An Emissions Trading Scheme for Australia: National and Regional Impacts

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Abstract

Computable general equilibrium modelling in Australia is oriented towards providing inputs to the policy-formation process, a process that requires detail. We explain how the necessary level of detail can be provided using analysis of the potential economic impacts of a carbon price on the Australian economy that operates as part of a global emissions trading scheme. The global scheme sets the price and allocation of permits across countries. We find that domestic abatement falls well short of targeted abatement, Australia's GDP is 1.1% lower relative to the basecase, and some industries and regions are vulnerable to employment losses.

i

Table of contents

Tables

Figures

1. Introduction

Computable general equilibrium (CGE) modelling in Australia is oriented towards providing inputs to the policy-formation process. This reflects the dominant involvement of the Australian Government and its agencies in the history of CGE research funding, which began with the IMPACT Project, now the Centre of Policy Studies (CoPS), in 1975. Universities, principally Monash University, have also played an important role in the development of CGE models but the focus of the work has always been as much on practical application of the models as on contributing to the academic literature. Policy makers require detail to be able to identify convincingly how industries, occupations, households and regions are affected by policy changes. Economic theory or abstract general-equilibrium analysis is not well suited to providing the necessary level of detail. But combining theory in a CGE framework with disaggregated input-output data, labour-force survey statistics, data on the sectoral composition of regions, and household income and expenditure data provides the tool that policy makers require.

Starting in the early 1990s, greenhouse-gas emissions, global warming and climate change emerged as prime policy concerns in Australia, culminating in 2007 with the Australian government's decision to ratify the Kyoto Protocol and to attempt to introduce a greenhouse-gas emissions trading scheme. CGE modelling has played a prominent role in informing Australia's emissions-policy debate.[1] As in earlier key policy debates, such as trade liberalisation, detail has been a key issue for economic modellers engaged in the emissions policy debate. In this context, modellers face a number of questions relating to model, data and simulation design.

- Stationary energy (i.e., electricity) accounts for more than 50% of Australia's greenhouse-gas emissions. At what level of detail must the stationary-energy sector be modelled for the effects of policy on its emissions to be captured adequately?

- Investment in electricity generation is typically lumpy. Is it necessary to include this lumpiness explicitly in CGE computations of the effects of climate-change policy? To what aspects of the results does lumpiness matter?

- Greenhouse-gas emissions are a global externality. Does this mean that the consequences of emissions policy can only be investigated using a global model, especially given that the domestic effects of a country's policy will depend on actions by other countries?

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[1] Academic contributions started with Dixon *et al.* (1990) and Dixon and Johnson (1993), followed by McDougall and Dixon (1996) and McKibbin and Pearce (1996).

- Emissions policy is long term, with the underlying global externality and many abatement options involving complex dynamics. What dynamic mechanisms are required for CGE models to make a meaningful input to decisions about emissions policy?

- The possibility of international emissions leakage is a problem that proponents of unilateral emissions policy must face. What representation of a country's emission-intensive trade-exposed industries is required to handle this?

- Emission-intensive industries tend to be geographically concentrated, due mainly to the availability of primary energy sources; therefore emissions policy could have significant regional effects. How can policy models inform policy makers about such effects?

- Carbon taxes and most emissions trading schemes (ETSs) would raise large amounts of government revenue and increase consumer prices. To understand how these affect the efficiency costs of the policy and income distribution requires a model with a detailed representation of the country's fiscal system and the ability to identify the income-distribution consequences of policy options.

Here we explain how these issues have been handled by Australian CGE modellers. This is illustrated using analysis of the potential impacts on the Australian economy of a carbon-price policy outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper* (Department of Climate Change, 2008; Department of Treasury, 2008) and the Garnaut Climate Change Review (Garnaut, 2008). The policy is assumed to apply as part of a global ETS. Over time, the global ETS becomes the dominant emissions abatement policy for all countries, including Australia. Since the announcement of the Government's proposed ETS in 2008, global and domestic policy has not developed in way assumed under the scheme. There has not been a gradual spreading of ETS schemes from the EU to other countries. In Australia, an ETS was not introduced in 2010 as planned; instead, a carbon tax was introduced in 2012. Regardless, it is still possible that a scheme resembling that identified in the Government's *Green Paper* may eventually be implemented. To the extent that current and future policy settings diverge from the scheme analysed here, there may also be a divergence of the modelled outcomes. We identify some of these possible divergences in our analysis.

The analysis of the Government's proposed ETS relies on a series of applications of three CGE models developed in Australia: the Global Trade and Environment Model (GTEM) (Pant,

2007); the G-Cubed model (McKibbin and Wilcoxen, 1998); and the Monash Multi-Regional Forecasting model (MMRF) (Adams *et al.,* 2011).[2] GTEM and G-Cubed are multi-country models; MMRF is a single-country multi-regional model of Australia. Much of the modelling of the global aspects of the ETS was undertaken using the GTEM model. Information from GTEM was then used to inform simulations of MMRF.[3] The role of MMRF was to supply estimates of the effects of the scheme on the Australian economy at the level of detail required by the policy makers. A key dimension was detail about the electricity system. For this purpose, MMRF was linked to a bottom-up model of the Australian electricity system: Frontier Economics's WHIRLYGIG (Frontier Economics, 2009). Below we describe the MMRF model and the enhancements that were necessary for the ETS modelling. We also describe aspects of simulation design and the exogenous shocks that drive the policy simulations.

We explain three dimensions of the effects of the proposed ETS: national outcomes, industry outcomes, and state and territory outcomes. We find a negative impact on national economic activity (i.e., real GDP); this is due to a fall in the use of production factors (due to a fall in the capital stock) and a fall in the efficiency with which production factors are used (i.e., a contraction in the base upon which net indirect taxes are levied). These changes work through three channels. One, to achieve the emissions target Australia must import and pay for a large volume of emissions permits from overseas. Two, the ETS places a price on international emissions and world demand for coal falls, reducing Australia's largest export. Three, the ETS causes a fall in emissions, the production and consumption of petroleum products and total consumption by households.

Although the ETS may reduce future global climate change and hence lead to potential economic benefits for Australia, these are not captured in the modelling presented here. There are several reasons for this. One, while the costs of the Government's ETS are largely an issue for economic analysis, the benefits are heavily dependent on physical-scientific analysis. Two, the magnitude of the benefits is more uncertain than the magnitude of the costs. Three, since 2008 little progress has been made in implementing a global ETS so the reduction in global emissions assumed in Government's ETS, and the associated benefits, remain a matter for conjecture. In contrast, a carbon tax was introduced in 2012, so the costs are real.

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[2] MMRF and GTEM are solved using GEMPACK software (Harrison and Pearson, 1996).

[3] G-Cubed was broadly calibrated to the GTEM basecase scenario, and provided comparative global cost estimates for the policy scenarios based on different rate-of-adjustment assumptions for global capital markets.

2. The MMRF model

2.1 Overview

MMRF is a dynamic, multi-sector, multi-region model of Australia. It distinguishes 58 industries, 63 products and 8 regions representing the states and territories (Table 1). Each regional economy is a fully-specified bottom-up system that interacts with other regional economies. Of key importance to modelling an ETS, three industries produce primary fuels (coal, oil and gas), one produces refined fuel (petroleum products), six generate electricity and one supplies electricity to final users. The six generation industries are defined according to primary source of fuel: *Electricity generation – coal* includes all coal-fired generation technologies; *Electricity generation – gas* includes all gas-fired generation technologies; *Electricity generation – oil products* covers all liquid-fuel generators; *Electricity generation – hydro* covers hydro generation; and *Electricity generation – other renewable* covers renewable generation from biomass, biogas, wind, etc. Apart from *Grains* and *Petroleum products*, industries produce single products. *Grains* produces grains for animal and human consumption and biofuel used as feedstock by *Petroleum products*. *Petroleum products* produces gasoline (including gasoline-based biofuel blends), diesel (including diesel-based biofuel blends), LPG, aviation fuel, and other refinery products (mainly heating oil).

2.2 General equilibrium core

2.2.1 The nature of markets

MMRF determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders in response to relative regional employment opportunities and relative rates of return.

The assumption of competitive markets implies equality between the supply price (the price received by the producer) and marginal cost in each regional sector. Demand is assumed to equal supply in all markets other than the labour market. The government intervenes in markets by imposing *ad valorem* sales taxes on commodities. This places wedges between the prices paid by purchasers and the prices received by producers. The model recognises margin commodities (e.g., retail trade and road transport) that are required for the movement of commodities from

producers to purchasers. The costs of margins are included in purchasers' prices of goods and services.

2.2.2 Demands for inputs used in the production of commodities

MMRF recognises two broad categories of production inputs: intermediate inputs and primary factors. Firms in each regional sector are assumed to choose the mix of inputs that minimises the costs of production for their levels of output. They are constrained in their choices by a three-level nested production technology. At the first level, intermediate-input bundles and a primary-factor bundle are used in fixed proportions to output. These bundles are formed at the second level. Intermediate-input bundles are constant-elasticity-of-substitution (CES) combinations of domestic goods and goods imported from overseas. The primary-factor bundle is a CES combination of labour, capital and land. At the third level, inputs of domestic goods are formed as CES combinations of goods sourced from each of the eight domestic regions, and the input of labour is formed as a CES combination of inputs from nine occupations.

2.2.3 Domestic final demand: household consumption, investment and government

In each region, the household buys bundles of goods to maximise a utility function subject to an expenditure constraint. The bundles are CES combinations of imported and domestic goods, with domestic goods being CES combinations of goods from each domestic region. A Keynesian consumption function determines aggregate household expenditure as a function of household disposable income (HDI). Capital creators for each regional sector combine inputs to form units of capital. In doing so, they minimise costs subject to a technology similar to that used for current production, with the main difference being that they do not use primary factors directly. Regional governments and the Federal government demand commodities from each region.

2.2.4 Foreign demand

MMRF adopts the ORANI (Dixon *et al.,* 1982) specification of foreign demand. Each regional sector faces its own downward-sloping foreign demand curve. Thus, a shock that reduces the unit costs of an export sector will increase the quantity exported but reduce the foreign-currency price. By assuming that foreign demand schedules are specific to product and

region of production, the model allows for differential movements in foreign-currency prices across domestic regions.

2.2.5 Regional labour markets

The response of regional labour markets to policy shocks depends on the treatment of three variables – regional labour supplies, regional unemployment rates and regional wage differentials. In this work, regional wage differentials and regional unemployment rates are set exogenously and regional labour supplies are determined endogenously (via interstate migration or changes in regional participation rates). Under this treatment, workers move freely (and instantaneously) across state borders in response to changes in relative regional unemployment rates. With regional wage rates indexed to the national wage rate, regional employment is demand determined.

2.2.6 Physical capital accumulation

Investment undertaken in year t is assumed to become operational at the start of year t+1. Under this assumption, capital in industry i in region q accumulates according to:

$$K_{i,q}(t+1) = (1 - DEP_{i,q}) \times K_{i,q}(t) + Y_{i,q}(t), \quad (1)$$

where $K_{i,q}(t)$ is the quantity of capital available in industry i in region q at the start of year t, $Y_{i,q}(t)$ is the quantity of new capital created in industry i in region q during year t, and $DEP_{i,q}$ is the rate of depreciation for industry i in region q. Given a starting value for capital in t=0, and with a mechanism for explaining investment, equation (1) traces out the time paths of industries' capital stocks.

Following the approach taken in the MONASH model (Dixon and Rimmer, 2002), investment in year t is explained via a mechanism of the form

$$\frac{K_{i,q}(t+1)}{K_{i,q}(t)} = F_{i,q} \left[\frac{EROR_{i,q}(t)}{RROR_{i,q}(t)} \right], \quad (2)$$

where $EROR_{i,q}(t)$ is the expected rate of return in year t, $RROR_{i,q}(t)$ is the required rate of return on investment in year t, and $F_{i,q}$ is an increasing function of the ratio of expected to required rate of return. In this work, it is assumed that investors take account only of current rentals and asset prices when forming expectations about rates of return (static expectations).

2.2.7 Lagged adjustment process in the national labour market

The ETS simulations are year-to-year recursive-dynamic simulations, in which it is assumed that deviations in the national real wage rate from its basecase level increase through time in inverse proportion to deviations in the national unemployment rate. That is, in response to a shock-induced increase (decrease) in the unemployment rate, the real wage rate declines (increases), stimulating (reducing) employment growth. The coefficient of adjustment is chosen so that effects of a shock on the unemployment rate are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the NAIRU is exogenous.

2.3 Environmental enhancements

A number of key environmental enhancements of MMRF are necessary to facilitate modelling of the ETS.

2.3.1 Energy and emissions accounting

MMRF tracks emissions of greenhouse gases according to: emitting agent (58 industries and the household sector); emitting region (8); and emitting activity (9). Most of the emitting activities are the burning of fuels (coal, natural gas and five types of petroleum products). A residual category (activity emissions) covers non-combustion emissions such as emissions from mines and agricultural emissions not arising from fuel burning. The resulting $59 \times 8 \times 9$ array of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon-dioxide equivalents, CO_2-e. Table 2 summarises MMRF's emission data for the starting year of the simulations – the financial year 2006. Note that MMRF accounts for domestic emissions only; emissions from combustion of Australian coal exports, say, are not included, but fugitive emissions from the mining of the coal are included.

According to Table 2, the burning of coal, gas and refinery products account for around 38%, 10% and 23% of Australia's total greenhouse emissions. The residual, about 29%, comes from non-combustion sources. The largest emitting industry is electricity generation, which contributes around 39% of total emissions. The next largest is animal-agriculture, which contributes 14%; agriculture in total contributes nearly 20%.

2.3.2 Carbon taxes and prices

MMRF treats the ETS price on emissions as a specific tax on emissions of CO_2-e. On emissions from fuel combustion, the tax is imposed as a sales tax on the use of fuel. On activity emissions, it is imposed as a tax on production of the relevant industries. In MMRF, sales and production taxes are generally assumed to be *ad valorem*, levied on the basic (i.e., pre-tax) value of the underlying flow. Carbon taxes, however, are specific, levied on the quantity emitted by the associated flow. Hence, equations are required to translate a carbon tax, expressed per unit of CO_2-e, into *ad valorem* taxes, expressed as percentages of basic values.

2.3.3 Inter-fuel substitution

To allow for fuel-fuel and fuel-factor substitution that a carbon tax would be expected to induce, we (i) introduce inter-fuel substitution in electricity generation using the "technology bundle" approach;[4] and by introducing a weak form of input substitution in sectors other than electricity generation to mimic "KLEM substitution".[5]

Electricity-generating industries are distinguished based on the type of fuel used. There is also an end-use supplier (*Electricity supply*) in each region and an industry (*NEM*) covering the six regions that are included in Australia's National Electricity Market: New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), the Australian Capital Territory (ACT) and Tasmania (TAS). Electricity flows to the local end-use supplier either directly in the case of Western Australia (WA) and the Northern Territory (NT) or via *NEM* in the remaining regions.

Purchasers of electricity from the generation industries can substitute between the different generation technologies in response to changes in generation costs. Such substitution is price-induced, with the elasticity of substitution between the technologies typically set at around 5. For other energy-intensive commodities used by industries, MMRF allows for a weak form of input substitution. In most cases, a substitution elasticity of 0.1 is imposed. Thus, if the price of cement rises by 10% relative to the average price of other inputs to construction, the construction

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[4] The technology bundle approach has its origins in the work done at CoPS in the early 1990s (McDougall, 1993) and at the Australian Bureau of Agricultural and Resource Economics for the MEGABARE model (Hinchy and Hanslow, 1996).

[5] KLEM substitution allows for substitution between capital (K), labour (L), energy (E) and materials (M) for each sector: see Hudson and Jorgenson (1974) and Berndt and Wood (1975). Other substitution schemes used in Australian models are described in Chapter 4 of Pezzy and Lambie (2001).

industry will use 1% less cement and a little more labour, capital and other materials. For important energy goods (petroleum products, electricity supply, and gas) the substitution elasticity in industrial use is 0.25. Being driven by price changes, this input substitution is especially important in an ETS scenario where outputs of emitting industries are made more expensive.

2.3.4 The National Electricity Market

The National Electricity Market is a wholesale market covering nearly all of the supply of electricity to retailers and large end-users in NSW, VIC, QLD, SA, ACT and TAS. Final demand for electricity in each of these regions is determined within the CGE-core of the model in the same manner as demand for all other goods and services. All end users of electricity in these six regions purchase their supplies from their own-state *Electricity supply* industry. Each of the *Electricity supply* industries in these six regions sources its electricity from the industry *NEM*, which does not have a regional dimension; it is a single industry that sells a single product (electricity) to the *Electricity supply* industry in each of the six regions. *NEM* sources its electricity from generation industries in each *NEM* region. Its demand for electricity is price-sensitive. For the ETS simulations described below, this modelling of the National Electricity Market was mostly overwritten by results from Frontier Economics's detailed bottom-up model of the electricity system (discussed below).

2.3.5 Services of energy-using equipment in private household demand

The final three industries shown in Table 1 provide services of energy-using equipment to private households. These industries enable households to treat energy and energy-using equipment as complementary; this is not possible in MMRF's standard budget-allocation specification based on the Linear Expenditure System.

The output of *Private transport services* are sold to the household sector, using inputs of capital (private motor vehicles), automotive fuel and other inputs required for the day-to-day servicing and running of vehicles. *Private electricity equipment services* provides the services of electrical equipment (including air conditioners) to households, using inputs of capital (electrical equipment) and electricity. *Private heating services* provides the services of appliances used for heating and cooking, using inputs of capital (heating and cooking appliances), gas and electricity.

Energy used by these three industries accounts for all of the energy consumption of the residential sector.

Including these three industries improves the model's treatment of price-induced energy substitution and its treatment of the relationship between energy and energy equipment in household demand. This is because a change in the price of electricity induces substitution only through its effect on the prices of electrical equipment services and private heating services. If the change in the electricity price reduces the price of electrical equipment services relative to the price of other products, then electrical equipment services (including its inputs of appliances and energy) will be substituted for other items in the household budget.

3. Additional enhancement for ETS modelling

In this section we describe enhancements to our modelling framework that are necessary for simulating the effects of a real-world ETS.

3.1 Linking with GTEM

An important part of enhancing our modelling for simulating the effects of a real-world ETS is linking MMRF to GTEM, in order to enhance MMRF's handling of global aspects of the ETS and of changes to Australia's trading conditions. GTEM (Pant, 2007) and MMRF are based on a common theoretical framework – the ORANI model[6]. GTEM can be likened to a series of ORANI models, one for each national region, linked by a matrix of bilateral international trade flows. Similarly, MMRF can be likened to a series of ORANI models, one for each state and territory, linked by a matrix of inter-state trade flows. But unlike the static ORANI model, MMRF and GTEM are recursively dynamic models developed to address long-term global policy issues such as climate-change mitigation costs. GTEM contains a number of enhancements relative to the MEGABARE and GTAP systems to improve its capability for environmental analysis. Many of these enhancements are similar to those described above for MMRF. We do not describe the enhancements to GTEM here; a comprehensive description is provided in Adams and Parmenter (2013), Section 9.3.1.2.

Linking economic models with different economic structures is not straightforward. For example, MMRF and GTEM have similar production structures, but their industrial

[6] GTEM was derived from MEGABARE Hinchy and Hanslow (1996) and the static GTAP model (Hertel, 1997).

classifications are not the same: GTEM's industrial classification is much more aggregated than MMRF's. Also, the elasticities of supply and demand associated with comparable industries are not necessarily consistent across the two models. In general, the degree of linking required will vary depending on the number and nature of variables that are common between the models. For example, if the only common variables are exogenous in the primary model (MMRF), then a relatively simple top-down linking from the secondary model (GTEM) is sufficient. A more complex linking with two-way transmission of results may be necessary if there are many common variables with some endogenous to both systems.

Our analysis relates to a global ETS with a global cap, a global price and allocations of permits to participating countries. GTEM was used to model the global scheme. GTEM's projection for the global permit price and Australia's emissions allocation were fed directly into MMRF. In MMRF, the global permit price and Australia's emissions allocation are typically exogenous variables so a simple one-way link from GTEM to MMRF is sufficient. GTEM also simulates changes in world trading conditions faced by Australia (i.e., changes in the positions of foreign export-demand and import-supply schedules), with and without the global ETS. In MMRF, import supply is assumed to be perfectly elastic and foreign-currency import prices are typically exogenous, once again allowing for one-way transmission from GTEM to MMRF.

For exports, however, foreign demand schedules are assumed to be downward sloping in MMRF; thus, one-way transmission is problematic because export prices and quantities are endogenous in both models. Despite the potential for feedback, the linking between GTEM and MMRF for export variables was done via one-way transmission from GTEM to MMRF.

3.2 Linking with WHIRLYGIG

The idea that environmental issues can be tackled effectively by linking a CGE model with a detailed bottom-up energy model has a long history with Australian modellers. The first attempts were in a joint CoPS/ABARES (Australian Bureau of Agricultural and Resource Economics and Sciences) project using ORANI and MENSA (Adams *et al.*, 1992; Powell 1993). Frontier Economic's WHIRLYGIG model simulates the least-cost expansion and operation of

generation and transmission capacity in the Australian electricity system.[7] In linking MMRF to WHIRLYGIG, the electricity sector in MMRF is effectively replaced with WHIRLYGIG's specification. MMRF provides information on fuel prices and other electricity-sector costs and on electricity demand from industrial, commercial and residential users. This is fed into WHIRLYGIG, which generates a detailed description of supply, covering generation by generation type, capacity by generation type, fuel use, emissions, and wholesale and retail electricity prices. Retail electricity prices are a key endogenous variable in both systems. Information is passed back and forth between the two models in a series of iterations that stop when the average retail price in the electricity model has stabilised. Experience suggests that up to three iterations for each year are necessary to achieve convergence.

There are a number of reasons to prefer linking to a detailed electricity model over the use of MMRF's standard treatment of electricity.

Technological detail. MMRF recognises six generation technologies whereas WHIRLYGIG recognises many hundreds, some of which are not fully proved and/or are not in operation, e.g., cleaner coal gasification technologies and generation in combination with carbon capture and storage (CCS). Having all known technologies available for production now or in the future allows for greater realism in simulating the technological changes available in electricity generation in response to a price on emissions.

Changes in capacity. MMRF treats investment in electricity generation like all other forms of investment: capital supply is assumed to be a smooth increasing function of expected rates of return that are set equal to current rates of return. But changes in generation capacity are generally lumpy and investment decisions are forward looking, given long asset lives. WHIRLYGIG allows for lumpy investments and for realistic lead times between investment and capacity change. It also allows for forward-looking expectations; thus when demand for electricity in WHIRLYGIG is linked to MMRF, investment in the electricity sector is driven by model-consistent expectations.

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[7] Here we describe aspects of WHIRLYGIG and the advantages of linking it to MMRF. Due to space constraints, we do not provide a detailed description of the model or how it was linked to MMRF. Readers interested in such detail should consult Adams and Parmenter (2013), Sections 9.3.2.1-9.3.2.2.

Policy detail. Currently, in Australia there are around 100 policies at the state, territory and commonwealth levels affecting electricity generation and supply.[8] Some of these policies interact with an ETS. For example, the market-based Renewable Energy Target (RET) operates by requiring electricity retailers to acquire and surrender Renewable Energy Certificates (RECs). The RECs have a market price that will be sensitive to an ETS. Associated interactions and policy details are handled well in WHIRLYGIG but are generally outside the scope of stand-alone modelling in MMRF.

Sector detail. In MMRF, electricity production is undertaken by symbolic industries, e.g., *Electricity generation – coal VIC*, *Electricity generation – gas NSW*, etc. In WHIRLYGIG, actual generation units within particular power stations are recognised. Thus results from WHIRLYGIG can be reported at a much finer level and in a way that industry experts fully understand. This adds to credibility in reporting results.

3.3 Transitional arrangements

In the policy framework outlined in the Australian government's ETS design-paper (Department of Treasury, 2008), certain emission-intensive trade-exposed industries (EITEIs) are to be shielded from some of the cost effects of the permit price during the initial years when a global ETS is being established. Shielding reduces the adverse effects of the carbon price on the EITEIs and limits the carbon leakage that imposing a carbon tax in Australia in advance of its adoption by major international-trade competitors would otherwise induce. In the ETS modelling reported here, shielding is implemented as a general production subsidy to offset the combined direct and indirect effects of the emissions price on an industry's average cost. The direct effects arise from the imposition of the emission price on the industry's combustion emissions or on the emissions directly associated with its activity; the indirect effects arise from the increased cost of electricity.

To offset the direct impacts of a carbon price, the proposed ETS specified shielding proportional to the emission price and the shielded industry's output level. The coefficient of proportionality reflects the coverage of the shielding scheme and the industry's initial (2005-06) emissions intensity. Having determined the necessary offsets for the direct and indirect costs

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[8] These include: market-based instruments to encourage increased use of renewable generation; regulations affecting the prices paid by final residential customers; and regional policies that offer subsidies to attract certain generator types.

associated with emissions pricing, the model then applies the offset to each shielded industry via a production subsidy. The subsidy is initially paid by the Federal government. But as government budget balances are held fixed at basecase case levels in the ETS simulations via endogenous lump-sum payments to households, the shielding subsidy is ultimately paid by Australian households.

Shielding has macroeconomic and welfare impacts due to its role in recycling the revenue raised from the sale of emissions permits (or a carbon tax). Shielding payments reduce the lump-sum payments to households that are the revenue-recycling method in the ETS simulation. By definition, lump-sum payments to households are non-distorting in the conventional public-finance sense. Since the carbon tax is distorting and ignoring any environmental benefits that it might have, the policy of imposing the tax and recycling its revenue through lump-sum payments reduces GDP and economic welfare. Shielding represents a reduction in the effective energy-tax impost associated with the ETS and a corresponding reduction in the lump-sum payments that are required to recycle the ETS revenue. This reduces the adverse effects on GDP and conventionally measured welfare. Proponents of the ETS (or a carbon tax) often argue that these adverse effects could be reduced further, or even eliminated, by using the revenue to reduce other distorting taxes – the so-called double-dividend argument (Goulder, 1995).

3.4 Land use in forestry

In MMRF, land is an input to production for the agricultural industries and forestry. For the ETS simulations, land is considered region-specific but not industry-specific and there are regional supply constraints. This means that within a region, an industry can increase its land usage but that increase has to be met by reduced usage by other industries within the region. Land is assumed to be allocated across users to maximise the total return to land subject to a constant-elasticity-of-transformation function defining production possibilities across the various land-using sectors. This is the same treatment as adopted in GTEM. With this mechanism, if demand for bio-sequestration pushes up demand for land in the forestry sector, then forestry's use of land will increase, increasing the region-wide price of land and causing non-forestry industries to reduce their land usage and overall production.

4. Basecase

The basecase is the control projection against which the policy scenario (with an ETS in place) is compared. In our modelling of the ETS, much importance was placed on establishing a detailed basecase with a credible projection for emissions across regions and sectors. There were two reasons for this. One, the cost of implementing the ETS in each year depends critically on the underlying level of basecase emissions (Weyant and Hill, 1999). Two, acceptance of the modelling outcomes, including the level of shielding necessary for emission-intensive industries, is reliant on the credibility of the basecase.

4.1 Key assumptions

The basecase incorporates a large amount of information from specialist forecasting agencies. MMRF traces out the implications of the specialists' forecasts at a fine level of industrial and regional detail. Information imposed on the model includes:

- regional macroeconomic forecasts to 2014, generated in the main from published state-government information;
- national-level assumptions for changes in industry production technologies and in household preferences developed from MONASH and MMRF historical-decomposition modelling;[9]
- forecasts through to 2014 for the quantities of agricultural and mineral exports from a range of industry sources;
- estimates of changes in generation mix, generation capacity, fuel use, emissions and wholesale prices for electricity from the WHIRLYGIG model;
- forecasts for regional populations and participation rates drawing, in part, on projections in the Treasury's Intergeneration Report (Department of Treasury, 2007);
- forecasts for land-use change and for forestry sequestration from experts at ABARES; and
- forecasts for changes in Australia's aggregate terms of trade and for the foreign export and import prices for Australia's key traded goods in agriculture, mining and manufacturing drawn from simulations of GTEM undertaken for the Treasury.

Below we provide detail on the most important basecase assumptions; detail on other basecase assumptions is provided in Adams and Parmenter (2013), Section 9.4.

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[9] Historical decomposition modelling is discussed in Dixon and Rimmer (2002), Chapter 5.

4.2 Macroeconomic variables

Key features of the basecase projection for selected macroeconomic variables are as follows.

- Real GDP grows at an average annual rate of 3.1% over 2010-2020 slowing to an average rate of 2.6% over 2020-2030. Average annual growth over the full projection period (2.9%) is consistent with the historical norm for Australia.

- In line with recent history, the export-oriented states – QLD and WA – are projected to be the fastest growing regions, followed by NSW and VIC. SA and TAS are the slowest growing regions.

- Real national private consumption grows at an average annual rate of 3% in the first half of the period and 2.9% in the second half; a time profile similar to that for real GDP.

- The regional pattern of growth for consumption is also similar to that for GDP: fastest growth occurs in QLD and WA, and slowest growth in TAS and SA.

- Over 1996-2010, the volumes of international trade grew rapidly relative to real GDP reflecting declining transport costs, improvements in communications, reductions in protection in Australia and overseas and technological changes favouring the use of import-intensive goods (e.g., computers). All these factors are extrapolated into the early years of the basecase but their influence is assumed to weaken over time. On average, trade volumes grow relative to GDP by about 1.5% annually, but unlike recent history import growth is projected to be in line with export growth.

- Australia's terms of trade are assumed to decline sharply in the first few years of the basecase returning to a historically normal level by 2020 from their initial 50-year high.

4.3 Industry production

Table 3 lists average annual percentage changes in basecase output for all industries; key features of these projections are as follows.

- *Electricity generation – other renewable* has the strongest growth prospects, with average annual growth of 7.3%, most of which occurs in the first half of the projection period. This industry generates electricity from non-hydro renewable sources. Its prospects are greatly enhanced by the RET. Other forms of electricity generation have mixed prospects. Generation from gas is projected to grow at a relatively strong average growth of 4%, supported by environmental policies at both the federal and state level. The same

policies restrict average growth of emission-intensive coal generation to 0.4%. It is assumed that generation from oil products and hydro will not change over the projection period.

- Average growth in overall *Electricity supply* is relatively slow at 1.7%. In line with recent history, the basecase includes an autonomous annual 0.5% rate of electricity-saving technological change in all forms of end-use demand. This, coupled with relatively slow average annual growth in two of the main electricity-using industries – *Aluminium* (1.8%) and *Private heating services* (1.7%) – explains the relatively slow growth projected for *Electricity supply*.

- There is strong growth in softwood plantations on land previously used in marginal broad-acre agriculture. The GTEM model projects significant growth in world demand for *Forestry*, which absorbs much of the additional forestry supply with relatively little change in the supply price. The expansion in exports explains how *Forestry* can expand strongly while its main domestic customer, *Wood products*, has a relatively low growth ranking (rank 43).

- *Air transport* is the third ranked industry, with a projected average growth rate of 5.2%. Prospects for this industry are good because of expected strong growth in inbound tourism, and the assumed continuation of a taste shift in household spending towards air and away from road as the preferred mode for long-distance travel.

- *Gas mining* and *Coal mining* have good growth prospects reflecting very strong growth in exports of liquefied natural gas and coal.

- Prospects for the non-energy mining industries are governed by projections for world demand taken from GTEM. Production of *Oil* is expected to increase at an average annual rate of just 0.6%, reflecting estimates of supply availability from current reserves.

- Forecasts for the agricultural sector are largely determined by the prospects of downstream food and beverage industries. These have below-average growth prospects, reflecting fairly weak growth in exports and expected increases in import penetration on local markets; other manufacturing industries also have weak growth prospects for the same reasons.

4.4 Emissions by source

Figure 1 shows the level of emissions over the basecase. It covers all emissions except for emissions from land clearing in line with Kyoto accounting principles. Key features of basecase emissions growth include the following.

- In aggregate, emissions are projected to grow at an average annual rate of 1.5% over the projection period. Relative to 2010 levels, emissions are projected to be 19.6% higher by 2020 and 34.5% higher by 2030.

- The largest source of emissions is electricity generation, especially generation from coal combustion; in 2010, electricity contributed almost 36% to total emissions. WHIRLYGIG modelling indicates that average annual growth in emissions from electricity will be only 0.2% through the projection period.

- The second largest source of emissions is agriculture, with a 2010-share of 17.7%. In the Kyoto-accounting framework, most of Australia's agricultural emissions come from methane emitted by cattle and sheep. As basecase growth prospects for these livestock industries are well below GDP growth, average annual growth in emissions from agriculture is only 1.3%.

- Transport contributes 16% to total emissions in 2010, and has projected annual emissions growth of 1.6%. Around 60% of transport emissions are due to *Private transport services*, which is projected to grow at an average annual rate of 1.7%. Much of the remaining transport emissions come from *Road freight transport*, which grows at an average annual rate of 3%. Emissions grow by less than output in these two key industries because it is assumed that use of bio-products will increase.

- The modelling ignores all emissions from land-use change except for sequestration from forestation and reforestation in areas where the preceding vegetation or land use was not forest. For the basecase, projections for forestry sequestration were supplied by ABARES. The projections take account of the life cycle of individual forests established since 1990, accounting for carbon sequestered when the forest is planted and growing, and for carbon released when the forest is harvested. Note that this makes a negative contribution to emissions in 2010 but a positive contribution in 2020 and later years.

5. ETS simulation design

Section 6 reports the results of the MMRF simulation of a global ETS with a global allocation of permits sufficient to reduce global emissions in 2050 to 5% below their level in the year 2000: this is the CPRS-5 scheme identified by the Australian Treasury (Department of Treasury, 2008). The simulation examines the effects of the scheme to 2030. The effects are reported as deviations from the values of variables in the basecase projection described in Section 4.

5.1 Scheme design

Table 4 summarises the design features of the ETS as modelled. Further features of the scheme are discussed below.

5.1.1 Permit price

The GTEM projection of the international permit price, converted to real Australian dollars in MMRF, starts at $24.3 per tonne in 2012 and thereafter increases at an annual rate of around 4%, reaching $33.3 per tonne in 2020 and $49.3 per tonne in 2030.

5.1.2 Australia's allocation of permits

In the basecase, Australia's emissions rise from 528 Mt of CO_2-e in 2010 to 710 Mt in 2030; by 2030, Australia's permit allocation is for emissions of 365 Mt of CO_2-e. The gap between basecase emissions and permit allocation represents the international abatement obligation faced by Australia under the global ETS. Initially there is no gap between emissions and permit allocation, but this gap widens over the life of the scheme. Australia can meet this gap in two ways: by domestic abatement in response to the emission price; and by purchasing permits from overseas.

5.1.3 Electricity inputs from WHIRLYGIG

Following the iterative process described in Section 3.2, the WHIRLYGIG model provides deviations from basecase values for electricity generation, energy use, generation capacity, emissions and electricity prices. These projections are accommodated in the MMRF modelling of the ETS. In the WHIRLYGIG modelling, the electricity sector responds to the permit price by switching technologies, changing the utilisation of existing capacity, and replacing old plants

with new more-efficient plants. The modelling also includes the reduction in electricity usage projected in MMRF's modelling of demand. Compared to the basecase, the overall level of generation in 2030 is down by 6.9% and the mix of generation has changed appreciably away from coal and towards gas and non-hydro renewables. By assumption, there is no change in generation from oil products and hydro.

5.1.4 Road transport inputs from the BITRE and CSIRO

The Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) provide data for changes away from basecase values in fuel use and emissions for private transport by region. The assumptions suggest that by 2030 the emissions price will have little impact on fuel choice and emissions in private transport. Projections for the use of gasoline, diesel and LPG in road transport are accommodated in MMRF by endogenous shifts in fuel-usage coefficients in industries' production functions. The BITRE/CSIRO emissions projections are accommodated by endogenous shifts in emissions per unit of fuel used.

5.1.5 Forestry land and bio-sequestration inputs from ABARES

According to the ABARES inputs, the global ETS would have a significant impact on forestry production and forest bio-sequestration. By 2030, forestry production rises by 80% above basecase and sequestration rises by 30 Mt. Corresponding changes in land under forestry are also imposed. With total land availability by region is fixed, land available for agriculture falls. The ABARES estimates of the response of forestry sequestration to the emissions price is accommodated in MMRF by endogenous shifts in emissions per unit of forestry output.

5.1.6 Trade variables based on information from GTEM

Projections of changes in foreign-currency import prices and in the positions of foreign export-demand schedules for Australia in response to a global emissions price are sourced from GTEM modelling, see Figure 2. The long-term effect of the ETS on Australia's terms of trade is negative. About half of this is due to higher import prices, as the ETS increases production costs for overseas producers, and about half is due to lower export prices. About two-thirds of the reduction in export prices is driven by a reduction in the world price of coal as users switch to

less emission-intensive fuels. However, when China joins the international coalition in 2015[10] there is a temporary jump in global coal prices as Chinese demand is diverted from local to foreign supplied product. This effect dissipates in 2020 when India and the rest of the world join the scheme and world coal demand falls.

5.2 Macroeconomic assumptions for the ETS

5.2.1 Labour markets

As described in Section 2.2.7, lagged adjustment of the national real-wage rate to changes in national employment is assumed. Adoption of the ETS can cause employment to deviate from its basecase value initially, but thereafter, real wage adjustment steadily eliminates the short-run employment consequences of the emissions price. In the long run, the costs of emissions pricing are realised almost entirely as a fall in the national real wage rate, rather than as a fall in national employment. This labour-market assumption reflects the idea that in the long run national employment is determined by demographic factors, which are unaffected by the adoption of an emissions price.

At the regional level, labour is assumed to be mobile across state economies. Labour is assumed to move across regions so as to maintain inter-state unemployment-rate differentials at their basecase levels. Accordingly, regions that are relatively favourably affected by emissions pricing will experience increases in their labour forces as well as in employment, at the expense of regions that are relatively less favourably affected.

5.2.2 Private consumption and investment

As described in Section 2.2.3, private consumption expenditure is determined by a consumption function that links nominal consumption to HDI: HDI includes the lump-sum return of permit income that is part of the ETS design. In the ETS simulation, the average propensity to consume (APC) is an endogenous variable that moves to ensure that the balance on current account in the balance of payments remains at its basecase level. Thus any change in aggregate investment brought about by the ETS is accommodated by a change in domestic saving, leaving Australia's call on foreign savings unchanged.

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[10] The CPRS-5 assumes a multi-stage approach to international emissions trading. Developed countries act first, then developing countries join over time.

This treatment of domestic and foreign savings is sufficient, but more extreme than is necessary, to ensure that the long-run deviation in real private consumption from its basecase level is a valid measure of the impacts of the ETS on the welfare of Australians. A less extreme treatment would be to impose a foreign-debt constraint directly and allow the year-to-year pattern of aggregate consumption and the current account to reflect year-to-year changes in HDI.

Investment in all but a few industries is allowed to deviate from its basecase value in line with deviations in expected rates of return on the industries' capital stocks. In the ETS scenario, MMRF allows for short-run divergences in rates of return from their basecase levels. These cause divergences in investment and hence capital stocks that gradually erode the initial divergences in rates of return. Provided there are no further shocks, rates of return revert to their basecase levels in the long run. An exception to this rule is the electricity generating industries, for which changes in capacity are taken from WHIRLYGIG. The changes are accommodated by allowing the required rates of return on investment to shift endogenously.

5.2.3 Government consumption and fiscal balances

In the ETS simulation, public consumption is a fixed share of nominal GDP. The fiscal balances of each jurisdiction (federal, state and territory) as a share of nominal GDP are fixed at their values in the basecase. Budget-balance constraints are accommodated by endogenous movements in lump-sum payments to households.

6. Economic effects

In interpreting the effects of the ETS, we compare the values of MMRF variables in basecase to their values in a simulation modelling the ETS. We have a number of options for reporting the effects of the ETS, all of which will tell a similar story. Option (1) is to compare average annual growth in the basecase with average annual growth in the ETS simulation. Another option is to compare the value of variables in a specific year in the ETS simulation with values in the basecase. Deviations can be expressed as percentage changes from basecase values in the final year of the simulation period [option (2)] or as absolute ($m or Mt, etc.) changes from basecase values [option (3)].

Users of model-based projections of the effects of the ETS policy have often been tempted to select their preferred reporting option according to how it is likely to be interpreted by non-specialists. Proponents of the ETS opt for measures that appear superficially to suggest that its

cost will be small while opponents opt for measures that appear to suggest large costs. To illustrate this, in Table 5 we report the effects of the ETS on Australian real GDP in 2020 and 2030 according to options (1)-(3) and according to a fourth option that emphasises that negative deviations from basecase values are compatible with continuing strong growth in an economy that would have been enjoying strong growth in the absence of the ETS. Option (4) expresses the deviation as the number of months of basecase growth that are lost as a consequence of the ETS.

Below we discuss the deviations from basecase values in the ETS simulations. Deviations for 2030 are given in Tables 6 (macro variables), 8 (industry output) and 9 (emissions of CO_2-e); the discussion mainly focuses on the final year (2030).

6.1 National results

6.1.1 *Employment falls in the short run but is constant in the long run as the real wage rate adjusts downwards*

Figure 3 shows percentage deviations in national employment, the national real wage rate and the national real cost of labour (i.e., the ratio of the nominal wage rate to the national price of output). As MMRF assumes competitive markets, the equilibrium nominal wage will be equal to the value of the marginal product of labour. The labour-market specification in MMRF makes the real wage rate sticky in the short run but responsive with a lag downwards (upwards) if employment falls (rises). When the ETS begins, the emissions price increases the price of spending relative to the price of output, and hence moves the nominal wage above the value of the marginal product of labour in the short run. In Figure 3 this shows as an increase in the real cost of labour and a fall in employment. If there were no further shocks, over time the real wage rate would progressively fall relative to basecase levels, reducing the real cost of labour and forcing employment back to its basecase level. But with the ETS, shocks continue with the permit price increasing under a progressively tighter regime of tradable permits. Hence the employment deviation is never fully eliminated and the real wage rate declines steadily. In 2030, the employment deviation is -0.2% and the real wage rate deviation is -2.6%.

6.1.2 *The economy-wide labour/capital ratio rises*

In 2030, the capital-stock deviation is -1.7%, implying an increase in the ratio of labour to capital of around 1.6%. In the same year, the real cost of capital (i.e., the ratio of the rental cost of capital relative to the national price of output) is up 0.6% relative to the basecase. The

reduction in capital is due, in part, to changes in relative factor prices. As the real cost of labour falls relative to the real cost of capital (see Section 6.1.1), producers substitute labour for capital across the economy. In 2030, with the real cost of capital relative to the real cost of labour rising by around 1.1%, the shift in relative factor prices could be expected to contribute about $0.5 \times 3.0 = 1.5$ percentage points to the eventual 1.6% increase in the labour/capital ratio.[11] In addition, there is a compositional effect due to the fact that the energy-related mining and coal-fired electricity sectors that are suppressed by the ETS are capital-intensive.

6.1.3 The reduction in capital leads to a fall in real GDP at factor cost

The percentage change in real GDP at factor cost is a share-weighted average of the percentage changes in quantities of factor inputs (labour, capital and agricultural land), with allowance for technological change. Real GDP at factor cost falls relative to its basecase level in all years of the simulation. In the final year it is down 0.9%. The possibility of achieving large cuts in emissions at a relatively low macroeconomic cost is a common theme in all of the analyses of carbon taxes and emission trading schemes undertaken at CoPS (see, for example, Adams, 2007). Nearly all of the fall in factor-cost GDP is due to the reduction in capital.

The ETS does induce some technological change but its contribution to the deviation in real GDP is small. In the ETS simulation, the carbon price leads to technological deterioration primarily through the adoption of more expensive, but less emission-intensive, production technologies. In the later years the technological deterioration is offset and eventually dominated by a compositional factor. If the ETS policy increases the shares in GDP of industries with rapid technological progress and reduces the shares of industries with less rapid technological progress, then real GDP growth will be elevated in the ETS simulation relative to the basecase. In our basecase simulation, service industries are assumed to have stronger labour-saving technological progress than mining and manufacturing industries. As the carbon price shifts the composition of the economy towards services, this allows technological change to make a small positive contribution to the deviation in real GDP from 2019 onwards.

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[11] The capital to labour substitution elasticity is 0.5 in MMRF.

6.1.4 Real GDP at market prices falls by more than real GDP at factor cost, due to a contraction in real indirect-tax bases

The percentage change in real GDP at market prices is a share-weighted average of the percentage change in real GDP at factor cost and real net-indirect-tax bases. Market-price GDP falls through the projection period by 1.1% below its basecase level in 2030, compared to a fall of 0.9% in factor-cost GDP: the difference is due to the contraction in the real indirect-tax bases. CO_2-e emissions, petroleum products and consumption are the principal bases on which indirect taxes are levied; all of these contract relative to their basecase values in 2030: emissions are down 25.6%, petroleum usage is down 3.8%, and real consumption is down 1.5%.

6.1.5 Australia must import a significant quantity of permits

Figure 4 plots Australia's permit allocation, basecase emissions and emissions-permit imports from the ETS simulation. Permit imports fill the gap between the permit allocation and actual emissions under the ETS. The permit price effectively stabilises total emissions near to their 2010 levels. Hence, with Australia's allocation of permits progressively falling, there is an increasing need to purchase permits from overseas. In 2030, around 160 Mt of permits are required. At a price of nearly $50 per tonne, this translates into an annual financing cost of close to $8 billion. This financing cost represents a reduction in domestic welfare in the form of a transfer to foreigners.

An alternative way in which Australia might meet its emissions target would be to impose a domestic emissions tax on top of the international permit price. This would involve a transfer of tax revenue from the domestic private sector to the Australian government and a deadweight loss. The latter represents a reduction in domestic welfare and is additional to the loss represented by the purchase of permits from the international market under the scheme that we have simulated. Hence, relying on imported permits minimises the global cost of abatement and the loss of domestic welfare.

It should be noted that if the amount of emissions abatement under the ETS is less than that projected by the WHIRLYGIG modelling, the requirement to import permits, and the associated loss of national income, would be greater. Under current policy settings, a carbon tax is in place. The key difference between a carbon tax and an ETS, for a given carbon price, is that a carbon tax does not involve an emissions cap or international trade in permits. Hence, the permits import cost does not apply under the current carbon tax regime.

6.1.6 Real household disposal income and real private consumption fall

In 2030, real HDI is down 2.3% and real private consumption is down 1.5%. The difference is due to an increase in the APC of 0.9%. The carbon charge reduces real HDI by reducing the factor incomes that domestic residents receive from domestic enterprises. However, the charge does not reduce real HDI by the entire amount of the gross revenue that it raises. Some of that revenue is required to purchase emissions permits from overseas but some is returned to domestic households, either indirectly via shielding payments that are made to domestic EITEIs or directly via lump-sum recycling payments. In a partial-equilibrium world, the lump-sum payments would be equal to the difference between the gross ETS revenue and the costs of shielding and international-permit purchases. But our general-equilibrium calculations take account of the indirect effects that the ETS might have on the government budget balance. Lump-sum payments to households are then whatever is necessary to insulate the government budget balance (as a share of GDP) from the total effects of the ETS. The first part of Table 7 decomposes the $b change in real HDI in 2030 into its components. Note that the excess of gross ETS revenue over the international permit cost is $18.1b but only $14.5b of this is returned to households via lump-sum payments. The reason is that the indirect effects of the ETS on the government budget are negative; for example, the ETS reduces income-tax revenue.

Recall that the APC is an endogenous variable, moving to ensure that the national balance on current account remains at its basecase level. To maintain an unchanged balance on current account, domestic savings (private plus public) must change to accommodate changes in aggregate investment. As shown in Table 7, the ETS generates an $18.1 billion (or 3.4%) reduction in aggregate investment relative to basecase. Public saving falls by $3.4 billion. Hence, private saving must fall by around $15 billion. Given a fall in HDI of $29.8 billion and a basecase value for the APC of 0.78, the APC must rise to achieve the necessary change in saving.

6.1.7 Production increases in some industries and falls in others

Table 8 gives percentage deviations from basecase production levels for industries in 2030. There are a number of industries for which the ETS raises output significantly. The most favourably affected industry is *Forestry*, for which the carbon charge is effectively a production subsidy on bio-sequestration. Two other industries very favourably affected are *Electricity generation – other renewable* and *Electricity generation – gas*. The carbon price causes substitution in favour of these industries at the expense of high-emissions *Electricity generation –*

coal. Another negative factor for coal generation is the reduction in overall electricity demand due to the increased price of electricity to final customers. In Table 8, this shows up as a decline in production in the *Electricity supply* industry.

Table 8 shows significant increases in production for *Iron & steel* and *Alumina*. Both are energy-intensive and trade-exposed and under a unilateral ETS would contract unless shielded. However, GTEM analysis of the multilateral aspects of the ETS projects trade diversion towards these Australian industries due to the availability of cheap energy-abatement options in Australia that are not matched by competing suppliers. Another positive factor for these industries, and for all other traded goods sectors, is the projected depreciation in the real exchange rate. A lower real exchange rate means that exports of industries such as the metal producers are more competitive on world markets.

Coal production is projected to fall by 12.8% compared to its basecase level. The imposition of the ETS adversely affects coal demand for electricity generation and steel production in Australia and overseas. Domestic demand for coal falls by 14.6%. Foreign demand, which contributes around 85% to overall demand, is down 12.5%. These projections are remarkably sanguine when compared to the dire predictions in industry-commissioned studies with regard to an ETS (see, for example, ACIL Tasman, 2009; Wallace, 2009). In terms of average annual growth, the projections imply a reduction from 4.0% in the basecase to 3.3% with the ETS in place. The key factor underlying this small effect is rapid uptake of clean-coal technologies for electricity generation. In Australia, the new technologies are mainly based on CCS. In the rest of the world, as modelled by GTEM, the new technologies include CCS and other less radical innovations that have already started to be used in Australia.

Other adversely affected industries are *Private transport services*, *Private electricity equipment services* and *Private heating services*. These industries are affected by increases in the price of energy: automotive fuels for transport services, electricity for electrical equipment services, and gas for heating services. Increased energy costs shift their supply schedules up, leading to adverse substitution in residential demand. Most of the remaining industries suffer mild contractions in output relative to basecase levels, in line with the general shrinkage of the economy. General economic conditions are particularly influential for service industries.

As discussed in Section 1, since the announcement of the Government's proposed ETS in 2008, global and domestic policy has not developed in way assumed under the scheme. Instead, a carbon tax was introduced in Australia in 2012. The sectoral results discussed above

potentially give some guidance as to what may be expected under the present carbon tax. It is likely that the major divergences in the sectoral effects would be for *Forestry*, *Iron & steel*, *Alumina* and *Coal*. *Forestry* would expand less under the present carbon tax compared to the global ETS as the effective production subsidy on bio-sequestration would be smaller. *Iron & steel* and *Alumina* receive less shielding under the present carbon tax than that proposed under the global ETS and would likely contract rather than expand. In contrast, *Coal* production is likely to fall by less than under a global ETS as overseas coal demand would be largely unaffected by the unilateral carbon tax, and foreign demand contributes around 85% to total Australian coal sales.

6.1.8 *Emissions from most sources fall*

Table 9 shows deviations from domestic basecase emissions. In 2030, total domestic emissions are down by 25.6%, or 181.8 Mt of CO_2-e. In addition, permits for 160 Mt of CO_2-e are imported, making Australia's total contribution to global emissions reduction 342 Mt of CO_2-e (i.e., minor relative to global emissions). Domestic emissions from stationary energy and fugitive sources deliver the bulk of the overall abatement. Emissions from stationary energy are down 47.5 Mt relative to their basecase levels, with emissions from electricity generation down by 37.4 Mt, and emissions from other forms of direct combustion down by 10.1 Mt. Fugitive emissions fall by 41.4%. Significant abatement also occurs in other areas, and in terms of percentage deviations are larger than abatement from stationary-energy and fugitive sources. From waste, emissions are down by 75.9%, while emissions from industrial processes fall by 56.1%.

All of the emission reductions outside of electricity and transport occur via reductions in the output of the relevant emitting industry or reductions in emissions intensity brought about by the price-responsive mechanisms outlined in Sections 2.3.3 and 2.3.5. The abatement from stationary energy and transport is achieved via industry activity effects, fuel switching and technology changes. Technology changes are most important for electricity where, according to WHIRLYGIG modelling, extensive abatement is achieved from the uptake of clean coal technologies, especially in the later part of the projection period.

6.1.9 *A check on reality: an informal back-of-the-envelope calculation*

We have noted above that by 2030 real GDP is projected to be 1.1% lower than it otherwise would have been and emissions are around 25% lower due to the ETS. Is this result plausible?

To answer this question, CoPS modellers typically make use of back-of-the-envelope (BOTE) calculations. This can be done in a formal way using an abstract model (see the Appendix in Adams and Parmenter, 2013), or it can be done less formally. For example, we know that the main CO_2-e emitting activities are the fossil-fuel-based provision of electricity and transport services. According to the MMRF database, in 2011 these activities represent about 2.5% of GDP and about 55% of total emissions. Based on the Frontier Economics electricity model and expert transport-sector input, Australia can reduce its emissions from these sectors by about 45% with roughly a 55% increase in the costs of electricity and motor fuels. As a BOTE calculation, this suggests that Australia could make a 25% cut in emissions at a cost of around 1.4% (= 55% of 2.5) of GDP. The projected outcome for real GDP is a little smaller than this, suggesting that cheaper abatement opportunities exist than might be available from electricity and transport alone.

6.2 State variables

Figure 5 shows projected deviations from basecase levels of real gross state product (GSP) over 2010-2030; deviations in 2030 are given in Table 6. The pattern of impacts on real GSP in 2030 reflects the industry effects of the ETS. Just as some industries experience output gains and some experience output loss, so some regions experience output gain and others output loss; the differences across regions are explained by differences in industrial composition.

QLD and to a lesser extent NSW have over-representations of *Coal mining* and *Electricity generation – coal*, which is the main reason why the ETS is expected to reduce their shares in the national economy. The ACT's economy is almost entirely service oriented, with an over representation of energy-intensive providers of private transport, private electricity-equipment and private heating services. This is the main reason why the territory is relatively adversely affected by the ETS. WA is favoured by an industrial composition with an over-representation of gas-fired generation, natural gas and trade-exposed industries that benefit from trade diversion under the global ETS (*Iron ore*, *Alumina* and *Other non-ferrous metals*).

In the basecase, SA's coal-fired generation industry is phased out by 2015 and its gas industry ceases production by 2025.[12] The absence of these two significantly adversely affected

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[12] SA government policy mandates that coal-fired generation is phased out by 2015. SA's gas fields are almost used up now and are expected to completely run dry by 2025.

industries and an over-representation of agricultural industries, which do relatively well under the ETS, is enough to elevate SA's GDP share. TAS does not have coal-fired generation or gas and coal mining. *Forestry* and agriculture are over represented. Hence, it gains share in the national economy. The NT has an over-representation of animal-agriculture and *Alumina* production. Thus, even though it has no *Forestry*, it too gains share in the national economy.

7. Discussion and concluding remarks

We report on issues that arise in using a CGE model of the Australian economy to provide advice to policy makers and other stakeholders about the effects of complex real-world policy proposals. We illustrate the issues using a study of the effects of the Australian government's 2008 emissions-trading policy proposal. The proposal integrates Australia into a global trading scheme by 2015 and requires Australia to progressively reduce emissions to around 40% below their basecase level by 2030. This reduction can be achieved by a mix of domestic abatement and purchases of emissions permits from the global market. The global price of permits rises from around $AUD 25 per tonne in 2015 to around $AUD 50 per tonne in inflation-adjusted terms in 2030.

Six key findings emerge from our analysis. One, domestic abatement accounts for only half of targeted abatement; this requires the remainder to be met from foreign-permit purchases. Two, despite the requirement for deep cuts in emissions, the ETS reduces Australia's GDP by just over 1.1% in 2030 relative to the basecase. Three, the negative impact on real household consumption is greater than the effect on GDP (1.5% viz. 1.1%) reflecting the need to import permits. Four, while the national macroeconomic impacts of the ETS are modest this is not reflected in the industry and regional impacts. Five, the ETS significantly raises output for the forestry industry, for which the carbon charge effectively is a production subsidy. Also, non-hydro renewable and gas-fired electricity generation gain at the expense of coal-fired electricity generation. Other adversely affected industries include private transport services, private electricity equipment services and private heating services, all of which are affected by increases in the price of energy. Six, at the regional level, Queensland is the most adversely affected region, due to its over representation of coal and coal-fired generation, and Tasmania is the most favourably affected, due to the importance of forestry.

Our introduction raised seven questions regarding the level of detail required by policy makers and other stakeholders when considering CGE-based analyses of an ETS. Our experience from the Australian study suggests the following answers.

- *At what level of detail must the stationary-energy sector be modelled for the effects of policy on its emissions to be captured adequately?* For credibility, we think that very fine detail is required. This is done by linking the electricity sector in MMRF with a detailed electricity model (WHIRLYGIG).

- *Is it necessary to include the lumpiness of generation investment explicitly in CGE computations of the effects of climate-change policy?* This is a timing issue. If the stakeholder is interested only in broad-based analysis of outcomes for some far-off future year, or a net present value calculation of effects across many years, then the answer is probably no, assuming that the existing treatment of investment is realistic for the projected long-run change in capital. Whereas if the focus is on year-to-year changes for investment and other variables, then incorporating lumpiness does matter.

- *Greenhouse-gas emissions are a global externality problem: does this mean that the consequences of emissions policy can only be investigated using a global model?* Certainly for Australia, and probably for most other countries, changes in trading conditions brought about by global action on climate change will be significant and therefore should be incorporated into modelling the effects of reducing greenhouse emissions. We show how this can be done by linking a detailed country model (MMRF) with a multi-country system (GTEM). GTEM provides MMRF with a carbon price and projections of changes in Australia's trading environment for the basecase and the ETS-inclusive projections.

- *In modelling the effects of an emissions policy, do we need agents with full inter-temporal optimisation or will recursive dynamics do?* An ETS is normally designed to ensure a measure of certainty – there will be a non-zero carbon price after a specified date, that price will probably increase given a scheme of increasing tightness of emission allocation, etc. Under such arrangements, investment in industries such as electricity generation, where asset lives are very long, would be expected to change in line with anticipated future changes in permit price, rather than immediate changes post announcement. Thus a degree of forward-looking expectations is important, especially in the early years of any arrangement. Our analysis generally assumes recursive dynamics. But it does

incorporate forward-looking expectations in electricity and transport *via* linking with the specialised bottom-up models that assume full inter-temporal optimisation. This improves the analysis considerably, particularly for the early years.

- *What representation of a country's emission-intensive trade-exposed industries (EITEIs) is required when early action against climate change is unilateral?* Unilateral action has the potential to disadvantage a country's EITEIs. Accordingly, nearly all such schemes specify some form of assistance or shielding during the period of transition to a fully global ETS. Modelling such assistance is necessary if realistic projections of industry output and employment are required. In our modelling, a detailed representation is put in place. The influence of the associated shielding is evident in early transition years to 2020 where some of Australia's key ETIEIs suffer little if any production loss despite the significant direct increase in unit cost due to a domestic carbon price.

- *What effect will the recycling of revenue from a carbon tax or sale of permits under an ETS have on the efficiency costs of the policy and on income distribution?* Revenue can be recycled in a number of ways, such as increasing government spending or transfer payments, or reducing existing taxes. We find that the net welfare effects of the ETS depend on the extent to which recycling of the ETS revenue adds to or offsets the distortionary effects of the ETS charge. The double-dividend literature suggest that it is possible to recycle in such a way as achieve conventional resource-allocation gains by using the revenue to reduce existing tax distortions. Another view is that the revenue churn associated with the ETS is likely to introduce inefficiencies.

The above answers suggest that to meet the needs of stakeholders engaging in real-world policy debates, the analysis requires substantially more detail than is included in most CGE models. The analysis also requires a detailed intuitive explanation of key results. Users of economic models are often faced with sceptical audiences of policy advisors who may have some economic training, but have little knowledge of economic modelling. In this context, a key to modelling success is interpretation of results. On the one hand, interpretation is about telling a story true to the modelling outcomes without referring to the technicalities of the modelling. This is difficult but essential for the general acceptance of the results. On the other hand, interpretation is about explaining results in quantitative detail. This aids credibility and acceptance of the modelling, but it is also a check on whether the modelling has been done

correctly. To this end, CoPS modellers make extensive use of BOTE calculations, often supported by formal abstract models.

The approach to environmental modelling described here – based on linking models – has an obvious parallel with integrated assessment models (IAMs).[13] IAMs also depend on linking models of different types but unlike the system we have described they include the benefit side of emissions control as well as its costs. An Australian example of this is work by ABARES to develop its global integrated assessment model (GIAM) model in collaboration with CSIRO (Gunasekera *et al.*, 2008). In the GIAM project, ABARES supplies economic modelling and CSIRO supplies physical climate modelling. For the simulations discussed here, no effort is made to include the possible effects of climate change in the basecase projection. Not including climate change means that we do not account for any of the possible direct economic benefits arising from the abatement achieved by an ETS. Including the potential benefits, and hence being able to show a net economic gain from an ETS, is an important item for further research with MMRF. The way forward is likely to be through linking MMRF with a climate model, such as that developed at CSIRO.

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[13] An up-to-date overview of IAMs is provided by Nordhaus (2013). To our knowledge, most other IAMs applied around the world use aggregated economic accounts. These include DICE, MERGE, WIAGEM and MiniCAM (see Mastrandrea, 2010).

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Table 1: Industries and products in MMRF

Industries	Products
1. Sheep & beef cattle	1. Sheep & beef cattle
2. Dairy cattle	2. Dairy cattle
3. Other livestock	3. Other livestock
4. Grains	4. Grains for animal and human consumption
	5. Biofuel used as a feedstock
5. Other agriculture	6. Other agriculture
6. Agricultural services, fishing and hunting	7. Agricultural services, fishing and hunting
7. Forestry	8. Forestry
8. Coal mining	9. Coal mining
9. Oil mining	10. Oil mining
10. Gas mining	11. Gas mining
11. Iron ore mining	12. Iron ore mining
12. Non-ferrous ore mining	13. Non-ferrous ore mining
13. Other mining	14. Other mining
14. Meat & meat products	15. Meat & meat products
15. Other food, beverages & tobacco	16. Other food, beverages & tobacco
16. Textiles, clothing & footwear	17. Textiles, clothing & footwear
17. Wood products	18. Wood products
18. Paper products	19. Paper products
19. Printing and publishing	20. Printing and publishing
20. Petroleum products	21. Gasoline
	22. Diesel
	23. LPG
	24. Aviation fuel
	25. Other refinery products
21. Basic chemicals	26. Basic chemicals
22. Rubber & plastic products	27. Rubber & plastic products
23. Non-metal construction products	28. Non-metal construction products
24. Cement	29. Cement
25. Iron & steel	30. Iron & steel
26. Alumina	31. Alumina
27. Aluminium	32. Aluminium
28. Other non-ferrous metals	33. Other non-ferrous metals
29. Metal products	34. Metal products
30. Motor vehicles and parts	35. Motor vehicles and parts
31. Other manufacturing	36. Other manufacturing
32. Electricity generation – coal	37. Electricity generation – coal
33. Electricity generation – gas	38. Electricity generation – gas
34. Electricity generation – oil products	39. Electricity generation – oil products
35. Electricity generation – nuclear	40. Electricity generation – nuclear
36. Electricity generation – hydro	41. Electricity generation – hydro
37. Electricity generation – other renewable	42. Electricity generation – other
38. Electricity supply	43. Electricity supply
39. Gas supply	44. Gas supply
40. Water supply	45. Water supply
41. Construction services	46. Construction services
42. Trade services	47. Trade services
43. Accommodation, hotels & cafes	48. Accommodation, hotels & cafes
44. Road passenger transport	49. Road passenger transport
45. Road freight transport	50. Road freight transport
46. Rail passenger transport	51. Rail passenger transport
47. Rail freight transport	52. Rail freight transport
48. Water, pipeline & transport services	53. Water, pipeline & transport services
49. Air transport	54. Air transport
50. Communication services	55. Communication services
51. Financial services	56. Financial services
52. Business services	57. Business services
53. Dwelling services	58. Dwelling services
54. Public services	59. Public services
55. Other services	60. Other services
56. Private transport services	61. Private transport services
57. Private electricity equipment services	62. Private electricity equipment services
58. Private heating services	63. Private heating services

Table 2: Summary of MMRF emissions data for Australia, 2005-06 (Kt of CO$_2$-e)

Fuel User	Source of Emissions (fuel and non-fuel)				
	Coal	Gas	Refinery	Non-fuel	Total
1. Sheep & beef cattle	0.0	1.3	1,179.6	70,179.0	71,360.0
2. Dairy cattle	0.0	0.4	483.8	9,297.0	9,781.3
3. Other livestock	0.0	0.7	192.4	2,983.0	3,176.1
4. Grains	0.0	0.8	1,650.1	2,399.0	4,050.0
5. Other agriculture	0.0	0.7	1,248.3	3,085.0	4,333.9
6. Agricultural services, fishing and hunting	0.0	1.2	1,231.2	13.0	1,245.5
7. Forestry	0.0	0.0	473.6	-19,610.0	-19,136.4
8. Coal mining	0.0	0.0	2,761.5	21,610.0	24,371.5
9. Oil mining	0.0	0.0	136.4	818.0	954.3
10. Gas mining	0.0	8,991.0	263.2	6,360.0	15,614.1
11. Iron ore mining	37.1	312.0	321.8	0.0	670.9
12. Non-ferrous ore mining	699.9	660.0	3,699.9	1,634.0	6,693.7
13. Other mining	0.0	0.0	926.4	0.0	926.4
14. Meat & meat products	78.7	83.2	21.1	0.0	182.9
15. Other food, beverages & tobacco	718.4	1,529.8	124.8	0.0	2,373.0
16. Textiles, clothing & footwear	2.8	350.3	12.8	0.0	365.9
17. Wood products	371.1	96.1	14.1	0.0	481.4
18. Paper products	606.7	682.3	17.2	704.0	2,010.3
19. Printing and publishing	13.0	174.0	32.6	0.0	219.6
20. Petroleum products	0.0	1,255.1	4,740.4	490.0	6,485.5
21. Basic chemicals	507.0	1,332.2	2,073.0	2,513.0	6,425.2
22. Rubber & plastic products	27.0	982.9	398.0	0.0	1,407.9
23. Non-metal construction products	404.2	1,814.1	156.4	1,499.0	3,873.7
24. Cement	2,004.8	1,011.9	406.5	4,738.0	8,161.2
25. Iron & steel	3,532.0	1,295.0	170.4	8,961.0	13,958.5
26. Alumina	3,488.7	3,023.6	1,958.9	0.0	8,471.2
27. Aluminium	0.0	0.0	291.6	4,642.0	4,933.6
28. Other non-ferrous metals	1,778.1	3,380.8	481.0	0.0	5,640.0
29. Metal products	0.0	76.6	25.6	0.0	102.2
30. Motor vehicles and parts	0.0	62.1	20.5	0.0	82.5
31. Other manufacturing	97.1	228.0	73.3	674.0	1,072.4
32. Electricity generation – coal	179,163.0	0.0	0.0	0.0	179,163.0
33. Electricity generation – gas	0.0	14,573.0	0.0	0.0	14,573.0
34. Electricity generation – oil products	0.0	0.0	1,042.3	0.0	1,042.3
35. Electricity generation – nuclear	0.0	0.0	0.0	0.0	0.0
36. Electricity generation – hydro	0.0	0.0	0.0	0.0	0.0
37. Electricity generation – other renewable	0.0	0.0	0.0	0.0	0.0
38. Electricity supply	0.0	0.0	662.6	0.0	662.6
39. Gas supply	0.0	0.0	15.5	2,132.0	2,147.5
40. Water supply	0.0	0.0	307.4	0.0	307.4
41. Construction services	0.0	159.3	1,696.7	0.0	1,856.0
42. Trade services	0.0	1,490.4	5,299.0	361.0	7,150.4
43. Accommodation, hotels & cafes	0.0	232.9	705.3	302.0	1,240.2
44. Road passenger transport	0.0	5.6	2,371.0	728.0	3,104.7
45. Road freight transport	0.0	71.5	22,468.7	0.0	22,540.3
46. Rail passenger transport	0.0	0.0	341.3	0.0	341.3
47. Rail freight transport	0.0	0.0	1,793.6	0.0	1,793.6
48. Water, pipeline & transport services	0.0	4.1	2,657.8	0.0	2,661.8
49. Air transport	0.0	0.0	5,136.3	0.0	5,136.3
50. Communication services	0.0	98.2	1,574.1	0.0	1,672.3
51. Financial services	0.0	2.3	3.2	0.0	5.6
52. Business services	0.0	262.3	1,635.9	0.0	1,898.2
53. Dwelling services	0.0	5.4	18.5	0.0	23.9
54. Public services	0.0	187.4	1,867.9	0.0	2,055.4
55. Other services	0.0	44.1	1,634.0	17,037.0	18,715.1
56. Private transport services	0.0	0.0	36,905.0	1,613.0	38,518.0
57. Private electricity equipment services	0.0	0.0	0.0	835.0	835.0
58. Private heating services	0.0	6,983.6	0.0	0.0	6,983.6
Residential	16.8	0.0	277.9	0.0	294.7
Total	193,546.4	51,466.3	114,000.6	145,997.0	505,010.4

Table 3: Basecase projections for industry output (average annual percentage changes, ranked)

Rank	Industry	2010 to 2030
1	37. Electricity generation – other renewable	7.3
2	7. Forestry	7.0
3	49. Air transport	5.2
4	50. Communication services	4.6
5	52. Business services	4.6
6	10. Gas mining	4.2
7	8. Coal mining	4.0
8	33. Electricity generation – gas	4.0
9	47. Rail freight transport	3.7
10	51. Financial services	3.6
11	46. Rail passenger transport	3.6
12	13. Other mining	3.5
13	54. Public services	3.4
14	44. Road passenger transport	3.4
15	55. Other services	3.1
16	12. Non-ferrous ore mining	3.1
17	45. Road freight transport	3.0
18	41. Construction services	3.0
19	57. Private electricity equipment services	3.0
20	48. Water, pipeline & transport services	2.9
21	43. Accommodation, hotels & cafes	2.9
22	53. Dwelling services	2.8
23	11. Iron ore mining	2.8
24	4. Grains	2.7
25	39. Gas supply	2.6
26	26. Alumina	2.6
27	42. Trade services	2.5
28	19. Printing and publishing	2.3
29	24. Cement	2.2
30	5. Other agriculture	2.1
31	28. Other non-ferrous metals	1.9
32	40. Water supply	1.8
33	27. Aluminium	1.8
34	56. Private transport services	1.7
35	6. Agricultural services, fishing and hunting	1.7
36	58. Private heating services	1.7
37	38. Electricity supply	1.7
38	1. Sheep & beef cattle	1.6
39	20. Petroleum products	1.5
40	23. Non-metal construction products	1.5
41	3. Other livestock	1.3
42	22. Rubber & plastic products	1.3
43	17. Wood products	1.3
44	29. Metal products	1.2
45	15. Other food, beverages & tobacco	1.1
46	14. Meat & meat products	1.1
47	25. Iron & steel	1.1
48	2. Dairy cattle	0.9
49	18. Paper products	0.9
50	9. Oil mining	0.6
51	21. Basic chemicals	0.5
52	32. Electricity generation – coal	0.4
53	30. Motor vehicles and parts	0.1
54	36. Electricity generation – hydro	0.0
55	34. Electricity generation – oil products	0.0
56	35. Electricity generation – nuclear	0.0
57	31. Other manufacturing	-0.1
58	16. Textiles, clothing & footwear	-0.8

Table 4: Features of the ETS as modelled

Assumption	Details
Timing and relationship to global action	Scheme starts in 2011 as a domestic scheme with a specified emissions price. From 2012 to 2020 it continues to operate as a domestic scheme, but with permits allowed to be purchased from overseas such as credits generated through projects under the Kyoto Protocol's Clean Development Mechanism. From 2020 onwards, Australia's scheme is fully integrated into the global scheme. Scheme price is specified for each year. The allocation of permits in Australia is specified from 2012 onwards. Emission price and permit allocation come from GTEM and are given in Sections 5.1.1 and 5.1.2.
Coverage	Phased coverage of sectors: • All emissions other than from agriculture and transport from 2011 onwards. • Transport emissions from 2012. • Agricultural emissions from 2015. All sectors covered by the scheme face the same emissions price.
Free permit allocation to generators	Limited free allocation of permits to electricity generators to 2020. Emission permits are allocated to offset net loss in profits.
Compensation for energy-intensive trade-exposed industries	Energy-intensive trade-exposed industries are compensated through to 2020 via shielding (see Section 3.3). Category 1 industries* are: *Sheep & beef cattle*, *Dairy cattle*, *Grains*, *Cement*, *Iron & steel* and *Aluminium*. Category 2 industries* are: *Other livestock*, *Gas mining*, *Paper products*, *Basic chemicals*, *Non-metal construction products*, *Alumina* and *Other non-ferrous metals*. From 2020 onwards the shielding rates decline in a linear way to zero in 2025.
Recycling of surplus revenue	Remaining permits, beyond those used to compensate generators and trade exposed energy sectors, are assumed to be auctioned, with surplus revenue recycled as a lump sum to households.
Other Australian mitigation policies	The RET continues to operate through to 2020. Most other mitigation policies included in the basecase cease with the exception of a QLD scheme designed to increase gas generation in that state to 15% of total generation.
Banking	Unconstrained banking is allowed, but no borrowing. The impact of banking is reflected in the WHIRLYGIG modelling of the electricity generation sector and thus influences the permit price adopted in the MMRF modelling. Banking allows arbitrage between higher permit prices later in the ETS period and lower permit prices earlier. This has the effect of increasing the amount of (cheaper) abatement undertaken early, and reducing the amount of (more expensive) abatement later.

* See Department of Climate Change (2008) for an explanation of these categories.

Table 5: Alternative interpretation of ETS impacts on real GDP

Option	Description of measure	2020	2030
1	Average annual growth rates (%)	2.91(Base) 2.87(ETS)	2.63(Base) 2.56(ETS)
2	Deviations from basecase (%)	-0.5	-1.1
3	Absolute deviations from basecase ($m)	-7268.7	-20138.4
4	Months of growth lost due to the ETS	2.0	4.9

Table 6: Macroeconomic variables (percentage changes from basecase values, 2030)

	Real GDP/GSP	Real household consumption	Real international exports	Real international imports	Employment
NSW	-1.2	-1.9	1.2	-2.4	-0.5
VIC	-0.9	-2.0	6.9	-1.6	0.1
QLD	-1.8	-1.1	-2.0	-2.8	-0.9
SA	-0.7	-2.5	7.2	-1.6	0.0
WA	-0.8	0.8	-1.5	-1.4	1.0
TAS	3.3	-1.8	21.4	1.6	3.1
NT	1.5	2.2	3.3	1.0	2.2
ACT	-1.2	-3.0	3.0	-2.8	-0.9
National	-1.1	-1.5	1.2	-2.0	-0.1

Table 7: Household income, consumption, savings and investment (changes from basecase values, 2030)

	$b deviation
Household Disposable Income	
Household income from labour and capital after income tax	-33.4
Permit price times emissions (Gross permit tax)	26.0
Minus value of permits purchased from overseas	-7.9
Minus value of shielding	0.0*
Government handout to maintain budget balances (ex permit income)	-14.5
Total Household disposable income	-29.8
Private consumption expenditure	***-14.8***
Public consumption expenditure	***-6.3***
Private saving (ΔHDI – Δprivate consumption)	***-15.1***
Public saving (Δgovernment income - Δpublic consumption)	***-3.4***
Investment	***-18.1***

 *Shielding rates decline to zero after 2020.

Table 8: Industry output (percentage changes from basecase values, 2030, ranked)

Rank	Industry	2030
1	7. Forestry	80.2
2	33. Electricity generation – gas	15.5
3	37. Electricity generation – other renewable	12.9
4	25. Iron & steel	9.1
5	28. Other non-ferrous metals	9.1
6	26. Alumina	6.5
7	21. Basic chemicals	3.8
8	3. Other livestock	1.9
9	46. Rail passenger transport	1.8
10	16. Textiles, clothing & footwear	1.7
11	23. Non-metal construction products	1.6
12	30. Motor vehicles and parts	1.5
13	18. Paper products	1.4
14	17. Wood products	1.2
15	22. Rubber & plastic products	1.0
16	2. Dairy cattle	0.8
17	45. Road freight transport	0.8
18	15. Other food, beverages & tobacco	0.7
19	6. Agricultural services, fishing and hunting	0.3
20	19. Printing and publishing	0.2
21	34. Electricity generation – oil products	0.0
22	36. Electricity generation – hydro	0.0
23	35. Electricity generation – nuclear	0.0
24	9. Oil mining	0.0
25	1 Sheep and cattle	-0.1
26	31. Other manufacturing	-0.1
27	29. Metal products	-0.2
28	4. Grains	-0.2
29	53. Dwelling services	-0.2
30	54. Public services	-0.2
31	51. Financial services	-0.2
32	48. Water, pipeline & transport services	-0.2
33	42. Trade services	-0.3
34	52. Business services	-0.3
35	11. Iron ore mining	-0.4
36	12. Non-ferrous ore mining	-0.5
37	5. Other agriculture	-0.6
38	50. Communication services	-0.7
39	40. Water supply	-0.8
40	14. Meat & meat products	-0.8
41	39. Gas supply	-1.0
42	55. Other services	-1.2
43	43. Accommodation, hotels & cafes	-1.6
44	13. Other mining	-1.7
45	24. Cement	-1.7
46	47. Rail freight transport	-2.1
47	49. Air transport	-2.1
48	27. Aluminium	-2.4
49	56. Private transport services	-2.4
50	44. Road passenger transport	-2.4
51	41. Construction services	-3.1
52	58. Private heating services	-4.6
53	10. Gas mining	-5.8
54	20. Petroleum products	-5.9
55	38. Electricity supply	-6.8
56	57. Private electricity equipment services	-7.7
57	8. Coal mining	-12.8
58	32. Electricity generation – coal	-18.8

Table 9: CO$_2$-e emissions by major source category for Australia (changes from basecase values)

Percentage deviations from basecase values	2030
Energy sector, total	-17.3
Fuel combustion	-13.6
Stationary	-14.3
Electricity generation	-19.2
Other	-7.3
Transport	-11.7
Fugitive emissions from fuels	-41.1
Industrial processes	-56.1
Agriculture	-17.6
Waste	-75.9
Land use change, forestry	na
Total	-25.6

Figure 1: Emissions by major source in the basecase
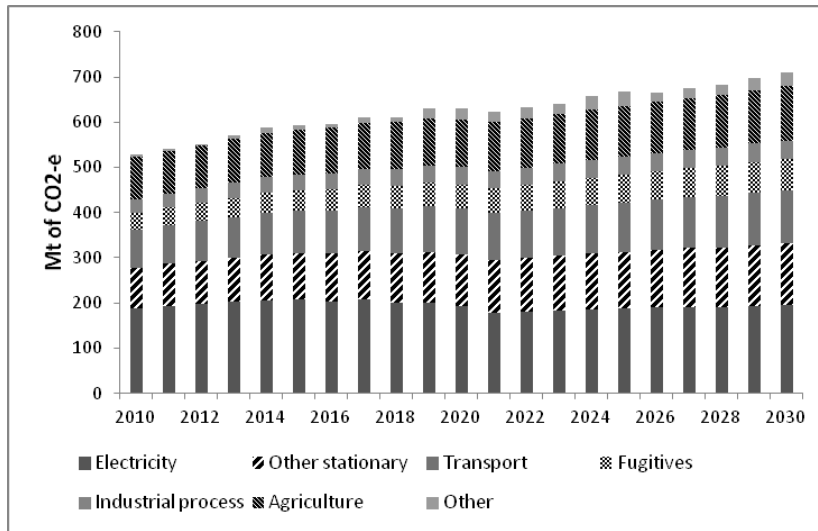
Figure 2: The response of Australia's terms of trade due to the ETS
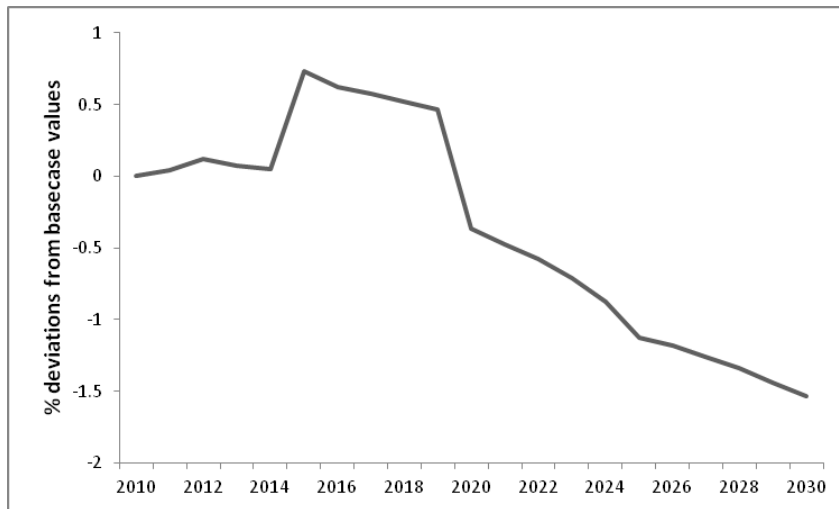
Figure 3: Deviations in employment and real wage rates
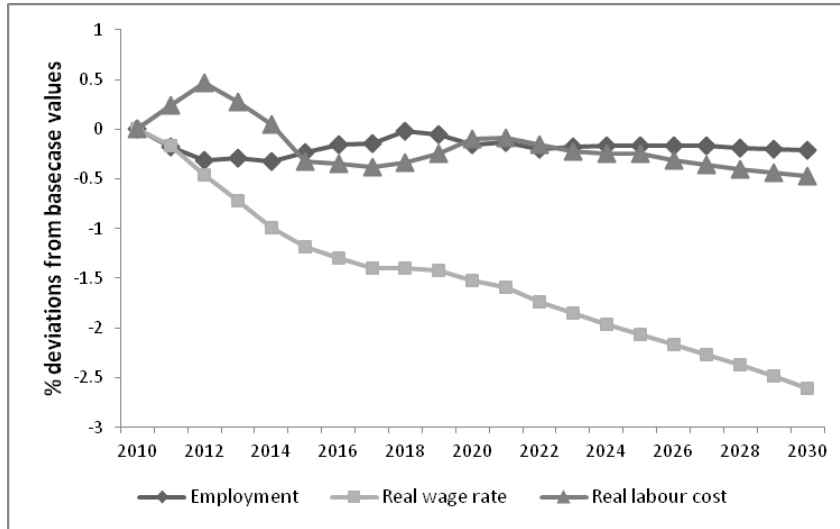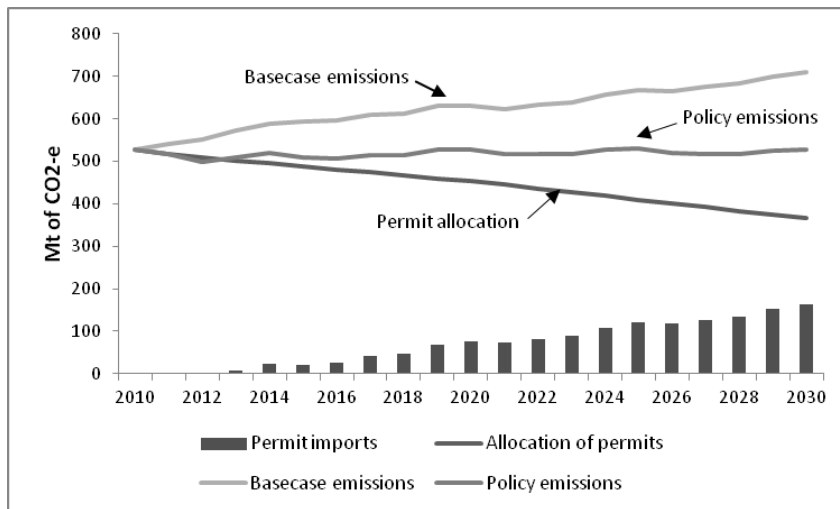

Figure 4: Emissions, permit allocation and permit imports

Figure 5: Deviations in real gross state product