CHAPTER 2: FRAMEWORK FOR ANALYSIS

Key points

This analysis uses a suite of models to explore the global, national, sectoral and household dimensions of emission reductions. A suite of models approach provides a natural hedge against the inherent uncertainty in economic modelling.

This chapter sets out the framework used to analyse the macroeconomic, sectoral and household impacts of Australian and global action to reduce greenhouse gas emissions.

2.1 STABILISING EMISSIONS IS AN ECONOMIC PROBLEM

The policy scenarios in this report assume Australia and the world implement emissions trading schemes to reduce greenhouse gas emissions and stabilise atmospheric concentrations of greenhouse gases.

Many types of economic activity lead to the emission of greenhouse gases (Box 2.1). While fossil fuel combustion is the major source of human induced greenhouse gas emissions, it has also delivered heat, light and motion to firms and households, and underpinned rising living standards.

Continued growth in greenhouse gases emissions from human activities increases the risk of dangerous, human-driven interference with the Earth's climate (IPCC, 2007a). To respond to these risks, the international community needs to agree to limit the right of nations to release greenhouse gases into the atmosphere.

This report analyses the impacts on Australia of such an agreement. Because climate change impacts are related to the concentration of emissions in the atmosphere over time, and not emissions in any one year, this report assumes global mitigation action over time will be sufficient to stabilise atmospheric concentrations at low levels.[1]

To stabilise the atmospheric concentration of greenhouse gases, the world will need to limit its emissions in the long term to no more than the capacity of the natural environment to absorb carbon. This limit is currently understood to be much less than half of current emissions levels (Canadell et al., 2007; Pearman, 2008).

The transition from current trends in emissions growth to levels consistent with atmospheric stabilisation will involve policies across national, multinational and global jurisdictions. Such policies must face the challenge of limiting emissions without compromising economic growth and living standards, particularly in parts of the world where living standards currently are low.

1 The relationship between the concentration of emissions and projected climate change is addressed in detail in Pearman, 2008.

Box 2.1: Sources of greenhouse gas emissions

Emissions come from a range of sources:

- **Stationary energy** includes combustion emissions from fuel in generating electricity and refining petroleum; combustion emissions from fuels used in manufacturing, construction and commercial sectors; and other sources, such as domestic heating.
- **Transport** includes direct combustion (or end-use emissions) of fuels used by road, rail, domestic air transport and domestic shipping.
- **Fugitives** include methane, carbon dioxide and nitrous oxide emitted in producing, processing, transporting, storing and distributing raw fossil fuels (coal, oil and gas).
- **Industrial processes** covers non-energy emissions from mineral processing, chemicals and metal production. These emissions usually arise from chemical reactions during manufacture (for example, calcification during cement manufacture releases carbon dioxide).
- **Agriculture** includes methane and nitrous oxide emissions from soil, manure management, rice cultivation and livestock.
- **Waste** includes methane emissions from solid waste disposed to landfill and the treatment of domestic, commercial and industrial wastewater.
- **Land-use, land-use change and forestry** include emissions from burning forests and decaying unburnt vegetation, and from soil disturbed during land clearing. Emissions from these sources are offset partly by sequestration as vegetation regrows.

Source: Australian Government, 2008.

The most efficient, low-cost mechanism to reduce greenhouse gas emissions is to price emissions from all sources in all regions (Box 2.2). The Garnaut scenarios modelled as part of the Garnaut Climate Change Review explore this comprehensive framework. For the Carbon Pollution Reduction Scheme (CPRS) scenarios, the emissions trading scheme component outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper* was the primary domestic mitigation mechanism applied to Australia (Box 2.3) (DCC, 2008).

This report assumes that Australia links its emissions trading scheme into the world trading scheme. Australia is a small economy representing around 1.5 per cent of the world's emissions; consequently, the buying and selling of Australian emission permits is unlikely to materially affect the world emission price. If the number of international permits that can be used within Australia is not limited, the global emission price will drive the emission price in Australia (Baumert et al., 2005).

Individuals, firms, sectors and nations facing an emission price will have incentives to mitigate — that is, to reduce their production and consumption of emissions. For instance, electricity consumers will be encouraged to economise on their use of electricity; electricity producers will look for ways to become more efficient in their use of fossil fuels to generate electricity; and nations will look for options to move towards low or zero emissions sources of electricity.

Box 2.2: Market-based policy responses to climate change

From an economic perspective, climate change is a global 'externality'. The externality, a form of market failure, arises because those emitting the gases do not bear all the risks of adverse climate change impacts from emissions, but share them across the world.

As a result of this externality, the prices of goods, services and activities that generate emissions do not incorporate the costs of climate change, leading to an oversupply. This is an inefficient allocation of resources that does not maximise economic wellbeing when the risks of adverse climate change impacts are included. A similar externality is over-fishing, where individual decisions about how many fish to catch do not take account of the ability of fish stocks to reproduce, affecting others' ability to catch fish.

The most effective way to reduce risks of climate change at the lowest cost is to price emissions. Two market-based approaches would price emissions: first, a cap and trade system, where the amount of emissions is capped, and then rights to emit are traded in a market; and, second an emissions tax. By pricing emissions, the price of goods and services that generate emissions rises to better reflect their true costs. Pricing the externality improves the efficiency of the economy. The emission price balances the value of emissions in economic activity with climate change risk management objectives.

An emission price operates by increasing the price of emission-intensive goods relative to other forms of economic activity. This achieves the emission reduction goal at least cost by allowing individual firms and households to evaluate their options and decide whether to pay the emission price or reduce emissions by changing practices or consumption mixes. It also stimulates innovation to find new ways to do things without emissions.

Other policy options are available to reduce emissions, such as more command and control style regulations, that prescribe technology standards or ban certain types of activity that lead to emissions. However, these generally will be more costly than a market-based policy mechanism, because regulators do not have perfect knowledge of mitigation opportunities, costs, and preferences of firms and households. Non-market policies have often obscured less transparent costs and welfare consequences (Productivity Commission, 2008 and 2005).

As over time the world's greenhouse gas emission reduction objectives become more ambitious, the emission price is likely to rise, as relatively easier options to reduce emissions are exhausted, and individuals, firms, sectors and nations need incentives to undertake relatively more expensive mitigation options.

Just as the buying and selling of any commodity determines how that commodity is allocated among different economic activities and nations, the buying and selling of the right to emit will also determine how the world's allowable emissions are allocated among different types of economic activities at any time.

Some firms or nations will find it relatively easy to reduce emissions. They will likely sell their rights to emit to others engaged in other types of economic activity that find it relatively difficult to reduce emissions.

Given that Australia's emissions trading scheme is assumed to be linked into the international emissions trading scheme, this means that if Australia finds it more costly to reduce emissions than other economies, Australia can buy permits on the international market at the world emission price. Conversely, if mitigation opportunities in Australia are cheaper, Australia will sell permits to the world markets.

Box 2.3: Policy assumptions in the modelling

This report makes several assumptions about future Australian and international policy responses to climate change. These assumptions do not represent the Treasury's or the Australian Government's formal position or proposal. Rather, the assumptions explore the possible economic costs of responding to climate change.

Global stabilisation objectives modelled in the policy scenarios are not the bounds of 'acceptable' levels or judgments on what the world should aim for. Instead, the 450-550 ppm range draws on targets in literature and illustrates the implications of achieving different levels of emissions reductions.

The nature of the post-2012 global mitigation framework and possible Australia contributions to global efforts are being negotiated. The outcomes are impossible to predict. This report makes simplifying assumptions about global frameworks and the relative contributions of Australia and other nations.

The domestic policy assumptions for the CPRS scenarios come from the *Carbon Pollution Reduction Scheme Green Paper* (DCC, 2008). Where the Government's preferred position was not indicated, but the modelling required an assumption, this should not be taken as the Australian Government's formal position. The economic modelling in this report is one input into the Government's decision-making framework.

Policy assumptions are more fully discussed in Chapter 4 and Annex B.

2.2 MODELLING FRAMEWORK

Climate change operates over very long timeframes, with significant time lags projected between greenhouse gas emissions and resulting impacts. As a result, quantitative analysis of climate change must take a long-term view. This report makes projections to the year 2050, and in some scenarios, 2100. This difficult exercise requires assumptions for a wide range of economic, social and environmental variables which can change in unpredictable ways.

To make long-term projections and analyse greenhouse gas mitigation costs to Australia, this report uses economic models. Economic models mathematically represent how the economy operates and how various agents respond to changing signals. Economic models are a useful tool for exploring the costs of climate change mitigation, as they ensure internally consistent long-term projections of economic activity and the resulting greenhouse gas emissions.

The approach to estimating greenhouse gas mitigation costs to Australia is a two-step process.

First, the models are used to construct the reference scenario, which projects the future path of the world and Australian economies if new policies to reduce emissions are not introduced.

Second, the models are used to project several policy scenarios where the world reduces greenhouse emissions. The comparison of outcomes between the reference scenario and the policy scenarios shows the impact of emissions reduction policies on the Australian and global economies.

This report uses economic models to analyse climate change mitigation policy in Australia in four dimensions:

- **Global** — including the rate and pattern of economic growth, technology development and greenhouse gas emissions. This determines the magnitude of climate change that will occur, the scale of the global mitigation task, and the trade and capital flows affecting the Australian economy (Box 2.4).
- **National** — including the overall performance of the macroeconomy and patterns of growth across industry sectors and the states and territories.
- **Sectoral** — including likely technology developments and the timing and scale of opportunities to reduce energy use and greenhouse gas emissions.
- **Household** — including the impact on household prices, incomes and consumption.

Box 2.4: Australia as a part of international action

Achieving the United Nations Framework Convention on Climate Change goal of stabilising the atmospheric concentration of greenhouse gases requires that, in the long term, global emissions come down to the level that creates a balance with the Earth's natural capacity to remove greenhouse gases from the atmosphere. That capacity is currently estimated to be significantly less than half of current emission levels.[2]

Accordingly, global action to reduce emissions is required. Australia, which accounted for around 1.5 per cent of total world emissions in 2000[3] (Baumert et al, 2005) and around 1.4 per cent of global CO_2 emissions from energy (Table 2.1), will contribute to any concerted global effort. Accordingly, the analysis of the impacts of Australia reducing emissions is nested in the context of a global mitigation effort.

Table 2.1: CO_2 emissions from energy, 2005

	Emissions			Emissions per capita	
	Mt CO_2	Rank	Per cent	tCO_2/person	Rank
United States	5,817	1	21.4	19.6	7
China	5,060	2	18.6	3.9	66
India	1,147	5	4.2	1.0	101
Australia	377	14	1.4	18.4	8
World	27,136			4.2	

Source: International Energy Agency, 2007.

2 Recent evidence suggests that the efficiency of natural emission sinks (such as forests, soils and the ocean) is declining, so that if emission reductions are delayed, deeper cuts will be required to achieve stabilisation (Canadell et al., 2007).

3 This includes the greenhouse gases covered by the Kyoto Protocol: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6.

2.2.1 The suite of models approach

No single existing model adequately captures the global, national, sectoral and household dimensions or focuses on all relevant aspects of climate change policy in Australia. Previous Australian studies of climate change mitigation policy focus on one or other of these dimensions — a particular sector (for example, electricity generation) in isolation from the broader national economy, or on the national economy but without a consistent global analysis. In contrast, this analysis uses a suite of models that together span global, national, sectoral and household scales to simultaneously explore these four dimensions.

The following section briefly describes the range of models used in this report. (See Annex A for more detail, including modifications made to the models and the process used for linking models.)

Computable general equilibrium models

The Treasury's climate change mitigation policy modelling is centred on three top-down, computable general equilibrium (CGE) models developed in Australia: Global Trade and Environment Model (GTEM); G-Cubed model; and the Monash Multi-Regional Forecasting (MMRF) model. These CGE models are whole-of-economy models that capture the interactions between different sectors of the economy. GTEM and G-Cubed are models of the global economy; whereas, MMRF is a model of the Australian economy with state and territory level detail.

GTEM: a technology-rich global model

GTEM is a recursively dynamic general equilibrium model developed by the Australian Bureau of Agricultural and Resource Economics (ABARE) to address policy issues with long-term global dimensions, such as climate change mitigation costs (Pant, 2007).[4] It is derived from the MEGABARE model (ABARE, 1996) and the static Global Trade Analysis Project (GTAP) model (Hertel, 1997). The dimension of GTEM used for this report represents the global economy through 13 regions (including Australia, the United States, China and India) and 19 industry sectors. The model also disaggregates three energy-intensive sectors into specific technologies: electricity generation, transport and iron and steel.

G-Cubed: a forward-looking global model with macro dynamics

G-Cubed is a model of the global economy designed for climate policy mitigation cost analysis (McKibbin and Wilcoxen, 1998). The version used for this report represents the global economy through nine regions (including Australia, the United States and China) and 12 industry sectors (including coal, oil, gas, agriculture and manufacturing). An important characteristic of G-Cubed is that economic agents are partly forward-looking: they make decisions based not only on the present day economic situation, but also based on expectations of the future. G-Cubed has limited technology detail.

MMRF: a detailed model of Australia

The Monash Multi-Regional Forecasting (MMRF) model is a detailed model of the Australian economy developed by the Centre of Policy Studies at Monash University (Adams et al., 2008).

4 A recursively dynamic model solves for equilibrium in each year without taking account of information about the future.

MMRF has rich industry detail (with 58 industrial sectors) and provides results for all eight states and territories. In this modelling exercise, MMRF draws international assumptions from GTEM and is augmented with disaggregated bottom-up modelling for three emission-intensive sectors: electricity, transport and forestry.

Sectoral models

The CGE models are complemented by a series of bottom-up sector specific models for electricity generation, transport, land use change and forestry. Detailed analysis of these emission-intensive sectors is useful in understanding the economy's likely response to climate change mitigation policy, particularly over the short to medium term.

Detailed analysis which relies on current views about technology is generally less robust over the long term, as technology and other mitigation opportunities become more uncertain. As a result, bottom-up modelling of the transport and electricity sectors is limited to 2050. However, technology plays a much smaller role in land use change and forestry emissions, so analysis of this goes to 2100.

Electricity sector modelling

McLennan Magasanik Associates provides detailed bottom-up modelling of the Australian electricity generation sector with projections of electricity generation by technology and by state, fuel use, new investments and retirements, and electricity prices (McLennan Magasanik Associates, 2008). The highly detailed models aim to closely represent actual market conditions and take account of the economic relationships between individual generating plants in the system, with each power plant divided into generating units, defined by their technical and cost profiles.

A range of fuels and technologies are incorporated, including black and brown coal, natural gas, renewables (including hydro, biomass, solar and wind) as well as new technologies, such as carbon capture and storage and geothermal. Electricity demand is modelled on an hourly and monthly basis to capture the daily and seasonal fluctuations in energy use.

Transportation sector modelling

Australian transport sector modelling was conducted with CSIRO in conjunction with the Bureau of Infrastructure, Transport and Regional Economics (BITRE). CSIRO use a partial equilibrium model, the Energy Sector Model (ESM), of the Australian energy sector which includes detailed transport sector representation (CSIRO, 2008). The ESM was co-developed by CSIRO and ABARE in 2006. The model has an economic decision-making framework based around the cost of alternative fuels and vehicles. It incorporates detailed information about technical fuel and vehicle technical characterisation.

The model evaluates the uptake of different technologies based on cost competitiveness, practical constraints in transport markets, current excise and mandated fuel-mix legislation, greenhouse gas emission limits, each state's existing plant and vehicle stock, and lead times in the availability of new vehicles or plant.

Land use, land use change and forestry

The Treasury commissioned modelling of the forestry sector from ABARE (for Australia) and from Lawrence Berkeley National Laboratory (for the rest of the world).

ABARE's modelling examines the impact of an emission price on forestry and land-use change in the Australian agriculture sector (ABARE, 2008). The framework used is spatially explicit, and involves analysing the opportunities for emission sequestration provided by land use change and forestry on cleared agricultural land. These opportunities are determined when the net present value of returns from forestry investments are compared to the corresponding expected agricultural land value to estimate the potential area of clear agricultural land that is competitive for forestry within each spatial grid cell.

The Lawrence Berkeley National Laboratory uses its GCOMAP model (Sathaye et al., 2006). GCOMAP simulates how forest land users respond to changes in prices in forest land and products and to emission prices. GCOMAP calculations of net change in emission stocks associated with land use change and forestry were incorporated into GTEM and G-Cubed.

Other sectors

Sectors other than electricity, transport and land use change and forestry were modelled within the CGE models. Assumptions about mitigation options for these sectors were informed by historical data, stakeholder consultations and literature reviews.

Households modelling

Modelling of the impact of the emission price on households and the consumer price index is undertaken with the Treasury's Price Revenue Incidence Simulation Model (PRISMOD). PRISMOD is a large-scale, highly disaggregated model of the Australian economy which captures the flows of goods between industries and final consumers. The data used in PRISMOD comprise the transactions and consumption patterns of 109 industry categories and seven categories of final demand. The 2008 version of PRISMOD is based on data from the ABS (2008) publication *Australian National Accounts, Input-Output Tables 2004-05,* (Cat. no. 5209.0.55.001).

This distributional implication for households of emission pricing was analysed using Treasury's Price Revenue Incidence Simulation Model and Distribution Model (PRISMOD.DIST). This model is a static micro simulation model which can be used to examine the distributional effects of government policies on household income. The 2008 version of the model is based on data from the ABS (2006) publication *Household Expenditure Survey 2003-04*, (Cat. no. 6540.0).

2.2.2 Integrating the models

The results from each of these models are drawn together into an integrated set of projections that are broadly consistent at the macroeconomic level and sufficiently detailed in large emission-intensive sectors (Chart 2.1).

Modelling of the global economy with GTEM and global land use change and forestry with GCOMAP provides the international economic and emissions context for modelling of the Australian economy within MMRF, which in turn is informed by the bottom-up modelling of the electricity, transport and land use and forestry sectors. G-Cubed is broadly calibrated to the GTEM reference scenario, and provides comparative cost estimates for the policy scenarios, strongly emphasising the macroeconomic adjustment process.

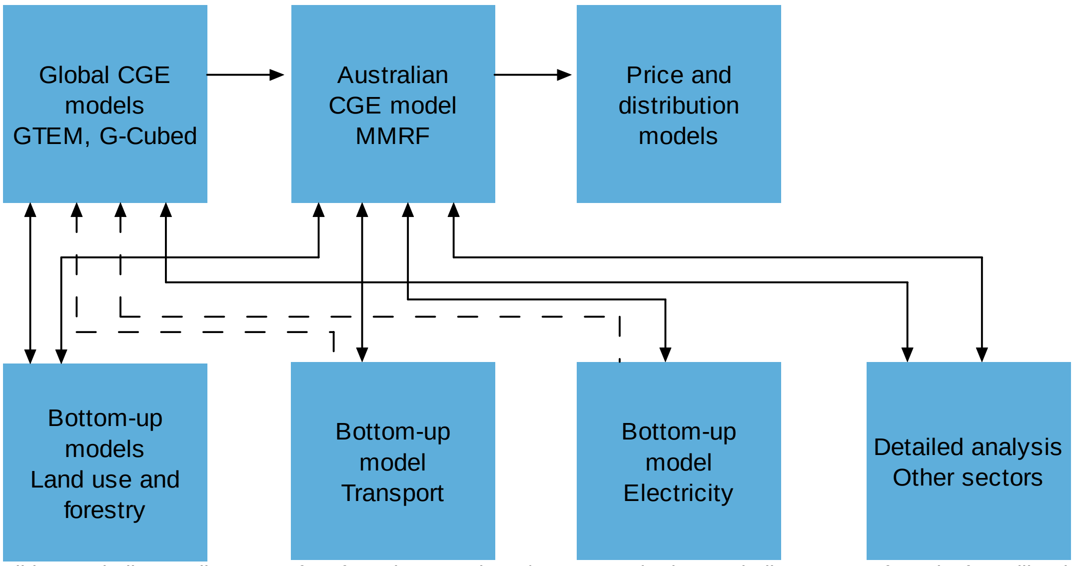
Linking economics models with different economic structures is not straightforward. The report team undertook significant research to ensure the models in the 'suite of models' were linked sensibly.

For example, MMRF and GTEM both have internally consistent, but different, assumptions about the supply responsiveness of Australian exports. Harmonising the structural features of the models for this exercise was not possible or desirable. However, MMRF requires input assumptions about world demand and price responses to determine shifts in its export demand schedules. This required careful linking to ensure the world demand curve determined within GTEM was made into an appropriate input for MMRF.

Similarly, ensuring that the bottom-up electricity (and transport) supply side information was correctly integrated within MMRF often required several iterations. The initial level of electricity (transport) demand was determined within MMRF. The level of demand, combined with emission prices and other input assumptions, then were inputted into the bottom-up supply side models. The detailed supply side information such as technology shares and price levels was fed back into MMRF, which then modelled a new level of demand. This feedback loop was continued until the changes in demand were minimal.

However, some models were relatively easy to link as they took outputs from one model to provide additional detail. For example, PRISMOD was used to determine a highly disaggregated set of industry price impacts from a certain emission price. This information was then fed into PRISMOD.DIST, which captured the distributional implications for households.

Chart 2.1: Integrating the suite of models



Note: Solid arrow indicates direct transfer of results as an input/output. Dashed arrow indicates use of results for calibration.

Using a suite of models provides a natural hedge against the inherent uncertainty of economic modelling. While input assumptions, as much as possible, have been harmonised across GTEM, G-Cubed and MMRF, the projections in the three models generated for Australia are not identical. The differences arise primarily from the different structures of the models, and these differences demonstrate the uncertainty surrounding modelling estimates.

To ensure that this report remains tractable, most Australian results are from MMRF in the first instance. However, where the Australian results determined in the global models differ significantly, or provide additional insights, these are provided for comparison. Similarly, the global results — including Australia as a region of the world — are from GTEM, with comparative analysis from G-Cubed. Where the bottom-up models provide insights, these results are given primacy.

2.3 How to interpret the results

To estimate the macroeconomic, sectoral and household impacts to Australia of reducing emissions, this report uses a range of economic and other models to project five scenarios for Australia and the world to 2050, and in three of these scenarios, to 2100. As with all modelling assessments, caveats need to be kept in mind when interpreting the results. Despite these limitations, models continue to be important analytical tools to help questions and answer questions relevant to long-term economic policies.

The scenarios analysed in this report, including the reference scenario, are illustrative and do not represent the official policy or negotiating position of the Australian Government, are not an official Government or Treasury forecast.

2.3.1 Scenario modelling

This report estimated the costs of reducing emissions by modelling five scenarios. Scenario modelling does not predict what *will* happen in the future. Rather, it is an assessment of what *could* happen in the future, given the structure of the models and input assumptions.

Scenarios are an analytical lens through which to view a problem; they are not the 'real world', especially as this exercise assumes no new mitigation policy and no climate change impacts. Scenarios guide understanding of the impacts of policy, the relativities between different policy options, and the extent to which development paths (technology, preferences and so on) need to shift from current trends.

Input and policy assumptions are particularly important. Many important variables affect the estimated cost of responding to climate change. The future path of these variables is not known, but values are required for the modelling analysis, so assumptions must be made.

The Treasury developed these assumptions through research, through consultation with stakeholders and domestic and international experts, and on the basis of expert consultancies. While they intend to be plausible central estimates within a range of uncertainty, other analysts could well form different judgments.

For instance, the assumptions underpinning the reference scenario determine the level of baseline emissions which is a major (and perhaps the single biggest) determinant of the estimated costs of mitigation, as it determines the magnitude of emissions reductions required (IPCC 2007b; den Elzen et al., 2007; Stern, 2007). To the extent that the reference scenario over (or under) estimates emissions, all else equal, the costs of mitigation are over (or under) estimated.

Equally, the policy scenarios assume that the world implements emissions reduction arrangements through a global emissions trading scheme. While the international emissions trading scheme is an analytical proxy for the mix of policy instruments that are likely to be deployed, such an 'optimal' policy mechanism, with complete coverage of regions, gases and emissions sources, tends to give lower cost estimates than a less efficient global arrangement (Box 2.5, Stern, 2007). For instance, a global emissions trading scheme with only partial coverage of regions could increase costs for achieving the same environmental objective, as it prevents access to low-cost abatement in non-participant regions.

Box 2.5: Measuring emissions

Carbon dioxide (CO_2) the most important anthropogenic greenhouse gas, accounts for around three quarters of global emissions (IPCC, 2007a). Other important gases include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF_6).

This report expresses emissions and emissions pathways in CO_2-equivalent (CO_2-e), which aggregates the different gases based on their relative warming potential. The CO_2-e emission values indicate total emissions of the six gases covered under the Kyoto Protocol, from all sources, combined using the 100-year global warming potentials applied under the Protocol. While the global warming potential concept is the subject of scientific debate (IPCC, 2007a), this is a convenient and widely used measure, and is embedded in the structure of the models used in this report.

The atmospheric concentration levels presented in this report are not calculated using global warming potentials. The concentrations are calculated directly from the combined radiative forcing of the six Kyoto gases using the simple climate model MAGICC.[5]

The inherent difficulty in developing assumptions and undertaking simulations is compounded by the long timeframes involved (Box 2.6). As the model looks further into the future, historical information used to build the model or provide input assumptions becomes less robust. While different models are more useful over different timeframes, generally the further into the future the projections extend, the greater the caution required in interpreting results. For this reason, while the modelling continues to 2100 for the Garnaut scenarios, the focus of long-term results is generally 2050 in this report.

Given all the uncertainties about future variables, the Treasury has explored several sensitivities around the reference scenario and the policy scenarios.

5 Model for the Assessment of Greenhouse Gas Induced Climate Change (Wigley, 2008).

Box 2.6: Projections over long timeframes

Climate change operates over very long timeframes, with significant time lags between greenhouse gas emissions and resulting impacts. As a result, quantitative analysis of climate change must take a long-term view.

As the timeframe expands, assumptions necessarily become more speculative. Just as it would have been impossible to accurately foresee the current state of the world in 1908, it is today impossible to accurately foresee the state of the world in 2100.

For instance, 1908 saw the beginning of the popular use of cars with production of the Model T Ford. The first two-person plane flew in May of that year, but the first flight of Qantas was still 12 years away. Australia's GDP per capita was around the same level as China's today. Bendigo was the seventh largest city in Australia. Less than 3 per cent of Australian imports came from Asia. The largest occupation was agriculture, making up over 15 per cent of employment (Commonwealth Bureau of Consensus and Statistics, 1908). Who at that time could have predicted developments such as the internet, containerised shipping or modern air freight?

Results therefore must be interpreted with caution. The economic and greenhouse gas emission projections presented here are not forecasts or predictions. The results illustrate a scenario, constructed to allow analysis of the possible economic impacts of policies to reduce greenhouse gas emissions.

2.3.2 How to measure costs?

The modelling underpinning this report encompasses many variables that could be used as measures of economic cost.

Measuring economic output

This report focuses on gross national product (GNP) as the high level measure of economic welfare impact rather than gross domestic product (GDP). GNP reflects changes in GDP, terms of trade and international income transfers. Reducing greenhouse emissions, in a least-cost efficient way, may involve the transfers of income between economies, and influence nations' terms of trade. In that context, GNP is a better measure of welfare, as it excludes income accruing to overseas residents, thereby better depicting the current and future consumption possibilities available to Australians; it measures what a nation can afford to buy.

Likewise, different measures indicate the output of an industry or economy. Two common definitions are gross value added (GVA) and gross output. GVA measures the returns accruing to the owners of the primary factors such as land, labour and capital used in the production process plus taxes less subsidies on production. GDP is the sum of GVA across industries. Gross output is the value of output produced by an industry — the value of inputs produced by other industries used in the production process (intermediate inputs) plus GVA and any taxes less subsidies on production. Gross output is a measure of turnover or activity. The most appropriate measure of output will vary with context. GVA provides an indication of the contribution that an industry makes to national economic activity as it excludes the value of inputs produced by other industries. Gross output is important for emissions analysis as emissions are created during the production process.

After a relative price change, gross output and GVA can move in different directions. Introducing emission pricing results in substantial substitution between intermediate inputs and primary factors, driving a wedge between these two measures. Value added by industry sums to GDP, and thus is a good measure of the 'economic impact' of an emission price. However, gross output is an important concept in the modelling, as a substantial share of emissions is produced in the production process and substitution among intermediate inputs is an important part of the transformation in response to an emission price.

All gross world product (GWP) and regional comparisons of gross domestic product (GDP) levels and growth rates in this report are reported in 2005 US dollar purchasing power parity terms (Box 2.7).

Box 2.7: Market exchange rate versus purchasing power parity

The market exchange rate (MER) is the rate of exchange between currencies in foreign exchange markets in the 'real world'. In contrast, purchasing power parity (PPP) exchange rates are hypothetical exchange rates that adjust for differences in prices levels across countries. Under a PPP exchange rate, one Australian dollar buys the same amount of goods and services in every country: no more, no less.

The MER/PPP debate is about which exchange rate is more appropriate for converting different countries' GDP into a single currency (usually US dollars) to make economic comparisons and growth projections. The choice of measurement method significantly affects the validity of economic growth projections and energy use and, hence, projections of future climate change (Castles and Henderson, 2003).

PPP exchange rates take into account the different price levels across countries, so they more accurately describe relative standards of living between the developed and developing world. In contrast, MER valuations undervalue developing economies relative to developed economies, so they overstate GDP gaps.

The MER/PPP debate is important for productivity convergence assumptions, as overstating income gaps will overstate economic growth in developing countries. This assumption is also important for estimates of global mitigation costs: cost estimates based on MER exchange rates tend to understate global abatement costs. Accordingly, whether modelling uses MER or PPP exchange rates is important in comparing costs estimates between models.

All national and trade accounts in the models in this report use MER data. However, global aggregate labour productivity assumptions were derived using PPP data. Using PPP data to compare starting level income per capita ensures that the level of developed economies' GDP is not under-estimated. Sector-specific productivity assumptions result in productivity growth being faster in tradable than in non-tradable industries. These differences lead to an appreciation of the real exchange rate through the Baumol-Balassa-Samuelson effect. Along with the conditional convergence framework, these productivity assumptions suggest the PPP and MER exchange rates converge over time, reducing the implications of the MER data used in the CGE models (Bagnoli, Chateau and Sahin, 2006).

Presenting cost estimates

As with any quantitative analysis, care needs to be used when reporting and interpreting modelling results. Statistics and numbers can mean different things when reported within different contexts.

For example, discussing results relative to a hypothetical future such as the reference scenario is the more common way of explaining the impact of a policy intervention within an economic model. This is a sensible approach when attempting to see how the policy will influence the economy in isolation from other events. However, a focus on the opportunity cost of a policy could give rise to a reference point bias where people believe the loss is relative to current levels rather than a forgone gain through smaller increases in future incomes.

Therefore, results reported in this way must not be interpreted as suggesting that policy will have an absolute impact relative to the current world. For example, if cutting interest rates would raise economic growth by 1 percentage point relative to what would have happened otherwise, this should not be interpreted as saying that the economy will fall by 1 per cent from its current levels.

Furthermore, empirical research indicates some economic cost measures could be commonly misunderstood and public attitudes to action on climate change are significantly affected by how these costs are communicated (Hatfield-Dodds, 2006; Morrison, 2008).

To represent as complete a picture as possible of the economic implications of reducing greenhouse emissions, this report presents a range of measures when reporting high level results (Box 2.8).

Discount rates and inflation

Discount rates in climate change policy are highly topical (Quiggin, 1996; Nordhaus, 2007; and Stern, 2007). They are used to compare estimates of the costs and benefits of climate change mitigation over long timeframes.

This report only focuses on the costs of mitigation, not the benefits, so the debate about discount rates is not important here. The modelling shows the costs of mitigation as they happen in that year. In other words, a loss of one dollar in 2050 is equivalent to a loss of one dollar in 2010, which is akin to assuming a zero discount rate. If, however, these modelling results are used to judge the importance of future costs from today's perspective, this would require a consideration of discount rates.

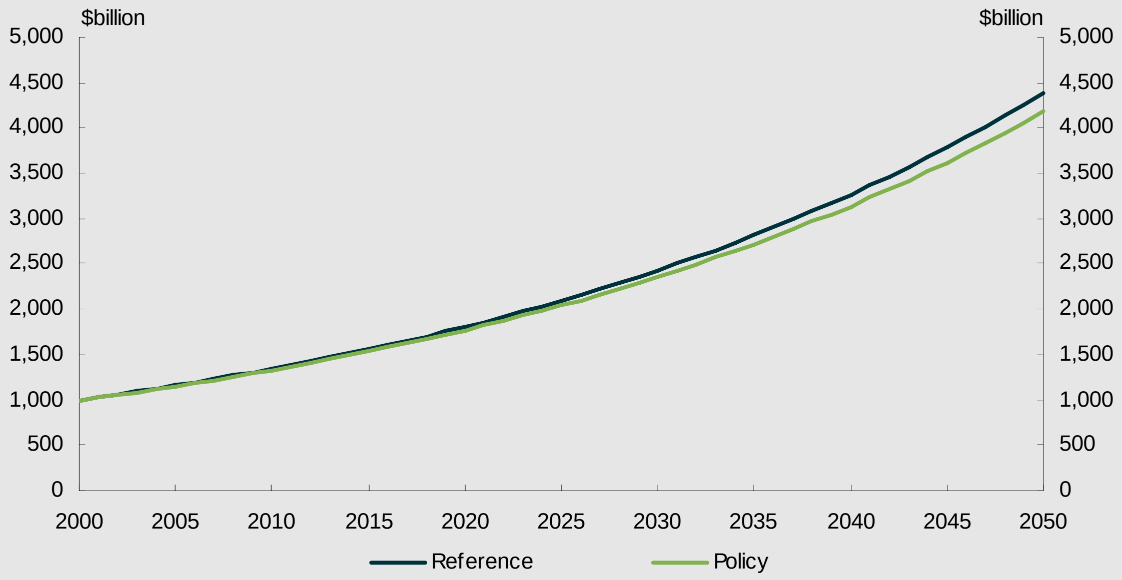
Box 2.8: Alternative way to report on modelling — a hypothetical example

The same modelling results reported differently can convey different impressions to non-experts. For instance, Chart 2.2 presents the impact on GDP of a policy scenario on a hypothetical economy where under a reference scenario the economy grows from $1,000 billion in 2000 to nearly $4,500 billion by 2050.

These six statements describe the 'cost' of the policy scenario relative to the reference scenario. They all report exactly the same result.

- GDP growth is 0.1 per cent per year lower over 50 years.
- GDP is $208 billion lower at 2050.
- GDP is 4.7 per cent lower at 2050.
- The cumulative GDP loss is $3,485 billion over 50 years.
- The cumulative GDP loss is 3 per cent of total GDP over 50 years.
- GDP is 4.4 times higher than 2000 levels in 2052 instead of in 2050, a delay of two years.

Chart 2.2: GDP — hypothetical reference and policy scenarios



In addition, the CGE models are all in 'real' dollars, and thus abstract from the devaluing influence on purchasing power from inflation.

Across the suite of models used in this report are a range of databases, all with their own base years when prices are set equal to one. For example, GTEM has a base year of 2001; MMRF has a base year of 2005; and G-Cubed has a base year of 2006. To compare real variables across models, the data were adjusted to the same base years.

Emission prices can be reported in different units. Nominal emission prices include the impact of inflation on prices. When an emission price is reported in nominal terms, such as A$23 in 2010, this would be the actual nominal price of a permit in 2010 using the dollars available in 2010. Often, to abstract from inflation, emission prices are referred to in base year prices: for example, an emission price of A$20 in 2010, in 2005 prices. This reflects the purchasing power of A$20 in 2005 dollars. Emission prices in this report are reported in both measures, depending on the context, and are clearly labelled.

2.3.3 Model limitations and uncertainties

Economic models are always an approximation, or simplified version, of the vastly complex real world. Thus, models always have limitations. The models used in this exercise have high level limitations; this affects the interpretation of results. However, despite their limitations, models examine complex issues rigorously and in an internally consistent way across long timeframes.

The models used for this exercise are aggregated models. The least aggregated is PRISMOD, which has 109 industries. Aggregation is a necessary simplification of the real economy owing to limitations in data and in computing power. In industries where the firms are reasonably homogenous, with similar patterns of inputs and emissions intensity, this simplification has little effect. But in industries where firms have different, sometimes dramatically different, patterns of inputs and emissions intensity this simplification will reduce the accuracy of the modelling and the results.

The models exclude the risks and impacts of climate change itself. This means that mitigation policies are assumed to impose a 'cost' by moving the economy away from its 'optimal' economic path in the reference scenario to a 'less efficient' economic structure. This result requires careful interpretation: in an economic sense, mitigation policy improves the efficiency of the economy by pricing the externality associated with emissions (Box 2.2). The costs presented in this report need to be considered in the context of broader benefits of mitigation action, including the economic benefits of reduced risks and impacts of climate change (Stern, 2007; Garnaut, 2008).

The models do not capture well the short-term economic adjustment costs; instead, they explore long-term multi-sector impacts. To different degrees, the CGE models approximate short-term adjustment paths. At one end of the spectrum, GTEM assumes that labour and capital are perfectly mobile across industries, at all times and at no cost. Thus, GTEM does not capture any short-term adjustment costs. At the other end of the spectrum, G-Cubed assumes immobility of capital, slow adjustments to wages and liquidity constraints, and includes partial forward-looking behaviour. MMRF assumes capital and labour take time to adjust, but does not attach any cost to that adjustment process. The CGE models, therefore, provide a more robust analysis of the post-transition economy than of the transitional process. The bottom-up models do provide some insights into the adjustment process electricity generation and transport sectors.

The models do not capture market failures caused by asymmetric information, strategic interaction between agents, public goods and externalities.

The models do make some allowance for learning to reduce the cost of some technologies. However, the industry-level technological pathways are exogenous in the CGE models. For example, an increase in the scale of adoption of renewable technologies in electricity generation sector results in faster capital cost reductions. The models used in this report do not allow for endogenous economy-wide technological improvements, or for development of a 'backstop' technology.[6] The sensitivity of the results to alternative technology assumptions are explored in the sensitivity analysis.

The models do not capture transaction costs associated with emission permit allocation, whether domestically or internationally. In the real world, transaction costs will be associated with implementing and monitoring emission markets, and search costs associated with identifying mitigation opportunities. These costs may be particularly high in some developing economies, where the legal and regulatory regimes required for efficient market operation are not yet established.

The models do not capture the potential co-benefits of climate change mitigation policy. In some circumstances, co-benefits can occur between mitigation policy and other environmental objectives. For example, the simultaneous reduction in local and regional air pollution, alongside a reduction in greenhouse emission from coal burning.

The models do not capture non-market goods and services. In addition to reducing the risks of climate change, mitigation policies will affect other non-market values. Non-market benefits include improved health outcomes and lower urban pollution stemming from reductions in petroleum fuel use in road transport; non-market costs include the personal impacts of changing employment and relocation arising from structural adjustment.

6 A 'backstop' technology provides an unlimited amount of emissions mitigation at a given cost. It effectively acts as a global ceiling on the emission price.

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