in aggregate, certain countries, especially significant exporters of fossil fuels, can be expected to incur losses in GNE owing to reduced demand for fossil fuels from Annex I regions.

Impacts in Annex I regions

The marginal costs of emission abatement in Annex I regions change when moving from uniform abatement to a grandfathered tradable quotas scheme. Under a grandfathered tradable quota scheme, the marginal costs of abatement are lower for all Annex I regions, except the Former Soviet Union and Eastern Europe, than is projected under uniform abatement (figure 37).

37 Marginal cost of abatement at 2010 under uniform abatement and grandfathered tradable quotas

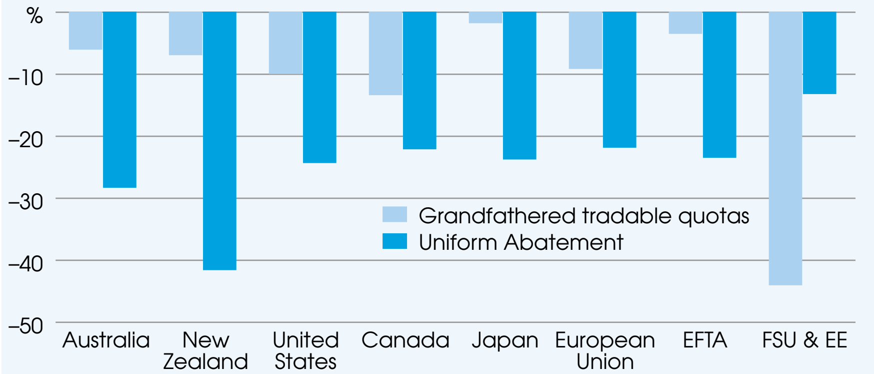


Changes to marginal emission abatement costs affect production costs in each economy as well as its competitiveness and terms of trade. The combined impact of these changes will determine the magnitude of gain, if any, for a region from the move to a tradable quotas scheme.

Given the initial allocation of quotas, the marginal cost of abatement projected for the uniform targets approach is equivalent to the pre-trade marginal cost under the tradable quotas scheme. Because the Former Soviet Union and Eastern European grouping has a low marginal emission cost of abatement prior to trading, other Annex I regions have an incentive to purchase emission permits from it. As this trade proceeds, emission reduction requirements for the other Annex I countries are transferred to the Former Soviet Union and Eastern Europe. Consequently, the marginal emission abatement cost in the Former Soviet Union and Eastern Europe rises relative to the pre-trade or uniform target level while the marginal cost falls for the other regions. Ultimately marginal abatement costs are equalised across Annex I regions with emissions trading.

Emission reductions by the Former Soviet Union and Eastern Europe increase to 44 per cent below business-as-usual levels by the year 2010 from only 13 per cent under uniform abatement (figure 38). In contrast, emission reductions in the rest of the Annex I regions are smaller under grandfathered tradable quotas than under uniform abatement. To compensate the Former Soviet Union and Eastern Europe for taking on the additional abatement, income is transferred to them from all other Annex I regions (figure 39) in the form of payments for emission permits.

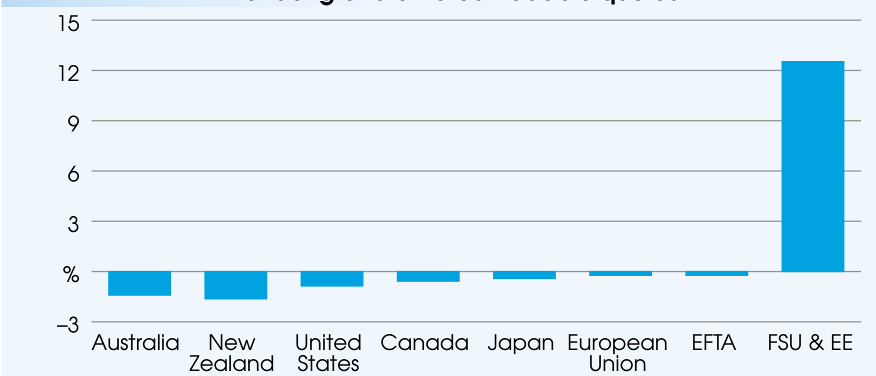
38 Change in CO_2 emissions at 2010 relative to business-as-usual under uniform abatement and grandfathered tradable quotas



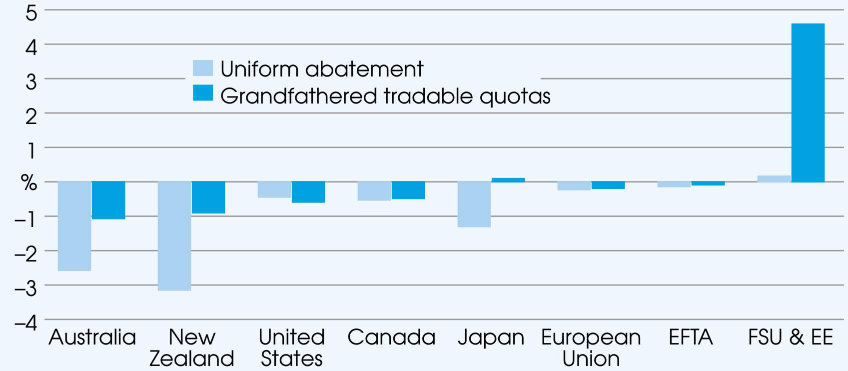
Changes in the gross national expenditure of Annex I regions summarise how the benefits of lower marginal abatement costs, changes in competitive advantage (terms of trade) and income transfer effects impact on economies. Results in figure 40 show that impacts on GNE are projected to vary significantly between Annex I regions under the two approaches.

Compared with the uniform targets result, countries such as Japan, Australia and New Zealand (where marginal abatement costs are projected to be the highest under uniform targets) experience the greatest benefit from the shift to grandfathered tradable quotas. Despite gaining from the shift to grandfathered tradable quotas, Australia and New Zealand continue to suffer large GNE losses relative to other Annex I regions. For example, in Australia, this is due to large trade related losses resulting from reduced demand for its coal exports. Canada experiences a small gain in GNE from

39 Income transfers as a percentage of GNP at 2010 under grandfathered tradable quotas



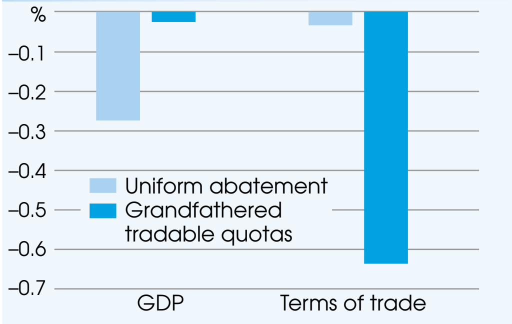
40 Change in GNE at 2010 relative to business-as-usual under uniform abatement and grandfathered tradable quotas



the move to tradable quotas and total emission abatement costs are also reduced for EFTA and the European Union. The principal source of gain for these regions is the reduction in marginal cost associated with the possibility of trade in emission permits. These gains are offset to some extent by the foreign income transfers associated with the purchase of emission quotas from the Former Soviet Union and European Union. In Japan the substantial reduction in marginal costs compared with reduction experienced by other Annex I countries confers a competitive advantage on Japanese industries over industries in other Annex I countries. This trade related benefit leads to an improvement in Japan's GNE relative to business-as-usual. The Former Soviet Union and Eastern Europe also experience a gain in GNE relative to business-as-usual. This is because the increase in national income from payments for emission quotas more than offsets the losses associated with needing to undertake greater emission abatement.

A key result is that the United States experiences a greater loss in GNE under the grandfathered approach than under the uniform targets approach. This occurs for two reasons. First, the United States does not experience as great a reduction in marginal emission abatement costs from the move to tradable quotas as do countries such as Japan and New Zealand (see figure 37). As a result, the gains to fossil fuel using industries in the United States are not as great as those for industries in many other Annex I regions. Second, the significant reduction in marginal emission abatement costs in other Annex I regions relative to that for the United States reduces the competitiveness of US industry compared to the situation it faced with uniform targets. Consequently, the terms of trade (or the rate at which US exports can be exchanged for imports) decline relative to the uniform targets outcome. This

41 Change in US GDP and terms of trade at 2010, relative to business-as-usual under uniform abatement and grandfathered tradable quotas



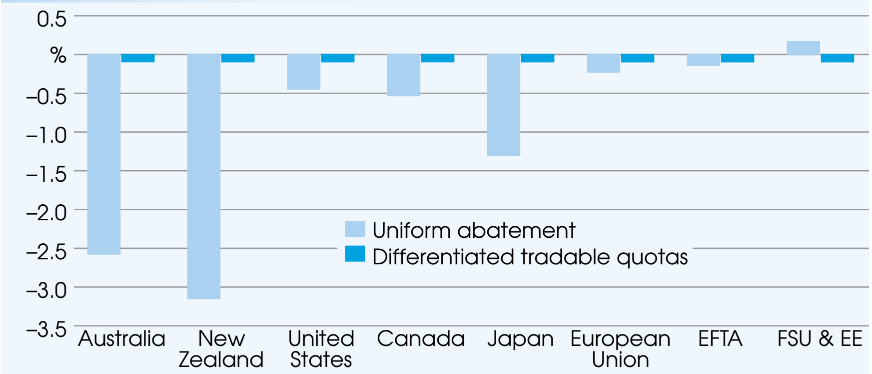
leads to a substantial trade related loss in GNE for the United States that in combination with the income outflows associated with quota purchases (see figure 39) outweigh any benefits (in terms of reduced GDP impacts) from reduced marginal emission abatement costs (figure 41).

Differentiated tradable quotas

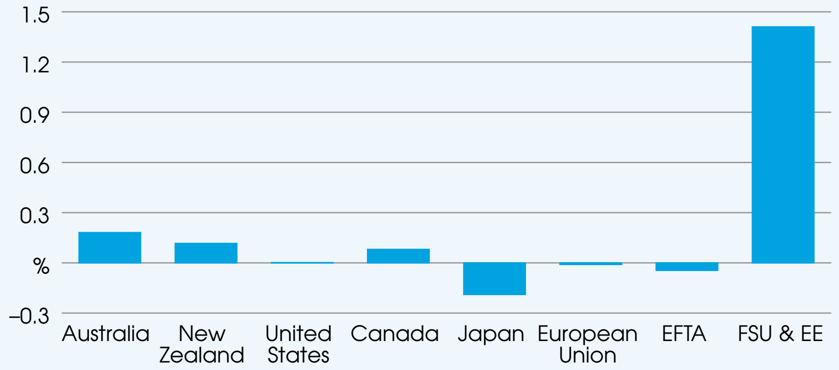
The results in figure 40 showed that a grandfathered tradable quota scheme would lead to an inequitable distribution of the costs associated with achieving the Annex I abatement target. Through a differentiated allocation of quotas it is possible to achieve an equitable outcome. The implications of a differentiated tradable quota scheme are shown in figure 42.

Under the differentiated scheme, the changes to marginal costs and emission abatement levels are almost identical to those estimated for the grandfathered scheme (figures 37 and 38). The principle difference in GNE outcomes for the two schemes is the difference in income transfers associated with the differing quota allocations. Under the differentiated

42 Change in GNE at 2010 relative to business-as-usual under uniform abatement and differentiated tradable quotas



43 Income transfers as a percentage of GNP at 2010 under differentiated tradable quotas



allocation scheme, countries that experience negative trade related impacts when marginal emission abatement costs are equalised across regions are compensated with quotas over and above their requirements in order to equalise GNE losses across regions.

The income transfers associated with the differentiated quota scheme are shown in figure 43. The Former Soviet Union and Eastern Europe continues to receive an income transfer. However, the transfer is smaller than under the grandfathered scheme. The United States receives a transfer in its favour under the differentiated scheme; however, the size of the transfer is small as a proportion of total United States GNP.

A move to a tradable quota regime from a uniform target approach is estimated to confer substantial cost savings on the global community. However, in arriving at these results it has been assumed that quota and product markets are competitive so that no one participant exercises power in the quota market. The results obtained would be altered if market power in emission trading existed or if quotas were distributed under another allocation rule. Projected outcomes would also change with a change in country participation in the quota market. In particular, without the participation of the Former Soviet Union, global gains resulting from the move to tradable quotas would be significantly lower than those estimated in this study.

8

Kyoto in December – developing good long term policies

In the very long term the United Nations Framework Convention on Climate Change will be judged to have been effective if a balance has been achieved between the net damages from climate change itself and the economic costs imposed as a result of emission abatement and adaptation. One of the necessary conditions for such a balance is that all major emitters are part of an agreement to reduce emissions. This type of participation will be encouraged only if emission abatement actions undertaken by signatories are equitable and least cost.

Results presented in this report show that uniform emission reduction targets implies unequal economic burdens across Annex I countries. The incidence of that burden changes as the targets become more ambitious, falling more and more heavily on countries such as Japan, Australia, Norway and New Zealand. In Japan, this occurs because Japanese industries have already taken major steps to improve energy efficiency and reduce fossil fuel use. Further action to reduce emissions by significant amounts in Japan would imply further structural adjustment to the Japanese economy, for example, in the iron and steel industry and manufacturing, which are responsible for employing a significant proportion of the workforce. Such adjustments would carry large costs. In the case of Australia, which supplies a large share of the world's processed minerals from energy intensive production processes, emission abatement activities would also entail major structural adjustment in industry and high economic costs.

A demand for simplicity by some Parties to the convention has led them to insist on uniform abatement targets. But such an approach carries high costs and implies inequitable burdens across countries. As such, it does not lay the long term foundation for an agreement that will be implemented whole-heartedly, that will provide a mechanism for signing on developing countries to undertake future commitments, or that will form the basis for introduction of innovative such as tradable emissions quotas.

An emission trading scheme has the potential to be the least cost approach to meeting the challenge of reducing emissions at the international level. However, insistence on grandfathered initial allocations regardless of the special characteristics of different economies or their stage of development will not encourage participation in emissions trading schemes over the longer term. Instead, the initial allocation of emission permits could be used to compensate countries (at least to some extent) for the costs of meeting emission abatement targets, thereby encouraging the participation of new entrants to the international emission abatement process.

As illustrated in chapter 3, carbon dioxide emissions from fossil fuel combustion from non-Annex I regions will have overtaken emissions from Annex I regions by 2016. At 2020, non-Annex I regions are projected to be responsible for 52 per cent of global emissions. It is clear, therefore, that a way must be found to involve these countries in an agreement to reduce emissions if the very long term aim is to stabilise atmospheric concentrations of greenhouse gases. The establishment of equitable and efficient policy options at Kyoto will facilitate this process.

A Appendix

The technology bundle

Main features

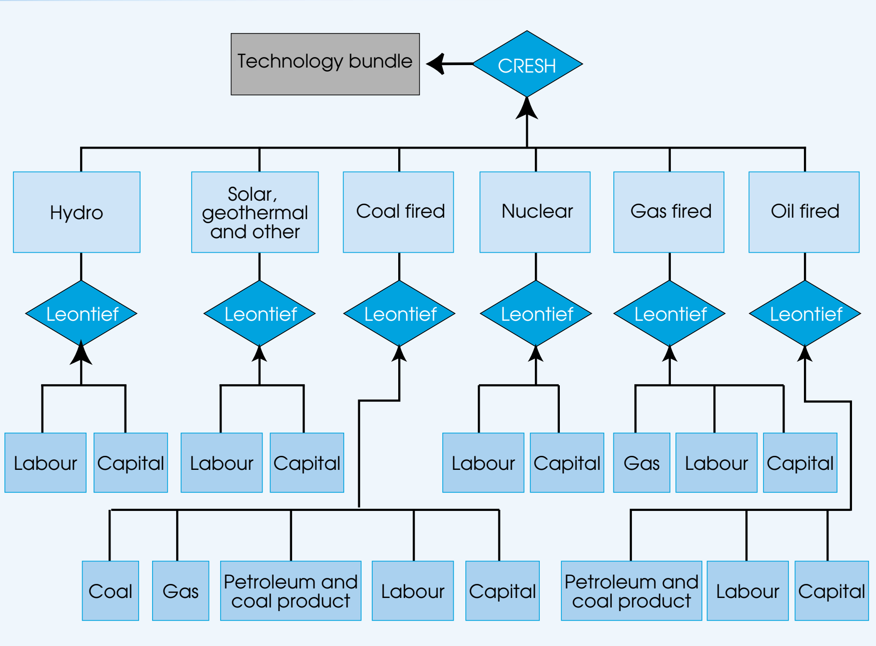
The concept of the technology bundle was developed to try to improve accuracy in modelling substitution options, especially in energy using activities. It also improves model transparency and the scope for validating model results. The technology bundle is currently applied to the electricity and iron and steel industries in MEGABARE.

The standard approach to modelling substitution options based on the energy economics literature is to use nested production functions. ORANI-E (McDougall 1993) provides a typical example of the use of the nesting approach in the production of electricity. At the deepest level of the nest, different fuel types are combined to produce an energy composite. At the next level in the nest, the energy composite is combined with capital to form a capital–energy composite. Finally, the capital–energy composite is combined with labour to produce electricity.

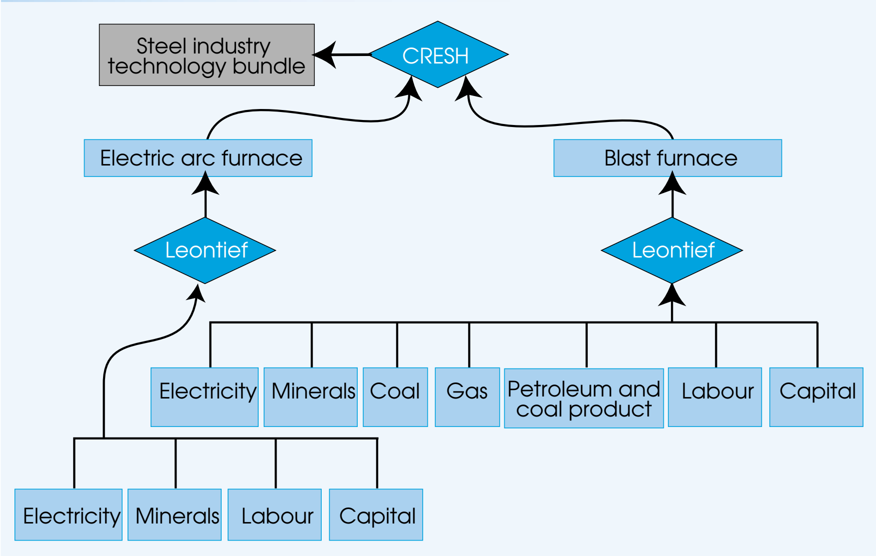
A deficiency of the nested production function approach is that it does not ensure that the implied pattern of input use is consistent with any feasible combination of activity levels for known technologies. If there are only a small number of feasible technologies, the range of feasible input combinations may be severely constrained. However, the assumption of continuous substitution options in the nested production function approach may imply a much wider range of feasible input combinations (for a diagrammatic analysis see ABARE 1996).

In the technology bundle, it is assumed that output of a given industry is produced by only a finite number of technologies with distinct fixed (Leontief) input requirements. For example, in MEGABARE it is assumed that electricity can be produced by the following technologies: coal, oil, gas, nuclear, hydro and renewables, while iron and steel can be produced using blast furnace and electric arc technologies. Data on the input requirements of each technology are based on average data for each region in the model rather than input requirements of a plant with given specifications (see figures 44 and 45).

44 Composition of technology bundle in the electricity industry



45 Composition of technology bundle in the steel industry



The output of each technology is taken as an input into industry output (electricity and iron and steel). In MEGABARE the relationship between technology outputs and industry output is governed by a CRESH production function (see ABARE 1996 for more details). If the price of an input used by only one technology rises while other input prices remain constant, there will be substitution away from the technology that uses that input. The extent of substitution will be governed by the assumed value of the elasticity of substitution which in a CRESH production function can differ between pairs of technologies.

Under the technology bundle approach, the pattern of input use is constrained to be consistent with the range feasible for the specified technologies. It is apparent how the shares of the different technologies vary in response to some specified change, which is not the case under the nested production function approach. The elasticity of substitution parameters can be calibrated to produce a pattern of changing technology use to correspond as closely as desired to the results from simulations with activity analysis models.

Example

To investigate the possible advantages of the technology bundle approach over nested production functions in appropriately constraining input demand, simulation experiments were conducted typical of those undertaken in greenhouse policy analysis. Data were drawn from the ORANI-E model (McDougall 1993) relating to Australia-wide averages of fuels, capital and labour used by different electricity generating technologies (see table 12). It was assumed that electricity could be produced either by the standard ORANI-E specification of nested CES production functions with the nesting structure described above or by a technology bundle where a CES function was used to aggregate the output of the different technologies into industry output.

For the experiment, the carbon tax required to induce a 20 per cent reduction in carbon dioxide emissions from the electricity sector was calculated using the nested CES function model. The same tax was then applied to the technology bundle model under different assumptions about the elasticity of substitution between technologies. Differences in changes in input use and carbon dioxide emissions between the various simulations are noted.

12 Selected inputs' shares in costs: Australian electricity generating technologies, 1986-87

	Steam turbine	Hydro	Gas turbine	Combined cycle	Other fuel burning	Aggregate input share in industry costs
	%	%	%	%	%	%
Black coal	20.27	0.00	0.00	0.00	0.00	17.33
Natural gas	6.66	0.00	35.29	62.50	9.22	7.49
Brown coal (briquettes)	0.20	0.00	0.00	0.00	0.00	0.17
Brown coal (lignite)	4.94	0.00	0.00	0.00	0.00	4.23
Petroleum and coal products	2.08	0.00	1.96	0.00	78.72	3.89
Reticulated gas supply	2.47	0.00	13.07	22.92	3.55	2.78
Labour	42.16	11.16	29.41	10.42	4.96	38.02
Capital	21.22	88.84	20.26	4.17	3.55	26.08
Total	100.00	100.00	100.00	100.00	100.00	100.00
Technology share in industry costs	85.52	8.14	2.84	0.89	2.61	100.00

Under the nested CES model, at the deepest level of the nest, the different fuel types are combined into an energy composite assuming an elasticity of substitution of 1.2. At the next level, the energy composite is combined with capital to form a capital–energy composite assuming an elasticity of substitution of 0.5. At the highest level, the capital–energy composite is combined with labour to produce electricity assuming an elasticity of substitution of 0.8.

Elasticities of supply assumed for the various inputs are shown in table 13. The price elasticity of demand for electricity was assumed to be 1.2. Under the nested CES model, the price of electricity is a cost shared weighted sum of the prices of inputs. The price of each technology is similarly determined. Under the technology bundle model, the price of electricity is a cost share weighted sum of the prices of technologies. Equilibrium conditions involve equality between quantities demanded and supplied.

For the experiment, the prices of fuel inputs that emit carbon dioxide under combustion were increased by the amount of a carbon tax needed to achieve a 20 per cent reduction in emissions from electricity production under the nested CES model. The percentage changes in the quantity of inputs required to achieve a new equilibrium were computed. The same carbon tax was then

13 Supply elasticities for inputs

Commodity	Elasticity
Black coal	25
Natural gas	11
Brown coal (briquettes)	36
Brown coal (lignite)	36
Petroleum and coal products	10
Reticulated gas supply	11
Labour	1
Capital	∞

applied to the technology bundle model. Resulting changes in input use and carbon dioxide emissions are shown in table 14.

The first point about the results can be made most clearly by applying the percentage changes in the first column of table 14 to the base period data to calculate the implied new input cost shares. These results are shown in table 15 together with the original input cost shares from the last column of table 12.

Imposing the carbon tax results in a decrease in the cost share of all types of coal and an increase in the labour share. Such a result is inconsistent with

14 Change in quantity of inputs and carbon dioxide emissions in response to given carbon tax

	Nested CES	TB e.s.=5	TB e.s.=10	TB e.s.=20	TB e.s.=50	TB e.s.=100
	%	%	%	%	%	%
Black coal	–18.54	–8.83	–10.92	–14.28	–20.95	–27.35
Natural gas	–4.77	–6.75	–7.35	–8.83	–13.56	–19.85
Brown coal (briquettes)	–25.13	–8.83	–10.92	–14.28	–20.95	–27.35
Brown coal (lignite)	–32.30	–8.83	–10.92	–14.28	–20.95	–27.35
Petroleum and coal products	4.54	–1.89	0.06	0.31	–6.24	–16.09
Reticulated gas supply	4.18	–6.73	–7.32	–8.78	–13.46	–19.64
Labour	–0.95	–7.75	–8.92	–10.78	–14.35	–17.48
Capital	–4.48	0.13	6.35	18.11	48.80	88.62
Carbon dioxide emissions	–20.00	–8.48	–10.32	–13.40	–19.82	–26.26

Note: TB = technology bundle. e.s. = elasticity of substitution between technologies.

15 Initial and final shares in input costs under nested CES production functions

Input	Initial share	New share
	%	%
Black coal	17.33	15.06
Natural gas	7.49	7.61
Brown coal (briquettes)	0.17	0.13
Brown coal (lignite)	4.23	3.05
Petroleum and coal products	3.89	4.34
Reticulated gas supply	2.78	3.09
Labour	38.02	40.16
Capital	26.08	26.57
Total	100.00	100.00

any linear combination of the technologies identified in table 12. Steam turbines are the only coal using technology, so a reduction in the coal share would imply a reduction in the steam turbine share. However, steam turbines are the most labour intensive technology by a wide margin so any decline in the steam turbine share should also reduce the labour share whereas it rises. Thus, the nested production function model implies a change in the pattern of input use inconsistent with the characteristics of the identified technologies.

The second point to notice in table 14 is that under the technology bundle model, the given carbon tax achieves a reduction in emissions equivalent to that in the nested CES model only for extremely high values of the elasticity of substitution between technologies. Such large values are associated with implausibly large changes in the outputs of different technologies as shown in table 16.

The final point to note in table 14 is that capital use declines in the nested CES model whereas it increases for all values of the elasticity of substitution in the technology bundle model. In activity analysis models, a carbon tax usually stimulates a shift toward more capital intensive technologies.

To conclude, the fact that the nested CES model permits input combinations inconsistent with the characteristics of known technologies appears to be a serious problem in the context of greenhouse policy analysis according to the results presented in this appendix. By allowing such inconsistent combinations, there is a tendency to underestimate the size of a carbon tax

16 Changes in technology outputs in response to carbon tax

Technology	e.s.=5	e.s.=10	e.s.=20	e.s.=50	e.s.=100
	%	%	%	%	%
Steam turbine	–8.83	–10.92	–14.28	–20.95	–27.35
Hydro	25.98	64.12	158.81	594.02	1764.74
Gas turbine	8.12	23.71	59.22	220.38	896.84
Combined cycle	–14.18	–23.61	–42.94	–81.32	–97.78
Other fuel burning	4.26	10.00	13.49	5.11	–11.11

Note: e.s. = elasticity of substitution between technologies.

required to achieve a given reduction in emissions. The technology bundle model avoids such inconsistent combinations and provides a more transparent approach to the problem by explicitly determining changes in the shares of different technologies.

Appendix B

The implications of price responsive technical change

The efficiency of fossil fuel usage across industries may improve in response to increases in the cost of fossil fuels resulting from emission abatement policies. For example, it is possible that such cost increases may induce fossil fuel users to adopt new and more fossil fuel efficient technologies at a more rapid pace than would otherwise have been the case. Alternatively, the abatement policies could induce innovation leading to reduced requirements for fossil fuels per unit of output. Such responses are known as 'price induced technical changes'.

The policy scenarios considered in this report induce large changes in the user prices of fossil fuels. To assess the possible impacts of introducing price responsive technical change into MEGABARE the less stringent emission reduction scenario was modelled and, in addition, greater efficiency improvements in fossil fuel energy use above business-as-usual levels were imposed to simulate the potential impacts of price responsive technical change. For illustrative purposes, the additional efficiency gain was provided to Australia only.

Under the emission abatement scenarios the annual growth rate of fossil fuel energy efficiency improvement for Australia was assigned a value 0.5 percentage points higher than in the business-as-usual scenario. This represents a 70 per cent increase in annual rates of efficiency improvement. The magnitude of the assumed increase is illustrative. It serves only to highlight the implications of a very substantial improvement in fossil energy efficiency induced by abatement policies on the national economy.

A key assumption in this analysis is that the economy experiences the same amount of overall improvement in the efficiency of input use in each period under the business-as-usual and the emission abatement scenarios. In essence there is a fixed endowment of technical change for the economy. Consequently, increases in fossil fuel energy efficiency are offset by reductions in the rate of efficiency improvement in the use of other inputs. This captures the idea that the resources required to improve fossil fuel energy efficiency must be drawn from other sectors of the economy, leading to reduced activity levels in those sectors. Effectively, changes to relative prices influence only the distribution of technical change in the economy, not its level.

The introduction of price responsive technical change in Australia reduces the economic costs associated with the less stringent emission reduction scenario from 3.4 per cent to 3.1 per cent relative to business-as-usual at 2020. The impact on the economic costs decreases by 0.006 percentage points for each additional 0.1 percentage point of energy efficiency growth in the policy scenarios compared with the business-as-usual projection.

On balance, in this example, the introduction of price responsive technical change in Australia has little effect on the GNE impacts of assumed abatement policies. This is because, while the improvement in energy efficiency improves outcomes for fossil fuel users, the decline in the efficiency of use of non energy inputs imposes costs on users of those inputs, which largely offset the gains from the policy induced technological change.

The introduction of price responsive technical change for all Annex I regions would have both positive and negative effects on the economic costs associated with emission abatement. The overall outcome would depend on both the structure of the region's domestic economy and its pattern of trade. For example, if other Annex I countries were also to respond to the introduction of emission abatement policies with improvements in their efficiency of fossil fuel use, the competitiveness of Australian industry could be adversely affected. The net effect of such factors with a global specification of price responsive technical change has not been simulated for this report as a more rigorous specification of price responsive technical change is now being developed. Nevertheless, the simulation discussed in this appendix is indicative of the types and magnitudes of effects involved.

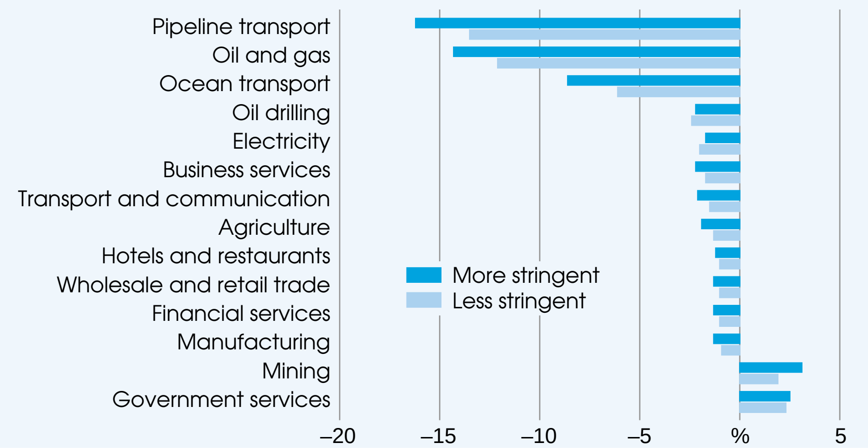
The effects of emission abatement on Norway

This appendix contains estimates of the impacts on Norway of the more and less stringent Annex I emission abatement scenarios described in chapter 4. These estimates are based on the application of a post simulation input–output model to disaggregate MEGABARE projections for EFTA. The post simulation model is described in detail at the end of this appendix.

Gross domestic product in Norway declines by 2.6 per cent in 2020 relative to business-as-usual under the less stringent scenario and by 3.3 per cent under the more stringent scenario. These falls are among the highest of those estimated for Annex I economies. The main contributors to the fall in output are declines in oil and gas production and production activities related to these sectors. The sectoral effects for Norway under the less and more stringent emission abatement scenarios are presented in figure 46.

Oil and gas production in Norway is projected to fall by 12 per cent relative to business-as-usual under the less stringent scenario and by 14 per cent under the more stringent scenario. The output of the pipeline transport services sector, which is sold almost entirely to the oil and gas sector, is projected to fall by around the same amount as oil and gas output. Output in the oil drilling sector also declines relative to business-as-usual as a result

46 Change in Norwegian sectoral output at 2020 relative to business-as-usual due to uniform emission reduction



of reduced oil production and exploration activity. There are also reductions in manufacturing and construction activity, owing principally to increased production costs in these sectors.

Offsetting the declines in gross domestic product to some extent, there are increases in the outputs of a range of resource intensive industries aggregated under mining. The output of government services is also projected to increase as demand increases with the introduction of abatement policies. The production of government services is less fossil fuel intensive than other production activities and, consequently, their costs and prices are not affected to the same extent as the costs and prices of other items. This leads consumers in Norway to substitute toward government services.

Post simulation input–output model

The post simulation input–output model uses national input–output tables, which provide a wealth of information that can be used as a basis for analysis to determine a country's direct and indirect fossil fuel reliance. MEGABARE projections for each category of demand, including final demand (private consumption, government consumption, investment and exports) and intermediate demand, are used to infer changes to the post simulation input–output model. The overall change in a sector's output depends on the share of output demanded by each category and the inferred change in demand for each category.

A modification of standard input–output analysis can be used to estimate the effects of a policy on a subregion of a MEGABARE region if an input–output table is available for the subregion. First, a concordance between MEGABARE commodities and the commodities represented in the subregional input–output table is created. Second, the percentage changes in the quantities of each domestically produced commodity in each final demand category (private consumption, government consumption, investment and exports) are assumed to be the same for the MEGABARE region and the subregion. Third, the input–output coefficients for the subregion are modified according to the simulated changes for the MEGABARE region. This process allows demands for primary factors, imports and industry outputs to be estimated for the subregion. Macroeconomic aggregates such as gross domestic product can then be calculated.

Data derived from the subregional input–output table and used in the input–output analysis are:

V_{ij} = Value of use of input i in activity j

GDP = Gross domestic product

Sets of rows and columns of the input–output table referenced in the equations of the following section are:

dcom = rows (columns) of the input–output table corresponding to domestically produced commodities (industries)

icom = rows of the input–output table corresponding to imported commodities

final = columns of the input–output table corresponding to final demands (private consumption, government consumption, investment and exports)

pfact = rows of the input–output table corresponding to primary factors (labour, capital and land)

Inputs and outputs of the subregional input–output analysis are:

q_{ij} = Percentage change in the quantity of input i used in activity j

$q_{\bullet j}$ = Percentage change in the output of activity j

s_{ij} = Percentage change in the per unit output requirement for input i by activity j

gdpi = Percentage change in real GDP calculated from the income side

gdpe = Percentage change in real GDP calculated from the expenditure side.

Description of the modified input–output analysis

Since input–output coefficients are changed in this modified input–output analysis, a nonlinear set of equations must be solved in contrast to standard input–output analysis. The nonlinear equations are specified in linearised form and solved using GEMPACK (Pearson 1991). The linearised equations are:

market clearing

$$\Sigma_j V_{ij} . q_{\cdot i} = \Sigma_j V_{ij} . q_{ij}$$

per unit output requirements

$S_{ij} = q_{ij} - q_{\bullet j}$

definition of GDP from the expenditure side

$$GDP.gdpe = \sum_i \sum_{j \in final} \left(V_{ij}.q_{ij}\right) - \sum_{i \in icom} \sum_j \left(V_{ij}.q_{ij}\right)$$

definition of GDP from the income side

$$GDP.gdpi = \sum_{i \in pfact} \sum_j V_{ij}.q_{ij}$$

Appendix D

The estimated effects of emission abatement policies on electricity inputs

Emission abatement actions undertaken by Annex I countries imply significant restructuring of the electricity sectors throughout Annex I regions.

Table 1 shows three data sets: the initial 1992 shares of various electricity generation technologies in Annex I countries; the projected technology mix for electricity generation in 2020 under the business-as-usual scenario; and the projected technology mix for electricity generation in 2020 under the less stringent uniform emission reduction scenario outlined in chapter 4.

Business-as-usual projections

The percentages of electricity generated by oil, nuclear and hydro based technologies fall in most Annex I countries under the business-as-usual scenario. The Former Soviet Union and Eastern Europe is an exception as there the share of nuclear powered electricity is projected to increase from 13.7 per cent in 1992 to 16.1 per cent in 2020.

As natural gas reserves are further exploited over the time frame of the business-as-usual projection, Annex I regions, excluding the Former Soviet Union and Eastern Europe, increase their reliance on gas fired electricity generation. For example, in Australia the share of gas fired electricity generation increases from 8.8 per cent to 13.5 per cent in the business-as-usual scenario. In New Zealand the increase is from 25.1 per cent to 51.5 per cent. In recent projections for Canada by the Energy Forecasting Division of Natural Resources Canada (1997) the share of coal fired power generation is not projected to change significantly, while the share of hydroelectricity is projected to fall by only a small amount relative to 1990 levels by 2020. This indicates a substantial assumed absolute increase in hydro power generation. In this study, however, assumed restrictions on the growth of nuclear power and hydroelectricity production prevent their expansion from current levels. This leads to substantial increases in fossil fuel based electricity generation and, in particular, for coal. On balance, given the continuing large share of hydroelectricity, Canadian electricity production remains significantly less fossil fuel intensive than is projected for the United States.

17 Percentage of total electricity generated by various technologies

Percentage of total electricity generated by each technology, 1992

	Australia	New Zealand	United States	Canada	Japan	European Union	EFTA	FSU/EE
	%	%	%	%	%	%	%	%
Coal	79.2	1.3	53.2	17.5	17.3	34.8	0.1	26.1
Oil	2.3	0.4	3.3	2.9	25.4	10.2	0.4	8.8
Gas	8.8	25.1	13.0	2.6	21.6	6.6	0.2	37.4
Nuclear	0.0	0.0	20.1	15.5	25.1	34.4	13.1	13.7
Hydro	9.2	73.1	8.3	60.7	9.5	13.4	85.3	13.8
Renewables	0.4	0.1	2.1	0.8	1.1	0.6	1.0	0.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Percentage of total electricity generated by each technology under business-as-usual assumptions, 2020

	Australia	New Zealand	United States	Canada	Japan	European Union	EFTA	FSU/EE
	%	%	%	%	%	%	%	%
Coal	79.0	0.9	56.4	42.3	22.2	46.1	0.1	36.4
Oil	1.4	0.2	2.3	1.8	18.3	7.9	0.3	5.7
Gas	13.5	51.5	19.2	6.0	32.0	8.0	13.8	28.8
Nuclear	0.0	0.0	13.9	9.6	18.1	26.7	11.4	16.1
Hydro	5.7	47.4	5.7	37.5	6.8	10.4	74.4	12.9
Renewables	0.4	0.0	2.5	2.9	2.6	0.9	0.0	0.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Percentage of electricity generated by each technology under the less stringent emission reduction scenario, 2020

	Australia	New Zealand	United States	Canada	Japan	European Union	EFTA	FSU/EE
	%	%	%	%	%	%	%	%
Coal	21.9	0.9	8.2	0.0	0.0	1.6	0.1	2.8
Oil	3.0	0.2	1.9	0.2	0.1	28.3	0.1	1.1
Gas	9.1	3.0	8.9	11.7	43.6	18.7	8.3	13.3
Nuclear	0.0	0.0	14.5	9.2	18.9	27.7	11.5	45.4
Hydro	6.2	50.4	6.0	36.0	7.2	10.8	75.1	37.1
Renewables	59.7	45.4	60.5	43.0	30.1	12.9	4.9	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: MEGABARE database and projections.

Less stringent emission abatement

Under the emission abatement scenarios it is assumed that Annex I regions cannot increase production of nuclear power or hydroelectricity above business-as-usual levels.

The adoption of the less stringent emission reduction target leads to restructuring of electricity generation toward less emission intensive fuels throughout Annex I regions. The results show a marked substitution away from coal fired electricity. The share of coal fired electricity in total electricity production in both Australia and the United States decreases by more than 50 percentage points in response to the emission abatement action.

Substitution away from gas fired electricity is not as pronounced as substitution away from coal fired electricty generation in response to the emission abatement action. In Canada and the European Union, the share of gas fired electricity in total electricity production increases due to its lower emission intensity relative to coal.

Oil based electricity generation is relatively less emission intensive than coal fired electricity. In the European Union oil fired electricity generation is also projected to increase.

The share of nuclear power generation increases relative to business-as-usual in the Former Soviet Union and Eastern Europe, where growth in this power source has not been constrained.

The share of renewable technologies (including solar, wind, geothermal etc.) in electricity generation is projected to increase in all Annex I regions. Other studies (Jones et al. 1994) have also found a significant increase in the use of solar technologies in Australia under the assumption of high marginal abatement costs.

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