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 (ETS) on the Australian economy and the emissions levels. The simulation results indicate that the price of carbon permits would increase from A$4.6 in 2015 through A$13.3 in 2020 to A$43.5 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% and 1.84% lower in 2020 and in 2030, respectively. The result also lends strong support towards the transition to renewable energy because the price of electricity will increase considerably with the ETS. The income of households and household welfares in terms of equivalent variations are also considerably reduced.

Keywords: Emissions trading scheme; energy industries; dynamic CGE modeling; MONASH model; household income groups; Australian economy.

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1 Introduction

At the 2015 Paris Climate Conference, the Australian Prime Minister committed Australia to the 2030 emissions target[3] (Arup, 2015). This target, however, is unlikely to be achieved by the 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[4]. The government bought an abatement of 92Mt of CO_2-e (Carbon Dioxide equivalent) by using half of the 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 the following 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 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, 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 proposed 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

[3] Australia committed to reduce its emissions level below 26-28% the 2005 level by 2030.
[4] Clarke et al. (2014) stated that the ERF only allows the government to buy 50% of abatement needed by 2020.

(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[5] 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 further sections of this paper are as follows. Section 2 reviews permit auctioning theory and applications. Section 3 provides modelling with enhancements to the MONASH model and database. Section 4 describes the baseline forecasts in 2015-30. Section 5 outlines the development of the policy closures while Section 6 provides the emissions caps under the policy scenario. Section 7 analyses the simulation results whereas Section 8 provides concluding remarks.

2 Emissions Trading Scheme in Practice

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 marginal abatement cost (MAC) between participants (sectors or countries), whereby all participants will be benefited (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 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

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

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 (EPPA-EU) 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 the 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 developed another CGE model by modifying the MONASH model to evaluate an ETS in Australia. Unlike Adams (2007) and Adams et al. (2014), this version of MONASH model was developed to independently implement the ETS in one model and provide detailed permit transactions between Australia sectors. An extensive database was also compiled and updated to recent years with details of energy sectors, including nine electricity generation sectors. Such adaptations were considered appropriate in analysing multi-dimensions of an ETS.

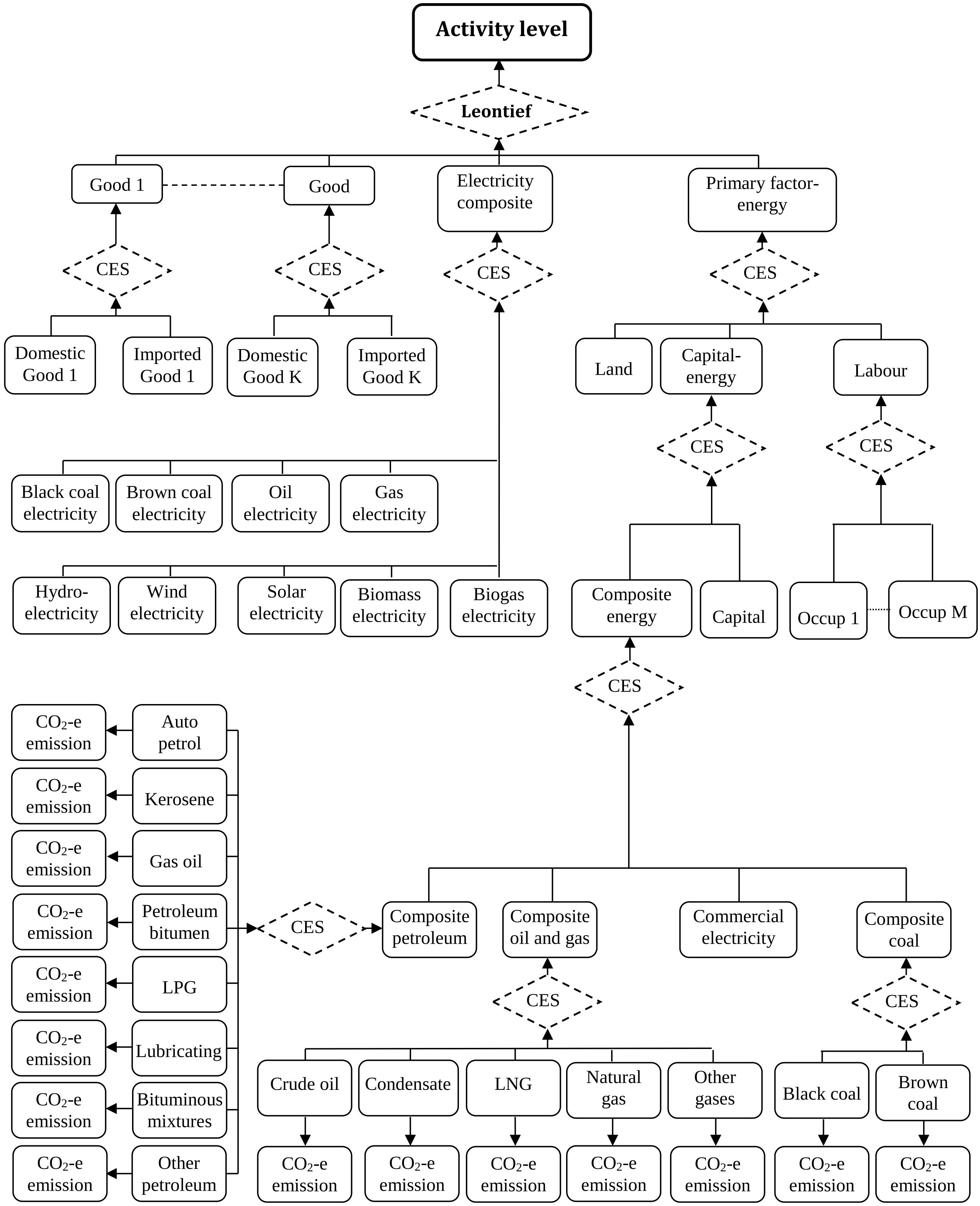
3 Modelling and database

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.

3.1 The production structure

In this 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[6]. 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[7].

3.2 Database

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 2009-10, and the National Greenhouse Gas Inventory 2009. The details of database compilation can be found in Nong et al. (2015).

There are 39 sectors, including 24 energy sectors in the database. Households are disaggregated into 10 groups depending on their incomes. Occupations are divided into 10

[6] Australia does not generate electricity from nuclear power.
[7] Details of Greenhouse gas emissions compilation can be seen in Nong et al. (2015).

groups of occupation according to Australian and New Zealand Standard Classification of Occupations (2013).

4 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, Organisation for Economic Co-operation and Development (OECD), Australian Bureau of Statistics (ABS), Australian Treasury and Reserve Bank of Australia (RBA). 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. 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
Normally shocked to unity	1.0	1.0	…	1.0	…	1.0	1.0
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
Labour supply	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

5 Policy closures

This study adopted the macro connections from the policy closure used for annual policy simulations in Dixon and Rimmer (2002). There are also additional closures for ETS in the modelling. The permit price variable of the bloc (ΔPRICE(bloc)) is endogenous whereas the power of emissions purchase variable (pempb_e(bloc)) is exogenous. 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 quota or cap[8]. Such power of emissions purchase is set exogenously or shocked at value zero in the percentage change form. Such setting indicates that the actual bloc emissions will be equal to the bloc emissions quota in the percentage change form and no permit is traded internationally. In the policy simulation, 5% reduction in bloc emissions quota, for example, also leads to 5% reduction in actual bloc emissions. The actual emissions level of each industry within that bloc will vary and would be higher or lower than its emissions cap or quota, depending on its 'emissions abatement technology'[9] and level of the cap[10]. If an actual

[8] The bloc emissions quota or cap is the maximum level of emissions, which is allowed by all sectors in that bloc to emit pollution.

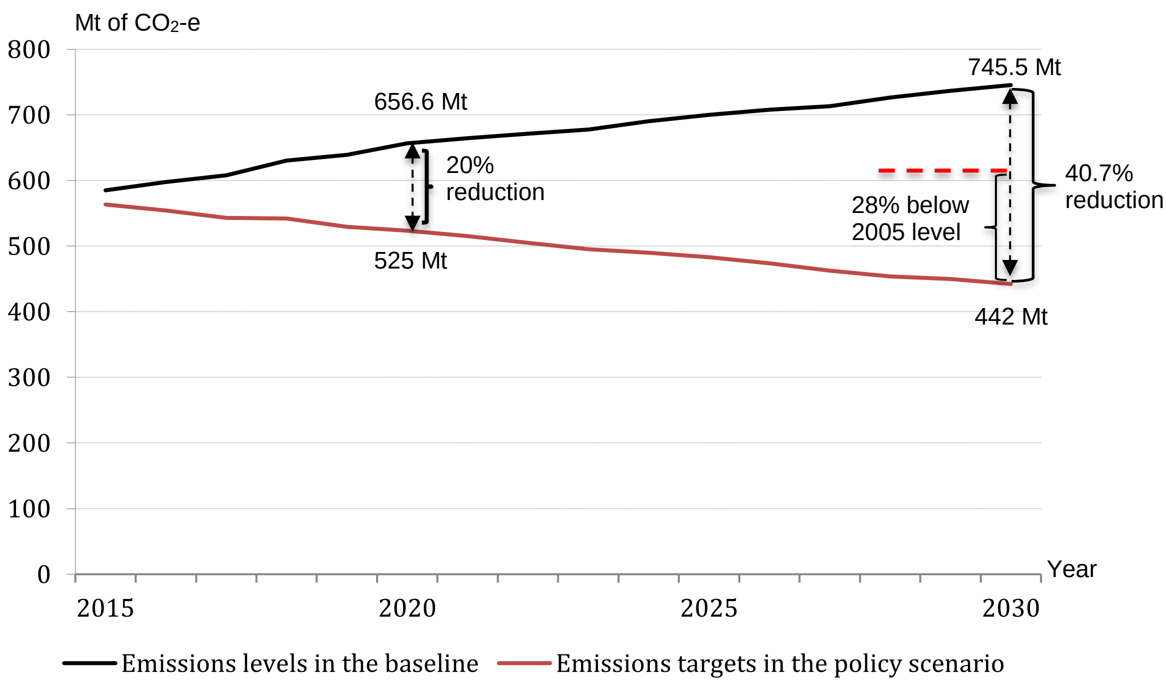
[9] Such technology includes improvement of energy efficiency techniques, reduction in production levels and high substitution possibilities. For example, an industry, which has high substitution possibilities for cleaner energy resources, will present low marginal abatement cost, thereby easily reducing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

emissions level goes below its emissions cap, it becomes a permit seller and vice versa. For example, if an industry faces a cap of 50Mt of CO_2-e, it will initially buy permits equivalent to 50Mt from the Federal Government. Then if its actual emissions level is 40Mt of CO_2-e, that industry can sell surplus permits equivalent of 10Mt of CO_2-e to other sectors. The total actual emissions of that bloc are eventually equal to total emissions quota of that bloc.

6 Emissions caps in the policy scenario

Once the baseline forecast is carried out, changes in emissions at country level over the years are calculated. The emissions levels in the baseline and targets in the policy scenario are shown in Figure 2. 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. Such projections are consistent with projections in the previous studies (for example, see Adams (2007) and Adams et al. (2014)). The emissions target by 2020 was set by the government to achieve 525Mt (Department of the Environment, 2015b). In addition, the emissions target by 2030 is to reduce emissions by 28% below the 2005 level of 614Mt (Deparment of the Environment, 2015a). The emissions target by 2030 is therefore to reduce emissions level to 442Mt (=614*(1 – 0.28)).

Figure 2: Emissions levels in the baseline and emissions targets in the policy scenario (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).

[10] Emissions caps might be readily achievable for some sectors (high emissions cap) or they are low for others.

Since the 2020 target is to reduce emissions by 20% (= 1 – 525/656.6) relative to the baseline, the average emissions quota for the whole economy is therefore reduced by 3.66% (= $1 - (1 - 0.2)^{1/6}$) each year from 2015 to 2020. In the period 2021-30, the target reduction will capture the recent cumulative reduction from 2015 to 2020. That is, a requirement of 40.7% (1 – 454.36/735.77) by 2030 relative to the baseline will be achieved by setting a gradual reduction in quota for the whole economy of 2.94% (=$1 - [(1 - 40.7\%)/(1 - 3.66\%)^{6}]^{1/10}$) in each year from 2021 to 2030.

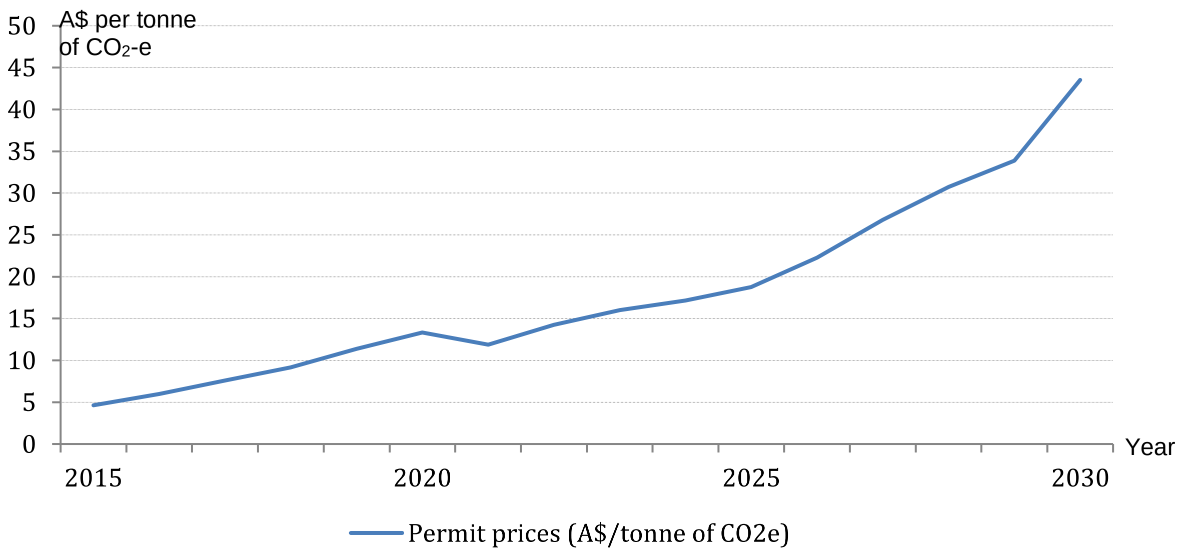
Electricity generation from black coal and brown coal are considered to be the key sectors to enable Australia to reduce emissions, as they are the largest polluters in Australia (Miller, 2014). It was therefore projected that these two sectors are responsible for 60% of total emissions abatement. Consequently, emissions from these two sectors are projected to be reduced cumulatively by 182.1Mt (=0.6*(745.5 - 442)) by 2030. This will result in a cumulative abatement of 86% relative to the baseline by 2030 for these two sectors. Hence, an average emissions cap for these two sectors in each year is set at a gradual annual decreasing rate of 11.5% (= 1 - (1-0.86)^(1/16)) in the policy scenario. Emissions caps for remaining sectors are set equally in each year in order to enable the whole economy to achieve the average abatement by 3.66% each year in 2015-20 and 2.94% each year in 2021-30.

7 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.

7.1 Permits price and emissions trading revenue

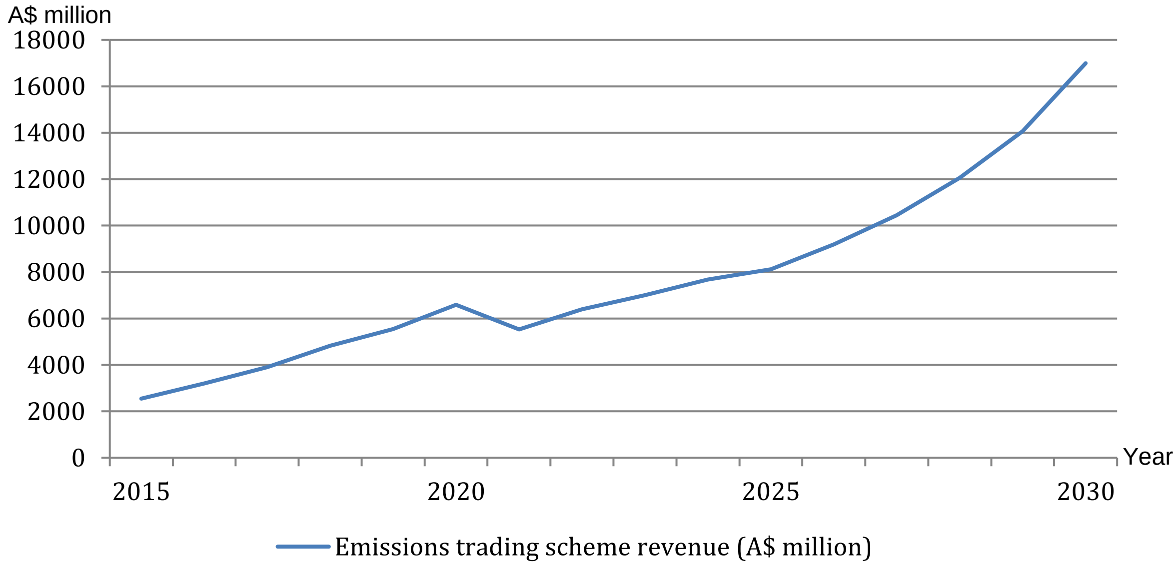
Figure 3: Permit price over years from 2015 to 2030



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). The results on the price of permits are also in line with the results projected for Australia conducted by Adams (2007) and Adams et al. (2014). 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 as the code in MONASH only deals with *ad valorem* rates of tax.

Figure 4: Emissions trading revenue each year in 2015-2030



Source: From the modelling results.

Figure 4 outlines the ETS revenue[11] for the government in 2015-30. The trend of revenues is very similar to the pattern of permit price in Figure 3. This is because the country's emissions cap is gradually reduced by 3.66% per annum in 2015-20 and 2.94% in 2021-30, indicating a similar amount of emissions reduction each year, hence, when permit prices increase the revenues also increase. Such revenues actually increase from A$2,548 million in 2015 to A$16,994 million in 2030 corresponding with increases of permit prices from A$4.6 in 2015 to A$43.5 in 2030. These revenues are a considerable financial resource for the Federal Government in order to reduce its budget deficit.

[11] The revenue in each year is a product of the permit price times the sum of emissions caps of all sectors in the bloc.

7.2 Macroeconomic effects

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

Macroeconomic variables	2020	2030
Price of coal	-16.4	-41.4
Price of natural gas	9.7	47.3
Price of wholesale electricity	35.8	132.8
Price of exports	1.43	2.25
Price of imports	0.00	0.00
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 wage rate	-0.73	-2.81
Aggregate employment	-0.42	-0.19
Labour cost	-1.15	-3.01
Change in BOT/GDP ratio	0.46	1.48
Real Gross Domestic Product (GDP)	-0.77	-1.84
Real Gross national expenditure (GNE)	-0.53	-0.94
Household disposable income	-2.27	-9.73
Real household consumption	-0.53	-1.08

Source: From the modelling results.

Table 2 shows the key macroeconomic deviations from the baseline. Under 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 the ETS raises considerable 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 significantly improved. 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 [12]. 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 will probably occur due to high demands for Australian commodities from other countries. In fact, Australia exports huge amounts of energy resources and agricultural products to the world at an increasing rate, particularly to China, Japan and the US (DFAT, 2015). These countries still maintain high demands for Australia’s commodities with or without operation of an ETS in Australia in order to secure their domestic production. In addition, although overall export prices will increase, the price of coal will decline. This is really attractive for importers of Australian coal, especially China and Japan, as they have been importing large amounts of coal from Australia for decades. The increase in demand for the Australian coal might outweigh the reduction in demand for other Australian commodities. Consequently, Australia’s exports will still slightly increase by 0.04% by 2020 and 0.43% by 2030 relative to the baseline.

Australia’s imports are likely to increase at higher rates of 1.35% by 2020 and 5.85% by 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 between the balance of trade and 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.

Since sectoral production levels are reduced, their employment levels are also likely to decline. Deviations of aggregate employment level, for example, are -0.42% by 2020 and -0.19% by 2030. Such employment levels, however, gradually return to original levels in the long term, as labour becomes cheaper from 2020 to 2030. Consumers will also face higher prices for commodities, that may result in their disposable income and real consumption levels declining. Household disposable income deviations from baseline are -2.27% in 2015-20 and -9.73% in 2021-30, while deviations for real household consumptions are -0.53% and -1.08%.

[12] 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.

The ETS also causes additional unfavourable effects, as revealed by many other economic indicators. Reductions in production levels of sectors (see Table 4) reflect the contractions in real GDP of 0.77% by 2020 and 1.84% by 2030, which are in lines with the findings in the previous studies on the Australian ETS (Adams (2007); Asafu-Adjaye and Mahadevan (2013); Adams et al. (2014)). Reductions in real household consumptions also indicate the reductions in Gross National Expenditure (GNE). Since the government increases revenue through the ETS, the government's expenditure on goods and services is likely to increase, leading to lower reduction rates in GNE compared to the impact arising from the real household consumption.

7.3 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. All sectors initially buy permits up to their emissions caps from the Federal Government. They in turn sell their surplus permits if their emissions levels are below their emissions caps and vice versa. In Table 3, the negative numbers indicate emissions permits purchased by buyers while the positive numbers refer to sellers of permits. It is found that the positions of sellers and buyers are not significantly changed over several years and the main buyers are the black coal and brown coal electricity generation sectors over the period 2015-30. This is because they are among the most polluting sectors and their emissions caps are relatively low. In addition, agriculture, black coal mining, liquefied natural gas extraction, other mining and gas supply sectors are also significant buyers of permits. The emissions from these sectors mostly come from production activities such as fugitive emissions, industrial processes and agricultural activities. Although these sectors have substituted cleaner inputs for dirty inputs, it is still greatly 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 will become a small seller over the 2015-30 period while the gas electricity generation sector will become a significant seller from 2018 with increasing permits selling until 2030. These sectors might have low abatement costs relative to other sectors, as they use high emission-intensive inputs and they do not have emissions from production activities. Another reason might be that the emissions caps are high for these sectors. 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 caps gradually become lower for them over years, e.g. caps for the agriculture sector. When the gas electricity generation sector becomes a low abatement cost sector, it will assume this advantage as a larger seller of permits over time.

The natural gas extraction and transportation sectors might substitute effectively clean energy inputs for dirty inputs and the caps will be high for them, they thereby become significant sellers over the period 2015-30. Sectors 10 to sector 20 are permits sellers over the period of the domestic ETS. The chemical, rubber, cement, metal and merchandise manufacturing sectors become permits sellers in some periods. This 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 high emission-intensive inputs, otherwise they have to reduce their production levels to cut emissions.

It was assumed that the black and brown coal electricity sectors are mainly responsible for emissions abatement by setting their caps relatively low, then becoming permits buyers. The 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 each year (thousand tonne of CO_2-e)

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1 Agriculture	-147	-611	-974	-1222	-1584	-1863	-261	-429	-675	-726	-947	-1026	-1327	-1465	-1699	-1851
2 Black coal mining	10.8	-108	-200	-257	-350	-403	-29	-82	-128	-134	-180	-194	-256	-284	-289	-377
3 Brown coal mining	58.5	52.1	45.8	40.7	36.1	32	22.5	19.7	18	16.4	15.4	14	13.2	11.6	10.2	9.2
4 Oil extraction	-1.2	-5.9	-9.5	-12.2	-16	-18.9	-3.3	-4.7	-7	-7.6	-9.8	-10.5	-13.3	-14.3	-16.2	-17.1
5 Condensate extraction	-0.4	-2	-3.3	-4.2	-5.5	-6.5	-1.1	-1.6	-2.4	-2.6	-3.4	-3.6	-4.6	-4.9	-5.6	-5.9
6 LNG extraction	-8.3	-21.4	-31.4	-38.4	-47.5	-54.2	-7.1	-9.9	-18	-19.5	-24.6	-25.8	-32.6	-34.4	-39	-41.4
7 Natural gas extraction	177.4	174.8	199.8	245	290.5	336.7	399.1	396.4	388.6	387.1	388	383	385.3	386.6	411.7	396.8
8 Other gas extraction	1	-1.9	-4.1	-5.2	-7.5	-8.7	1.8	0	-0.9	-1	-2.3	-2.8	-4.7	-5.9	-6.2	-9.5
9 Other mining	-8.7	-24.1	-35.5	-43.3	-55	-63.1	-6.7	-11.8	-19.2	-20.5	-26.9	-28.9	-37.5	-40.9	-44.4	-52.9
10 Food & drink	121.3	110.5	98.9	90.7	76.7	66.6	65.8	53.2	50.4	47.4	42.2	37.8	32.3	25.3	20.5	12.1
11 Textile clothes	26.7	26.9	26.3	25.3	23.7	21.6	16.4	15	13.6	12.4	11.6	10.7	10.1	9.1	7.2	8.1
12 Wood manufacturing	48.3	46.6	44.9	44.2	41.2	38.4	39.5	35.5	33.1	31.5	29.7	27.9	25.8	22.9	16.7	19.1
13 Petroleum	121.9	107.7	92.3	78.5	66.1	54.8	48.7	42.9	37.8	34.5	31.6	29.2	26.5	23.5	14.4	20.2
14 Kerosene	29.6	25.3	20.8	16.4	12.7	9.2	10.5	9.8	7.8	7	6.2	5.9	5.3	5.1	2.5	5.3
15 Fuel oil	88.3	78.5	67.9	59.4	51.6	44.9	39.3	35.3	31.8	29.7	28.3	26.9	25.7	23.9	17.9	22.3
16 Residual oils	40.4	37.8	33.9	30.6	26.1	22.4	16	13.2	11.8	10.6	9.6	8.6	7.8	6.7	5.6	5.2
17 LPG	17.9	17.9	17.9	17.7	17.5	16.8	13.6	13.1	12.3	11.5	11.1	10.4	10.1	9.4	7.4	8.7
18 Lubricate	7.6	7.2	6.5	6	5.1	4.4	4.4	3.8	3.6	3.4	3.2	3.1	2.9	2.6	1.9	2.3
19 Bituminous	27.6	24.7	21.5	18.4	15.6	13	9.1	7.8	6.8	5.9	5.3	4.6	4.2	3.6	2.8	2.8
20 Other Petroleum	98.9	91.2	83.4	76.2	69.6	62.5	47.5	43.6	39.2	35.4	33.2	30.6	28.9	26.3	20.6	23.3

Note: the positive numbers indicate sellers and vice versa.

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

Sector \ Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
21 Chemical manufacturing	105.1	70.9	40.4	16.8	-23.9	-56.1	54.8	28.2	8.7	0	-24.6	-37.7	-68.9	-89.9	-103	-148
22 Rubber manufacturing	2.4	2.6	2.8	3	3	2.9	2.5	2.2	2.1	2	1.9	1.8	1.6	1.4	1.3	1
23 Cement manufacturing	235	206.2	177	166.4	117.4	89.9	156	93.4	93	88.6	61.5	42	7.7	-30.5	-43.3	-114
24 Metal manufacturing	92.6	24.7	-17.6	-34.7	-77.5	-100.6	155.3	114.9	92.5	90.1	59.7	46.8	5.9	-25.7	-56.7	-103
25 Merchandise manufacturing	3.6	1.7	0.6	0.1	-1	-1.7	4.6	3.5	3.1	3.1	2.3	1.9	0.8	-0.3	-1.3	-2.5
26 Black coal electricity	-1318	-921	-687	-583	-426	-297	-2236	-2122	-1766	-1696	-1495	-1415	-1143	-1087	-1177	-851
27 Brown coal electricity	-1756	-1328	-1059	-1026	-747	-671	-1807	-1480	-1351	-1297	-1111	-998	-780	-654	-745	-363
28 Oil electricity	52.8	59.1	65.5	73.2	76.8	81.4	77.9	72.9	71.8	70.9	70.8	69.5	69.6	66	56.9	62.3
29 Gas electricity	-386	-314	-124	156	530	951	1115	1342	1448	1548	1724	1841	2078	2407	3214	3099
30 Hydro electricity	-0.5	-0.8	-1	-1.2	-1.6	-1.9	-1.3	-1.5	-1.6	-1.7	-1.9	-2	-2.3	-2.4	-2.2	-3
31 Wind electricity	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5
32 Solar electricity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33 Biomass electricity	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5	-0.5	-0.5	-0.6
34 Biogas electricity	-3.1	-4	-4.8	-5.6	-6.6	-7.4	-4.7	-5.1	-5.4	-5.5	-5.9	-6	-6.5	-6.6	-6.2	-7.2
35 Electricity distribution	3.8	3.6	3.3	2.9	2.5	2.1	1.6	1.3	1.1	1	0.9	0.8	0.6	0.5	0.5	0.3
36 Gas supply	-22	-84.4	-132	-161	-208	-241	-17.6	-49.8	-79	-84.8	-119	-134	-182	-210	-232	-288
37 Construction	7.3	-4.4	-13.2	-17.9	-26.2	-31.6	9.6	2.4	-1	-0.8	-5.2	-6.6	-12.9	-17	-24.9	-24.6
38 Transportation	2273	2274	2269	2271	2157	2017	2054	1846	1682	1564	1429	1305	1149	966	711	625.4
39 Other services	0.2	-13	-22.2	-26.7	-35.6	-40.9	9.4	2.5	-2.2	-2.1	-7.8	-9.9	-18.5	-24.5	-32	-40.3

Note: the positive numbers indicate sellers and vice versa.

Source: From the modeling results.

7.4 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 upstream sectors, i.e. energy sectors, are largely affected by the ETS since they are directly hit by the ETS policy, which causes their output prices to increase significantly. 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 their outputs. 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 over the two periods relative to the baseline are the brown coal mining, natural gas extraction, black coal electricity generation, brown coal electricity generation, oil electricity generation, gas electricity generation and electricity distribution sectors. 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 as 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 (sectors 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.

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.

Table 4: Industry output and employment (percentage change 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.

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%.

Table 5: Employment by occupation (percentage change from the baseline)

Occupations	2020	2030
1 Managers	-0.425	-0.200
2 Professional	-0.435	-0.212
3 Technicians	-0.424	-0.199
4 Personal services workers	-0.417	-0.216
5 Clerical workers	-0.434	-0.210
6 Sales workers	-0.353	-0.121
7 Drivers	-0.430	-0.206
8 Labourers	-0.471	-0.228
9 Others	-0.426	-0.185

Source: From the modelling results.

Table 5 shows employment changes by occupations. Burdens from the ETS impose higher costs on firms and lower demands for outputs, hence they subsequently reduce their production levels. Consequently, people might lose their jobs. The simulation results show that jobs are cut at similar rates through all occupations. By 2020, all occupation deviations are about -0.43%, there is no significant difference among reduction rates of different occupations. The reduction rates of all occupations by 2030 are around 0.2% because labour becomes cheaper from 2020 to 2030. Labour cost deviations, for example, are -1.15% by 2020 and -3.01% by 2030.

7.5 Effects on households

Table 6 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 6: Effects of the domestic ETS on households (deviations from the baseline, percentage change)

Household income deciles	Real household consumption		Electricity demand		Gas demand		Emissions from household usage (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 6 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. 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 is 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 electric appliances have gradually replaced gas appliances over time, as it is considered safer and more convenient. In addition, electric appliances are cheaper than gas appliances in many cases. Air conditioning, for example, is much cheaper than a gas heater system. Households thereby tend to use less gas, leading to small negative deviations in gas demands compared with electricity demands. The poorer people, however, are likely to still retain their installations of gas appliances, e.g. gas cookers and gas heaters. This probably 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 of households, however, are very small, as they do not pay any price directly for their emissions. They only have to pay relatively higher prices induced by the ETS for energy. By 2020, the reductions in emissions are 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 is probably 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 6 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.

8 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.

Though the proposed ETS in average presents a small cost on the Australian economy, the fossil fuel energy sectors are largely unfavourable affected. 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, which are consistent with findings in studies provided by Australian Treasury (2008; 2011). 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

The emissions intensities for each institution are calculated according to (i) the basic values of intermediate usage, production output, household consumptions and government consumption and (ii) emissions matrices of these institutions. These emissions intensities are considered as parameters and are unchanged over simulations. For example, emissions intensities for industries are calculated as follows:

$$CXI_{c,s,j} = EII_{c,s,j} * BAS1_{c,s,j} \quad (1)$$

where $CXI_{c,s,j}$ is emissions from intermediate usage; $EII_{c,s,j}$ is emissions intensity from intermediate usage; and $BAS1_{c,s,j}$ is the basic value of intermediate usage. Letter c denotes commodities, s denotes source (domestic and import) and j denotes industries.

The percentage-change form of equation (1) is:

$$delCXI_{c,s,j} = 0.01 * EII_{c,s,j} * BAS1_{c,s,j} * x1csi_{c,s,j} \quad (2)$$

where $delCXI_{c,s,j}$ is the change form of $CXI_{c,s,j}$.

Equation (2) shows that the change in emissions from intermediate usage depends on percentage change in intermediate quantity usage, not the price. As emissions intensity is unchanged over simulations, changes in emissions are linked with percentage changes in quantity demands. Any shock imposed on the model, which propagates effects on intermediate quantity usage, will change emissions from such purchases. Emissions and emissions fluctuations from output activity, household consumption and general government consumption are similar to those in equations (1) and (2).

In MONASH-Green, coding is only developed to place a tax or price on emissions from intermediate usage and output activities. Such a tax may be a carbon tax per tonne of CO_2-e or permit price per tonne of CO_2-e in the case of an ETS. Hence, a tax on emissions from intermediate usage and output activities are written as:

$$TAX1A_{c,s,j} = CXI_{c,s,j} * PRICE_j \quad (3)$$

$$TAX0A_{c,j} = CX0_{c,j} * PRICE_j \quad (4)$$

where $TAX1A_{c,s,j}$ is tax revenue from imposing a tax on emissions from intermediate usage; $PRICE_j$ is a price on each tonne of emissions (i.e. tonne of CO_2-e); $TAX0A_{c,j}$ is tax revenue from imposing a tax on emissions from output activities; and $CX0_{c,j}$ is emissions from output activities.

The change form of equations (3) and (4) can be written as:

$$delTAX1A_{c,s,j} = CXI_{c,s,j} * delPRICE_j + PRICE_j * delCXI_{c,s,j} \quad (5)$$

$$delTAX0A_{c,j} = CX0_{c,j} * delPRICE_j + PRICE_j * delCX0_{c,j} \quad (6)$$

where $delTAX1A_{c,s,j}$, $delTAX0A_{c,j}$ and $delPRICE_j$ are respectively a change form of $TAX1A_{c,s,j}$, $TAX0A_{c,j}$ and $PRICE_j$.

Equations (5) and (6) indicate the change forms in tax revenue from a tax on emissions from intermediate usage and output activities. Instead of percentage change forms, the change forms are applied because tax revenues and price change from zero to positive numbers.

The following section provides the extension to implement an ETS in MONASH-Green. In particular, the percentage change of total emissions of industry j, $gco2et_j$, is calculated as the sum of emissions from intermediate usage and output activities of industry j. The percentage change of emissions quota of industry j, $gco2eq_j$, is initially equal to the total emissions of industry j, $gco2et_j$. As MONASH-Green is a dynamic model and there are three steps of simulations (baseline forecast run, baseline forecast re-run and policy run) if the percentage change of emissions quota, $gco2eq_j$, is set exogenously in the baseline forecast simulation, then it cannot be shocked in the policy run simulation. This is because $gco2eq_j$ is already shocked in the baseline forecast simulation; hence, it cannot be shocked twice. Consequently, two shift variables for emissions quota are added. That is:

$$gco2eq_j = fgco2eq_j + ffgco2eq_j \tag{7}$$

where $fgco2eq_j$ and $ffgco2eq_j$ are shift variables for emissions quota of industry j.

In equation (7), $gco2eq_j$ and $fgco2eq_j$ will be set exogenously whereas $ffgco2eq_j$ is endogenous. The first step in the ETS simulation is to run the baseline forecast as usual in order to obtain percentage change of total emissions of industry j, $gco2et_j$. We then take these values to place a shock on percentage change of emissions quota, $gco2eq_j$, and run the baseline forecast again. The endogenous shift variable, $ffgco2eq_j$, will consequently equal $gco2eq_j$ as shown in equation (7). Since the emissions quota fluctuates in the same ratio as total emissions in each industry, the permit price is still zero. In the baseline re-run simulation, percentage change of emissions quota, $gco2eq_j$, and the shift variable, $ffgco2eq_j$, are still unchanged with the values imposed. Finally, in the policy run simulation, a shock on shift variable, $fgco2eq_j$, will be imposed to obtain the intended emissions target.

The way to impose a domestic ETS in the MONASH-Green model may need more explanation. For example, a bloc is created in order to allow targeted industries to trade within this bloc. For each industry, there is a power of emissions purchases in percentage change form, $pempe_j$, where:

$$pempe_j = gco2et_j - \ gco2eq_j \tag{8}$$

Equation (8) indicates that the different fluctuations in percentage changes of total emissions, $gco2et_j$, and emissions quota, $gco2eq_j$, will determine industry j as a buyer or seller of emissions permits. If $gco2et_j$ reduces more than a reduction in $gco2eq_j$, industry j will be a seller and vice versa.

Similarly, percentage changes of total emissions, emissions quota and power of emissions purchases are created for the bloc (b). That is:

$$pempbe_b = gco2etb_b - \ gco2eqb_b \tag{9}$$

Equation (9) is a key coding for emissions trading. When setting percentage change of power of emissions purchases for the bloc, $pempbe_j$, exogenously, the total fluctuations of total bloc emissions will equal a total bloc emissions quota. Then total permit purchases will equal total permit selling within that bloc; hence, no permit is traded in the international markets. The price on each tonne of emissions above, $PRICE_j$, is replaced by a price on each tonne of emissions in a bloc, $PRICE_{INDTOBLOC(j)}$. If industry k is not set in the bloc, e.g. the construction sector, there is no price on its emissions and all industries within the bloc will face the same price on their emissions.