A Dynamic Evaluation of the Impacts of an Emissions Trading Scheme on the Australian Economy and Emissions Levels[1]

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Abstract

Using an environmentally extended MONASH model and a database containing detailed energy sectors, this paper evaluates the effects of an Emissions Trading Scheme on the Australian economy and the emissions levels. The simulation results indicate that to achieve the Australian emissions reduction target in 2030, the price of carbon permits would increase from A$4.6 per tonne in 2015 through A$13.3 per tonne in 2020 to A$43.5 per tonne in 2030. The main buyer of permits would be the agricultural sector, black-coal electricity sector and brown-coal electricity sector. Compared with the business-as-usual scenario, Australia's GDP is projected to be 0.77% lower in 2020 and 1.84% lower in 2030. The income of households and household welfares measured in terms of equivalent variations are also reduced considerably. The results also lend strong support towards the transition to renewable energy.

Keywords: Emissions trading scheme, energy industries, dynamic CGE modelling, MONASH model, Australian economy.

1 Introduction

At the 2015 Paris Climate Conference, the Australian Prime Minister committed Australia to the 2030 emissions target by reducing its emissions level below 26-28% the 2005 level (Arup, 2015). This target, however, is unlikely to be achieved by the current subsidized emissions abatement policy. Politicians and economists have already criticized the current projected budget (A$2.55 billion) of the Emissions Reduction Fund (ERF) as being inadequate to enable Australia to achieve even the 2020 target[2]. The government, in fact, bought an abatement of 92Mt of CO_2-e (Carbon Dioxide equivalent) by using half of the

[1] The authors would like to acknowledge funding from the Australian Research Council under the ARC Linkage Project LP120200192. In addition, the authors are very grateful to Dr. Judith McNeill for useful advices.

[2] Clarke et al. (2014) stated that the ERF only allows the government to buy 50% of abatement needed by 2020.

budget but the awarded contracts (over 95%) were from 6 to 10 years in order to sell all emissions abatement for the government (Clean Energy Regulator, 2015).

To achieve the 2030 Australian emissions abatement target, a stronger climate policy must be considered. An Emissions Trading Scheme (ETS) thereby could be a potential option for Australia in order to achieve both 2020 and 2030 emissions targets. Such an option is likely to be of continuing relevance to Australia and be desirable in Australia in the future for a number of reasons. (1) The ETS was discussed thoroughly in the National Emissions Trading Taskforce (2007), Report of the Task Group on Emissions Trading (Prime Ministerial Task Group on Emissions Trading, 2007) and the Carbon Pollution Reduction Scheme (Parliament of Australia, 2010). (2) The Australian Environment Minister Greg Hunt requested the Climate Change Authority to consider a possibility of an ETS (Minister for the Environment, 2014). (3) The ETS has been an internationally recognised policy strategy, led by European countries (Parliament of Australia, 2013). (4) The domestic ETS is an appropriate mechanism to link with global emissions markets, thereby reducing costs and increasing global competitiveness of participants. It is because marginal abatement costs (MACs) of firms converge to an intermediate level with the same price of permits (Babiker et al., 2004). (5) Emissions caps under the ETS are likely to secure achievements of the emissions targets compared with a carbon tax, since an ETS sets a maximum level of emissions for the whole country while emissions levels would vary depending on the carbon price under a carbon tax. In addition, neither an Australian Labor nor Coalition Government is likely to introduce a carbon tax again, as the Labor Government intended to move to a period of floating prices for carbon since 2015 under the Carbon Price Mechanism (Parliament of Australia, 2011) and the Coalition Government repealed the carbon tax in 2014.

Against this backdrop, this study intends to evaluate the possible costs of a domestic ETS on the Australian economy, households and industrial sectors. The analysis is based on simulations of the MONASH model with specific enhancements, outlined in the modelling section. The deviations between the policy scenario outcomes and the baseline scenario indicate the differences in the economy when such an ETS is taken into account. This scheme covers all emissions reported in the Australian National Greenhouse Gas Inventory (Deparment of the Environment, 2013) and all industrial sectors are involved in the scheme. Under such a scheme, all permits are auctioned and all firms (sectors) will face the same price for a permit (e.g. tonne of CO_2-e). Sectors initially purchase permits up to their emissions caps[3] from the Federal Government. A sector can sell their surplus permits, if their emissions levels were below their emissions caps, to other sectors at the auction price or vice versa but no permits are traded with overseas markets. Revenues from permits selling are not recycled but endogenously considered in the budget for the government's purposes such as consumption, transfers to households and compensation for a public deficit. These activities work via a system of equations related to the government's demands and transfers.

The remainder of this paper is as follows. Section 2 reviews previous studies on the impacts of an ETS. Section 3 explains the model and the database used. Section 4 describes the simulation designs for the modelling. Section 5 analyses the simulation results whereas Section 6 provides concluding remarks.

2 Literature Review

The Australian public has paid considerable attention to climate change issues and policies for decades but the current government has not yet concluded a long-term climate change policy. The emissions trading mechanism has attracted a considerable support from public and the next federal election in 2016 would be a peak time to raise such a policy issue.

Both advantages and disadvantages of an ETS has been thoroughly discussed by many scholars, including Hawkins and Jegou (2014), Stavins and Judson (2007), Jaffe and Stavins (2008), Tuerk et al. (2009) and Flachsland et al. (2009). Compared to a carbon tax, an ETS provides opportunities for emissions reduction with least cost because it is based on market forces to generate an efficient price for permits of emissions. It also gives firms a saleable asset. The ETS in fact equalises the MAC between participants (sectors or countries), whereby benefiting all participants (Babiker et al., 2003). In this regard, Babiker et al. (2004) graphically outlined net gains of an international ETS with the joining of two countries, instead of independently maintaining their two domestic markets. An international ETS yields a lower MAC than each particular MAC of a participant. Utilising this reasoning, many economists prefer the permit auctioning mechanism to curb emissions (Folmer & Tietenberg, 2005).

There is a wide range of empirical literature that develops applications of Computable General Equilibrium (CGE) modelling in order to estimate the effects of ETSs. Many studies

[3] Emissions cap for a firm is the maximum level of emissions that allow that firm to release pollution.

have focused on the European Union emissions trading scheme (EU-ETS) subject to the Kyoto Protocol commitment. Böhringer (2002) investigated how the restricted levels for trading emissions to the energy-intensive power sector will affect the magnitude and distribution of abatement costs across EU countries. The targets are subject to the Kyoto Protocol by 2010. Böhringer applied a world economy CGE model, including 7 sectors and 23 regions, including 15 EU member states, Annex-B parties and major non-Annex-B countries. The author compiled a benchmark data set for the year 1995 from four sources: GTAP4 (contains global Input-Output tables), EUROSTAT (contains Input-Output tables for all EU member countries), IEA energy balances and energy prices/taxes and CHELEM (supplies harmonized accounts on bilateral trade between countries). Such combinations allow analysis of each EU member country. The study found that allowance of trading possibility between power sectors across country borders would provide the highest efficiency gains, instead of restricting them to domestic markets but subject to the electricity sectors receiving permits at an auctioned price, rather than free.

Babiker et al. (2003) addressed two questions: (1) to what extent do the welfare costs with the burden sharing agreement implementation in EU rely on allocation of emissions permits between sectors? (2) what is the climate change strategy to favour domestic production? The authors applied the Emissions Prediction and Policy Analysis European Union model to answer these questions. This model is a global recursive dynamic multi-regional general equilibrium model, containing 11 sectors and 22 regions. To present data for individual EU countries, Babiker et al. (2003) incorporated GTAP-5 pre-release, which provides a complete disaggregation of the EU, into GTAP4-E database. The numerical simulations indicated that permit allocations would lower economic costs if such allocations differ from the trading solution in the simulations while the European economy will bear more costs in the case of exempting energy-intensive industries. Their findings also suggested that the divergence from the domestic economy-wide cap-and-trade system increases economic costs but the EU economy is better off rather than having an economy-wide cap-and-trade system due to existing energy taxes in various economies. Other studies related to the EU-ETS are Böhringer and Welsch (2004; 2006), Fischer and Fox (2007), Kemfert et al. (2006), Viguier et al. (2003), Böhringer and Lange (2005) and Lokhov and Welsch (2008).

Studies on Australian climate change policies are diverse, including carbon tax to ETS and Direct Action Plan. Regarding the ETS analyses, the most comprehensive studies were performed by Adams and his colleagues. Adams (2007) estimated the possible costs of an ETS for Australia to find out if such a policy should be implemented. He applied the Monash Multi-Regional Forecasting (MMRF) model with key inputs related to the electricity sector supplied by McLennan, Magasanik Associates (MMA). The MMRF model is a dynamic model, containing 52 industries, 56 commodities, 8 states/territories and 56 sub-state regions of Australia. The ETS was designed in a similar way to those in the National Emissions Trading Taskforce (2007) and the Prime Minister's Taskforce (Prime Ministerial Task Group on Emissions Trading, 2007). The analyses were aimed at comparing the implementation of an ETS with the business-as-usual growth rate until 2030. The outputs of the MMA model indicated an increase of permit price from A$18.3 per tonne of CO_2-e in 2010 to A$50.2 per tonne in 2030. Such outputs associated with other outputs from the MMA model were the inputs to the MMRF model. In conclusion, Adams favoured the carbon pricing policy in Australia with emissions trading, as the economy would grow strongly in the case of ETS. In a subsequent study, Adams et al. (2014) continued their investigations of the ETS, mainly addressing the electricity sector in Australia but using a different approach. Unlike Adams (2007), Adams et al. (2014) used a dynamic multi-country CGE model, namely the GTEM model, in order to generate the prices and allocations of permits for Australia. Such an ETS in Australia was considered as a part of a global ETS. The outputs from this became inputs to the MMRF model. In addition, the electricity sector in MMRF was replaced with WHIRLYGIG's specification. The WHIRLYGIG model includes detailed information of the Australian electricity sector, including wholesale and retail electricity prices, capacity by generation type, fuel use, emissions, etc. The main finding was that the global price of permits increases from A$25 per tonne in 2015 to A$50 in 2030, Australia needs to buy half of its abatement needed from oversea markets and Australia would only experiences a reduction in GDP by 1.1% in 2030 relative to the baseline.

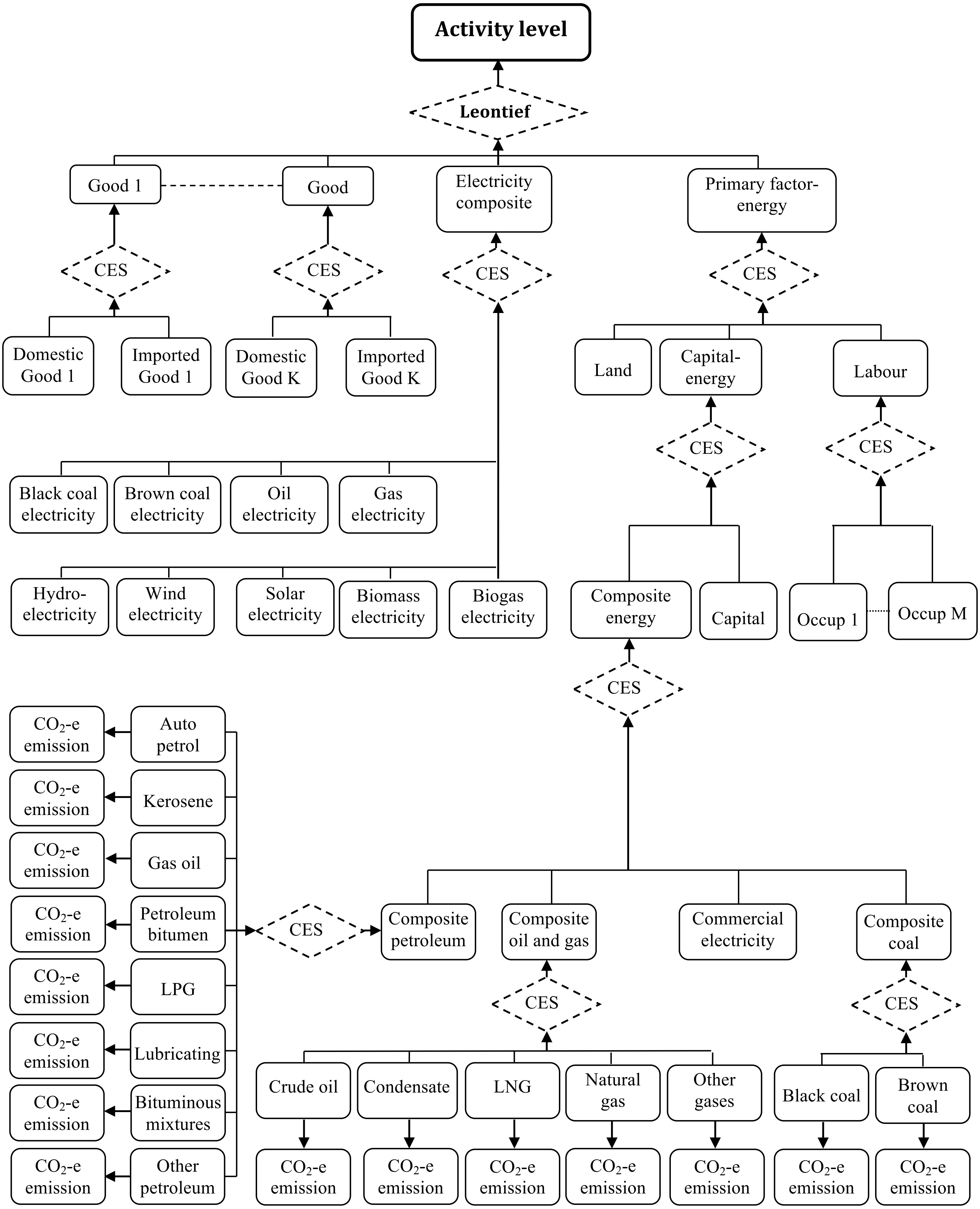
In this study we have used the extended MONASH model in order to evaluate the effects of an ETS on the Australian economy at its emissions. An extensive database was compiled and updated to recent years with details of energy sectors, including nine electricity generation sectors. Such extensions were considered appropriate in analysing multi-dimensions of an ETS.

3 Model and database

This study specifically bases its analysis on the MONASH model with some additional developments. These enhancements involve (i) re-structuring of the production function, (ii) inserting multi-household groups dimension and institutional income accounts, (iii) development of the domestic ETS coding and (iv) inserting of GHG emissions in the database. These additional specifications make our version of the MONASH model an original one in Australia targeting climate change policy analysis.

In this extended version of the MONASH model, the output production function is replaced by the ORANI-G model production system (Horridge et al., 2000) because our study does not contain output composite commodities. In the MONASH model, joint-production industries produce different combinations of several agricultural commodities.

Figure 1: The structure of input production function



Source: Adapted from Siriwardana et al. (2013).

Figure 1 shows the input structure of industries, which is adapted from Siriwardana et al. (2013). The input composite demand of each industry is a five-layer nested Leontief-CES (Constant Elasticity of Substitution) function in order to minimise their costs. At the top level, a Leontief function is applied to select intermediate inputs, electricity composite and primary factor-energy composites. There is no substitutability between factors in the Leontief function. The other four levels show various CES functions at lower levels, which allow a sector to substitute less expensive inputs for more expensive inputs at each CES level. For example, if crude oil is more expensive relative to natural gas, sectors will substitute natural gas for crude oil. The possibility of such substitution depends on the values of substitution elasticities.

We have divided electricity commodities into composite electricity commodity and commercial electricity. One reason for this division is that industries and final users can only purchase electricity from agents, not generators. At the Leontief function level, composite electricity commodity is therefore selected by the electricity distribution sector (agent) and self-consumed by the electricity generation sectors only. Other industries use commercial electricity. The composite electricity commodity is treated differently to the other intermediate input commodities (see Figure 1). Agents will select composite electricity commodity from nine sources via a CES function, namely electricity generated from black coal, brown coal, oil, gas, hydro, wind, solar, biomass and biogass[4]. This structure allows the electricity generation to shift from high emission-intensive inputs (e.g. black coal and brown coal) to cleaner inputs (e.g. gas and renewable). In this development of the production structure, energy inputs are nested with capital, as the investment on energy saving devices and energy efficiency are positively related, e.g. a modern truck uses less oil than an older model with the same load and engine capacity. Different energy nests are outlined at the lower levels. Another enhancement to the model is an addition of CO_2-e emissions; they are linked with the uses of energy and output activity[5].

In the modelling, we have added some equations in order to simulate an ETS for Australia. Emissions from energy uses and output activities will vary as the same rates as fluctuations in demand for energy and supply of outputs. There is also a price on emissions. In the case of an ETS, the government sets emissions caps[6] for each sector and sectors initially have to buy

[4] Australia does not generate electricity from nuclear power.
[5] Details of Greenhouse gas emissions compilation can be seen in Nong et al. (2015).
[6] An emissions cap is the maximum level of emissions that allows a sector to emit.

emissions permits up to their caps from the government. Such activities will put extra costs on each sector. Sectors can also buy or sell domestically their permits to other sectors. In the modelling, sectors will base on their 'emissions abatement technology[7]' in order to determine how much inputs and outputs to operate, hence maximising their profits. These steps are simultaneously simulated in the model in order to determine an equilibrium price for permits, input uses, output supplies and emissions levels.

The database used in this study was collected and compiled from the Australian Input-Output (I-O) Tables 2008-09, the I-O product details Table 2008-09, the Australian System of National Accounts 2010-11, the Extended Household Expenditure Survey (HES) 2009-10, and the National Greenhouse Gas Inventory (NGGI) 2009.

There are 39 sectors, including 24 energy sectors, in the database. The 24 sub-energy sectors were disaggregated from the four original energy sectors. Such a disaggregation was primarily based on the information in the I-O product details Table 2008-09, which provides very detailed information regarding demand and supply of sub-commodities by each industries. We also based on the information from the NGGI 2009 for such a disaggregation, as it provides emissions from fuel combustions by industries. Hence, we could observe which sub-energy commodities are used by sub-energy industries. The energy industries were disaggregated from the initial industries as follows:

- The coal mining industry into two industries: black coal and brown coal industries.
- The oil and gas extraction industry into five industries: crude oil, condensate, liquefied natural gas, natural gas and other gas industries.
- The coal and petroleum product manufacturing industry into eight industries: automotive petrol, kerosene, fuel oil, petroleum bitumen, liquefied petroleum gas produced at refineries, lubricants, bituminous mixtures, and other coal and petroleum products n.e.c (not elsewhere classified).
- The electricity generation industry into nine industries: electricity generation from black coal, brown coal, oil, gas, wind, solar, biogas, biomass and hydro-electricity.

[7] Such technology includes improvement of energy efficiency techniques, reduction in production levels and high substitution possibilities. For example, an industry, which has high substitution possibilities for dirty energy resources, will present low marginal abatement cost, thereby easily reducing emissions. Sources of emissions can also affect the abatement level, for example, if emissions of sector M considerably come from output activity, though sector M tries to substitute cleaner inputs for dirty inputs, its emissions will still be very high.

In the database, households are also disaggregated into 10 groups. The information used for such a disaggregation is derived from the Extended HES 2009-10. When sorting out 10 household groups, according to their total income level variable, other variables would also be sorted to these corresponding groups. The following steps were to use the appropriate variables for each household flow disaggregation. The details of database compilation can be found in Nong et al. (2015).

4 Simulation designs

4.1 Baseline assumptions

This study mainly applies macroeconomic forecasts in the baseline or business-as-usual scenario. The baseline is a sequence of annual forecasts of the whole economy, constructed using external forecasts for macro variables. This baseline shows expected outcomes for the Australian economy from 2015 to 2030 in the absence of a domestic ETS.

Most of these forecasts are provided by the World Bank, Oganisation for Economic Co-operation and Development (OECD), Australian Bureau of Statistics (ABS), Australian Treasury and Reserve Bank of Australia. Other forecasts are assumed to keep the same growth rates from the previous period. The projections of technological changes, household preference changes and taste changes are not projected in the baseline forecast. This is because collection of such forecasts is beyond the capacity of the authors. In addition, such forecasts are uncertain over time and it is quite problematic in making such forecasts over a long term. The authors consequently assumed that technology, household preferences and taste are constant in 2015-30. The whole baseline forecasts are outlined in Table 1, whereas key assumptions for selected macroeconomic variables in the baseline from 2015 to 2030 are briefly described as follows:

- The world real GDP is predicted to increase by 2.9% in 2015, 3.3% in 2016 and 3.6% in 2017 (OECD, 2014). It is assumed that GDP will sustain a growth rate of 3.6% per annum in 2018-30. Such an assumption is consistent with the average growth rate of real world GDP in the last 20 years.
- The Australian real GDP is also forecasted to grow by 2.2% in 2015, 2.6% in 2016 and 3% in 2017 (OECD, 2014). In the following years until 2030, it is assumed to

increase annually by 2.8%, based on the forecasts made by the Australian Treasury in Intergenerational Report (Australian Treasury, 2015).

- The Australian population is projected to increase annually by 1.3%. This is based on an average long term forecast in Intergenerational Report (Australian Treasury, 2015) for the next 40 years.
- Over the last ten years, Australia's consumer price index (CPI) has fluctuated. Recently it was recorded at slightly increasing rates, hence an optimistic assumption is made about the economy and the CPI is expected to increase by 1.4% per annum.
- Consistent with growth patterns over 15 years, real household consumption is assumed to increase annually by 3%.
- Exports and imports are projected to continuously grow by 2.8% and 3%, respectively, as the demands for Australian energy and agricultural commodities from China and Japan continue to increase. In addition, since the domestic economy grows and real household consumption keeps rising, imports are projected to increase in response to the domestic market demands.

Table 1: Macroeconomic forecasts in 2015-30 (percentage change)

	2015	2016	…	2020	…	2029	2030
Number of households	1.3	1.3	…	1.3	…	1.3	1.3
Consumer price index	1.4	1.4	…	1.4	…	1.4	1.4
Real world Gross Domestic Product	2.9	3.3	…	3.6	…	3.6	3.6
Real Australian Gross Domestic Product	2.2	2.6	…	2.8	…	2.8	2.8
Aggregate employment	2.3	2.3	…	2.3	…	2.3	2.3
Total population	1.3	1.3	…	1.3	…	1.3	1.3
Population aged over 65	1.3	1.3	…	1.3	…	1.3	1.3
Real household consumption	3.0	3.0	…	3.0	…	3.0	3.0
Aggregate real government demands	3.0	3.0	…	3.0	…	3.0	3.0
Real public investment	1.2	1.2	…	1.2	…	1.2	1.2
Export volume index	2.8	2.8	…	2.8	…	2.8	2.8
Import volume index	3.0	3.0	…	3.0	…	3.0	3.0
The speed of direct adjustment of investment	0.5	0.5	…	0.5	…	0.5	0.5

4.2 Closure settings and allocation of emissions permit

In the annual baseline closure used for the baseline simulation, the macroeconomic variables are set exogenously and shocked. Such variables, however, are endogenous in the annual policy closure and the variables related to policy changes are set exogenously. In the baseline re-run simulation, the baseline scenario is run again but using the policy closure. The purpose of this step is to fix values of all exogenous variables set in the baseline closure. Hence, when shocking the 'policy' variables in the policy scenario, the macroeconomic variables will be determined and the analyses are based on the deviations between the policy simulation and the baseline re-run simulation. In this regard, this study adopted the macroeconomic settings in the policy closure according to Dixon and Rimmer (2002).

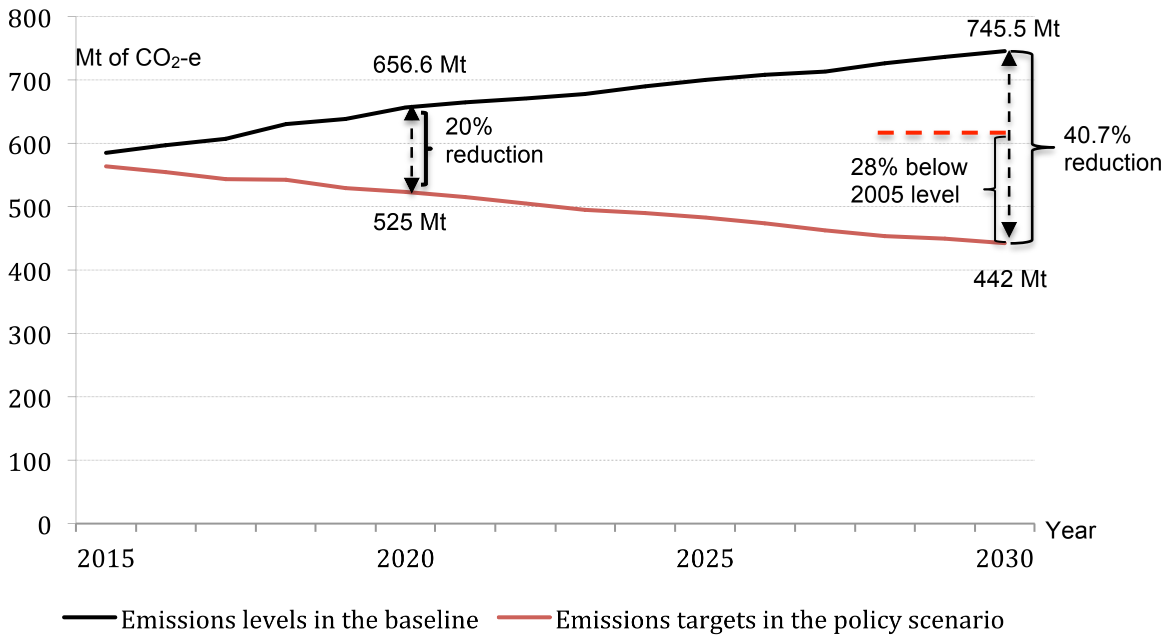
There are also additional settings in order to simulate an ETS in the modelling. From the emissions targets in 2020 and 2030, we assume that there are annual targets for Australia from 2015 to 2030. Such annual targets are gradually reduced in order to help Australia to meet the 2020 and 2030 targets. In the policy closure, we set the industry's emissions cap[8] variable exogenously. From the baseline scenario, we can observe annual emissions levels for each industry and all industries (or the bloc) as a total. We then shock the industry's emissions cap variable at the same rate for all industries in order to help Australia to meet the annual targets. Such a mechanism indicates that permit allocation to each industry is assumed to be based on their emissions levels. In addition, the permit price variable of the bloc (ΔPRICE(bloc)) is endogenous whereas the power of emissions purchase variable[9] (pempb_e(bloc)) is exogenous. The setting indicates that the 'actual' bloc emissions will be equal to the bloc emissions cap in the percentage change form and no permit is traded internationally. Within that bloc, an actual emissions level of an industry will be less or more than its emissions cap. If an actual emissions level goes below its emissions cap, it becomes a permit seller and vice versa. For example, if an industry faces a cap of 10Mt of CO_2-e, it will initially buy permits equivalent to 10Mt from the Federal Government. Then if its actual emissions level is 8Mt of CO_2-e, that industry can sell surplus permits equivalent of 2Mt of CO_2-e to other sectors.

In Figure 2, we outline the baseline emissions levels of Australia from 2015 to 2030 and the 2020 and 2030 emissions targets. The black line indicates the Australian emissions levels over years in the baseline. From 2014 to 2020, the emissions will rise by 14.2% and then again by 29.6% by 2030 relative to 2014 level (575.1Mt). Hence, the emissions levels in 2020 and 2030 are projected at 656.6Mt and 745.5Mt, respectively. The red line in Figure 2 represents the Australian emissions targets over years. That is the gradual reductions in emissions in order to achieve the emissions targets in 2020 and 2030 (Department of the

[8] Industry's emissions cap is equal to its 'actual' emissions level in the baseline simulation.
[9] The power of emissions purchase is the ratio between the 'actual' bloc emissions (the sum of all emissions from input and output activities of all industries within that bloc) and the bloc emissions cap.

Environment, 2015a; 2015b). Australia needs to reduce its emissions cumulatively by 20% and 40.7% in 2020 and 2030 respectively relative to its baseline emissions levels.

Figure 2: The Australian emissions levels in the baseline and emissions targets (Mt of CO_2-e)



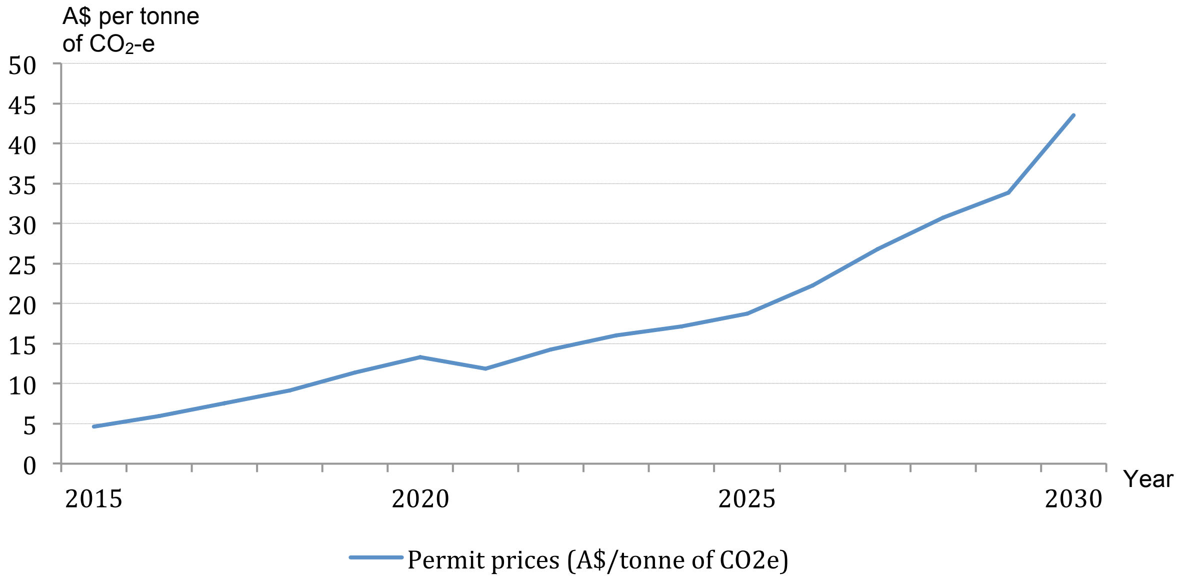
Sources: From the modelling results and emissions targets by 2020 (Department of the Environment, 2015b) and 2030 (Deparment of the Environment, 2015a).

5 Simulation results

With the emissions caps in place, the whole economy will determine an intermediate level for the MAC of all participating industries through their individual MACs. That is, costs to each industry and permit price are endogenously determined according to the levels of emissions caps.

5.1 Permits price

Figure 3: Permit price over years from 2015 to 2030



Source: From the modelling results.

The domestic ETS introduced in Australia in each year from 2015 to 2030 is a cost to producers, subsequently spreading the effects to the whole economy. In such a scheme, producers tend to pass the costs to final consumers as much as possible. Figure 3 outlines permit prices over years from 2015 to 2030. The permit prices will have increased from A$4.6 in 2015 to A$13.3 in 2020 and A$43.5 in 2030, as the caps are reduced over the period (see Figure 2). In MONASH, the permit price is modelled as a tax imposed per tonne of CO_2-e. We have converted this tax to *ad valorem* equivalents since the code in MONASH only deals with *ad valorem* rates of tax.

5.2 Macroeconomic effects

Table 2 shows the key macroeconomic deviations from the baseline. Under the ETS, emissions are priced similar to a tax, where sectors pay amounts to the government equivalent to their emissions levels (tonnes) times the permit price (dollar per tonne). Such an emissions price is a cost to the Australian economy, the cost will become higher when the ETS is operated in a long time associated with gradual reductions in emissions caps. The ETS would reduce economic efficiency and would also reduce the incentive for producers to employ labour and capital for their production processes. Investment is also declined under the ETS. Subsequently, aggregate employment level is declined. In Table 2, the Australian aggregate employment level is reduced by -0.42% in 2020 and -0.19% in 2030 relative to the baseline. In the MONASH model, the labour-market specification is assumed that when employment level is reduced below its baseline level, labour would accept a decrease in their real wage rate. This will encourage producers to substitute labour for capital, hence employment will recover to baseline levels over time and real wage rate keeps decreasing from 2020 to 2030.

Table 2: Main macroeconomic effects of the domestic ETS in Australia (percentage deviations from the baseline)

Macroeconomic variables	2020	2030
Aggregate employment	-0.42	-0.19
Real wage rate	-0.73	-2.81
Household disposable income	-2.27	-9.73
Real household consumption	-0.53	-1.08
Exchange rate	3.45	12.14
Volume of exports	0.04	0.43
Volume of imports	1.35	5.85
Terms of trade	1.43	2.25
Real Gross Domestic Product (GDP)	-0.77	-1.84
Real Gross national expenditure (GNE)	-0.53	-0.94
Change in BOT/GDP ratio	0.46	1.48
Price of energy	21.5	85.5
Price of coal	-16.4	-41.4
Price of natural gas	9.7	47.3
Price of electricity	35.8	132.8

Source: From the modelling results.

The reductions in real wage rate and increases in unemployment rates will cause household disposable income to decline. As the effects of the ETS are progressive when emissions caps are reduced over time, deviation of household disposable income in 2030 is much higher than it in 2020 (i.e. -9.73% in 2030 compared with -2.27% in 2020). Real household consumption is also declined as a result of increasing price of commodities, especially increases of energy prices.

Selling carbon permits under the ETS significantly raises extra revenue for the Australian Federal Government (e.g. the cumulative revenues by 2020 and 2030 are A$26,614 million and A$124,096 million, respectively); public debt, current account deficits and public saving are therefore improved considerably. Terms of trade are also improved by 1.43% in 2020 and 2.25% in 2030 as a result of an increase in export prices and given fixed import prices[10]. These changes will subsequently appreciate the Australian currency by 3.45% in 2020 and 12.14% in 2030.

Although the Australian currency will appreciate and the overall export prices in Australia will also increase, the volume of exports will still rise slightly. This is because price of coal considerably reduces even the overall export prices increase, hence the Australian coal is still very attractive in the international market. Export of coal is therefore increased. In the simulation results, export of coal is increased by 10.9% in 2020 and 33.2% in 2030 relative to the baseline. Such an increase in export of coal exceeds the reductions in exports of other commodities, hence the volume of exports will increase slightly by 0.04% in 2020 and 0.43% in 2030 relative to the baseline.

Australia's imports are likely to increase at higher rates of 1.35% in 2020 and 5.85% in 2030 relative to the baseline. Such shifts in imports indicate that Australian producers and final consumers will considerably seek substitutions away from domestic goods when the domestic prices are relatively higher than those from the international markets. In addition, improvement in the ratio of the balance of trade to GDP indicates that the trade-exposed sectors are less affected by the ETS relative to others and these sectors could partly pass cost increases on to foreign buyers of Australia's exports.

[10] In this study, the authors assume that domestic ETS in Australia cannot affect the world market, as Australia is a very small economy relative to the world market, hence import prices are fixed.

When the ETS is in place, real household consumption and investment are reduced while import is increased. Such outcomes are reflected in reductions of GDP. In this regard, deviations in real GDP are -0.77% in 2020 and -1.84% in 2030. Real gross national expenditure (GNE) is also reduced due to increases in overall prices but such reductions in real GNE are less than those for real household income because the ETS raises extra revenue for the government. The government's expenditure on goods and services is therefore likely to increase, leading to lower reduction rates in real GNE compared to those for real household consumption.

In the ETS scenario, sectors will bear the costs of their emissions, resulting in their supply of output being likely to decline. In the meantime, sectors will try to substitute cleaner energy (e.g. natural gas) for high emission-intensive energy (e.g. coal) in order to lower pollution, thereby reducing the cost burden from their emissions. Such effects on demand and supply curves will cause the prices of commodities to change. In this case, the price of coal is greatly reduced by 16.4% by 2020 and 41.4% by 2030 relative to the baseline because reduction in demand for coal will outweigh the reduction in supply of coal. The price of natural gas, on the other hand, will increase by 9.7% and 47.3% by 2020 and 2030 respectively, as natural gas is an alternative energy when users substitute other energy inputs for coal. Demand for natural gas is likely to increase eventually, leading to an increase in the price of natural gas.

It is observed that the price of electricity significantly increases from 2020 to 2030. By 2020, the deviation of the wholesale electricity price is 35.8% relative to the baseline and 132.8% by 2030. This is because the ETS considerably increases prices of fossil energy inputs, except prices for coal; such price movements in turn increase the cost of electricity sectors as the Australian electricity sectors mainly use fossil fuels. As shown in Table 2, though price of coal reduces considerably, the price of energy composite will still increase by 21.5% in 2020 and 85.5% in 2030 because prices of all other energy (i.e. electricity, petroleum products, natural gas, etc.) increase at very high rates.

5.3 Emissions trading among sectors

Table 3 shows the domestic emissions trading between sectors within the Australian economy – the number of permits sold equals to the number of permits purchased. The negative numbers indicate emissions permits purchased by buyers while the positive numbers refer to sellers of permits. It is found that the main buyers of permits are the agricultural sector, and the black-coal and brown-coal electricity generation sectors. These sectors have large volumes of emissions for trading because they are among the most polluting sectors. In addition, there are two reasons that they become the main buyers of permits. First, their emissions caps are relatively tight compared with their actual emissions levels, especially for the black and brown coals electricity generation sectors. Second, in the database, most emissions of agriculture sector come from its output activities, even if it considerably substitutes clean energy for dirty energy, it still has large amount of emissions from its activities. It is therefore very challenging for this sector to reduce its emissions; otherwise it needs to reduce production level in order to reduce its emissions level.

The black coal mining, liquefied natural gas extraction, other mining and gas supply sectors also become significant buyers of permits. Similar to the agriculture sector, emissions of these sectors mostly come from production activities, such as fugitive emissions, industrial processes and agricultural activities. Although these sectors have greatly substituted cleaner inputs (i.e. gas and petroleum products) for dirty inputs (i.e. coals and fuel oil), it is still challenging for them to reduce their emissions levels without reducing production levels. It is therefore cheaper for these sectors to buy permits from other lower abatement cost sectors.

The oil electricity generation sector only becomes a small seller while the gas electricity generation sector becomes a significant seller with increasing permits selling until 2030. These sectors have low abatement costs relative to other sectors because they use high emission-intensive inputs. This usage indicates that they have more opportunity to substitute for dirty energy. Another reason is that the emissions caps are relatively high for these sectors compared with their actual emissions levels. In addition, these sectors do not have emissions from production activities, hence when they substitute efficiently for dirty inputs, their emissions levels will be much lower than their emissions caps. A significant increase in the number of permits being sold by the gas electricity sector can be explained by demand increases for permits by other sectors when their caps gradually become tighter over years, e.g. caps for the agriculture sector. Hence, the gas electricity generation sector will assume this advantage as a larger seller of permits over time.

The natural gas extraction and transportation sectors also substitute effectively clean energy inputs for dirty inputs and the caps are relatively high for them, they thereby become significant sellers. Sectors 10 to sector 20 are permits sellers over the period of the domestic ETS. The chemical, cement, metal and merchandise manufacturing sectors become permits sellers in some periods. This outcome does not indicate that they are low abatement cost sectors because large emissions of these sectors come from output activities. Some of these sectors also use particular energy inputs, e.g. the cement and metal manufacturing sectors mainly use coal in their production processes. It is very challenging for them to reduce emissions levels by substituting for dirty energy inputs, otherwise they have to reduce their production levels to cut emissions. It was, however, assumed that the black and brown coal electricity sectors are mainly responsible for emissions abatement by setting their caps relatively low or tight, then becoming permits buyers. Agriculture, black coal mining and gas supply sectors are also important buyers of permits as they have very high abatement costs due to most emissions coming from production activities. Such consequences cause other sectors, e.g. the cement manufacturing sector, to become sellers of permits although they are still high abatement cost sectors.

Table 3: Emissions trading volume by sectors in selected year (thousand tonne of CO_2-e)

	2018	2020	2022	2024	2026	2028	2030
1 Agriculture	-1222	-1863	-429	-726	-1026	-1465	-1851
2 Black coal mining	-257	-403	-82	-134	-194	-284	-377
3 Brown coal mining	40.7	32	19.7	16.4	14	11.6	9.2
4 Oil extraction	-12.2	-18.9	-4.7	-7.6	-10.5	-14.3	-17.1
5 Condensate extraction	-4.2	-6.5	-1.6	-2.6	-3.6	-4.9	-5.9
6 LNG extraction	-38.4	-54.2	-9.9	-19.5	-25.8	-34.4	-41.4
7 Natural gas extraction	245	336.7	396.4	387.1	383	386.6	396.8
8 Other gas extraction	-5.2	-8.7	0	-1	-2.8	-5.9	-9.5
9 Other mining	-43.3	-63.1	-11.8	-20.5	-28.9	-40.9	-52.9
10 Food & drink	90.7	66.6	53.2	47.4	37.8	25.3	12.1
11 Textile clothes	25.3	21.6	15	12.4	10.7	9.1	8.1
12 Wood manufacturing	44.2	38.4	35.5	31.5	27.9	22.9	19.1
13 Petroleum	78.5	54.8	42.9	34.5	29.2	23.5	20.2
14 Kerosene	16.4	9.2	9.8	7	5.9	5.1	5.3
15 Fuel oil	59.4	44.9	35.3	29.7	26.9	23.9	22.3
16 Residual oils	30.6	22.4	13.2	10.6	8.6	6.7	5.2
17 LPG	17.7	16.8	13.1	11.5	10.4	9.4	8.7
18 Lubricate	6	4.4	3.8	3.4	3.1	2.6	2.3
19 Bituminous	18.4	13	7.8	5.9	4.6	3.6	2.8
20 Other Petroleum	76.2	62.5	43.6	35.4	30.6	26.3	23.3
21 Chemical manufacturing	16.8	-56.1	28.2	0	-37.7	-89.9	-148
22 Rubber manufacturing	3	2.9	2.2	2	1.8	1.4	1
23 Cement manufacturing	166.4	89.9	93.4	88.6	42	-30.5	-114
24 Metal manufacturing	-34.7	-100.6	114.9	90.1	46.8	-25.7	-103
25 Merchandise manufacturing	0.1	-1.7	3.5	3.1	1.9	-0.3	-2.5
26 Black coal electricity	-583	-297	-2122	-1696	-1415	-1087	-851
27 Brown coal electricity	-1026	-671	-1480	-1297	-998	-654	-363
28 Oil electricity	73.2	81.4	72.9	70.9	69.5	66	62.3
29 Gas electricity	156	951	1342	1548	1841	2407	3099
30 Hydro electricity	-1.2	-1.9	-1.5	-1.7	-2	-2.4	-3
31 Wind electricity	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4	-0.5
32 Solar electricity	0	0	0	0	0	0	0
33 Biomass electricity	-0.3	-0.4	-0.3	-0.4	-0.4	-0.5	-0.6
34 Biogas electricity	-5.6	-7.4	-5.1	-5.5	-6	-6.6	-7.2
35 Electricity distribution	2.9	2.1	1.3	1	0.8	0.5	0.3
36 Gas supply	-161	-241	-49.8	-84.8	-134	-210	-288
37 Construction	-17.9	-31.6	2.4	-0.8	-6.6	-17	-24.6
38 Transportation	2271	2017	1846	1564	1305	966	625.4
39 Other services	-26.7	-40.9	2.5	-2.1	-9.9	-24.5	-40.3

Note: The positive numbers indicate sellers and vice versa.

Source: From the modeling results.

5.4 Effects on sectoral outputs and employment

Table 4 shows deviations of industries' outputs and employment levels relative to the baseline by 2020 and 2030. As the domestic ETS adds extra costs on inputs and production activities, most sectors are adversely affected. The energy sectors are the most unfavourably affected under the ETS because sectors considerably reduce demands for energy in order to reduce their costs on emissions. In this regard, the prices of natural gas and electricity are significantly increased by 2020 and 2030 (see Table 2). This leads to reductions in demands for energy by other sectors, subsequently reducing outputs of the energy sectors. Although price of coal is reduced considerably but coal is the highest emission-intensive input, hence sectors have no incentive to use more coal in their production processes. Coal is also not a substitute for other energy resources in some cases, for example, the Australian transportation sector does not use coal for their activities. As a result, output of the coal sectors will reduce. The emissions caps also become much lower over time, causing the price of permits to increase from A$13.3 by 2020 to A$43.5 by 2030. The higher costs in turn cause industries' outputs to decline from 2020 to 2030. Higher prices for most energy lead to reductions both in output of energy industries and other sectors. This is because other non-energy sectors reduce their overall demands for energy but their output reductions might be much less than those of the energy sectors.

The most adversely affected sectors relative to the baseline in the first period are the brown coal mining, natural gas extraction, black-coal electricity generation and brown-coal electricity generation. In the second period, the oil electricity generation, gas electricity generation and electricity distribution sectors are also unfavourably affected. These sectors either include a high proportion of emissions in their activities or they experience difficulties in substituting away from dirty inputs. The brown coal sector shows very high reduction rates over the two periods because other sectors try to replace brown coal with cleaner inputs as much as possible. An ideal substitution for brown coal is black coal. Such reasoning leads to slower reduction rates in output of the black coal sector relative to those for the brown coal sector in both periods. Similarly, among oil-gas extraction sectors (sectors 4 to 8), the natural gas extraction sector will reduce its output considerably relative to the other oil-gas extraction sectors. This is because other sectors substitute other oil-gas extraction energy for natural gas. Among petroleum products manufacturing sectors (sectors 13 to 20), there will be increases in the outputs of kerosene, residual oils, lubricates and bituminous sectors (sectors 14, 16, 18 and 19) relative to reductions in the other petroleum products manufacturing sectors (sector 13, 15, 17 and 20). This is also due to substitution occurring by adopting cleaner energy among that group. At a higher level of selection, i.e. energy composite, as coal and oil-gas composite indicate relatively higher emission intensities than petroleum products, the outputs of these sectors experience higher reduction rates relative to the petroleum products manufacturing sectors.

The higher cost of energy leads the fossil fuel fired electricity generation sectors to reduce their inputs. Demands for electricity from other sectors are also reduced as their production levels are contracted. Both reasoning causes considerable reductions in electricity generation from fossil fuels, especially electricity generation from brown coal and black coal, as these sectors have the highest intensities of emissions. The renewable electricity generation sectors show strong growth in outputs from 2020 to 2030 as a result of substitution among the electricity group. The electricity distribution sector (agent), however, still experiences reduction in its output because the reduction in electricity generation from fossil fuels, which greatly exceeds the increase in electricity generation from renewable resources. Australia mainly depends on fossil fuels to generate much of its electricity. It is reported that 86% of electricity in Australia is generated from fossil fuels (Origin, 2015). As a result, the growth in renewable electricity generation sectors is still inadequate to compensate for reductions in electricity generation from fossil fuels. Another reason is due to increases in the price of electricity, thus leading to reduction in demands for electricity. Consequently, the output of the electricity distribution sector would reduce.

Table 4: Industry output and employment (percentage deviations from the baseline)

Sectors	Output		Employment	
	2020	2030	2020	2030
1 Agriculture	-0.9	-3.1	-1.0	-3.1
2 Black coal mining	-1.8	-3.9	-1.5	-2.3
3 Brown coal mining	-48.3	-78.4	-53.3	-83.9
4 Oil extraction	-1.2	-3.5	-1.1	-3.1
5 Condensate extraction	-1.2	-3.5	-1.1	-3.1
6 LNG extraction	-0.1	-0.6	0.5	2.1
7 Natural gas extraction	-10.0	-36.7	-5.4	-21.6
8 Other gas extraction	-2.0	-6.6	-1.8	-5.7
9 Other mining	-0.4	2.2	0.1	4.9
10 Food & drink	-1.2	-4.1	-0.8	-2.6
11 Textile clothes	-2.4	-6.2	-2.3	-5.8
12 Wood manufacturing	-1.5	-3.8	-1.0	-1.8
13 Petroleum	-1.5	-1.3	-1.8	-1.4
14 Kerosene	5.7	15.3	5.9	16.2
15 Fuel oil	-3.0	-12.7	-3.2	-13.1
16 Residual oils	2.1	9.2	2.9	12.2
17 LPG	-5.0	-7.7	-4.5	-5.0
18 Lubricate	2.8	6.7	2.6	6.7
19 Bituminous	0.5	3.7	1.2	6.3
20 Other Petroleum	0.0	-0.3	1.7	5.8
21 Chemical manufacturing	-2.6	-7.1	-1.3	-1.3
22 Rubber manufacturing	-2.2	-5.9	-1.9	-4.9
23 Cement manufacturing	-1.8	-4.9	0.04	2.4
24 Metal manufacturing	-1.9	-5.4	-0.03	2.1
25 Merchandise manufacturing	-3.3	-8.7	-3.2	-8.2
26 Black coal electricity	-21.6	-61.8	5.3	-17.3
27 Brown coal electricity	-36.5	-82.0	-11.8	-56.9
28 Oil electricity	-6.6	-42.2	18.9	12.4
29 Gas electricity	-5.1	-99.2	13.7	-98.7
30 Hydro electricity	51.7	213.4	82.3	382.7
31 Wind electricity	51.8	214.0	82.2	383.6
32 Solar electricity	48.7	193.3	77.2	341.0
33 Biomass electricity	51.3	209.9	81.4	375.8
34 Biogas electricity	41.3	118.8	66.1	212.6
35 Electricity distribution	-9.5	-21.2	-5.9	-8.6
36 Gas supply	-1.4	-4.3	-1.3	-4.1
37 Construction	-0.6	-0.9	-0.5	-0.2
38 Transportation	-1.3	-3.6	0.6	4.5
39 Other services	-0.4	-0.6	-0.3	-0.05

Source: From the modelling results.

Table 4 shows that labour demands by sectors are generally in line with fluctuations in sectoral outputs. Depending on reductions in production levels, the levels of demand for labour are reduced. The brown coal sector, for example, shows a large reduction in its output, hence its employment level is considerably reduced. Similarly, the other services sector (sector 39) will only be reduced by a small rate in its employment level due to the relatively small reduction in its output level. In addition, employment in the energy industries indicates high fluctuations as a result of their high output variations. The brown coal mining sector shows the highest deviations in employment level of -53.3% by 2020 and -83.9% by 2030. The brown coal electricity generation sector will also reduce its employment level by 11.8% by 2020 and 56.9% by 2030 relative to the baseline. As labour can move among industries and some industries increase their production levels, employment levels in some sectors significantly increase. This shows that the renewable and oil electricity generation sectors will considerably increase their employment levels from 2020 to 2030 due to expansions in their output and labour mobility among electricity generation sectors or from other sectors, particularly moving from the black coal and brown coal electricity generation sectors. The LNG extraction, other mining, kerosene, residual oils, lubricates, bituminous, other petroleum products manufacturing, metal manufacturing and transportation sectors will increase their employment levels in both 2020 and 2030 for similar reasons to the electricity generation sectors.

The gas electricity generation sector will initially increase its employment level by 2020 though its production level is slightly reduced. This is probably due to employment movement from other sectors. However, by 2030, when a large deviation of its production levels of -99.2% is experienced, this sector is likely to cut its level of employment by -98.7%.

5.5 Effects on households

Table 5 indicates some key effects on different household groups. Under the ETS, the poorest will experience the highest adverse effects in their real consumption over the two periods. This is because their income levels are relatively low compared to richer groups. Real wage rates are also reduced by 0.73% and 2.81% by 2020 and 2030 (see Table 2), and employment is also reduced over these two periods. Such reasoning could harm the poorer groups in terms of real income rather than the rich. In addition, increases in overall prices will also significantly affect them.

Table 5: Effects of the domestic ETS on households (deviations from the baseline)

Household income deciles	Real household consumption (% change)		Electricity demand (% change)		Gas demand (% change)		Emissions from household consumption (thousand tonne)		Equivalent variation (A$ million)	
	2020	2030	2020	2030	2020	2030	2020	2030	2020	2030
Decile_1	-0.63	-1.47	-1.56	-7.16	-0.55	-0.98	-6.66	-27.29	-35.22	-88.65
Decile_2	-0.54	-1.15	-1.61	-6.84	-0.35	-0.56	-5.16	-17.58	-37.00	-87.88
Decile_3	-0.54	-1.15	-0.86	-3.51	-0.17	-0.30	-6.06	-15.60	-56.43	-127.94
Decile_4	-0.59	-1.28	-1.43	-5.39	-0.29	-0.49	-8.05	-26.40	-69.54	-151.03
Decile_5	-0.51	-1.04	-2.25	-7.95	-0.30	-0.43	-9.49	-31.01	-95.55	-199.17
Decile_6	-0.52	-1.07	-2.62	-8.83	-0.32	-0.45	-12.27	-42.33	-128.36	-253.33
Decile_7	-0.50	-1.01	-3.32	-10.68	-0.34	-0.42	-16.00	-57.12	-95.23	-181.68
Decile_8	-0.47	-0.88	-4.15	-12.80	-0.33	-0.34	-19.10	-68.45	-79.56	-138.43
Decile_9	-0.48	-0.90	-5.00	-14.60	-0.35	-0.33	-25.81	-97.61	-207.29	-334.83
Decile_10	-0.55	-1.13	-5.81	-16.05	-0.43	-0.44	-42.97	-178.39	-330.80	-494.37

Source: From the modelling results.

Table 5 also highlights two crucial components of household consumption; they are the demands for electricity and gas. The electricity demands are reduced through all household groups with increasing reduction rates (i.e. from -0.86% to -5.81% by 2020 and from -3.51% to -16.05% by 2030) from the poorest to the richest. In this regard, the rich probably have many powerful electric appliances such as air conditioning, house heating systems, etc. On the other hand, the rich always represents higher demands for electricity than the poor. Hence, a significant increase in electricity prices would encourage the rich to reduce their use of electric appliances. The poor, on the other hand, are likely to more slightly reduce their usage of electricity, as they do not usually have as many electric appliances as the rich. Energy is also an essential good attracting a relatively higher proportion of the income of the poor. The higher reductions in electricity demands by 2030 relative to those by 2020 are due to increases in price of electricity from 35.8% by 2020 to 132.8% by 2030.

Gas demands by households are reduced at much lower rates relative to reduction rates in electricity demands over the two periods. This is because increases in price of gas are much lower than those for electricity price (see Table 2), hence households only slightly reduce their demands for gas while they considerably reduce demands of electricity. In addition, when price of electricity is increased at a higher rate relative to increasing rate for price of gas, households tend to substitute gas for electricity.

Among the household groups, as incomes of the poor groups are relatively lower than those for the rich hence the increase in price of gas will harm them more than the rich. This situation causes higher deviations of gas demand by the poor compared to the rich. The poorest decile shows the largest deviations of -0.55% and -0.98% by 2020 and 2030, respectively. But the deviations of gas demand among most household groups are only small.

In addition, as a result of negative deviation in real consumption for commodities including fossil fuels, emissions from household usages are reduced relative to the baseline. The emissions reductions from households, however, are very small because there is no cap on households' emissions. They only suffer relatively higher prices for commodities induced by the ETS. By 2020, the households' emissions are reduced from 5.16 to 42.97 thousand tonne of CO_2-e. The reductions are at higher levels of 15.6 to 178.39 thousand tonne of CO_2-e relative to the baseline by 2030, due to progressive shocks of the ETS over time. The higher reduction rates for the rich relative to the poor means the reductions in uses of fossil fuels by the rich are larger than those for the poor. This situation arises because the rich own farms, factories, etc. Hence, when prices of energy increase, they have greater possibilities to reduce use of energy, subsequently reducing more emissions.

The last column of Table 5 summarises households' welfare changes, measured by equivalent variation in dollar terms. The adverse effects become larger from the poor to the rich at increasing rates over time because the consumption levels of the rich are much higher relative to the poorer groups. Households' welfare is reduced at higher rates over all household income groups by 2030 relative to 2020, as the country experiences higher inflation rates when the domestic ETS is still under operation and caps are reduced over time.

6 Concluding remarks

The authors used an environmentally extended MONASH model in order to examine the effects of an ETS on the Australian economy, particularly on the energy sectors and multi-household groups. The simulation results indicated that the permit price increases from A$4.6 in 2015 through A$13.3 in 2020 to A$43.5 in 2030 in order to enable Australia to achieve the 2020 and 2030 emissions targets. The operation of an ETS in Australia causes the economy to contract progressively over the lifetime of the ETS. Deviations in real GDP are -0.77% in 2020 and -1.84% in 2030. Real private consumption reduces by -0.53% in 2020 and -1.08% in 2030 relative to the baseline. Employment level reduces in the short-term but recovers to the baseline level over time. Under such an ETS, Australia's exports still increase slightly while imports increase by 1.35% in 2020 and 5.85% in 2030 due to increases in overall prices in the Australian market. Such macroeconomic outcomes suggest that the emissions targets are achievable at acceptable costs to the Australian economy.

At sectoral level, prices of most energy commodities, except coal, increases considerably. Because Australia largely depends on fossil fuels to generate electricity, increases in fossil fuel prices will consequently increase the cost of electricity. In addition, output activities of the energy sectors are significantly affected. The brown coal mining sector will experience a considerable contraction over the lifetime of the ETS, as it is the highest emission-intensive energy commodity hence sectors tend to substitute other energy commodities, particularly black coal for brown coal. The fossil fuels fired electricity generation sectors also experience big losses under the ETS. Outputs of the renewable electricity generation sectors, however, will increase considerably. We also found that employment at sectoral level will fluctuate in line with variations in their outputs.

Although the Direct Action Plan is currently under operation in Australia, it still indicates many drawbacks. The government will face much higher auction prices in the next rounds of auction compared with those in the first two auctions, hence the current budget (A$2.55 billion) may not be adequate to buy the required abatement by 2020. Consequently, the 2030 target is unlikely to be achieved under such a policy. Even if the government intends to continue the Direct Action Plan until 2030, it has not clarified its sources of funding to increase its budget in order to buy additional emissions abatements. A carbon tax can be an alternative climate policy for Australia but it is very challenging for the government to determine an efficient price for emissions. It is also difficult to predict how much emissions are produced under a carbon tax. In addition, the Australian government is unlikely to introduce a carbon tax again. An ETS, on the other hand, presents many advantages over the Direct Action Plan and a carbon tax. Some major advantages of an ETS for Australia are (1) it sets a maximum level of emissions for Australia in each year, hence the targets are likely to be achievable, (2) the permit price is determined by the market force, thus increasing cost-efficiency, (3) the scheme raises more revenue for the government instead of spending money from its tax revenue, and (4) it creates an environment to link with other carbon markets in the longer term, thereby reducing costs of abatements. All in all our findings indicate that Australia can experience a reasonable trade-off between the emissions abatements and economic growth if an ETS is implemented. Consequently, an ETS appears to be the best option for Australia, compared with the Direct Action Plan and a carbon tax.

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Appendix

Table A1: Summary of emissions data for Australia 2008-09 (thousand tonnes of CO_2-e)

Sectors	Emissions from fuels combustion	Emissions from output activities
1 Agriculture	6291.63	110998.70
2 Black coal mining	4404.07	28328.85
3 Brown coal mining	76.79	494.05
4 Oil extraction	97.87	1193.07
5 Condensate extraction	33.77	411.76
6 LNG extraction	939.07	2895.34
7 Natural gas extraction	15127.54	3098.41
8 Other gas extraction	188.51	775.50
9 Other mining	4412.74	0
10 Food & drink	3348.05	161.40
11 Textile clothes	409.51	0
12 Wood manufacturing	1713.58	0
13 Petroleum	2080.97	0
14 Kerosene	599.06	0
15 Fuel oil	1526.01	0
16 Residual oils	419.89	0
17 LPG	326.97	0
18 Lubricate	132.82	0
19 Bituminous	300.39	0
20 Other Petroleum	1306.12	0
21 Chemical manufacturing	4819.93	6313.71
22 Rubber manufacturing	75.25	0
23 Cement manufacturing	6308.19	6535.57
24 Metal manufacturing	16514.40	9738.67
25 Merchandise manufacturing	642.81	0
26 Black coal electricity	116003.69	0
27 Brown coal electricity	69190.33	0
28 Oil electricity	2517.63	0
29 Gas electricity	22032.96	0
30 Hydro electricity	10.98	0
31 Wind electricity	1.82	0
32 Solar electricity	0.07	0
33 Biomass electricity	2.44	0
34 Biogas electricity	59.65	0
35 Electricity distribution	53.05	0
36 Gas supply	116.08	16292.57
37 Construction	3088.31	0
38 Transportation	85159.67	0
39 Other services	4004.41	0

Source: From NGGI 2009 (Deparment of the Environment, 2013).

Table A2: Baseline projections for industry output and emissions (average annual percentage change)

Sectors	Output		Emissions	
	2015-20	2021-30	2015-20	2021-30
1 Agriculture	2.55	1.82	2.56	1.80
2 Black coal mining	0.24	0.12	0.02	-0.05
3 Brown coal mining	1.37	0.67	1.20	0.53
4 Oil extraction	1.39	0.98	1.26	0.89
5 Condensate extraction	1.39	0.98	1.26	0.89
6 LNG extraction	0.11	0.08	-0.21	-0.15
7 Natural gas extraction	2.48	1.33	1.65	0.71
8 Other gas extraction	1.64	1.14	1.39	0.97
9 Other mining	1.86	0.75	1.14	-0.06
10 Food & drink	2.71	1.98	2.25	1.06
11 Textile clothes	5.33	3.15	4.77	2.12
12 Wood manufacturing	4.62	2.68	4.04	1.63
13 Petroleum	3.82	2.73	2.79	2.02
14 Kerosene	4.88	3.56	3.91	2.89
15 Fuel oil	3.43	1.77	2.40	1.06
16 Residual oils	5.59	1.99	4.58	1.31
17 LPG	5.23	3.94	4.19	3.26
18 Lubricate	11.74	5.57	10.70	4.86
19 Bituminous	1.63	0.39	0.55	-0.33
20 Other Petroleum	3.25	1.99	2.17	1.28
21 Chemical manufacturing	5.43	3.20	5.19	2.87
22 Rubber manufacturing	4.95	2.46	4.56	1.63
23 Cement manufacturing	4.94	1.98	4.66	1.52
24 Metal manufacturing	3.03	1.31	2.60	0.70
25 Merchandise manufacturing	5.75	2.79	5.42	2.13
26 Black coal electricity	2.42	1.46	1.49	0.68
27 Brown coal electricity	2.32	1.41	1.32	0.59
28 Oil electricity	2.59	1.53	1.69	0.75
29 Gas electricity	1.95	1.17	0.86	0.37
30 Hydro electricity	2.38	1.54	1.50	0.70
31 Wind electricity	2.39	1.54	1.50	0.71
32 Solar electricity	2.68	1.86	1.89	1.02
33 Biomass electricity	2.41	1.56	2.18	1.36
34 Biogas electricity	2.38	1.54	2.38	1.54
35 Electricity distribution	2.32	1.40	1.46	0.54
36 Gas supply	3.13	2.30	3.14	2.31
37 Construction	4.76	1.62	4.31	0.72
38 Transportation	4.06	2.98	3.63	2.16
39 Other services	3.50	2.81	3.03	2.04

Source: From the modelling results.

Table A3: Baseline projections for households

Household income deciles	Household disposal income (%)		Equivalent variation (A$ million)	
	2015-20	2021-30	2015-20	2021-30
Decile_1	2.88	1.40	92.82	143.56
Decile_2	3.25	1.51	114.92	141.65
Decile_3	3.32	1.58	213.45	236.20
Decile_4	3.13	1.57	283.89	299.48
Decile_5	3.38	1.79	395.85	409.66
Decile_6	3.45	2.04	590.19	640.64
Decile_7	2.71	2.04	651.72	851.16
Decile_8	2.38	2.04	745.38	1064.08
Decile_9	2.90	2.21	1395.71	1677.39
Decile_10	2.71	1.98	2442.26	2641.71

Source: From the modelling results