A CGE Analysis of Distributional and Welfare Effects of Australia's Carbon Emissions Reduction Strategies

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ABSTRACT

At the Copenhagen conference on climate change in 2009, the Australian Government committed to reduce carbon emissions by at least five per cent below 2000 levels by 2020. To achieve this target, the Labor Government introduced a carbon pricing mechanism comprising two periods: a three year fixed carbon price from July 2012; and a floating carbon price from July 2015. This thesis simulates the impact of an Emissions Trading Scheme (ETS) on the Australian economy. The scheme investigated is a government-imposed cap on emissions from all industries, in which the emissions reductions in the electricity-black coal and electricity-brown coal industries account for 80 percent of the total emissions reduction target, and all other sectors related to the ETS must reduce the remaining 20 percent of the total emissions reduction target. The polluting industries will be required to pay for their generation of emissions at the emissions permit price as determined by the market. The government accrues the revenue from auctions, then uses half of the revenue to compensate households through various revenue recycling options.

This study assesses the effects of an ETS and the various compensation policies to households on distribution and welfare in Australia. To do that, this thesis employs a static Computable General Equilibrium (CGE) model for Australia. In the structure of production, the study allows for substitution between energy sectors, between electricity generated from different sources, as well as substitution between capital and energy composite by using a CES function. A Social Accounting Matrix (SAM), the main data source for the CGE model, was constructed for the Australian economy for 2009. The SAM is mainly compiled from the Input-Output Tables, 2008-2009, and the Australian System of National Accounts, 2010 - 2011 for 2009. In order to provide further analysis in the distributional and welfare effects of the ETS, households are disaggregated into 20 household groups based on household income survey data. The household income and expenditure data are mainly from the Household Expenditure Survey, 2009-2010.

The research then examines the effects of the ETS on macro-economic variables, sectoral levels, as well as household group level. The results reveal that the imposition of caps on the quantity of emissions to industries induces negative impacts on the Australian economy, in particular it leads to an increase in prices of most goods and services, thus leading to a reduction in real GDP, real household consumption, and export and import volumes. Most sectors suffer from an output loss and reduction in employment demand. The changes in commodity prices and returns in primary factors result in negative impacts on household expenditure, income, as well as utility. To mitigate unexpected effects of the ETS, this study simulates five scenarios of the compensation policy to households that includes: (1) the goods and services tax reduction; (2) the income tax reduction; (3) the government payment increase; (4) a lump-sum transfer to all household groups; and (5) a lump-sum transfer to the 12 lowest income household groups. The results show that the income tax reduction results in an economic efficiency, but renders the policy more regressive, while lump-sum transfers make the policy progressive and an equal lump-sum transfer creates equity between household groups compared to other compensation policies.

CERTIFICATION

I certify that the substance of this thesis has not already been submtitted for any degree and is not currently being submitted for any other degree or qualification.

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ACRONYMS AND ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau Statistics
ASNA	Australian System of National Accounts
BREE	Bureau Resources and Energy Economics
CES	Constant Elasticity of Substitution
CET	Constant Elasticity Transformation
CFI	Carbon Farming Initiative
CO_2-e	CO_2 emissions-equivalent
CGE	Computable General Equilibrium
CoPS	Centre of Policy Studies
CPI	Consumer Price Index
CPRS	Carbon Pollution Reduction Scheme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CV	Compensating Variation
DAP	Direct Action Plan
EITES	Emissions- Intensive Trade-Exposed Sectors
ERF	Emissions Reduction Fund
ETS	Emissions Trading Scheme
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EV	Equivalent Variation
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GNE	Gross National Expenditure
GNP	Gross National Product
GST	Goods and Services Tax
GTEM	Global Trade and Environmental Model

HES	Household Expenditure Survey
ICMM	International Council on Mining Metals
IMF	International Monetary Fund
IO	Input-Output
IPCC	Intergovernmental Panel on Climate Change
LGC	Large-scale Generation Certificate
LRET	Large-scale Renewable Energy Target
MB	Marginal Benefit
MEC	Marginal External Cost
MMA	McLennan Megasanik Associates
MMRF	Monash Multi-Regional Forecasting model
MPC	Marginal Private Cost
MRET	Mandatory Renewable Energy Target
MS	Microsimulation
MSC	Marginal Social Cost
NATSEM	National Centre for Social and Economic Modelling
NGGI	National Greenhouse Gas Inventory
OECD	Organisation for Economic Co-operation and Development
RET	Renewable Energy Target
SAM	Social Accounting Matrix
SKM	Sinclair Knight Merz
SRES	Small-scale Renewable Energy Scheme
SSA	Systematic Sensitivity Analysis
tCO_2	Tonne of CO_2 emissions
UNFCCC	United National Framework Convention on Climate Change
US	United States
VAT	Value Added Tax
WB	World Bank

CHAPTER 1: INTRODUCTION

Climate change has become one of the most urgent problems facing humanity. Scientific evidence suggests that greenhouse gas emissions (GHG), especially carbon dioxide (CO_2), have contributed significantly to global increases in temperature. Governments around the world are now required to reduce their country's carbon emissions into the atmosphere. There are many instruments that can be utilised to reduce carbon emissions, such as a carbon tax, a cap-and-trade program (or an emissions trading scheme), regulations for energy efficiency and adoption of renewable energy sources. Imposing a price on carbon emissions is preferred to regulatory approaches for curbing emissions (IMF, 2015). In 2015, the International Monetary Fund (IMF) stated that putting a price on carbon is the most efficient and effective way to emissions reduction. Carbon pricing also raises substantial revenues for governments, which can be used to reduce distortionary taxes. Through its incentive effects, carbon pricing also assists in mobilising private finance for mitigation activities and encouraging the innovations needed to address undesirable climate challenges.

Placing a price on carbon emissions can improve environmental quality, but it simultaneously results in extra costs in the production of carbon-intensive products, as well as of other goods and services that use energy commodities as inputs in their production. The question is, who will bear these costs? Normally, producers initially bear the costs then pass them on to the final consumers in the form of higher prices of commodities, or pass them to investors and workers in the form of lower returns on investment and wages, respectively. Therefore, a carbon pricing policy has impacts on all social and economic aspects. This research aims to examine the distributional and welfare effects of Australia's carbon emissions reduction strategies.

1.1 Research background

In recent decades, there is increasing evidence that the climate is changing, with warming of the atmosphere and oceans, reductions in snow and ice, changes in global water cycles, and rising sea levels. Increasing frequency of climate extremes is also an expression of such climate change. The Intergovernmental Panel on Climate Change (IPCC) (2014, pp. 2-4) stated that global surface temperatures have increased by an average of 0.85^0C (0.66^0C to 1.06^0C) over the period 1880 to 2012. Anthropogenic greenhouse gas emissions, mainly carbon dioxide sourced from fossil fuel combustion, has been the substantial contributor to this surface temperature increase since the mid-20th century. The IPCC (2014, p. 20) also indicated that, without strong action by governments, the temperature increase is very likely to exceed the 2^0C by the year 2100 (about 3.7^0C to 4.8^0C), compared to the pre-industrial level. Limiting climate change requires substantial and sustained reduction in CO_2 emissions, thus leading to a decrease in climate change risks. In an analysis of the costs and benefits of emissions mitigation, Garnaut (2008, pp. 245-276) concluded that the costs of action are less than the costs of inaction.

In the last two decades, there have been many global efforts to reduce carbon emissions. Particularly, the Rio Earth Summit in 1992 established an environmental treaty called the *United Nations Framework Convention on Climate Change* (*UNFCCC*), which aimed to provide a program for stabilising GHG emissions in the atmosphere to a level that might prevent dangerous anthropogenic interference with the climate system. Five years later, in 1997, the *Kyoto Protocol*, the first international agreement focused on GHG emissions mitigation, was adopted in Kyoto, Japan, and came into force in 2005; *Protocol* participating countries committed to reduce their total GHG emissions.

There are two commitments in the *Kyoto Protocol*: a commitment period between 2008 and 2012 with the emissions reduction target of at least five per cent, below the 1990 levels of GHG emissions; and a commitment commencing in 2013 to 2020 to further reduce emissions by 18 per cent compared to the 1990 baseline. The emissions reduction target in the first commitment period was overachieved by participating countries by 24 per cent (Morel & Shishlov, 2014). Under the *Protocol*, countries must meet their targets primarily through national measures, but the *Protocol* also offers three market-based mechanisms: international emissions trading, the clean development mechanism, and joint implementation.

In 2015, for the first time in over 20 years of the United Nations (UN) negotiations on climate change, the Paris Climate Change Conference aimed to achieve the target of keeping global warming below 2^0C by the year 2100, with the governments of countries required to set their emissions reduction targets for the period beyond 2020. The Paris Conference gathered the emissions reduction commitments from both developed and developing countries. The United States, the world’s largest emitter, committed to reduce emissions by 26 to 28 per cent below 2005 levels by 2025; China, the world’s second-largest emitter, committed to lower emissions per unit of Gross Domestic Product (GDP) to 60-65 per cent from 2005 levels by 2030, and the European Union (EU), the third largest emitter, targeted to reduce emissions by at least 40 per cent domestic emissions by 2030, compared to 1990. Australia committed to reduce its emissions by 26 to 28 percent below 2005 levels by 2030 (UNFCCC, 2015).

Governments have raised concerns about how best to reduce carbon emissions. Aldy and Stavins (2012) stated that by internalising the externalities associated with CO_2 emissions, the carbon pricing mechanism can promote cost-effective reduction and create powerful incentives for innovations. By imposing a price on carbon emissions, governments encourage private firms and individuals to find and exploit the least cost ways to reduce emissions, thereby investing in the development of new technologies, processes and ideas that could further mitigate emissions. The two market-based instruments are generally known as a carbon tax and an emissions trading scheme. Economists argue that the main difference between a carbon tax and an emissions trading scheme involves the issue of certainty (Yale Environment 360, 2009). A carbon tax provides a cost certainty by setting a fixed price on carbon emissions, and the emissions uncertainty is determined by the price elasticity of supply and demand for emissions intensive products. An emissions trading scheme sets a clear goal for emissions reduction based on the targets established to achieve the international commitment, but this creates cost uncertainty because the emissions price is determined by the market. The World Bank (WB) (2014b, p. 15) noted that there were 40 nations and 20 sub-nations who put a price on carbon, which together account for about 12 per cent of annual global GHG emissions.

Some economists prefer a carbon tax to an emissions trading scheme (Goulder & Schein, 2013; Humphreys, 2007; Nordhaus, 2007; Pizer, 2002), the reason for supporting a carbon tax is certainty about the cost with a tax structure compared to an emissions trading scheme which is subject to the volatility of an emissions permit price. However, other economists prefer an emissions trading scheme to a carbon tax (Stavins, 2007). Weitzman (1974) advises that choosing a carbon tax or an emissions trading scheme depends on the marginal cost/benefit of abatement: a carbon tax would be favoured when the marginal benefit is relatively flat, and an emissions trading scheme would be favoured when the marginal cost is relatively flat. Lucas (2012) believes that the best way to address climate change and reduce Australia's carbon pollution is to place a price on pollution; that is a carbon price.

Australia is a country rich in natural resources. In 2011-2012, Australia was the world's ninth largest energy producer, accounting for 2.7 per cent of the world's energy production. Coal accounted for 60 per cent of the Australian energy production, followed by uranium (20 per cent), natural gas (13 per cent), and oil (6 per cent). Renewable energy accounted for only 2 per cent of total Australian energy production (Department of Industry, 2013, p. 21). Australia is a large net energy exporter, with the three largest export commodities being black coal, uranium oxide and natural gas. In 2012-2013, energy exports accounted for around 80 per cent of the

Australian energy production. In the Australian energy consumption, oil constituted about 37.7 percent, while black and brown coal accounted for 33.1 per cent of the total energy consumption, followed by gas (23.6 per cent), and renewable energy sources made up 5.6 per cent of the total energy consumption. Electricity supply, transport, and manufacturing sectors are the largest energy users, utilising 75.6 per cent of total Australian energy consumption in 2012-2013. For electricity generation, coal-fired generation accounted for 64 percent of total electricity generation, followed by gas (21 percent), oil (2 percent), and renewable generation accounted for 13 percent of total electricity generation in Australia (Bureau of Resource and Energy Economics [BREE], 2014).

Combining energy production and consumption figures explains why Australia is a high-emitting country in absolute and per capita terms. In particular, Garnaut (2008, p. 153) reported that Australia's per capita emissions was nearly twice the OECD average and more than four times the world average in 2006. The Australian Government (2014, p. 69) estimated that total Australian emissions accounts for 1.3 per cent of the world's emissions of greenhouse gas, making Australia the 15^{th} highest emitter of greenhouse gases in the world. Australia is one of 19 countries that have emissions of more than 1 per cent of the world emissions, with the emissions of these 19 countries accounting for approximately two-thirds of the world's total emissions.

In recent years, evidence of climate change has been observed in Australia, with increased temperatures and sea levels, declined amounts of snow and so on. The Climate Change Authority (2014, p. 35) stated that the average surface air temperature has increased by 0.9^0 C since 1910; as predicted, there has been a significant increase in the number of hot days and hot nights, and a decrease in the number of cold days and cold nights. According to Arndt, Johnson and Blunden (2015, p. 214), 2013 was Australia's warmest year on record, and 2014 the third warmest year since national temperature records began in 1910.

Over the past decade, Australian Governments and Oppositions have debated the question of how best to reduce emissions in light of international commitments to reduce carbon emissions. In particular, in 2007 the Australian Government ratified the *Kyoto Protocol* agreeing to an emissions reduction target of less than 108% of 1990 levels between 2008 and 2012, then made a second commitment, starting 1 January 2013, to reduce emissions to 99.5 per cent of 1990 levels. The second commitment is consistent with the UNFCCC target of at least 5 per cent reduction on 2000 emissions levels by 2020 (equivalent to 13 per cent below 2005 levels by 2020).

In order to meet these emissions reduction targets, the Prime Minister, Julia Gillard and the Labor Party Government implemented the carbon pricing mechanism with two periods, the first one was a three-year fixed-price period from 1 July 2012 to 30 June 2015 with an initial price of A$23 per tonne of CO_2, and an increase of 2.5 per cent per year plus an inflation rate; the second time period was to be a floating price period (called Emission Trading Scheme- ETS) from 1 July 2015 in which the market would set the emissions price. The mechanism of a carbon price in these two periods had the same objective of reducing the quantity of carbon emissions, but in the first time period the fixed price for carbon emissions resulted in the allowance of the quantity of emissions to vary; while in the second time period the quantity of emissions was set and the carbon pricing mechanism was allowed to vary depending on the market demand.

However, the subsequent Liberal Party Government, led at the time by Prime Minister Tony Abbott, repealed the carbon pricing mechanism and replaced it with a Direct Action Plan (DAP) from July 2014, ending two years of operation of the carbon tax. The DAP is a competitive grant program whereby businesses and farmers submit their proposals to the Government on how they would reduce their greenhouse gas emissions and how much it could cost. The Government then chooses the projects that have the least cost and then uses the taxpayer money to fund the projects. Some commentators judge the DAP to be costly to taxpayers and ineffective in fighting climate change, achieving the emissions reduction target at a higher cost than if a carbon price is used (Grudnoff, 2011). Sandiford (2014) reported that, in the first hundred days since the repeal of the carbon tax, emissions rose up to 4 million tonnes on the equivalent period in the previous financial year. In contrast, the impact attributable to the carbon price is estimated to be a reduction of between 5 and 8 million tonnes of CO_2 emissions (3.2 to 5.0 per cent) in 2012/13 and between 6 and 9 million tonnes of CO_2 emissions (3.5 and 5.6 per cent) in 2013/14, and together between 11 and 17 million tonnes in the two years of the operation of the carbon tax (O'Gorman & Jotzo, 2014).

Clearly the carbon pricing mechanism appears to create a better outcome for the environment, however it also impacts social and economic factors. In particular, retail residential electricity prices increased by 25 per cent. Of this increase, 10 per cent was a result of the carbon price and 15 per cent was related to other factors (O'Gorman & Jotzo, 2014). The carbon price caused an increase in prices of the energy-intensive products directly and other goods and services indirectly, thus leading to an increase in household expenditure. The Treasury (2011, p. 136) estimated that the carbon price results in an increase in household expenditure of A$9.90 per week, of this increase A$3.30 was attributed to electricity consumption, A$1.50 to gas consumption, A$0.80 to food consumption, and the remaining of A$4.30 to the consumption of other goods and services.

In order to lower the impact of the carbon price on household budgets, the Australian Government implemented the Household Assistance Package by recycling around half the carbon tax revenue to low and middle income households through the adoption of lower income tax and higher government payments, and other fiscal financial assistance. The Household Assistance Package was assessed to be higher than the average carbon price impact for low-income households and 60 to 95 per cent of the carbon price impact for middle income households (Hatfield-Dodds et al., 2011). The revenue raised from carbon pricing is significant, and efficiently using the revenue results in large economic benefits (IMF, 2015). In addition, the revenue that can be used to cut distortionary taxes might offer a double dividend, including an improvement in the environmental quality and economic efficiency (Bovenberg, 1999; Goulder, 1995). Because of the advantages of the carbon pricing, Frank Jotzo[1] stated that if a future Australian Government is serious about significantly reducing emissions in an economically sensible way, the emissions trading or carbon tax must be brought back.

The ETS has emerged as a popular instrument used to reduce carbon emissions in many other countries. EU countries have been implementing the carbon emissions trading scheme since 2005, with a decrease of emissions by 19.2 per cent (in 2012) below 1990 levels. EU countries are close to reaching their 2020 emissions reduction target of 20 per cent below 1990 levels. The EU is the largest emissions carbon market in the world, followed by China, in which seven pilot ETSs have been implemented, and a national emissions trading scheme is intended to be implemented for 2016-2020 (Tim, Gerry, & Andrew, 2014). If the Australian Government implements an ETS, it has the potential to link to international carbon markets.

The Australian Government, for more than a decade, has considered introducing a national ETS. In the 2007 election, both major political parties promised to introduce an ETS if elected, but legislation for such a scheme is yet to be passed. In spite of the repeal of Labor Party carbon pricing mechanism and its replacement by the DAP, an ETS is still favoured by economists. Under an ETS, a government would issue as many emissions permits as required to meet with the emissions reduction target. Each permit is equal to one tonne of equivalent CO_2 emission (CO_2-e). Then, the government would allocate the fixed amount of permits to emitters (or

[1] Access at http://theconversation.com/palmer-deal-gives-green-light-to-direct-action-experts-react-33601.

industries) based on their previously generated emissions. Emitters (or industries) can purchase emissions permits from the government, as well as from other emitters who generated less emissions than their allowances in auctions; the permit price is set in an auction.

An ETS is confidently regarded as the best program for achieving emissions reduction targets, but uncertain on costs to the economy, as well as, on the social aspects of Australian society. The ETS is aimed to achieve the Australian emissions reduction target of five percent below 2000 levels by 2020 as was committed in the *Kyoto Protocol*. In order to lower the effects of the ETS on the economy and other social aspects, the revenue raised from the permit auctions is used to compensate households to offset the higher prices that might be caused by the ETS. Therefore, this thesis measures the distributional and welfare effects of an ETS on Australia, and compares these effects with various revenue recycling policies.

1.2 Research objectives

The main objective of this research is to examine the impact of a domestic ETS on the macro-economic variables, sectoral and household levels in Australia. The research focuses on the distributional and welfare effects of a domestic ETS. Under an ETS, emitters must pay the cost for their generation of emissions and this cost is included in the production cost, thus resulting in higher prices for carbon-intensive products directly and for other goods and services indirectly. The thesis considers the extent to which an ETS affects commodity prices, industry output, as well as household consumption, income and welfare. For example, the research considers whether rich or poor households suffer an increased financial burden with the adoption and implementation of an ETS.

As already explained, by auctioning emissions permits to polluting industries, the government raises significant revenue; and in order to mitigate unexpected impacts, the revenue is used to compensate vulnerable populations. In this study, 50 per cent of the auction revenue is assumed to be recycled to households through various compensation policies. This thesis compares the impact of five scenarios of the revenue recycling options in order to determine: the best choice for the distribution of income which is the best choice for economic efficiency; and whether or not there is a trade-off between equity and efficiency.

The following are the specific objectives of the research:

1. To construct a Social Accounting Matrix (SAM) database. The SAM is a main database for a Computable General Equilibrium (CGE) model. There is a disaggregation on energy sectors, labour, and households in the SAM.
2. To develop a CGE model for the Australian economy with a system of equations and a database structure to examine the distributional and welfare effects of an ETS.
3. To measure the effects of an ETS on macro-economic variables, sectoral and household levels in the absence of a compensation policy.
4. To compare the distributional and welfare effects of an ETS under various revenue recycling policies. The change in household welfare is measured by the Equivalent Variation (EV).

1.3 Research methodology

To evaluate the distributional and welfare effects of Australia's carbon emissions reduction strategies, this research employs a CGE model, which incorporates a system of equations that describe the behaviour of producers and consumers in an economy for a given time period with some assumptions, such as a perfect competition, cost minimisation or profit maximisation for producers, and utility maximisation by consumers. The CGE models are widely used to analyse the effects of policy changes on all economic aspects. In particular, Burfisher (2011, p. xiii) stated that a CGE model is a powerful analytical tool that can help us gain a better understanding of real world economic issues. Dixon and Jorgenson (2013, p. 1) note that CGE modeling is the only practical way of quantifying the effects of policies and other shocks on industries, occupations, regions and socioeconomic groups.

The model used in this thesis is a static CGE model that is based on the ORANI-G model (Horridge, 2003). The production function consists of a five layer nested Leontief and Constant Elasticity of Substitution (CES) functions. At the top level, intermediate inputs, primary factors and other costs are combined by using a Leontief function, all bottom levels are nested by various CES functions. However, compared to the ORANI-G model, there have been modifications in treating energy commodities in the structure of production in this CGE model. The model treats energy commodities and non-energy commodities separately (see a similar type of modelling structure in Siriwardana, Meng, & McNeill, 2011). Hence, this model allows for substitution between energy inputs, between electricity produced by different sources and between capital and energy.

To measure the effects of carbon emissions reduction strategies, this CGE model incorporates equations describing emissions permit price as well as the emissions quantities generated by producers and final consumers. The price is endogenously determined in the model for finding the equilibrium point and the quantities of emissions generated by industries are set exogenously. To analyse the effects of fixed quantities of carbon emissions for industries on distribution of income and welfare, the CGE model contains equations showing the incomes and expenditure of households as well as of other institutions such as financial corporations, non-financial corporations, government, and the rest of the world.

In comparison to the original ORANI-G model, which is based on an Input-Output (IO) database, this CGE model is based on a SAM database. Apart from containing an IO database, the SAM database contains more details about the receipts and payments of institutional sectors. Round (2003a) states that the SAM is considered as a comprehensive and flexible framework, it also elaborates and articulates the generation of income by activities of production, and the distribution and redistribution of income between social and institutional groups. The data for the SAM is collected from the IO Tables 2008-2009, the Australian National Accounts (ASNA) 2010-2011, for the year 2009 and the Household Expenditure Survey (HES) 2009-2010. The emissions data is compiled from the National Greenhouse Gas Inventory (NGGI) for the year 2009.

1.4 Expected contribution of the research.

Expected contribution of the research is as follows:

First, the research contributes to the literature on methodology utilising the CGE model as applied to the analysis of the distributional and welfare effects of an ETS in Australia. The model allows for the substitution between energy commodities, between energy and capital, and between electricity produced from different sources. This substitution creates a shift from a high carbon emissions sector to a low carbon emissions sector, thus leading to a reduction in emissions to achieve the emissions reduction target. Differing from the studies conducted by Gaspe Ralalage LDS (2013) and Siriwardana et al. (2011), which evaluated the effects of fixed carbon prices, this research treats the emissions permit price the same for all emitters and sets it as an endogenous variable, while quantities of the emissions generated by emitters are fixed and set as shocks in the model.

Both consumers and producers bear the costs caused by an ETS, thus including the emissions cost into the purchaser prices for carbon intensive products results in an adjustment in the behaviour of both producers and consumers on production and consumption respectively. Therefore, this encourages the use of lower CO_2 technologies in both production and consumption, thus achieving the emissions reduction target. In this thesis, the ETS is a comprehensive scheme when it covers all sectors as well as all emissions generated from fuel combustion, fugitive emissions, industrial processes, agriculture, waste, and land use, land-use change and forestry. All emissions are defined in equivalent CO_2 emissions terms.

The CGE model includes equations describing both household income and expenditure in order to analyse the distributional and welfare effects of the ETS. In this thesis, households were disaggregated into 20 household groups according to household income levels. Household income and expenditure originate not only from production and consumption of goods and services but also from other institutions. Therefore, the model also contains equations describing the income and expenditure of all other institutions in the economy, including financial corporations, non-financial corporations, government and the rest of the world.

Second, the thesis contributes to the literature on the methods of constructing the SAM for the Australian economy in 2009. The SAM used in this research is a comprehensive database describing detailed receipts and outlays of all economic agents in the Australian economy with disaggregated energy sectors, labour categories and household groups. Furthermore, to measure the effects of the emissions reduction strategies on distribution of income and welfare, the SAM contains the carbon emissions accounts, in which the carbon emissions generated by industries were allocated consistently to those in the Use and Supply Tables. This research shows how the SAM is constructed from these sources.

Third, the expected contribution of the research is a measurement of the effects of an ETS on the Australian economy in general and on Australian households in particular. An ETS is simulated with a variety of revenue recycling options. The results indicate that an ETS has negative impacts on the Australian economy. However, the auction revenues that are used to recycle to households, results in an improvement to the Australian economy and households compared to the no revenue recycling scenario. There is a trade-off between efficiency and equity. If the compensation is through a reduction of income taxation, there is economic efficiency but inequality between households. If compensation is provided by financial lump sum transfers to all households, there is equality yet economic inefficiency, such as when the income tax reduction policy is applied. Thus, the findings have important policy implications.

1.5 Organisation of the thesis

This chapter provided an introduction to the thesis. The other six chapters of the thesis provide information as follows:

Chapter 2 presents the literature on the instruments used to reduce carbon emissions, mainly focusing on the carbon pricing mechanism. Furthermore, this chapter surveys the literature on the effects of the carbon pricing policy on distribution and welfare in both theoretical and empirical studies. Many previous studies that apply the CGE model to analyse the effects of environmental policies in Australia are outlined in this chapter.

Chapter 3 outlines the Australian environmental policies that have been proposed, implemented and in the process of being implemented in recent decades to reduce Australia's carbon emissions. The compensation packages accompanying these environmental policies were released in response to a need to mitigate undesirable impacts on the Australian economy. These compensation packages are discussed in detail in Chapter 3.

The thesis has developed a CGE model to examine the distributional and welfare effects of an ETS. The SAM construction is an essential part of this CGE model. Chapter 4 describes data collection methods and the procedure for constructing the SAM. Chapter 4 also provides in detail disaggregation and extension of SAM, in which there is disaggregation in energy sectors, labour categories, and household groups in SAM. Moreover, this chapter presents how to allocate carbon emissions to industries in the SAM.

Chapter 5 presents the theoretical structure of the CGE model with a system of equations describing the behaviour of producers and consumers in their production and consumption. The model implies cost minimisation or profit maximisation for producers and utility maximisation for consumers. Equations are described in more detail regarding the disaggregation of energy, electricity generation, labour and households. In order to measure the effects of an emissions trading scheme, the model reflects the carbon emissions pricing mechanism through equations describing the permit price as well as the emissions trading mechanism among emitters. In addition, this chapter outlines the compilation of elasticity parameters used in the CGE model.

Chapter 6 provides the emissions reduction target for the whole Australian economy as well as to all emitters participating in an emissions trading scheme. The revenue raised from auctions are recycled to households through tax reductions and lump-sum transfers by five revenue recycling options. This chapter compares and contrasts the outcome of an ETS without compensation and with various compensation policies with respect to macro-economic effects, sectoral effects, and household effects. Household effects are categorised into effects on household income, expenditure and welfare. The sensitivity of the parameters is tested using Systematic Sensitivity Analysis (SSA), a facility given in the RUNGEM program of the GEMPACK software.

Chapter 7 presents the key findings and policy implications, the contribution to the literature, the limitations and the suggestions for further research.

CHAPTER 2: LITERATURE REVIEW

Climate change has become an international concern the world over, thereby encouraging many studies on how to reduce the greenhouse gas emissions (GHG) into the atmosphere. Market-based mechanisms, such as a carbon tax and an emissions trading scheme (or cap-and-trade program), are considered to be cost-effective instruments to reduce carbon emissions. The imposition of a price on carbon emissions can be passed on to final consumers in the form of higher commodity prices, backward to investors, and to workers in the case of lower prices for primary factors, thus leading to a change in household consumption, income and welfare. The revenues raised from the carbon tax, or from auctions can be used to offset the effects of placing a carbon emissions price, but how best to allocate emissions and how best to recycle the revenue are questions that have been extensively researched in both developed and developing countries.

This chapter presents details regarding the studies conducted to investigate the distributional and welfare effects of both a carbon tax and an ETS in Australia and in other countries. Section 2.1 presents the policy instruments used to reduce carbon emissions. The theoretical studies on the distributional and welfare effects of carbon pricing mechanisms are described in section 2.2. Empirical studies on distributional and welfare effects of carbon pricing mechanisms are discussed in section 2.3. A conclusion is presented in section 2.4.

2.1 Policy instruments for carbon emissions reductions

There are many policy options for reducing carbon emissions, including non-market mechanisms and market mechanisms. The non-market mechanisms are known as command-and-control regulations, while market mechanisms include an ETS, a carbon tax and energy taxes. Most economists agree that a non-market approach requires a higher cost than a market approach to reach a given carbon emissions reduction. Market-based instruments can reach an emissions reduction target at, probably, a lowest cost (Goulder & Parry, 2008; Goulder & Schein, 2013). However, there is contention regarding which market-base instrument, a carbon tax or an ETS, is the better climate policy option. The following sections discuss various aspects of non-market and market mechanism approaches to reduce carbon emissions.

2.1.1 Command-and-control regulations

Direct regulations are generally known as command-and-control mechanisms. Environmental direct regulations refer to the laws and regulations on environmental standards that require producers to take specific actions to reduce emissions by applying a particular production method or meeting a specific performance emissions standard. Thus command-and-control regulations provide firms with little flexibility in achieving goals. Command-and-control regulations are divided into technology-based standards and performance standards. Technology-based regulations require the use of specified equipment, processes or procedures to comply with a regulation. Performance standards require firms to have specific goals and they grant firms with the flexibility to choose how to meet these goals. Thus, performance standards provide greater flexibility than technology-based standards (Hahn & Stavins, 1991). Goulder and Parry (2008) further note that, because of greater flexibility, performance standards generally are more cost-effective than technology-based standards. In Australia, the Renewable Energy Target (RET) can be seen as a command and control policy, in particular as a performance standard, because it requires Australian energy suppliers to generate 20 per cent of Australia's electricity from renewable energy sources by 2020.[2]

Command and control regulations are thought to be effective in achieving established environmental goals and standards (Hahn & Stavins, 1991). Fullerton, Leicester, and Smith (2008) suggested that, in some cases, it might be easier to monitor and enforce command and control regulations than alternative environmental policies. However, most analysts argue that command and control regulations incur a higher cost than market-based instruments. Hahn and Stavins (1992) estimate that the proposed emissions-rights market for curbing acid rain in the United States (US) could save US$1 billion annually in comparison to a command-and-control approach. Newell and Stavins (2003) found that a market-based policy could save about 38 per cent of abatement costs relative to the command-and-control mechanism. In reality, each firm has different marginal abatement costs, given the heterogeneity among firms, furthermore it is unlikely that governments have enough information to set regulations that cause the marginal cost of abatement to be equated across firms. Also, a command-and-control mechanism leads to non-cost-effective outcomes because some firms use excessively expensive means to control pollution (Aldy & Stavins, 2012).

Command-and-control regulations are not cost-effective instruments to reduce emissions (Goulder & Parry, 2008). Command-and-control policies limit the firm's ability to find the most cost-effective way to continue production while reducing emissions. Each firm has, likely, differing costs when implementing emissions reduction policies demanded by the government;

[2] The RET was implemented in August 2009, before the carbon tax was introduced and it is an extension of the previous Mandatory Renewable Energy Target (MRET) that began in 2001.

regulations do not allow firms the flexibility to address their particular externality problems, thus leading to economic inefficiency. Goulder and Parry (2008) also stated that both technology-based and performance-based standards fail to exploit optimally output reductions. Because firms are not charged for their remaining emissions, they may simply find a way to reduce the emissions intensity of production, either through input-substitution or post-combustion treatment. By reviewing the empirical literature on environmental regulations, Cole and Grossman (1999) concluded that command and control environmental regulations are inevitably inefficient or, at least, less efficient than alternative economic approaches to abate emissions.

Command-and-control regulations have been criticised as not providing an incentive for firms to innovate by going beyond the reductions required by the standards set by governments. When firms meet the requirement of command-and-control regulations, they have little incentive to develop and adopt cleaner technologies because they are likely to be afraid that if they adopt such new technology the government may propose a stricter regulation (Aldy & Stavins, 2012). Moreover, firms are not charged for their remaining emissions, thus the output price may be lower than in the case of emissions prices. Therefore, compared to the emissions pricing policy, the command-and-control policy does not provide incentives to reduce emissions. The limitations of command-and-control regulations can be avoided through the use of market-based policy instruments. Rather than equalising pollution levels, the market-based instruments equalise the marginal cost of emissions reduction that is the incremental amount that firms spend to reduce emissions. Thus, market-based mechanisms provide for a cost-effective allocation of pollution control.

Metcalf (2009) argued that market-based approaches are superior when compared to regulatory approaches in a number of ways, regardless of the industrial sector, all emitters face the same marginal cost of abatement in market-based approaches, a necessary condition for efficiency. Market-based instruments provide an effective incentive to shift the larger pollution reduction from firms, or sectors, with a high marginal abatement cost, to those with low marginal cost of abatement. Moreover, imposing a price on pollution emissions encourages technological innovation, thus leading to a reduction of emissions at a lower cost. A market-based mechanism is generally known as a carbon tax or an ETS.

2.1.2 Carbon tax

Production of some goods and services generate the GHG emissions into the atmosphere. The market price of these products reflect their private costs not their social costs. The private production costs are lower than the social costs. A divergence between private and social costs is caused by a negative externality that is caused by GHG emissions. The question raised in recent decades is: should governments and societies reduce the negative environmental externality? Pigou (1938) who was a pioneering economist, suggested that a tax imposed on emissions would internalise negative environmental externalities. A Pigouvian tax is set to be equal to the marginal damage cost. Baumol and Oates (1971) indicated that it is difficult to obtain a reasonable estimate of the money value of marginal damage cost, and taxes should be selected in order to achieve specific acceptability standards such as a specific emissions reduction target. When the standards of environmental quality are set, sufficient unit taxes should be imposed to achieve these standards. Therefore polluters would have to adapt their operations.

Carbon emissions make up the major part of GHG emissions and a tax on these emissions is generally referred to as a carbon tax (Metcalf, 2009). Carbon taxes are defined as taxes that explicitly place a price on carbon, or use a metric directly based on the carbon content (e.g. price per tCO_2-e) (World Bank, 2014b). The carbon price is set in terms of dollars per tonne of CO_2 (or tCO_2-e) by sources covered by the tax. The main purpose of carbon taxes is to reduce GHG emissions. Carbon taxes imposed on users are called a downstream system; carbon taxes imposed on producers are called an upstream system. A carbon price directly affects carbon-intensive products and indirectly affects other goods and services that use energy products as their inputs. Imposing a price on emissions raises the cost of production that affects both production and consumption, therefore changing the behaviour of both producers and consumers. In particular, Goulder and Parry (2008) argued that the production and consumption choices of producers and consumers account for their contribution to emissions reduction. Freebairn (2009) showed that higher production costs cause businesses to choose less pollution intensive production methods and the higher product prices cause households to shift consumption away from pollution intensive products, therefore leading to emissions reduction.

The level of carbon emissions reduction resulting from a carbon tax depends on how the carbon tax is designed, including the choice of the tax base and the tax rate. The tax base choice incorporates the coverage of the tax, the tax levy on producers or consumers, and optimal breadth. The tax rate is equal to the social marginal damages from an additional unit of emissions. Because marginal damages change with emissions, the tax rate needs to change as well (Clarke, 2011; Metcalf & Weisbach, 2009). The optimal tax is when the marginal cost of abatement equals the marginal benefit. Metcalf and Weisbach (2009) explained that Scandinavian countries adopted the carbon taxes in the 1990s. The taxes had narrow bases and did not impose a uniform tax on emissions from the sources that they covered and the countries provided a wide variety of different rates. For example, in Norway, a carbon tax covered 40 per cent of total emissions; the impact of the carbon tax on emissions reduction was weak because the numerous exemptions gave rise to competitive concerns. Whether a carbon tax imposes a burden on producers or consumers depends on the demand and supply elasticities. The more elastic the product supply relative to the product demand, the higher the proportion of the cost of the carbon tax is passed forward to consumers (Freebairn, 2009).

As a market-based instrument, carbon taxes can reduce carbon emissions at possible lowest costs. Minimising the cost of reducing pollution by a given target amount requires equating the marginal abatement costs across all potential emitters for emissions reduction (Goulder & Parry, 2008). With a fixed carbon price, all agents in the economy face the same carbon price. When faced with increased costs because of the imposition of a carbon tax, producers will have different reactions. First, they will change their production processes through fuel switching and investment in more energy-efficient technologies that reduces carbon emissions. Second, they will pass, partly or fully, this cost to final consumers in the form of higher prices of energy commodities and other goods and services that use these energies as inputs in the production processes. Ultimately, all agents in the economy face the same marginal abatement costs to reduce emissions that are equal to a carbon tax.

Bruvoll and Larsen (2004) estimated the effect of a carbon tax in Norway on GHG emissions reduction and concluded that a carbon tax of US$21 per tonne would have reduced emissions by approximately 14 per cent. Siriwardana et al. (2011) estimated the emission reduction in three different simulations of carbon price, in which a carbon price of A$15 resulted in an emissions reduction of nearly 60 mega tonnes, compared to over 73 mega tonnes from a carbon price of A$23 and over 89 mega tonnes from a carbon price of A$30.

Moreover, a carbon tax would provide certainty about the marginal cost of compliance that decreases uncertainty about returns to investment decisions, but would leave uncertainty about the level of emissions reduction in the economy. Some economists favour a carbon tax because of the certainty of marginal abatement costs (Duff & Hsu, 2010; Pizer, 2002). Weitzman (1974) indicated that a carbon tax would be favoured when the marginal damage curve (or the marginal benefit curve) is relatively flat. Using this insight, Norhaus (2007) found that a price control is likely to be more efficient than a quantity control, because by comparing the benefit and cost from the carbon emissions reduction, the marginal cost of emissions reductions is highly sensitive to the level of reductions, while the marginal benefit of emissions reduction is independent of the level of emissions reduction. Moreover, Pizer (2002) concluded that a carbon tax is more efficient than an ETS because a price control might offer five times higher welfare improvements than a quantity control: about US$338 billion compared to US$69 billion.

A carbon tax raises revenue for a government. The effects of the carbon tax on emissions reduction and the economy depend on how the revenue will be used. For example, a carbon tax of US$20 per tonne of CO_2 in the US would be likely to raise more than US$100 billion per year (Aldy & Stavins, 2012) and a carbon tax of A$23 per tonne of CO_2 was estimated to raise over A$6 billion in 2012-2013 for the Australian government (Siriwardana et al., 2011). The carbon tax revenue could be utilised in a variety of ways around the world. The International Council on Mining and Metals (ICMM, 2013) found that the revenues are being used in four ways: (1) supporting the development of climate-friendly technologies, (2) supporting wider governance issues; (3) protecting and/or helping ease the transition to low carbon regimes for specified populations; and (4) helping protect trade exposed economic sectors. If the revenues are returned through cuts in distortionary taxes, the marginal cost seems to be close to zero, this results in a double dividend, meanwhile the revenues are returned lump-sum and the marginal cost seems to be positive (Bovenberg & Goulder, 2002). The revenue could offset taxes on labour, capital and saving which could potentially result in a double dividend (Parry, 1995). The double dividend is one of five advantages of a carbon tax that was suggested by Pearce (1991).

Carbon taxes have been implemented in many countries around the world. Five European countries were the first to introduce a carbon tax in the early 1990s; Finland in 1990, followed soon by Netherlands (1990), Norway (1991) Sweden (1991), and Denmark (1992). With a different tax base and tax rate, a carbon tax resulted in a variety of emissions reductions in these countries. Finland's carbon tax reduced CO_2 emissions by 4 million metric tonne between 1990 and 1998, and GHGs in Sweden reduced by 9 per cent between 1990 and 2006 because of a carbon tax (Sumner, Bird, & Dobos, 2011). Recently, a carbon tax has been implemented in the

Canadian province of Quebec in 2007 and British Columbia in 2008. From July 2012 to July 2014, a carbon tax of A$23 per tonne of CO_2 was implemented in Australia.

2.1.3 Emissions trading scheme

The principle of an ETS can be attributed to the famous economist Coase (1960). Coase proposed that: 'If factors of production are thought of as rights, it becomes easier to understand that the right to do something which has a harmful effect (such as the creation of smoke, noise, smell, etc.) is also a factor of production" (Coase, 1960, p. 44). Coase argued that, if these property rights are explicit and transferable, the market could play an important role in valuing these rights. Dales (1968) applied Coase's theorem to water pollution, and Crocker (1966) applied it to air pollution. Dales noted that pollution control regimes imposed by a government had already established a property right in the right to emit. However, unlike the property right system envisioned by Coase, this property right was not transferable and was therefore inefficient. In the early 1970s, the literature on property rights suggested that firms were allowed to trade control responsibility among themselves by means of emissions trading, in which firms, who have relatively cheap cost and control more emissions, can sell to firms who control less (Tietenburg, 2006).

The ETS sets an aggregate limit on carbon emissions and creates permits for this amount. There are many ways to distribute these permits to regulated firms, such as free distribution (called grandfathering), auctions or a combination of free distribution and auctions. One of the advantages of tradable permits is that the level of emissions reduction will be met at a minimum cost. Under tradable permits, firms typically have very different costs in the reduction of emissions, thus firms who have a lower abatement cost can sell permits to other firms who have a higher emissions reduction cost. Buyers and sellers can find their opportunity cost in trading emissions. When the marginal abatement cost is equalised among firms, or all firms face the same price for permits, the target of emission reduction can be achieved with cost-effectiveness (Baumol & Oates, 1988). An ETS would be favoured when the marginal abatement cost curve is relatively flat (Weitzman, 1974).

The marginal abatement cost is reflected by the permit price in the ETS. While a carbon tax fixes the price of carbon emissions and leaves the market to determine the level of carbon emissions reduction, the tradable permit system fixes the quantity of emissions and leaves the market to determine the price of the permit. So, there is certainty about the emissions abatement costs in the case of a carbon tax, but there is uncertainty about this cost in the case of an ETS.

Under an ETS, a permit (or allowance) is equal to one tCO_2-e and the government issues the total allowable permits in the economy, which is usually equivalent to the emissions target set by international commitments. Some economists prefer a carbon tax to an ETS because of the volatility of the permit price under a tradable permit scheme.

The first ETS was the sulphur dioxide trading program, established under the *Clean Air Act Amendments of 1990* in the US with the purpose of reducing acid rain. The trading program was designed to reduce Sulphur Dioxide (SO_2) emissions by 10 million tonnes and nitrogen oxide emissions by 2 million tonnes from the 1980 levels (Metcalf, 2009). The SO_2 trading was generally regarded as a successful program that provided some experiences for later ETS (Elkins & Baker, 2001). The ten northeastern states in the US introduced a downstream cap-and-trade program under the Regional Greenhouse Gas Initiative in 2009. The aim was that from 2015 the emissions cap is set to reduce by 2.5 per cent each year until it reaches an ultimate level 10 per cent below the 2009 emissions by 2019. The program requires at least 25 per cent of the allowances to be auctioned, and the remaining 75 per cent of the allowances may be auctioned or distributed freely (Aldy & Stavins, 2012).

The world's largest carbon pricing regime is the EU ETS, a cap and trade system of CO_2 allowances. This scheme came into effect in 2005. It was designed to be implemented in phases: Phase I from 2005-2007, called a pilot or learning phase, a trial run to develop the market mechanism to support permit trading; Phase II from 2008-2012, aimed at reducing emissions to meet its Kyoto obligation of 8 per cent reduction below the 1990 emissions level; Phase III from 2013-2020, aimed to achieve 20 per cent below 1990 emissions level by 2020. In the first and the second phases of the EU ETS, all of the emissions allowances (a minimum of 95 per cent and 90 per cent, respectively) were given freely to regulated emitters, but from 2013, the proportion of auctioned permits would become larger and there was unlimited banking of allowances between Phase II and Phase III (Aldy & Stavins, 2012; Metcalf & Weisbach, 2009).

Under an ETS, the supply of allowances is perfectly inelastic; hence the generous emissions permits supplied to emitters results in changes in the emissions permit price. For example, in Phase I of the European Union Emissions Trading Scheme (EU ETS), the permit price dropped from €31.65 in April 2006 to €11.19 in May 2006. However, in 2008 the permit price increased from €13 in January to €30 in June (Goulder & Schein, 2013). In Phase II, the permit price was stable between €15 and €20 for almost two years from mid-2009 to mid-2011, then fell to €5 a tonne in early 2013 and stood at just €2.75 in April (The Economist, April 20, 2013). Moreover, the shifts in demand for allowances can cause significant allowance price changes, thus leading to high price volatility. Nordhaus (2007) noted that the demand for allowances is also likely to be highly inelastic in the short run, thus leading to a higher volatility for allowance prices. After studying the volatility of the price of SO_2 emissions allowances and other prices, such as the consumer price index, stock prices and oil prices for the period of 1995-2005, Nordhaus (2007) concluded that SO_2 prices were as volatile as oil prices and more volatile than prices of stock, other assets and most consumer goods. Thus, emissions price volatility is a problem for an ETS.

To reduce price uncertainty under an ETS, some authors propose that firms should be allowed to bank permits, or borrow permits. Banking permits allows firms to hold the current permits for later use when current permit prices are considered unusually low. Borrowing allows firms to use permits for a future period in the current time when the current permit price is considered unusually high. The banking and borrowing of permits allow firms the flexibility of time for installing new abatement equipment or changing the production process to reduce emissions, thus reducing price instability (Goulder & Parry, 2008; Tietenburg, 2006). Metcalf (2009) suggested that the absence of banking permits from Phase I to Phase II of the EU ETS, along with over-allocation of permits in the first phase, resulted in a decrease of the permit price to be zero by the middle of 2007.

The most successful experience with emissions trading is the Acid Rain Trading Program, which sought to abate the SO_2 emissions, Ellerman (2000) calculated that about US$1.3 billion of the US$20 billion cost saving in the Sulfur Allowance Program could be attributed to banking, which mitigated the issue of price volatility through applying nearly unlimited banking in the SO_2 trading (Ellerman & Harrison Jr, 2003). Conversely, the price volatility for Phase I in the EU ETS has been attributed in part to the fact that the program prevented banking of allowances from the Phase I to Phase II (Market Advisory Committee, 2007). The price volatility of a permit can also be reduced by adding to the ETS a price control, such as a price ceiling or a price floor. Imposing a price ceiling on allowances prevents the price from rising further, likewise imposing a price floor limits prices falling further. The ceiling price and floor price are considered as a ‘safety valve’, or hybrid option, to reduce the price volatility in the ETS (Goulder & Schein, 2013; Pizer, 2002).

Under an ETS, the key decision is how to allocate emissions permits. In the initial stage of an ETS, some permits are distributed freely to emitters, and then the free allocation is set to be zero. For example, in the world’s largest ETS is the EU ETS, which covers around 45 per cent of European CO_2 emissions (Klepper & Peterson, 2005), a minimum of 95 per cent and 90 per cent of the total emissions allowances in the first and second phases were distributed freely to regulated sources respectively, but from 2013 the proportion of auctioned allowance was planned to be larger (Aldy & Stavins, 2012). These methods of allocations provide the same incentive for emissions reduction, but there is a difference in distribution. An auction transfers resources from emitters to the government, thus yielding revenue for the government, meanwhile grandfathering gives assets in the form of tradable property rights to firms and the government does not raise any revenue from the emissions.

2.1.4 Subsidies to carbon emissions reduction

Environmental pollution is an example of an externality that leads to a market failure and government intervention may be necessary to correct this market failure. In fact, there is a variety of policy instruments that have been implemented by a government to achieve its goal of environmental protection. These instruments are classified into regulatory and economic instruments that are considered as the 'sticks and carrots' governments may use to address environmental problems. Normally, sticks, such as stringent regulations, may cause political objections from polluters, while subsidies are considered as carrots that are more acceptable to polluters. Subsidies can be understood as financial assistance from government to the private sector in the form of government funding. With regard to environmental problems, subsidies are financial assistance paid by the government to firms for the purpose of emissions reductions below the baseline level.

As it is considered an economic instrument, subsidies could better address the pollution problem than regulatory approaches. It also provides the same incentive as an emissions tax and an ETS. Firms are subsidised based on the units of emissions reduction below the target level. Such a subsidy would induce firms to reduce pollution up to the point where marginal abatement costs are equal to the subsidy. The firm's opportunity cost for continued pollution is the subsidy foregone (Goulder & Parry, 2008; Kim, 2000). Goulder and Parry (2008) further stated that taxes and subsidies are often considered as two sides of the same coin, but subsidies are less cost-effective than emissions taxes and the ETS. Further, Kim (2000) indicated that subsidies are designed to correct the market failure by paying the polluters to reduce emissions.

This is apparently opposite to the polluter pays principle. Emissions taxes and ETSs are based on the polluter pays principle, whereas subsidies for emissions reduction are consistent with the victim pays principle; that is, the government uses the revenue from taxpayers to compensate firms for reductions in pollution. The most prominent feature of this instrument is that subsidies do not provide a price for externalities. Therefore, there is no revenue recycling effect in the subsidy. In Australia, after repealing the carbon tax, the Coalition Government proposed the Direct Action Plan with the emissions reduction fund of A$2.55 billion to pay for emissions reduction activities so as to achieve the emissions reduction target of 5 per cent below 2000 levels by 2020. Freebairn (2014) compared the carbon price and subsidies to reduce GHG emissions and concluded that the price strategy will have a larger effective base and lower transaction costs, together leading to lower costs per unit of GHG emissions reduction.

2.2 Theoretical studies on distributional and welfare effects of a carbon pricing mechanism

A carbon pricing mechanism, known as a carbon tax or an ETS is favoured to reduce emissions through imposing a price on carbon emissions. The emissions price that is determined by the government (in the case of a carbon tax) or by the market (in the case of an ETS) raises the production costs of energy-intensive products as well as of other goods and services. These costs, in turn, increase the prices of these goods and services, thus resulting in a reduction of the welfare of both producers and consumers. In comparison to command and control regulations, a carbon tax and ETS policies raise revenue that could be used to offset adverse effects. The distributional and welfare effects of these policies depend on how a carbon tax or an ETS affect the price changes and how the government allocates permits to emissions producers, as well as how the government uses the revenue to compensate the vulnerable populations.

2.2.1 Distributional effects of a carbon pricing mechanism

A market–based instrument is a preferred tool to reduce emissions through using a price signal. Based on the principle of polluter payment, producers or consumers have to pay for their activities related to generating carbon emissions into the atmosphere. Imposition of a price on carbon emissions would increase the costs of production, thus leading to reduced output and/or increased price of some energy products and of carbon-intensive goods and services. Hence it affects the production and consumption of these products. Who bears the burden of this policy? Who gets the benefit of an environmental policy? The burden of this policy depends on how producers and consumers react to the emissions prices and how the government allocates emissions and/or emissions permits.

Figure 2.1 represents the costs and benefits caused by the emissions price, calculated using a simple partial equilibrium model. The demand curve portrays the marginal private benefit or marginal social benefit (MB) of using polluting goods, the benefit reduces when more polluting goods are consumed. Given the marginal private cost and, in the case of without the carbon pricing mechanism, the quantity Q_1 of polluting goods is sold at price P_1. When the government imposes a price on carbon emissions, the marginal social cost (MSC) is comprised of the marginal private cost (MPC) and marginal external cost (MEC), the quantity of polluting goods that the society expected is defined at the point of intersection between the MB and MSC curves. At that point, the producers receive a price (P_s) that is smaller than P_1, meanwhile the consumers pay a price (P_d) that is higher than P_1. The difference between P_d and P_s reflects an emissions price. Therefore, because of the emissions price, there is a distribution of benefits and costs among the agents in the economy. The producers lose the producer surplus of area CAP_1P_s, consumers lose the consumer surplus of area BAP_1P_d, the government receives the revenue from imposing an emissions price that is equal to the area of BCP_sP_d, and the residue of these surplus losses is the area ABC.

The burden of a carbon pricing policy between the economy's producers and consumers depends only on the price elasticities of demand and supply for polluting goods not on the nominal incidence of the tax. If the demand is more elastic than the supply the emissions price is borne primarily by producers. In contrast, when the supply elasticity is greater than the demand elasticity, the emissions price is borne mainly by consumers (Clarke, 2011). The magnitude of these elasticities plays an important role in determining who should receive compensation for the impact of the emissions price. If demand is relatively inelastic, consumers who suffer the most impact from the emissions price should be considered for compensation, whereas, if supply is relatively inelastic, producers should be compensated for the damage caused by the emission price (Clarke, 2011). The elasticities of demand and supply also reflect the producers' ability to pass the production costs caused by the emissions price to consumers in the form of higher prices of carbon–intensive goods. Producers initially bear these costs but ultimately consumers bear the majority of these costs.

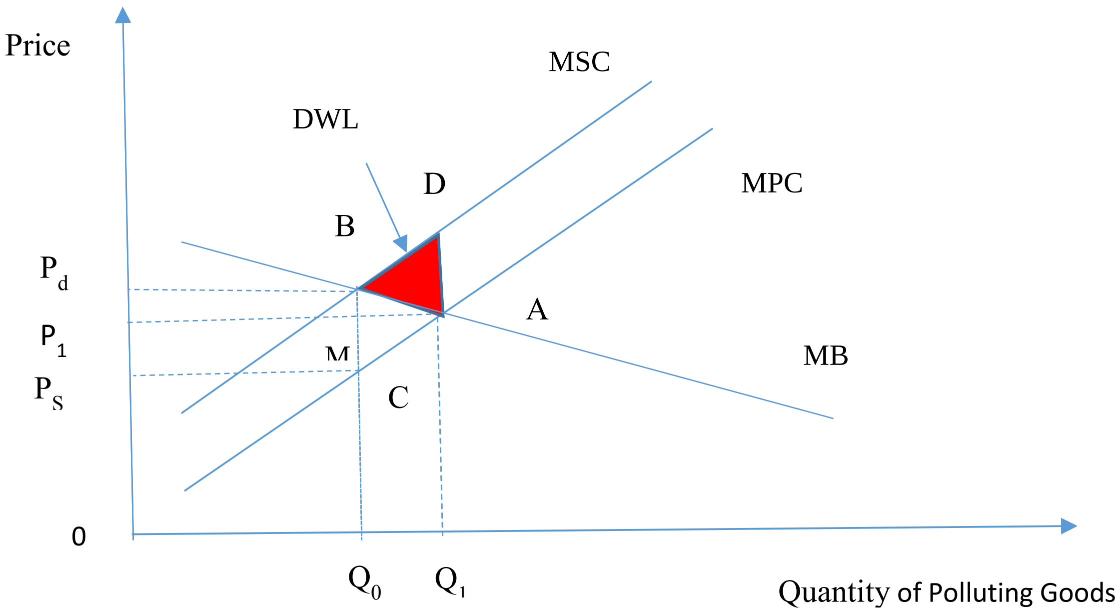

Figure 2.1: Gains and losses from carbon pricing mechanisms
Source: Adapted from Clarke (2011)

Beside the elasticities of demand and supply, the burden of distribution also depends on the proportion of income devoted to carbon-intensive goods and services (Fullerton, 2009). Compared to high-income households, low-income households tend to derive less benefits from environmental policies and bear a higher cost. This means that carbon pricing would impose a greater relative burden on low-income households. Thus, the emissions price is regressive (Baumol & Oates, 1988). The regressive effects can be reduced by using the revenue raised from a carbon tax or auctions to compensate losers. It is less regressive when the revenue is used to reduce wage taxes and it is progressive when the revenue is used to provide the same lump-sum rebate to each household (Fullerton, 2009).

Fullerton (2011) discussed six different types of distributional effects of environmental policy: (1) an increase in prices of carbon-intensive products; (2) changes in returns to the factors of production, such as labour, capital and land; (3) benefits of using the revenue raised from a carbon tax or auction of permits to help low-income households; (4) benefits of improved environmental quality, thus reducing morbidity and mortality rates that may provide benefits to the poor; (5) the costs of adjustment and transition due to a carbon emissions price that benefits some industries but costs to other industries; (6) effects on asset prices such as stock prices of affected industries or house prices in terms of environmental quality. By applying the general equilibrium model, most aspects of the distributional effects of environmental policy can be measured.

2.2.2 Welfare effects of a carbon pricing mechanism

A carbon pricing policy aims to reduce carbon emissions in the atmosphere through imposing a price on such carbon emissions, thus leading to an increase in the production costs of carbon-intensive products that affect the welfare of both producers and consumers. When producers are faced with higher production costs, they pass the costs onto consumers in the form of higher prices of carbon-intensive products. If they do not pass these costs onto consumers, they could pass them back to investors and employees in the forms of lower returns on investments and lower wages. Ultimately, investors could be faced with a reduction in their investment or workers could lose their jobs. Consumers are likely to reduce their purchases of these products because of the higher prices of carbon-intensive products, thus there is a reduction in welfare. Indeed, investors, employees and consumers will experience welfare losses due to such an environmental policy (Dinan & Spoor, 2003).

As shown in Figure 2.1, without the environmental policy, there is Q_1 of polluting commodities produced where the MB is equal to MPC. However, the expected quantity of the society (Q_0) where the MB intersects with MSC is smaller than $Q_{1.}$ The MSC consists of the MPC and the MEC. Under the carbon pricing policy, an emissions price is imposed on polluting products equivalent to the MEC, the expected quantity of the society, $Q_{0,}$ would be reached. Thus, because of the environmental policy, the welfare gains is achieved in the sense of the deadweight loss (the area ABD) is avoided, because of the emissions price, the output of polluting product reduces from Q_1 to Q_0 thus creating the gross cost or net reduction in benefits. Meanwhile, the government can raise the revenue.

The carbon tax, as well as auction permits trading, raises revenues, while the welfare effect of carbon emissions reduction policy depends on how the government uses these revenues to compensate the affected agents in the economy. The revenues can be used to cut distortionary taxes and might offer a double dividend, such as an improvement in environmental quality and a reduction in certain costs of the tax system (Bovenberg, 1999; Goulder, 1995). Goulder (1995) classified double dividends into weak double dividend and a strong double dividend. Returning the revenue through cuts in distortionary taxes leads to cost saving relative to the case where revenue is returned as a lump-sum transfer, this is called a weak double dividend. If revenue is returned to reduce distortionary taxes that induce zero or negative gross costs[3] this is known as a strong double dividend. De Mooij (2000, p. 3) added one more form of double dividend that

[3] Gross costs correspond to welfare changes abstracting from welfare changes associated with improvements in environmental quality.

is the employment double dividend. The employment double dividend incorporates both improvement to the quality of the environment and boosts employment. According to Goulder (1995) the weak double dividend notion is relatively noncontroversial but the strong double dividend is still a matter of debate. The revenue is returned by ways of income tax cuts, and capital tax, in which the strong double dividend would incur. De Mooij (2000) concluded that an environmental policy can boost employment in cases of a lower labour tax, better substitution of labour for polluting inputs, and real wage resistance.

Primarily, households suffer the costs from the carbon emissions reduction policy through changes in prices of carbon-intensive products as well as changes in other goods and services, which in turn affect the consumption of individuals and households. Welfare depends directly on individual consumption of goods, services and enjoyment of leisure (Goulder, 1995). Therefore, the changes in prices of goods and services caused by an emissions reduction policy produce a change in the welfare of households and individuals. Welfare effects of the change in prices caused by a carbon emissions reduction policy are defined in terms of Compensating Variation (CV) and Equivalent Variation (EV) (Cornwell & Creedy, 1998).

The CV is the amount of money that must be given to a loser, or taken from a gainer, in order to retain the individual's initial utility. In terms of the expenditure function, it can be written as:

$$CV= E(p_1, U_0) – E(p_0,U_0)$$

The EV is the amount that needs to be taken from individuals after a price change in order to give the person the new utility at the old prices. It is defined as:

$$EV = E(p_1,U_1) – E(p_0, U_1)$$

In which, U_0 and U_1 are the initial and new utility levels, p_0 and p_1 are the initial and new price levels, respectively.

2.3 Empirical studies on distributional and welfare effects of a carbon pricing mechanism

A market-based mechanism is a cost-effective instrument to reduce carbon emissions. The mechanism is seemingly regressive but the degree of regressivity can be ameliorated, or reduced, by revenue recycling. The following sections present studies on effects of a carbon tax and an emissions trading scheme.

2.3.1 Empirical studies on a carbon tax

A carbon tax has been implemented in many countries in the world. Overall, a carbon tax seems to be regressive in developed countries but progressive in developing countries. This section outlines the distributional and welfare effects of a carbon tax in developing countries, Australia and other developed countries.

2.3.1.1 Studies in the developing countries

Many studies have been conducted regarding the implementation of a carbon tax in developing countries, such as China, India, South Africa, and Indonesia. The majority of these studies concluded that the carbon tax tends to be progressive in developing countries because poor income households, mainly in rural areas, experience minimal effects from the introduction of a carbon tax.

Zhang (1998) analysed the effects of a carbon tax on Chinese macro-economic indices and sectors in order to cut carbon emission by 20 per cent and 30 per cent in 2010. The study applied the CGE model, disaggregating energy use into four types: coal, oil, natural gas and electricity, using the 1991 Input-Output tables. The carbon emissions reduction target in 2010 required a carbon tax of 205 yuan (or US$18 at 1987 prices) and of 400 yuan (or US$35 at 1987 prices). Obviously, a greater reduction in CO_2 emission would require a higher carbon tax. The simulation results indicated that the imposition of a carbon tax leads to an increase in the price of energy goods as well as of other goods and services. A higher price leads to a decrease in demand for energy and other goods, thus affecting energy consumption, GNP and welfare. In particular, energy consumption, GNP and welfare are estimated to decrease by 19.47 per cent, 1.52 per cent and 1.08 per cent respectively for a carbon tax of 205 yuan, and they continue to reduce by 29.32 per cent, 2.76 per cent and 1.75 per cent for a carbon tax of 405 yuan respectively. In order to reduce the negative effects of the carbon tax, the study compared four scenarios of reduction with indirect taxes by 5 per cent and 10 per cent in the two cases of the carbon tax price. The results illustrated that a greater reduction in indirect tax rates results in an increased improvement in GNP and welfare.

Mainly focusing on the distributional incidence of carbon charges, Brenner et al. (2007) examined the effects of a carbon charge of 300 yuan per tonne of carbon on income distribution in China, and how the recycling revenue could be used to compensate all Chinese households on a per capita basis. Households were disaggregated into deciles ranked by both household income and expenditure. The results concluded that, the effects of carbon charge would be progressive if households are ranked by expenditure level, whereas they would be regressive as ranking households by income level, but the policy would be progressive when it is measured as a percentage of expenditure. This is explained by different consumption levels of carbon intensive products between the rich and the poor. For instance, households in the lowest decile spend three-quarters of their total expenditure on food, meanwhile this proportion is less than 40 percent for the highest decile.

Brenner et al. (2007) compared the impact of a carbon price between rural and urban areas of China. Households in urban areas spend more on carbon-intensive products, such as energy and industrial goods; by contrast households in rural areas devote a larger share of their expenditure on food items that are much less carbon-intensive. Therefore, the incidence of a carbon price in urban areas is higher than in rural areas. If the revenue generated from the carbon price is returned to households on a per capita basis, after deducting 1 per cent for administrative cost, each person receives 69 yuan. The combination of the carbon price and dividend redistribution results in a strong progressive effect, in which 70 per cent of China's population would receive a net benefit and the households in the poorest decile would see their income rising by the equivalent of 10.3 per cent of total expenditure, while the richest decile would see a 2.3 per cent decline. Comparing urban and rural areas, 90 per cent of rural people would be net winners, while 90 per cent of urban households would be net loser. Poverty would be reduced by more than 20 per cent by the headcount measure.

Van Heerden et al. (2006) compared the effects of four environmental taxes combined with three revenue-recycling schemes in South Africa. The authors employed the CGE model to measure these effects. The findings concluded that all four environmental taxes reduce CO_2, but the emissions reduction caused by a carbon tax is largest because all emissions related to fuels are included in the carbon tax base. When the revenue is recycled, food tax reductions combined with all four environmental taxes, yield a GDP increase, poverty reduction, and improved environmental quality, together creating triple dividends. A food tax reduction results in the highest GDP increase, followed by the general reduction in consumption tax and then the direct tax cut. The food tax handback is effective because food production contains a higher component of unskilled labour than the consumption average. The effects of a food tax falls on unskilled labour, while the impact of indirect tax falls on capital and skilled labour. Moreover, in South Africa, most skilled labour is employed, while unskilled unemployment is high; thus, it is assumed that unskilled labour has infinite supply. For the effects on poverty, the electricity tax increases the degree of poverty more than other environmental taxes, while the fuel tax increases the poverty the least. The reason is that the poor spend a larger share of their expenditure on electricity than on fuels; that is, 2.1 per cent of total electricity demand compared to 0.5 per cent of total fuel demand. The results indicated that a fuel tax combined with indirect tax cuts results in triple dividends. However, a direct tax cut when combined with any of the environmental taxes does not create a second and third dividend. The study concluded that a direct tax is not suitable for South Africa.

Yusuf and Resosudarmo (2007) analysed the effects of a carbon tax on distributional income in Indonesia, one of the largest carbon emitters among developing countries. The study employed the combined methodology of a CGE model and micro-simulation model. A CGE model was used to measure the effect of a carbon tax on price change, then the change in prices is transferred to a micro-simulation model to measure distributional impacts. With a carbon tax of Rp 280,000/tCO_2 (around US$32.60), the study compared the effects of three scenarios on the Indonesian economy in general and distributional income in particular. The three scenarios were: a carbon tax without revenue recycling (SIM 1); a carbon tax with revenue-neutrality through a reduction in the ad valorem sales tax rate for all commodities (SIM 2); and a carbon tax with a uniform lump-sum transfer to all households (SIM 3). The simulation results suggested that SIM 2 produced the lowest decrease in welfare effects with the lowest CPI percentage increase of 0.58 per cent and increase in exports and imports. The imposition of a carbon tax leads to an increase in energy product prices. For example, the price of coal increased most by more than 100 per cent, followed by diesel, kerosene, natural petroleum gas, natural gas and electricity. An increase in the prices of energy products, in turn, resulted in a decrease in their output. However, the study concluded that the carbon tax is progressive when almost all rural households obtained a welfare gain and their real expenditure per capita increased, and when the percentage change in welfare of poorer households was higher than that of richer households. The results of the three revenue recycling options suggested that a reduction in the commodity tax rate would have a favourable welfare effect, whereas the lump-sum transfer had a more favourable distributional impact, poverty impact and decreased inequality.

2.3.1.2 Australian studies

The Australian Labor Government implemented a carbon tax of A$23 per tonne of CO_2 for two years from July 2012 to July 2014. The policy has now shifted to the DAP under the Liberal-National Coalition Government. Numerous studies have been conducted to calculate the impact of a carbon tax on energy prices, income distribution and welfare in Australia. This thesis discusses some of these studies, mainly focusing on energy prices, household income and welfare.

Dougall (1993b) simulated the short-run effects of a carbon tax on the Australian economy using an enhanced ORANI model with the disaggregation of energy sectors. In order to achieve the Toronto target of a 20 per cent reduction in CO_2-e below the 1988 levels by 2005, the study applied a carbon tax rate of A$19 per tonne at 1986-87 price level (equivalent to 1991-92 rate of A$25 per tonne). The model is very strict because it does not allow flexibility in fuel mix and energy use in production, and many variables such as the capital stock, wage rate, exchange rate and macro components of aggregate domestic absorption in real terms (e.g. household spending, government consumption and investment). The simulation results indicated that the imposition of a carbon tax would result in an increase in the consumer price index of 1.9 per cent and in an export price index of 0.6 per cent. Meanwhile real GDP, employment and export volume were reduced by 0.9 per cent, 1.2 per cent and 6.0 per cent respectively. Some sectors were affected by the carbon tax, of which metal products were the most affected with a contraction of 6.5 per cent, followed by mining with 5.8 per cent, electricity, gas and water with 3.4 per cent. The results also showed that the carbon tax led to a decrease in the output of brown coal, non-ferrous metals and black coal of 20.8 per cent, 17.8 per cent and 11.2 per cent respectively. In order to reduce the negative effects of the carbon tax, a lower real wage rate policy was suggested to the government.

Dougall (1993a) compared the effects of a carbon tax, an energy tax and a fuel tax on the Australian economy, using an ORANI-E model. The study disaggregated the electricity industry into six types according to the electricity generation technology used. Deviating from Dougall (1993b), the study allowed for substitution between energy inputs, between energy and capital, and substitution between different electricity generation technologies to measure these effects. With the same revenue collection of 0.5 per cent of the base case GDP, the tax rate of three taxes - a tax on carbon emissions, fossil fuels, and petroleum production - were chosen. The results indicated that all three taxes lead to a reduction in CO_2, while a carbon tax would be, theoretically, the ideal instrument for CO_2 abatement. A tax on petroleum products would be much less effective in reducing greenhouse gases and considerably more costly than either an energy or a carbon tax. The energy and carbon taxes resulted in a fall of GDP of about 0.5 per cent.

Cornwell and Creedy (1996) examined the distributional effects of a carbon tax on prices and inequality in Australia. In order to meet the Toronto target of a reduction in emissions of 20 per cent of 1988 levels by 2005, the carbon tax was A$113 per tonne CO_2. With such a tax, the price of all goods increased, of which fuels and power had the highest increases in price. Lower income earners spend a higher proportion of their budget on fuels and power than higher income earners, thus the carbon tax was regressive. In order to offset the negative effects of a carbon tax, the study offered transfer payments using a minimum income guarantee (MIG) of A$8,000. If after-tax income falls below a minimum level, a transfer was to be paid to bring net income up to the minimum level. There are many measures used to assess the distributional impacts of a carbon tax, including the GINI measure, the Reynolds-Smolensky measure and Kakwani progressivity measure. All measures reached the same conclusion: that a carbon tax increased the degree of inequality in Australia. The study illustrated that if carbon tax was A$150 per tonne CO_2 and a MIG of A$12,000, inequality decreased, progressivity increased, the welfare premium increased, and CO_2 emissions were reduced by 21.6 per cent; thus, the negative effects of a carbon tax could be compensated by adjustments to transfer payments.

Creedy and Martin (2000) applied a partial equilibrium approach to examine the implications of a carbon tax on Australian households in terms of price changes, inequality and social welfare. Differing from Cornwell and Creedy (1996), this model allows for substitution among fuel produced electricity. Because about 98.7 per cent of Australian electricity is produced from black and brown coal, natural gas and hydro, substitution between fuels producing electricity might achieve the emissions reduction target of 20 per cent from 1993 levels. The carbon price was estimated at A$101/t$CO_2$. The revenue raised from a carbon tax can be used to subsidise lower or zero emissions production techniques, in particular if the revenue was used to subsidise a solar thermal of A$60 per MWh, the carbon price would be A$100/t$CO_2$, if the emissions reduction target was implemented over a ten-year period, the carbon price would be A$74 in the subsidy case, instead of A$97 without a compensation. Thus, the target of emissions reduction can be met with a lower tax rate. However, the fuel subsidy resulted in a small effect on the regressivity of a carbon tax.

Siriwardana et al. (2011) examined the effects of a carbon tax on the Australian economy, using a static CGE model. The model allowed substitutions between non-renewable and renewable energy sources producing electricity, between capital and energy as well as among energies in the production function. The study compared the effects of three carbon tax scenarios: A$15, A$23 and A$35/t$CO_2$-e on various aspects of the Australian economy. The simulation results showed that a higher level of a carbon tax tends to increase the electricity price, export prices as well as the CPI. The higher carbon price also resulted in a decrease in GDP, real household consumption and export volume. The higher a carbon price, the larger the emissions reduction, but with a carbon price of A$23/t$CO_2$-e, Australia would achieve the emissions reduction target of 5 per cent below 2000 levels by 2020. A decrease in output of most sectors was attributable to the carbon tax. Electricity produced by black and brown coal suffered the highest output loss, whereas electricity produced by oil, gas and renewable sources tend to increase their outputs and become the biggest winners from a carbon tax. A reduction of employment levels in most sectors leads to a fall in real household consumption of all deciles because of the rising costs of living after the tax. The carbon tax is regressive and, in order to mitigate the regressivity of the carbon tax, Siriwardana et al. (2011) suggested that each household receive an annual lump-sum payment of A$685.

Meng, Siriwardana and McNeill (2011) compared the effects of the carbon tax of A$23/t$CO_2$-e on the Australian economy in two scenarios of carbon tax only and carbon tax plus compensation. It was assumed that all tax revenue was returned in an equal lump-sum transfer to all household deciles. The data was from the Australian National Accounts: Input-Output tables 2004-2005, published by the Australian Bureau Statistics, and household data was from the Household Expenditure Survey 2004. The simulation results indicated that the carbon tax led to a reduction in CO_2 emission in both cases and the main contributors in the CO_2 emission reductions were from electricity-black coal and electricity-brown coal, which accounted for 53 mega tonnes in the total emissions reduction of 70 mega tonnes. The results also illustrated that electricity-black coal, electricity-brown coal, and brown coal mining were the biggest losers, with the highest change in their output, profit and employment. In contrast, electricity-gas and electricity-renewable sources were the biggest winners, representing a sharp increase in employment, profitability and real output. Government income was higher in the compensation scenario than in the carbon tax only, A$8.3 billion compared to A$6.1 billion. Thus, if the government transfers all carbon tax revenue of A$6.1 billion to households it can claim back more than A$2 billion through indirect taxes. For the distributional effects, low income deciles were the biggest losers under the scenario of the carbon tax only, and the biggest winners under the compensation scenario. However, in the case of the change in equivalent variation, richer household deciles were the biggest losers under the carbon tax only and biggest winners under the compensation scenario. Therefore, the effects of a carbon tax on the household income decile depend on what criterion used in welfare analysis.

Meng, Siriwardana and McNeill (2014) applied the CGE model to measure the distributional effects of the Australian carbon tax in the cases of carbon tax only and of carbon tax with compensation. These effects are analysed through percentage change in real income, utility per household and equivalent variation. In terms of real income and utility per household, the authors found that a carbon tax is moderately regressive in the carbon tax only scenario when low-income households experience a higher percentage change than high-income households. With compensation, low-income households experienced a much larger percentage increase, and the two richest deciles experienced a decrease in their income but an increase in their utility. Thus the policy is progressive under the compensation scenario. The results showed that high-income households would suffer with the imposition of a carbon tax, but gain more benefits in the compensation scenario. In conclusion, the influence of a carbon tax on household income deciles depends on which criterion is used in distributional and welfare analysis.

2.3.1.3 Studies in other developed countries

One of the earliest studies on the effect of the carbon tax on distributional income was undertaken by Poterba (1991). The partial equilibrium model using data from the US Consumer Expenditure Survey was used to evaluate the impact of the carbon tax. The research indicated that the carbon tax needed to be approximately US$100 per tonne in order to meet the CO_2-e reduction target at 1988 levels by 2000. The model showed that retail prices of fossil fuels would have increased at the highest rate of 114 per cent for coal and 23 per cent for the natural gas. The prices of fuel oil and gasoline increased by 27 per cent and 25 per cent, respectively, thus leading to an increase in the retail price for electricity of 36 per cent. Poterba (1991) measured the distributional incidence of the carbon tax on both income and expenditure patterns. In both cases the carbon tax was found to be regressive. In order to neutralise the distributional effects of the carbon tax, the author examined policies such as a transfer program to low income or expenditure households, redistributive income tax through changing the level of personal allowances, and tax credits for energy expenditure that allowed each household a tax credit equal to the first one or two per cent of income devoted to purchasing energy. The research concluded that none of the redistributive options completely offset the distributional effects of the carbon tax but a combination of the income tax and the transfer program could be used to neutralise the regressivity of the carbon tax.

Hamilton and Cameron (1994) conducted research on the distributional effects of a Canadian carbon tax. They applied the methodology of a combination of three different methods: the CGE model, cost-push methods, and a micro-simulation model of household expenditure. The research simulated an effective carbon tax of $27.70 per tonne of CO_2 (or $101.56 per tonne of carbon). The results indicated that the decrease in consumer income for the lowest quintile was from 1.1 per cent to 1.2 per cent larger than for the highest quintile. Therefore, the carbon tax in Canada is moderately regressive.

Symons, Speck and Proops (2002) examined the distributional income and welfare effects of carbon and energy taxes in a number of European countries. The research applied the input-output framework with the assumptions that there was no substitution possibilities in production and no response by consumers to the change in relative prices. The budget survey data from EuroStat (1992) was used for the analysis of the distributional effects for France, UK, Spain and Italy. Households were ranked according to equivalent expenditure. The German Income and Consumption survey was used for Germany and households were ranked by their absolute income. The results indicated that the carbon tax was regressive for France, slightly regressive for Spain, neutral for Italy, and progressive for UK except for the highest income group. These results are quite different from those found by Symons, Prooks and Gay (1994) for the UK, those of Labandeira and Labeaga (1999) for Spain, and those of Tiezzi (2005) for Italy.

Scott and Eakins (2004) measured the effects of the carbon tax of €20/tCO_2 on households in different income brackets and how the tax revenue might be used to compensate households, focusing mainly on low income household groups. The results indicated that the average household would pay €246 extra per year because of the higher prices of fuels caused by the carbon tax, but there would be variation depending on the deciles. This study analysed how the revenue returned to households in the forms of reducing indirect and direct taxes, and lump-sum transfer would impact on households. The results concluded that the Value-Added Tax (VAT) reduction does not offset the carbon tax paid by low-income households, however rich households are better off by this compensation. The reason is that rich households spend more on standard VAT rated goods, thus attract more benefits, by contrast, to poor income households who spend more on items rated zero tax. Scott and Eakins (2004) simulated the revenue recycling under a lump-sum transfer. Each household would receive a lump-sum transfer of €246 per year (equivalent to the carbon paid by the average household). This compensation is generous to low-income households as households in deciles 1 to 5 receive more benefits from the compensation than the cost caused by the carbon tax. Therefore, low-income households would be better off, making the carbon tax progressive. Whether one is a loser or gainer depends not so much on socio-economic factors, but more on geographical location and on the type of fuel used.

The degree of regressivity associated with a carbon tax depends on which measurement is used to gauge the effect of the carbon tax. Carbon taxes measured by annual income tend to be more regressive than those measured by lifetime income or current consumption (Grainger & Kolstad, 2010; Hassett, Mathur, & Metcalf, 2007). Hassett et al. (2007) compared the household burden of a $15/tCO_2$ in three different years 1987, 1997 and 2003 using household ranked by current income, current consumption and lifetime consumption as the basis for the incidence measures. When households are ranked by annual income, the carbon tax is regressive but the overall burden declines slightly from 1.54 per cent of income in 1987 to 1.3 per cent by 2003. The carbon tax is less regressive or even progressive as the incidence is measured by current consumption or lifetime consumption. Grainger and Kolstad (2010) concluded that when a carbon price of $15/tCO_2$ is imposed, an average household in the lowest income quintile would pay around $325 per year, while an average household in the richest quintile would pay $1140 annually. However the poorest quintile's burden as measured by a share of annual income is 3.2 times that of the wealthiest quintile. However, if it is measured by a share of annual expenditure, this is 1.4 times. Hence the carbon price measured on annual income is 2-3 times more regressive than on annual expenditure.

Callan et al. (2009) examined the effects of a carbon tax on income distribution in Ireland. In order to meet the emissions reduction target, the study simulated a carbon price of €20/tCO_2. The authors used the Irish Household Budget Survey 2005 and Input-Output tables to separately analyse the direct and indirect effects of carbon taxation on household income. The results show that the direct effects of the tax is estimated to range between €3 and €4 per week per household while the indirect impact is estimated to range between €0.5 and €1.5 per week per household. The study concluded that the impact of a carbon tax is considerably regressive, because the average tax payment is an estimated 2.1 per cent of disposable income for the poorest decile and 0.3 per cent for the richest decile. In order to alleviate the negative effect of a carbon tax on households, the study used the SWITCH model to simulate the three alternative revenue recycling options with the compensation to the lowest income households. Particularly, the first scenario used a €2 increase per week for all welfare payments, the second scenario used a €0.8 payment per week for each child of social welfare recipients and the third scenario used a €2 increase per week for all social welfare payments and adds a decrease in half a percentage point of income tax rate for the lowest income group. The results illustrated that the second scenario is preferable.

Williams et al. (2014) linked a dynamic overlapping generation model to a microsimulation model to assess the distributional and welfare effects of the carbon tax across household income groups. The study compared the effects of three policy approaches regarding use of revenue raised from a carbon tax. It concluded that recycling revenue to reduce the capital income tax caused the economy the least cost on, but it is a regressive approach in which only the highest income quintile benefits. Meanwhile, returning revenue in an equal lump sum to households results in costs that are about three times as much as capital tax recycling, but it is a progressive approach that benefits a majority of households and leads to a reduction in inequality. Using revenue to reduce a labour tax is a clear middle-of-the-road option, even though it is less efficient than recycling revenue to cut capital taxes, because it offsets some of the natural regressivity of a carbon tax. Thus, depending on the purpose of the policy maker, the compensation with the desired outcome and the associated suitable carbon tax will be chosen.

2.3.2 Studies on an emissions trading scheme

The significant decision in designing an emissions trading program is how to allocate allowances. A government can give allowances away freely to emitters, or sell allowances through auctions. Similar to a carbon tax, auctions raise revenue and the government can then use this revenue to compensate affected households and industries. The distributional and welfare effects of an ETS depend on how the emissions permits are distributed and how the revenue is recycled to the vulnerable populations. In practice, an ETS has been implemented in the US and the EU, as well as proposed in some countries, such as Australia, Canada and China.

2.3.2.1 Australian studies

Adams (2007) evaluated the possible costs of an ETS for Australia by applying a CGE model interacted between the Monash Multi-Regional Forecasting (MMRF) model and the McLennan, Magasanik and Associates (MMA) model. The ETS excluded emissions from non-combustion sources in agriculture, industrial processes and waste management. Electricity generators using fossil fuels received a free allocation of permits to compensate for losses in profit and trade-exposed emissions intensive industries are compensated for 100 per cent of increased energy costs. Limited banking of permits was allowed. The permit price would rise from A$18.30/ t$CO_2$-e in 2010 to A$50.20/ tCO_2-e in 2030 in order to achieve the total emissions in 2030 decline of 21.1 per cent (equivalent to 169.6 Mt of CO_2-e). The ETS resulted in a reduction in real GDP of 1.3 per cent relative to its baseline value in 2030, equivalent to about A$21.5 billion a year in terms of current dollar values. It also induced a decline in real consumption by 1.4 per cent relative to its baseline value in 2030.

The change in real consumption reflects the change in real income from traditional sources (wages and capital) and disbursements from the ETS. Real income from wages and capital after income tax is reduced by 2.4 per cent (equivalent to A$27.1 billion). Unless auction revenue is returned to households or distributed to generators, the loss of real consumption would be higher. Employment is estimated to reduce by about 0.6 per cent relative to the baseline level that caused the real wage decrease; this created incentives for producers to substitute labour for capital. Consequently, employment would recover to baseline levels over time. The ETS significantly raises output of electricity-renewable industries, but reduces output of electricity-coal industry by 30.5 per cent, electricity supply by 12.3 per cent and air transport services by 6.8 per cent.

Buddelmeyer et al. (2012) linked a dynamic CGE model, the MMRF-Green model to a Microsimulation (MS) model, and the Melbourne Institute Tax and Transfer Simulator (MITTS) to assess the impact of climate change mitigation policy on income and inequality in Australia for the period from 2005 to 2030 at five-yearly intervals. A reweighting procedure was used to transmit employment changes from the CGE model to the MS model. The results estimated from the CGE model were used as exogenous and given inputs for the MS model to produce estimated effects on income distribution. An ETS was assumed to be implemented in 2013 which aimed to achieve an emissions target of 80 per cent below the 2000 level by 2050 (scenario 1) and of 90 per cent below 2000 level by 2050 (scenario 2). The results indicated that income growth will slow down between 2010 and 2015, but accelerates after 2015. Gross incomes grow at a faster rate than the CPI and the share of benefit payment in the household income declines over time, which results in an increase in inequality. The returned permit revenue had a positive impact on the lower income quintile but a negative impact on the higher income quintile. The reason is that, given their income sources, the low income quintile suffer less than the other quintiles from slower factor income growth caused by the introduction of the ETS while they benefit more from the increasing lump sum transfer. Therefore, the lump-sum transfer plays an important role in reducing inequality.

Adams, Parmenter and Verikios (2014) applied the CGE model to evaluate the effects of an ETS on the Australian economy through national and regional impact levels. The scheme they modelled started in 2011 as a domestic scheme but allows permits to be purchased from a pre-existing arrangement, such as the Clean Development Mechanism. All emissions, other than those from agriculture and transport, were included in the scheme in the first year. Transport emissions were included from 2012, and agricultural emissions were included from 2015. From 2020 onwards, Australia's scheme was envisaged as fully integrated into the global scheme. Limited free allocation of permits was given to electricity generators, and energy intensive trade exposed industries were compensated until 2020 in order to shield them from the impact of the permit prices. Remaining permits, beyond those compensated to electricity generators and trade exposed energy sectors, were assumed to be auctioned with surplus revenue recycled as lump sum payments to households. In this analysis, the MMRF model that is linked with both the GTEM model and the Frontier's energy model (named WHIRLYGIG) was used to evaluate the effects of the ETS on the Australian economy.

The effects of the ETS were measured by percentage changes from baseline values. The results showed that the the ETS induced real GDP reduction by 1.1 per cent. Some regions, such as Tasmania and the Northern Territory, would be better off, but Queensland (with coal mining and coal based electricity generation) would be worse off. Real household consumption was estimated to decline by 1.5 per cent relative to its baseline and employment was reduced by about 0.1 per cent. Some industries were favourably affected by the emissions trading scheme, notably forestry, electricity generation by gas and renewable sources. The shielding of the Emission Intensive Trade-Exposed Sectors (EITES) prevents these industries from contraction and they are favoured in the case of depreciation in the real exchange rate. Coal production was estimated to fall by 12.8 per cent relative to its baseline level. The reason is that there is rapid uptake of clean coal technologies for electricity generation. It seems that global emissions trading resulted in more positive effects on the Australian economy than just domestic emissions trading. In the global emissions market, Australia can purchase permits from overseas. About 160 Mt of permits were projected to be imported in 2030, with the permit price of A$50 per tonne, the annual financial costs of purchasing permits reaches A$8 billion. This financing cost represents a reduction in domestic welfare in the form of a transfer to foreigners.

2.3.2.2 Studies in other countries

The Congressional Budget Office (2000) studied the distributional effects of the emissions trading scheme designed to achieve emissions reduction of 15 per cent on households with different income quintiles by applying a partial equilibrium model. The distributional effects would vary depending on how the allowances were distributed and how the US government uses the revenue to compensate. It was assumed that the price of all goods would rise in proportion to carbon emissions generated by the fossil fuels used in their production and the costs caused by the emissions caps that were passed fully onto final consumers. The results illustrated that the price changes caused by the emissions caps would cost the average household in the lowest income quintile US$560 per year, or 3.3 per cent of its average income. Households in other quintiles would face higher costs in dollar terms but a smaller fraction of their average annual income; this share was 1.7 per cent in the case of the highest income quintile. The Congressional Budget Office compared the distributional effects of four scenarios of allowance-allocation and revenue-recycling. It concluded that the policy was most regressive in the case of the free distribution and corporate tax cuts, but it was progressive in the allowance auction with a lump-sum rebate to all households.

If allowances were traded in the international market instead of just in the domestic market, the allowance price was estimated to be lower than US$40, because of the lower allowance price, international trading of carbon allowances would lower the total cost imposed on US households. Households that would experience a loss in real income under domestic trading would be relatively better off under international trading. For example, in the free distribution and corporate tax cut, the after-tax income of the average household in the lowest quintile would be US$200 higher with international trading than with domestic trading alone.

Burtraw et al. (2001) examined the costs-effectiveness and distributional effects of three approaches for allocating emissions allowances under an emissions trading program in the electricity sector. These three approaches included grandfathering (GF), auction (AU), and generation performance standard (GPS). The authors compared the effects of these three alternative approaches to achieve the emissions reduction of 35 million metric tonnes of carbon (mtC) emissions, equivalent to 6 per cent reduction from the baseline with the assumption of no banking of allowances. The auction approach was considered as a more cost-effective option with one-half of the economic cost of the other two. The allowance price was quite different in these three alternative approaches, in particular US$25 per mtC under the AU, US$ 38 per mtC under GF, and US$40 per mtC under the GSP. The various allowance prices in the three approaches resulted in distinguishable effects of each approach to the energy price. For example, the AU led to the highest electricity price and lowest natural gas price. By contrast, the GPS created the lowest electricity price and highest natural gas price. The GF was an intermediate case in both measures. Because of the ability to pass the compliance cost from producers to consumers, consumers bear the highest cost under the AU, with the decline in consumer surplus of US$14 billion. Producers, however, benefit the most under the GF with a substantial increase of US$4.9 billion, compared to a decrease in a producer surplus of US$1.7 billion and of US$1.6 billion under the AU and GPS, respectively.

Cramton and Kerr (2002) argued that while grandfathering is inefficient, because it provides greater political control over the distributional effects of regulation; therefore auctioning is preferable. The authors suggested that if the permit price is US$100 per metric tonne, the auction could raise US$125 billion annually, which is about 10 per cent of federal receipts and around 2 per cent GNP. However if permits are grandfathered, this 2 per cent is given away. Moreover, auctioning allows the reduction of distortionary taxes, provides greater incentive for innovation, provides more flexibility in the distribution of costs, and reduces the need for politically contentious arguments over the allocation of rents. The revenue raised from auctions could be used to cut labour, capital, payroll and consumption taxes, or reduce deficits that would create efficiency gains. If the revenue of US$125 billion is used for tax cuts, the GNP could increase by up to US$40 billion relative to under a grandfathered system. In contrast, grandfathering of permits do not raise revenue, the government just grant permits to the companies or firms, it yields no benefits for employees of these firms, or to the consumer prices. Furthermore, grandfathering permits yields benefits to stakeholders or wealthy people. Meanwhile, poor people who tend to be employees and consumers are unlikely to benefit from grandfathering.

Parry (2002) preferred auctioned permits to grandfathered permits in terms of both economic efficiency and distributional effects. Auctioned permits are more economically efficiency because the revenue is returned to cut other distortionary taxes and thus society is better off. Parry (2002) stated that for each dollar of revenue used to reduce income tax there will be a gain in economic efficiency of between US$0.20 and US$0.50. Moreover, the economic costs under grandfathered permits is higher than auctioned permits; in particular, without fiscal interactions, the grandfathering scheme would produce estimated environmental benefits of US$20 billion in excess of costs but, with fiscal interactions, the environmental benefits would be around US$10 billion less than the costs. However, an auctioned permit policy results in a net benefit of US$10 to US$35 billion. In terms of distributional effects, grandfathered permits create benefits for shareholders who are most likely the wealthy. The top income quintile owns about 60 per cent of stock, the number of the bottom income quintile is less than 2 per cent. If permits were grandfathered to meet the US' original carbon pledge under the Kyoto agreement, more than $50 billion would be transferred each year in pre-tax income to the top quintile. It means that the policy is more regressive under the grandfathered permits.

Dinan and Rogers (2002) examined the distributional effects of a carbon allowance policy designed to achieve an emissions reduction of 15 per cent from a business-as-usual baseline. The allowances were allocated by giving away and auctioning, and the revenue was distributed through decreasing corporate tax, reducing payroll tax, and providing a lump-sum rebate to households. The research was analysed in the domestic trading level and the international trading level by applying a partial equilibrium model. The allowance price was estimated at US$100 in the emissions domestic market and US$60 in the emissions international market.

In the case of domestic emissions trading, the results illustrated that the policy effects appeared less progressive in the case of the auction/lump-sum rebate and more regressive in other cases when the consumption-to-income ratios were calculated from expenditure data. Regardless of whether consumption-to-income ratios were based on expenditure data or wealth data, households in the lowest income quintile would suffer the largest share of the policy costs if the government distributed allowances freely. However, in the case of auctioning, the average household income in the lowest quintile would increase, especially their receipts would be greater than their payments for increased costs that were caused by the increased price policy in the form of the lump-sum rebate policy. However, the highest income quintile would gain more benefits when the government decreased the corporate tax than when it decreased payroll tax, but they would experience the largest loss in the case of a lump-sum rebate.

In the case of international emissions trading, the results were obtained from expenditure data. Because of the lower allowance price, total costs per household were lower than under domestic trading, thus households were better off under international emissions trading. Even households who experience losses under domestic emissions trading were placed in a better circumstance by international emissions trading. By contrast, in the case of auction/lump-sum rebate, low-income households who received benefits under the domestic trading were made worse off by international trading. The limitation of this research is that it did not account for the effects of emissions prices on the relative returns to labour and capital and, because it is a static analysis, it does not account for the change in capital accumulation, invention and diffusion of technology.

Parry (2004) used an analytical model with lifetime income proxied by consumption to examine the distributional effects of different environmental policies. Grandfathered permits were compared to other environmental policies to control power plant emissions of CO_2, SO_2 and NO_x. The households were divided into quintiles according to household consumption. The study found that grandfathered permits are highly regressive for all pollutants for emissions reductions, with the top quintile better and the bottom income quintile much worse off, except in the case of the implementation of an input tax. The burden imposed on low-income households is lower under other policies than under grandfathered permits because the government has no revenue to alleviate the regressive effects of the price rise. Moreover, the social costs of grandfathered permits can be substantially increased because society has an aversion to inequality. However, if the revenues raised from an emissions tax or auctions are recycled proportionally to households, the policy is apparently much less regressive. In addition, if the revenues are recycled in a progressive manner, as in equal lump-sum transfer, the policy becomes progressive in the case of CO_2 and NO_x.

Burtraw et al. (2009) evaluated the effects of an emissions trading system in the US, with a price of US$20.91 per tonne of carbon (equivalent to 18.1 per cent of emissions reduction from business-as-usual emissions) on household groups by 11 regions. The authors measured the incidence on households according to their consumer surplus loss and the Suite Index that is calculated by plotting the relationship between cumulative tax paid and cumulative income earned. The results illustrated that, when comparing between tax dividends and untaxed dividends, the latter tends to lead to slightly more equal distribution of the net burden across income household groups than the former. The reason for this result is that there are differences in the marginal tax rates across income groups. Both cap-and-dividend options are progressive and the taxable dividends are more progressive. However, when compared with the policy of expanding the Earned Income Tax Credit (EITC), the EITC policy is likely to have stronger progressivity, in which the households in the lowest income decile obtain the higher net gain while households in the highest income decile experience an increased net loss. For the alternative ways of reducing income tax and payroll tax, households in the higher income deciles would prefer these two approaches because they experience the net gain of returning revenues, while the lowest income households experience the net cost. The Suite Index results show that these two options are strongly regressive.

Rausch, Metcalf and Reilly (2011) applied a general equilibrium model with a detailed disaggregation of 15,588 households as individual agents to explore the distributional and welfare impacts of the cap and trade system with fully auctioned permits. The authors compared the impact of three scenarios of using revenue returned to households by both annual and lifetime income measures and regional analysis using annual income. With a permit price of US$20/t$CO_2$-e and welfare impact as measured by the Equivalent Variation defined as a percentage of the household income, the results indicated that the revenue returned to lower personal income tax induced the lowest average cost of 0.18 per cent of household income; about half of revenue recycling to households in proportion to their capital income. Welfare costs are the highest at 0.46 per cent if the revenue is recycled on a per capita basis. The results also showed that there was a trade-off between efficiency and equity when the policy of compensation for lower income personal tax is most regressive, and per capita household rebate is progressive. Differing from previous studies, this study concluded that there is a bias of carbon pricing towards greater regressivity when households were ranked by lifetime income and annual income.

Beznoska, Cludius and Steiner (2012) examined the distributional and welfare effects of the EU ETS, which was designed to achieve a 20 per cent emissions reduction below the 1990 level by 2020. The emissions price was assumed to be €25 per permit. The effects on the prices of goods were classified for cases with and without accounting for behavioural responses of consumers to price changes caused by the EU ETS. In the former, the EU ETS resulted in an increase of 14 per cent in the cost of electricity and on average, German households would face an additional cost of €16 per month. In the latter case, household expenditure would be reduced by about 6 per cent and the tax burden would be reduced by 2.7 per cent as compared to the former. In both cases the effects were regressive. If auction revenue was used to provide a lump-sum rebate and reduce social security contributions, the results indicated that the effects would be progressive in the former and remained regressive in the latter. However, the revenue recycling in the form of lower social security contributions had a better positive impact on inequality than any other form. Thus, there is a trade-off between efficiency and equity in the two forms of the revenue recycling.

2.4 Conclusion

The literature has highlighted that a market-based instrument can reach the emissions reduction target at a lower cost. However, it is debatable which market-based instrument, a carbon tax or an emissions trading scheme, is a better climate policy option. For a carbon tax, a government imposes a fixed carbon price and lets the market determine the carbon emissions reduction. By contrast, under an ETS, the quantity of emissions reduction is fixed by the government and the emissions price is determined by the market. Thus a carbon tax would provide certainty about the marginal cost of compliance but uncertainty about the emissions reduction in the economy. Meanwhile, an emissions trading scheme would provide an emissions reduction quantity, but uncertainty about the cost of emissions abatement. Some economists favour a carbon tax to reduce carbon emissions because of the certain marginal abatement costs, but some other economists favour an ETS because it produces a fixed level of carbon emissions.

The major concern that attracted the attention of economists is the distributional and welfare effects of a carbon tax and an ETS. The question is who bears the burden resulting from an environmental policy and who receives the benefits. Most previous studies agree that who carries the burden depends on how the producers and consumers react to the emissions price and how a government allocates emissions or permits/allowances, as well as how a government uses the revenue raised from a carbon tax and auction to compensate the affected parties. Producers initially bear the cost caused by a carbon emissions price, but consumers ultimately pay this cost because producers tend to pass forward this cost to consumers in the form of highly priced carbon-intensive products, or pass it back to investors and employers in the form of lower returns on production factors. Thus consumers, investors and employers may experience a welfare loss. Low-income households tend to bear higher costs than high-income households. So both the carbon tax and an ETS is apparently regressive.

Economists indicate that using revenue raised by a carbon tax or an ETS is an optimal choice to reduce the level of regressivity. The question is how to distribute the revenues to the affected population. The revenue can be returned by providing a lump-sum transfer or reducing pre-existing distortionary taxes such as income tax, payroll tax, labour tax, and capital tax. There is a trade-off between efficiency and equity in the revenue recycling. The literature concludes generally that a lump-sum transfer can reduce the regressive level, but will require a higher cost, meanwhile reducing distortionary taxes will cost less than a lump-sum transfer but is likely to induce inequality.

In Australia, the carbon tax has been implemented for two years, from 2012 to 2014, there are numerous studies on the carbon tax and the distributional and welfare effects of the carbon tax. For an ETS, there are some studies that applied the MMRF model linked with the MMA model, or the MS model, to investigate the effects of an ETS. This thesis aims to provide an empirical study on the distributional and welfare effects of an ETS, in particular in the domestic ETS among industries in the Australian economy, by applying a CGE model.

CHAPTER 3: THE AUSTRALIAN CARBON POLICIES AND COMPENSATION PACKAGES

At the Copenhagen Conference on climate change in 2009, the Australian Government committed to reducing CO_2 emissions by at least five per cent below the 2000 levels by 2020 (Parliament House, 2009). In order to achieve this target, the Australian Government implemented, and is continuing to implement, policies on emissions reduction in recent years. This chapter describes Australian carbon policies and compensation packages. The chapter is organised as follows: section 3.1 presents the Australian policies on carbon emissions reduction; section 3.2 outlines compensation packages proposed or implemented to mitigate the unexpected effects of emissions reduction policies; and conclusion is presented in section 3.3.

3.1 The Australian policies on carbon emissions reduction.

Climate change has become a global issue and has attracted the concern of countries throughout the world. By contributing around 1.3 per cent of total global emissions and as the fifteenth largest emitter of greenhouse gases in the world, Australia has a relatively emissions-intensive economy and high per capita emissions (Department of the Environment, 2013b, p. 9). How to reduce carbon emissions has become a political debate between the Labor Party and The Coalition. Importantly, the proposed solutions to emissions reduction promoted by the two major political parties partially contribute to success in each federal election. Australian Governments, in recent years, have implemented emissions reduction measures in order to meet international emissions reduction targets. These policies will be presented in detail in the following sections.

3.1.1 Renewable energy target

Australia has considerable natural resources. Electricity is mainly produced by coal-fired plants and, therefore the emissions generated from the electricity sector are the major contributing factor to total Australian emissions. Emissions reduction from the electricity sector, through shifting electricity produced from fossil fuels to electricity produced from renewable energy sources, is the key potential source for the reduction of CO_2 emissions in Australia. To do this, the Howard Government introduced a Mandatory Renewable Energy Target (MRET) in the electricity sector in 2001 with the purpose of increasing the electricity produced by renewable sources. The initial target of the RET was an increase in renewable electricity by 9,500 GWh in 2010. This target was expanded in 2009 to reach 45,000GWh by 2020 (SKM, 2012, p. 9).

Since 2011, the RET scheme has operated in two parts: the Small-scale Renewable Energy Scheme (SRES) and the Large-scale Renewable Energy Target (LRET).

The LRET creates a financial incentive for the expansion of renewable energy power stations, such as wind and solar farms or hydro-electric power stations, by legislating demand for Large-scale Generation Certificates (LGCs). One certificate equals one megawatt-hour of eligible electricity produced by an accredited renewable power station. The LGCs can be sold to an entity (mainly electricity retailers) and then the compliance with the RET scheme's annual target is provided to the Clean Energy Regulator. That is an incentive for electricity producers to increase the amount of electricity produced by renewable sources. The LRET has a target of 41,000 GWh by 2020 (SKM, 2012, p. 4).

The SRES creates a financial incentive for households, small businesses and community groups to install eligible small-scale renewable energy systems, such as solar water heaters, heat pumps, small scale wind systems and hydro systems. It does this by legislating demand for small-scale Technology Certificates (STCs). According to the amount of electricity that is expected to be produced or displaced in the future, STCs are created for these systems at the time of installation. STCs are sold by the RET liable entities and are surrendered to the Clean Energy Regulator on a quarterly basis. The target is to produce 4,000 GWh by the year 2020.

The major objective of the RET is to reduce greenhouse gas emissions from the electricity sector by encouraging the production of electricity from renewable sources. In 2012 as required by the Clean Energy Council, Sinclair Knight Merz (SKM) provided a report titled *"Benefit of the Renewable Energy Target to Australia's Energy Markets and Economy"* and concluded that between 2001-2012, with an investment of A$18.5 billion in renewable energy infrastructure, the RET has contributed to the emissions reduction of around 22.5 Mt CO_2 over the last ten years. This report also concluded that without the RET, Australia would not have met its emissions reduction target under the Kyoto emissions reduction commitment. Moreover, the RET was estimated to have decreased wholesale prices by up to A$10/MWh (SKM, 2012, p. 1).

At the beginning of the RET scheme in 2001, electricity generated from renewable energy sources accounted for around 9 per cent of the total electricity generated and this proportion had increased to 10.9 per cent in 2011. Hydro-electricity generation is a key source of renewable energy generation, with 66 per cent of the total renewable energy generation in 2011, followed by wind generation at 21 per cent, biomass at 7 per cent and solar at 5 per cent (SKM, 2012, pp. 25-26). Australia's renewable electricity capacity has increased nearly twice from 10,650 megawatts (MW) in 2001 to around 19,700 MW in 2012.[4] The purpose of the RET is that renewable energy generation will account for at least 20 per cent of the total electricity generated by 2020.

3.1.2 Carbon Pollution Reduction Scheme

The Howard Government signed the *Kyoto Protocol* in 1998 but refused to ratify it in 2002 with the argument that the agreement would be a threat to the nation's economic interests and it would disadvantage Australian corporations (Firsova, Strezov, & Taplin, 2012). Therefore, most of the climate policy-making decisions under the Howard Government seem to be the same as that of previous governments, reflecting the 'no-regrets' approach (Firsova et al., 2012). However, carbon trading has been a global phenomenon since the late 1990s (Pearse, 2014) and the impact of climate change had become more visible and obvious in Australia and internationally by the late stages of the Howard Government (see IPCC, 2007). Thus, the Howard Government established a Task Group on emissions trading and announced its commitment to establish a national trading scheme in Australia by 2011.

Different from the previous Coalition Government, the Australian Labor Party and its leader, Kevin Rudd, supported ratification of the *Kyoto Protocol* and proposed a price on carbon through an emissions trading scheme in the successful election campaign of 2007. The Prime Minister, Kevin Rudd, described climate change as 'the greatest moral, economic and social challenge in our time'. After winning the election in 2007, Prime Minister Rudd implemented his promise by ratifying the *Kyoto Protocol* in December 2007, as well as by introducing a climate change policy called the Carbon Pollution Reduction Scheme (CPRS). The Department of Climate Change (2008a) reported that the CPRS was considered the Australian emissions trading scheme and was scheduled to be implemented in mid-2010. The objective of the CPRS was to meet Australia's emissions reduction target in a most flexible and cost-effective way, to support an effective global response to climate change, and to provide for transitional assistance for the most affected households and firms. According to the CPRS Green Paper (Department of Climate Change, 2008a) and the CPRS White Paper (Department of Climate Change, 2008b), the CPRS is:

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[4] Source is collected from the website http://www.climatechangeauthority.gov.au/chapter-2-performance-renewable-energy-target

+ Coverage

- The CPRS covered all sectors except agriculture that would be covered by 2015 with a final decision on inclusion or exclusion to be made in 2013.
- All greenhouse gas emissions counted under the Kyoto Protocol were covered by the CPRS.
- The CPRS covered approximately 75 per cent of all Australian greenhouse gas emissions.
- About 1,000 Australian corporations whose capacity generated from 25,000 tonne of CO_2-e per year covered by the CPRS.

+ Emissions targets and scheme caps

- The Australian Government released its White Paper CPRS on 15 December 2008. It was intended to take effect from 1 July 2010 (Australian Industry Group, 2008). The CPRS White Paper provided Australia's medium terms of emissions reduction by 2020 of between 5 to 15 per cent below 2000 levels,[5] and long-term emissions reduction target of 60 per cent below 2000 levels by 2050.
- The CPRS cap would be set and announced for a minimum period of five years in advance. The cap issued is equivalent to the number of permits, and each permit presents one tonne of CO_2-e. The majority of permits were to be auctioned, some permits to be freely distributed, and over the long term 100 per cent of permits issued were to be auctioned.

+ A safety valve, banking and borrowing

- A cap on the price of carbon was set for the first five years of the scheme, A$40 per tonne at the scheme's commencement, rising at five per cent in real terms per year.
- The CPRS included a safety valve, allowing liable entities to purchase permits for a fixed price.
- The CPRS allows pollution permits unlimited banking and limited borrowing of permits that contribute to the reduced price volatility and a more flexible supply of carbon pollution permits.

[5] Australian Government committed to an unconditional 5 percent in emissions reduction below 2000 levels by 2020, and up to 15 percent in emissions reduction below 2000 by 2020 with a condition that major economies agree to substantially restrain carbon pollution and advanced economies take on reduction comparable to Australia.

+ International linking

- The Australian Government allowed the CPRS to be linked with the international carbon market, in which emitters can purchase carbon pollution permits at a lower price to meet their emissions compliance in the scheme.
- International units that would be accepted include Certified Emissions Reductions (CERs), Emissions Reduction Units (EURs), and Removal Units (RMUs).
- The final decision on whether to allow export permits through the *Kyoto Protocol*'s joint implementation mechanism was to be made in 2013.

The *CPRS Bill* was introduced to the Parliament on 14 May 2009, but after twice being refused in the Senate, Prime Minister Kevin Rudd announced, on 27 April 2010, that the implementation of the CPRS would be delayed. Bailey et al. (2012) provided two reasons for Australia's troubled engagement with climate change: the first is that Australia depends on fossil fuels and, mainly, on coal for domestic electricity generation; and the second is the shortcomings in the political strategies used by the Rudd Government to overcome political resistance to the CPRS. This scheme was considered to be a comprehensive emissions trading scheme and a more ambitious scheme than the EU ETS (Maraseni, Maroulis, & Cockfield, 2009). The CPRS was criticised because it was not designed to significantly affect carbon reduction and it was too ambitious for Australia because of the expected negative impact on the economy and other factors (Firsova et al., 2012). The CPRS was abandoned with the replacement of Prime Minister Kevin Rudd by Prime Minister Julia Gillard and replaced by a carbon pricing policy to be implemented from 2012.

3.1.3 Clean Energy Future Package

Julia Gillard replaced Kevin Rudd as the Labor Prime Minster in 2010. Her Government introduced the Clean Energy Future Package and its centerpiece was a carbon pricing mechanism with a fixed carbon price for the first three years, from 1 July 2012 to 1 July 2015, and then switching to an ETS from 2015. This scheme was different to her predecessor's. To avoid political damage, Prime Minster Gillard and the Labor Party established a multi-party climate change committee and built a cross-party consensus-building strategy. Thus, with the support of the Greens and three independents, the Clean Energy Future Package was passed in both the House of Representative and the Senate on 8 November 2011.

There were three legislative pillars in the Package, including the *Clean Energy Act*, which established a carbon pricing mechanism, the Clean Energy Regulator, which set up a body to administer the carbon pricing mechanism, renewable energy policies, the Carbon Farming Initiative, and the Climate Change Authority, which would monitor and review the progress of the Package and provide periodic recommendations to Parliament (Patay & Sartor, 2012). The objective of the Clean Energy Future Package was to reduce the total Australian GHG emissions by at least five per cent below 2000 levels by 2020, and up to 15 or 25 per cent, depending on the scale of global action, and its long term target was to reduce by 80 per cent below 2000 levels by 2050. The Parliament of Australia (2011) provided in detail, in the *Clean Energy Future Plan*, that its core plan was the carbon pricing mechanism, as follows:

+ Carbon price

There were two stages to the carbon pricing mechanism, including:

- Fixed price: The carbon price was fixed for the first three years from 1 July 2012 to 30 June 2015 with the price of A$23/t$CO_2$-e in the first year, then increased at 2.5 per cent annually in real terms. The carbon price was A$24.15/t$CO_2$-e in 2013-2014 and A$25.40/tCO_2-e in 2014-2015 (The Parliament of Australia, 2011, pp. 130-131).
- Flexible price: From 1 July 2015, the price of carbon emissions would shift and be flexible as set by the market. The Australian Government would still control the price through the use of a price floor and price ceiling. The price floor would start at A$15/t$CO_2$-e, and then increases by 4 per cent in real terms per year, while the price ceiling was set at A$20 above the expected international price, and then increased by 5 per cent in real terms per year (Australian Government, 2012).

+ Coverage

Coverage refers to entities and emissions subject to the carbon price.

o ***Emissions***

Emissions covered by the Scheme included:

+ The combustion of energy sources

+ Fugitive emissions

+ Industrial processes

+ Waste emissions

The scheme did not include the following emissions:

+ Emissions attributable to the combustion of liquid petroleum fuel, liquid petroleum gas, liquefied natural gas, and compressed natural gas

+ Emissions attributable to the combustion of biomass, biofuel, biogas

+ Agricultural emissions

+ Fugitive emissions from decommissioned underground mines

+ Emissions from legacy waste

+ Emissions from closed landfill facilities

+ Emissions from certain synthetic greenhouse gases

Overall, the scheme covered an estimated 60 per cent of Australia's GHG emissions.

○ ***Liable entities***

The scheme covers the following entities:

+ Entities whose facilities release 25,000 tonnes or more of carbon emissions per year

+ Entities whose landfill facility emits 25,000 tonnes or more of carbon emission annually

+ Natural gas suppliers.

○ ***Sectors***

The mechanism covered the following sectors: the stationary energy sector, transport, industrial processes, non-legacy waste, and fugitive emissions.

Some sectors were excluded from the carbon price, including household transport fuels, light vehicle business transport, and off-road fuel used by agriculture, forestry and fishing industries.

An effective carbon price applied to domestic aviation, domestic shipping, rail transport, and non-transport use of fuels. Users of these fuels could opt-in to the mechanism under the Opt-in Scheme.

+ International linking

Liable entities were allowed to purchase emissions permits from the international carbon market or other emissions trading schemes, but at least half of the liability of the entity's carbon price obligation must be met through the use of domestic carbon units (The Parliament of Australia, 2011).

+ Governance

Governance requires the allocation of responsibility for particular roles that will need to be performed in relation to the operation of the scheme. Governance includes:

- ***Clean Energy Regulator***
  - The Clean Energy Regulator was the statutory authority responsible for administering the carbon pricing mechanism, the existing regulatory functions for the National Greenhouse and Energy Reporting Scheme, the Renewable Energy Target and the Carbon Farming Initiative.
  - The key responsibilities of the Clean Energy Regulator included: educating businesses on the administrative arrangements of the carbon pricing mechanism; assessing emissions data to determine each party's liability; publishing a database of liable or potentially liable entities; allocating carbon units; and monitoring and enforcing compliance with the carbon pricing mechanism.
- ***Climate Change Authority***
  - The Climate Change Authority was an independent statutory body which provided the Government with expert advice on key aspects of the carbon pricing mechanism, such as pollution caps, tracking emissions pollution levels, determining steps towards meeting targets and undertaking reviews of the carbon pricing mechanism. The first review on the operation of the carbon price was to be published by the end of 2016.
  - The Authority was also to undertake reviews of other major abatement measures, the first one was on the performance of the Renewable Energy Target in the second half of 2012.
- ***Productivity Commission Reviews***
  - The Productivity Commission was to undertake reviews relating to industry assistance such as the Job and Competitiveness Program and Coal Sector Job Package.
  - The Productivity Commission was to conduct reviews to ensure that the carbon pricing mechanism in Australia remained in line with the carbon pollution reduction activities of other nations.

From 1 July 2012, the carbon pricing policy has been implemented to address the serious environmental problem of climate change in Australia. However, in September 2013, the

Liberal-National Coalition and its leader, Prime Minister Tony Abbott, was elected and they implemented their promise to repeal the carbon tax and replaced it with the DAP. Abolishing the carbon tax was passed by both the House of Representatives and the Senate with effect from 1 July 2014. After two years of operation of the carbon tax, the carbon emissions reduction was 0.8 per cent for the first year, and 1.4 per cent in the second year (Milman, 2014).

3.1.4 Direct Action Plan

The Liberal and National Parties Coalition and Labor Parties agree on the same emissions reduction target of five per cent below 2000 levels by 2020, but they disagree on the mechanisms to reduce emissions. Under the Labor Party, polluters are charged for the amount of pollution they produce and the revenue raised from the carbon pricing policy is returned to the affected industries, households or individual to offset the increased costs caused by the carbon pricing policy. Under the Coalition, polluters will compete to win tenders for subsidies and be paid to undertake emissions reduction projects.

The Emissions Reduction Fund (ERF), a centerpiece of the DAP, was launched in 2010 with its aims to support 140 million tonnes of abatement per year by 2020 to meet the emissions reduction target of five per cent. To do that, the Coalition introduced a range of initiatives to boost renewable energy use in Australia, including funding for one million solar roof systems, the 20 million trees programs, and the solar towns and solar school initiatives. The ERF was designed to achieve lowest cost emissions reduction through providing incentives rather than penalties and rewarding positive actions rather than punishing Australian businesses and households (Coalition Government, 2010).

After winning the federal election in 2013, the Prime Minister, Tony Abbott, announced a repeal of the carbon price mechanism from 1 July 2014,[6] and replaced it with the DAP. The Emissions Reduction Fund Green Paper was released in December 2013 for public comment (Department of the Environment, 2013b) and in April 2014 the Emissions Reduction Fund White Paper was released (Australian Government, 2014). To meet the emissions reduction target by 2020, the ERF will provide incentives for businesses and communities to reduce emissions at the lowest available costs, without adding energy costs to businesses and households through the government's purchasing of emissions reduction. So, the ERF is a reverse auction to buy back the lowest cost abatement. To do that the Australian Government

[6] The carbon tax repeal legislation received the Royal Assent on 17 July 2014 and the Bills, as part of this package, are now law, with effect from 1 July 2014.

set out an initial commitment of A$1.55 billion in the green paper, then extended this commitment to A$2.55 billion in the 2014-2015 budget for the purchase of credited emissions reductions in the white paper.

The ERF has been built on the Carbon Farming Initiative by expanding its coverage beyond the land sector to enable the Clean Energy Regulator to credit emissions reduction from across the country (Department of the Environment, 2013b). There are three elements in the ERF: crediting emissions reductions, purchasing emissions reductions and safeguarding emissions reductions that are administered by the Clean Energy Regulators. Crediting emissions reductions involves determining the amount of emissions reductions by an emissions reduction project. To calculate real and additional emissions reductions, all projects need to estimate emissions reductions consistent with an approved method.

The emissions reduction methods are assessed, monitored and reviewed by the Emissions Reduction Assurance Committee, which replaces the Domestic Offsets Integrity Committee established under the Carbon Farming Initiatives. Moreover, to deliver real and additional emissions reduction, a proponent must estimate their emissions in the absence of the Emissions Reduction Fund or estimate their baseline emissions. The emissions baseline is set using data reported under the National Greenhouse and Energy Report scheme. The National Greenhouse and Energy Reporting Scheme provides credible, practical and well-established approaches to estimating emissions from different sources (Australian Government, 2014).

The emissions reduction projects that applied a relevant method and are assessed by an independent committee are submitted to the Clean Energy Regulator to auction. For each auction, the Clean Energy Regulator sets up a benchmark price in advance of the auction, which is the maximum amount it will pay for emissions reductions; this price differs with each auction. The bids with the lowest costs per tonne will be selected and the Clean Energy Regulator will establish a contract with the successful bidders and purchase their emissions reductions. Therefore, the Government will purchase the emissions reductions at the lowest available cost. After the auction, the Clean Energy Regulator will enter into contracts. For major projects, the Government will retain discretion to opt out of the contracts if these projects deliver emissions reductions over 250,000 tonne of CO_2-e per year on average. Payment is upon delivery of emissions reductions (Australian Government, 2014).

Providing incentives for emissions reduction through crediting and purchasing emissions reductions, the Emissions Reduction Fund also encourages businesses not to go above historical emissions levels through the safeguarding mechanism. While crediting and purchasing emissions reduction started after a repeal of the carbon tax, the safeguarding mechanism was started by the Emissions Reduction Fund on 1 July 2015. The coverage of the safeguarding mechanism is restricted to direct emissions of 100,000 tonnes of CO_2-e per year or more, this mechanism just covers around 52 per cent of Australia's emissions, covering a limited number of businesses of about 130.

To achieve the emissions reduction target, the Emissions Reduction Fund operates alongside existing programs that are already working to offset Australia's emissions growth, such as the Renewable Energy Target. The Renewable Energy Target has already been providing incentives for emissions reductions in the electricity sector by supporting the deployment of renewable energy technologies in order to achieve 20 per cent of supplied electricity sourced from renewable energy. In Australia, the electricity generation sector produces more than 35 per cent of the total emissions and is the single largest source of emissions by sector. The electricity sector also represents a key source of potential emissions reductions as it mainly relies on supplying electricity from less emissions intensive sources (Australian Government, 2014). The emissions reductions in the electricity sector will make the main contribution to Australia's emissions abatement.

With a significant contribution of the agricultural sector to Australia's emissions[7] as well as a significant potential to generate emissions reductions to 2020, the Carbon Farming Initiative legislation still continues to apply. The ERF still provides an ongoing market for Australian Carbon Credits and will purchase the credits from existing Carbon Farming Initiative projects that are successful at auctions. As established in 2011, the Clean Energy Regulator has registered more than 100 Carbon Farming Initiative projects and issued more than four million Australian Carbon Credit Units (Australian Government, 2014).

3.2 Compensation packages

The carbon pricing mechanism implemented by either a fixed carbon price or flexible carbon price results in extra costs for the production processes, thus leading to impacts on both producers and consumers. Producers are initially affected by the carbon pricing policy, then pass these extra costs forward to consumers through higher prices of commodities. They can

[7] The Government's White Paper released on 24 April 2014 noted that the electricity sector contributed the highest percentage, at 35 per cent, followed by Agriculture and land use, at 18 per cent. Stationary energy (excluding electricity) and Transport sectors, each generated 16 per cent, Fugitive emissions of 7 per cent and industrial processes of 6 per cent, waste of 2 per cent.

also pass them backward to investors by lower returns on investment or workers by lower wages. Therefore, the carbon pricing policy may create a burden on both producers and consumers. In order to reduce undesirable impacts caused by the carbon pricing policy, the government can use the revenue raised by a carbon tax or auctions to compensate vulnerable populations. This section presents financial packages that the Australian Government proposed when introduced the carbon pricing policy.

3.2.1 Compensation policies of the Carbon Pollution Reduction Scheme in 2008

The CPRS Green Paper indicated that all revenue raised from the CPRS would be used to assist households and businesses with adjustment to the scheme and used for investment in clean energy options. (Department of Climate Change, 2008a). The assistance to households and emissions-intensive, trade- exposed activities was presented in detail in the CPRS White Paper (Department of Climate Change, 2008b).

- **Assistance for households**

  The household assistance package was estimated to be A$6.0 billion in 2011-2012, including assistance for pensioners, seniors, carers, people with disabilities; self-funded retirees; recipients of allowance benefits; and low and middle income families. In particular:

  + Pensioners, seniors, carers and people with disabilities would receive around A$382 for a single and A$640 for a couple, meanwhile recipients of allowance benefits receive up to A$307 for a single and A$552 for a couple. Self-funded retirees also receive around A$382 for a single and A$640 for a couple.

  + Low and middle income families would receive one or a combination of:

  1. An increase A$390 in the low income tax offset.
  2. A 2.5 per cent increase in the maximum rate of the Family Tax Benefit Part A, the assistance provides A$124.10 per child aged 0-12 years, and A$156.95 per child aged 13-15 years.
  3. An increase in the base rate of the Family Tax Benefit Part A, the assistance is A$115 per child aged 0-17 years and A$140 per person aged 18-24 years.
  4. A 2.5 per cent increase in Family Tax Benefit Part B, where each family (child aged less than five years) receive A$98.55 and receive A$73 in the case of child aged over five years.

5. An increase of A$150 in the Dependency Tax Offsets.
6. A $500 transitional payment per adult for low-income households and others who can show they will not be assisted in accordance with the Government's commitments.

+ There were about 5.3 million households who would receive assistance equal to or greater than their living cost increase caused by the CPRS. In particular, around 89 per cent of low-income households (or 2.9 million households) would receive assistance, equivalent to 120 per cent or more of their increased cost of living and around 60 per cent of middle income households (or 2.4 million households) would receive sufficient assistance to meet the expected costs caused by the Scheme. Around 97 per cent of middle income households would receive direct cash assistance.

+ Motorists would be assisted through a cent for cent reduction in fuel tax for the first three years of the Scheme.

- **Assistance for emissions-intensive trade-exposed industries (EITEs)**

+ 25 per cent of the total carbon pollution permits issued (equivalent to around 35 per cent if agriculture were included in the Scheme) would be allocated free to the EITE industries at the commencement of the Scheme, and then will increase to around 45 per cent in 2020.

+ The Green Paper provided that 90 per cent free permits for those entities that had at least 2000 tCO_2-e per million dollars of revenue, and 60 per cent free permits for those entities that had at least 1500 tCO_2-e per million dollars of revenue. The White Paper extends the low level of assistance to activities that have at least 1000 tCO_2-e per million dollars of revenue.

+ The rate of assistance to EITE industries will decline over time at 1.3 per cent per year.

+ New entities conducting an existing EITE activity would receive the same assistance as existing entities. Allocation to existing entities conducting EITE activities would not be adjusted for allocations for new entrants.

- **Assistance for others**

+ Coal-fired electricity was considered as a strongly affected industry that is non trade exposed, emissions intensive, unable to pass on the costs of scheme compliance, experience significant losses in assets, significant sunk capital costs, and does not experience significant economically viable abatement opportunities. The most emissions-intensive coal-fired generators would be provided with a once for all fixed allocation of permits, amounting A$3.9 billion, based on an initial carbon price of A$25 per tonne. Assistance would be determined on the basis of historic energy output of the power station between 1 July 2004 and 30 June 2007 and the extent to which the generator's emissions intensity exceeds the threshold level of 0.86 tCO_2-e/MWH generated, which is the average emissions intensity of all fossil-fuel based generation.

+ A$2.15 billion for financial assistance over five years to businesses, community sector organisations, workers, regions and communities to an operating environment that includes a price on carbon.

In conclusion, the CPRS was proposed with various compensations to households and industries. However, the CPRS was refused in the Senate, and thus the compensation policy was not implemented.

3.2.2 Compensation policies of the Clean Energy Future Package in 2012

The carbon pricing mechanism was implemented for two years, from 2012 to 2014, with various compensations for households and industries. This section presents, in detail, the compensation policies.

3.2.2.1 Compensation for households

To offset the effects of the carbon price on households, the Australian Government committed to use more than 50 per cent of the carbon price revenue to assist households. Assistance to households is contained in the Household Assistance Package, presented in detail in the Australian Government's climate change plan, *Securing a Clean Energy Future* (Department of Climate Change and Energy Efficiency, 2012). The Household Assistance Package under the Labor Government commenced on 16 May 2012 with payments to families, parents, seniors and individuals who receive a government payment, followed by a tax cut from 1 July 2012. With a total assistance package of A$14.3 billion over four years from 2011-2012, the package provided financial assistance mainly to low and middle income households because these groups spend a higher proportion of their income on essential household expenses, such as energy products. The Household Assistance Package was categorised into assistance by the way of increased government payments, tax cuts and other payments.

- **Assistance through increased government payments**

  An initial payment in the Household Assistance Package was provided to the government payment recipients to prepare for the start of the carbon price. Pensioners received an initial payment of A$250 for a single and A$380 for a couple. Jobseekers and other individuals eligible for allowance payments received an initial payment of A$160 for a single and A$300 for a couple. Single parents received the Parent Payment Single in an initial payment of A$210. Veterans also received an initial payment under the Household Assistance Package. The initial payment was delivered by the Clean Energy Advance in May-June, 2012.

  From March 2013 to early 2014, the assistance was provided through the Clean Energy Supplement. The recipients received an annual assistance equivalent to a 1.7 per cent increase in the relevant annual maximum payment rate. This comprised an increase of 0.7 per cent to cover the expected consumer price index increase because of the introduction of an A$23 carbon price and a further 1 per cent increase in payments to provide additional assistance. To avoid the double payment of indexation, there was an adjustment to indexation for pensions and most allowances in March 2013, for the Family Tax Benefit in July 2013, and for Youth Allowance, and Austudy in January 2014.

  With a 1.7 per cent increase in the maximum payment rate, pensioners received around A$350 per year for a single and around A$530 per year for a couple. Self-funded retirees who held a Commonwealth Senior Health Card received assistance through the Senior Supplement. In the case of a Family Tax Benefit, there was a 1.7 per cent increase in the Family Tax Benefit, each child received A$110 and each family received A$69 in the receipt of the Family Tax Benefit Part B. Veterans received assistance equivalent to a 1.7 per cent increase in their payment.

- **Assistance through tax cuts**

  The Household Assistance Package included a personal income tax cut with a total amount of A$8 billion over three years from 2012-2013. This package comprised the changes in the free tax threshold and the marginal tax rates. In particular, as seen in Table 3.1, for the free tax threshold, there was an increase in this threshold from A$6000 to A$18200 per year from 1 July 2012. The purpose of the package was to increase this threshold to A$19400 per year from 1 July 2015. For the marginal tax rate, there is an adjustment to the first two marginal tax rates from 15 per cent to 19 per cent and from 30 per cent to 32.5 per cent in 2012-2013, while the second marginal tax rate was intended to increase to 33 per cent in 2015-2016. The last two marginal tax rates remained constant.

By changing the free tax threshold and marginal tax rates, there was a reduction in the Low Income Tax Offset from A$1,500 in 2011-2012 to A$445 in 2012-2013 and the estimated amount of A$300 in 2015-2016. The effective tax-free threshold increased from A$16,000 per year in 2011-2012 to A$20,542 per year in 2012-2013, and to A$20,979 per year in 2015-2016. Normally, an increase in the tax free threshold creates an identical tax cut to all taxpayers regardless of income. However, to deliver a higher benefit to low income individuals from the tax cut than those with a higher income, the package increases the bottom two tax rates. This increase in the first two marginal tax rates does not result in an overall increase in tax for low and middle income individuals because the increase in the marginal tax rate is more than offset by the increase in the tax free threshold.

Table 3.1: Personal income tax rates and thresholds

	2011-2012		2012-2013		2015-2016	
	Threshold ($)	Marginal rate	Threshold ($)	Marginal rate	Threshold ($)	Marginal rate
1st Rate	6,001	15%	18,201	19%	19,401	19%
2nd Rate	37,001	30%	37,001	32.5%	37,001	33%
3rd Rate	80,001	37%	80,001	37%	80,001	37%
4th Rate	180,001	45%	180,001	45%	180,001	45%
Low Income tax Offset (LITO)	$1,500	4% above $30,000	$445	1.5% above $37,000	$300	1% above $37,000
Effective tax-free threshold	$16,000		$20,542		$20,979	

Source: Quoted in Australian Council of Social Service (2011)

The Australian Council of Social Service (2011) stated that the adjustment in the income tax thresholds and marginal tax rates does not have an effect on the tax paid by individuals whose income is up to A$16,000 per year. For individuals whose income is A$20,000 per year, their income tax is reduced by around A$600 per year. Income tax is reduced by A$300 per year for those whose income is between A$30,000 and A$65,000 per year. Income tax is reduced by around A$3 for individuals whose income is above A$80,000 per year. Thus, by an increase of the tax-free threshold and an adjustment in the marginal tax rates, from 1 July 2012 every taxpayer earning up to

A$80,000 per year would have received a tax cut, with most getting at least A$300 annually. In the second round of tax cut from 1 July 2015, taxpayers who earn below A$80,000 per year would have receive at least A$380 annually.

- **Assistance through other payments**

  In some case, providing increased government payments and income tax cuts is not sufficient to offset the effects caused by the carbon price, the Household Assistance Package also provided other payments:

  + Low Income Supplement

    The Low Income Supplement of A$300 was available to people who did not receive enough assistance through tax cuts and other household assistance payments to offset the average cost raised by the carbon price. People could apply for this payment from 1 July 2012 if they had an annual adjusted taxable income less than A$30,000 for singles; A$45,000 for couples, and A$60,000 for people with dependent children. They must show that in 2011-2012, they were not required to pay tax or required to pay tax of less than A$300 and for most of the year they did not receive another government payment.

  + Single Income Family Supplement

    As a part of the Household Assistance Package, the Single Income Family Supplement provided additional support of up to A$300 per year for single income families where the primary income earner has a taxable income between A$68,000 and A$150,000 per year. This payment recognises that single income families receive less assistance through tax cuts compared with dual income families on similar incomes. This payment was available from 1 July 2013.

  + Essential Medical Equipment Payment

    The Australian Government provided for an Essential Medical Equipment Payment of around A$52.5 million over three years from 2012-2013 to assist individuals who experienced additional energy costs because of their use of essential medical equipment needed for their disability or medical condition. The Essential Medical Equipment Payment provided A$140 per year to individuals who are covered by a Commonwealth Government concession card or Department of Veteran’s Affairs gold or white card. This payment was available from 1 July 2012.

+ Support Aged Care Residents and Providers

As a part of the Household Assistance Package, the Clean Energy Advance and Clean Energy Supplement provided financial assistance to pensioners, Commonwealth Seniors, and Health Card holders in residential aged care. Half of this assistance was to support aged care providers because of an increase in the costs of living for their residents because of the introduction of the carbon price.

- **Assistance for household energy efficiency programs**

To improve energy efficiency in homes, the Australian Government planned to provide energy efficiency programs for households. For example, one program was a A$100 million Low Income Energy Efficiency Program that aimed to improve the energy efficiency of low-income households over four years from 2012-2013 to enable such households to better manage their energy use; another program was a A$29.90 million Home Energy Saver Scheme that was targeted at assisting around 100,000 low-income households to improve their energy efficiency and financial sustainability over four years from 2011-2012; and a third program was a 'Living Greener' program, which was to be through the provision of a A$5.5 million worth of grants from the Australian Government over four years, from 2011-2012, to further expand and enhance the 'Living Greener' website to include more information about energy efficiency and managing energy costs. The website was to be supplemented by a household information and advice telephone service.

In assessing the assistance to households, the Australian Government (2013) stated that one year after the implementation of the carbon price, the Household Assistance Package delivered various benefits to individuals as well as families. In particular, by increasing the tax free threshold, more than 7 million taxpayers earning up to A$80,000 per year received the personal income tax cuts from 1 July 2012, around 3.5 million pensioners received about A$350 a year for singles and A$530 a year for couples combined from March 2013. Over 1.6 million families received the Family Tax Benefit payment and would receive ongoing increases in their family payments.

With the combination of the tax cuts, increased government payments and other assistance, the Treasury (2011) estimated that the Clean Energy Future Package resulted in the average household assistance of A$10.10 per week to offset the average household expenditure increase of A$9.90. Phillips and Taylor (2011) estimated that the package assisted households with A$10.90 per week, on average, and households are A$2.50 per week better off on average, compared to A$0.20 per week in the Treasury's estimate. Of this A$10.90 per week, A$6.40 per week was obtained from the tax cuts and A$4.50 per week was gained from the increased government payments. Phillips and Taylor (2011) also concluded that the Clean Energy Future Plan was more generous than suggested by initial Treasury modelling. The carbon impact was lower while the assistance package for households was more generous.

By increasing the government payment and tax cuts through increasing the free tax threshold and the first two marginal tax rates, the assistance was mainly delivered to low and middle-income households. The Household Assistance Package was assessed to be higher than the average carbon price impact for low-income households, and accounted for 60 to 95 per cent of the carbon price impact for middle-income households (Hatfield-Dodds et al., 2011). The NATSEM found that by using the 'actual' impact, around 9 out of 10 households in the bottom two deciles would be better off, and only 11 per cent of the top decile would be better off. Under the 'average' impact, 100 per cent of households headed pensioners were estimated to be fully compensated, while 91 per cent of Allowee[8] headed households were fully compensated and 83 per cent of self-funded retiree headed households would be better off (Phillips & Taylor, 2011).

3.2.2.2 Compensation for industries

The Australian Government introduced many programs to assist industries transition smoothly to a clean energy future. Moreover, industries had a strong incentive to reduce their carbon pollution through these assistance programs. The Department of Climate Change and Energy Efficiency (2012) presented detailed programs to assist industries to invest in cleaner technology, encourage innovation and competiveness, as outlined below.

The Jobs and Competiveness Program would provide an estimated package of A$8.6 billion in the first three years of the carbon pricing mechanism to support production and encourage industries to invest in cleaner technology. The program aimed at assisting entities that produced high carbon pollution but had limited opportunities to pass their costs on in the global market. The entities that were the most emissions-intensive trade-exposed would receive assistance to cover 94.5 per cent of industry average carbon cost. Meanwhile, entities would receive assistance to cover 66 per cent of industry average carbon cost if they had less emissions-

[8] Allowee types include New Start Allowance, Youth Allowance, Austudy, and Parenting Payments.

intensive trade-exposed activities. The assistance would be reduced by 1.3 per cent per year to encourage industry to cut pollution.

The Coal Sector Assistance Package was targeted at supporting the coal mines that are high emissions intensive to adjust to the challenges due to the carbon pricing mechanism. The package included two programs such as the Coal Sector Jobs Package and the Coal Mining Abatement Technology Support Package. The Coal Sector Jobs Package would provide transitional assistance to assist the most fugitive emissions–intensive mines that were the most impacted by the introduction of the carbon price. The assistance was up to A$1.3 billion over six years from 2011-2012. Meanwhile, with the assistance package of A$70 million over five years from July 2012, the Coal Mining Abatement Technology Support Package aimed at supporting the development of carbon abatement technology.

The Clean Technology Program provided a package of A$1.2 billion to directly improve energy efficiency and reduce carbon pollution in manufacturing industries and support research and development of low pollution technologies. This package included three components, the first was the Clean Technology Investment Program that was an A$800 million grant over seven years from 2011-2012. The grant aimed at assisting manufacturers to invest in new plant and equipment to reduce carbon pollution or energy costs. The second was the Clean Technology Food and Foundries Investment Program with the purpose of providing A$150 million in grants over six years to the food and beverage industry and up to A$50 million over six years to the metal forging and foundry industries. The third was the Clean Technology Innovation Program with the assistance of A$200 million over five years from 2012-2013 to support business investment in research and development.

For the steel manufacturing industry, the Australian Government delivered the Steel Transformation Plan, with the assistance of A$300 million over six years from 2011-2012, to support the transformation into a low-carbon economy through encouraging investment, innovation and competitiveness. For businesses, the Australian Government also provided the assistance package to assist them to deal with the introduction of the carbon price, for example assistance of A$5 million over four years from 2011-2012 to enhance the clean technology, or the assistance of A$32 million over four years from 2011-2012 for educational institutions and industry to develop the materials and expertise needed to promote and build clean energy skills and workforce capability.

Finally, the Australian Government provided assistance of A$18 million over four years from 2011-2012 to the Productivity Commission to undertake reviews relating to industry assistance and fuel tax arrangements, and to implement ongoing work to quantify mitigation policies in other major economies.

3.2.2.3 Other compensation policies

Apart from revenue recycling policies for households and industries, the Australian Government proposed and implemented other policies aimed at increasing energy-saved technology usage and carbon emission reduction.

+ **Renewable Energy**

    - ***Renewable Energy Target***

      With the intention of 20 per cent of Australia's electricity generated from renewable sources by 2020, the Renewable Energy Target is a key part of the Government's Clean Energy Future plan. The RET has been administered by the Clean Energy Regulator, instead by Renewable Energy Regulator from 2 April 2012, and the RET is reviewed by the Climate Change Authority. By 2020 there would be an expected investment of A$20 billion from the private sectors in the RET.

    - ***Clean Energy Finance Corporation***

      The Australian Government would provide A$10 billion to the Clean Energy Finance Corporation (CEFC) to invest in clean energy over five years from 2013-2014. About 50 per cent or more would be invested in the renewable energy stream, and up to 50 per cent would be invested in the low-emissions and energy efficiency streams.

    - ***Australian Renewable Energy Agency***

      There was to be a funding of A$3.2 billion provided to the Australian Renewable Energy Agency to improve the competitiveness of renewable energy technologies and increase the supply of renewable energy from July 2012.

+ **Energy Security Fund**

    The Australian Government established the Energy Security Fund to assist with a smooth transition to a clean energy economy and preserve energy security. There were two components in the Energy Security Fund:

- Providing transitional assistance in the form of a cash payment and free carbon units to highly emissions-intensive coal-fired power stations that were greatly affected by the introduction of the carbon price over five years from 2012. This assistance was valued at A$5.5 billion, accounting for around 23 per cent of the expected liability of the coal-fired power stations over this time.
- Seeking to negotiate payment for the closure of around 2,000 megawatts (MW) of every highly emissions-intensive coal-fired generation capacity by 2020.

+ **Land use**

The Agricultural and Land sector was excluded from the carbon price but, as the second largest emissions contributor in Australia, creating opportunities in this sector to cut emissions while maintaining productivity and improving sustainability and resilience was a key component of the Clean Energy Future Package. There was to be over A$1.7 billion of carbon price revenue invested in the agricultural and land sector through new funding programs to assist farmers and land managers to reduce carbon pollution and increase the amount of carbon stored in the land.

The Carbon Farming Initiative (CFI) was a carbon offsets scheme that provides economic rewards for farmers and landholders to reduce carbon pollution and store carbon on the land through trading the Australian Carbon Credit Units (ACCUs). However, their participation in the CFI was voluntary. If they participate in the CFI they were to receive the ACCUs for the carbon pollution and could sell credits to other businesses wanting to offset their own carbon pollution. The CFI would create a new income stream for farmers, new jobs for rural and regional Australia and provide incentives to identify and implement low-cost methods for pollution reduction (Department of Climate Change and Energy Efficiency, 2012). The credit was limited to up to 5 per cent of their emissions for the first three years, and then is raised to up to 50 per cent from July 2015 (Patay & Sartor, 2012).

3.3 Conclusion

In conclusion, in order to meet the *Kyoto Protocol* target of emissions reduction of unconditional 5 per cent below 2000 levels by 2020 and conditional 15 per cent or more below 2000 level by 2020, the Australian Government introduced various policies in recent years. On 8 November 2011, the Clean Energy Future Package was passed by both the House of Representatives and the Senate, the carbon price mechanism is the centerpiece of this plan, which commenced its operation from 1 July 2012, but the carbon price was repealed by the Coalition Government who won the federal election in 2013 from 1st July 2014. The DAP replaces the carbon price mechanism to implement the carbon emissions reduction.

Accompanying the carbon emissions reduction policies, the Australian Government proposed and implemented compensation packages, which aimed to reduce unexpected impacts on producers and consumers. In accordance with the introduction of the carbon price, the Australian Government provided various assistance schemes to households to offset the impacts caused by the carbon tax through personal income tax cuts and increased government payments. This assistance to low-income households was assessed to be sufficient to offset the increased cost of living caused by the carbon price. Apart from the compensation policy to households, the Australian Government delivered financial support to vulnerable industries. The Australian Government also encouraged industries to develop carbon abatement technologies.

CHAPTER 4: CONSTRUCTING THE SOCIAL ACCOUNTING MATRIX

This research employs a Computable General Equilibrium (CEG) model to measure the effects of the ETS on distribution and welfare; a Social Accounting Matrix (SAM) is a core database of the CGE model. The purpose of this chapter is to present the framework of the SAM and the compilation procedure used to construct the SAM for the Australian economy in the year 2009. The construction of a SAM helps to bring together data from many different sources that help to describe the structural characteristics of an economy (Round, 2003b). An input-output table is just the beginning and not the end of the compilation process; a SAM also needs to display at least some further minimal disaggregation of the household, factor accounts to capture higher-order institutional features (Round, 2003a).

The SAM in this chapter presents an aggregated perspective of transactions among economic agents in the economy. To achieve the objectives of the research, there is disaggregation on energy sectors, electricity generating sectors, labour categories, and household groups in the SAM. Constructing the SAM requires data to be collected from various databases that are not always consistent, hence this chapter presents the methods of data reconciliation. This chapter is organised as follows: section 4.1 outlines the various accounts used in the SAM; section 4.2 describes the ways to construct the SAM; section 4.3 provides disaggregation and extension of the SAM; and the data on carbon emissions, with the sources of emissions, and how to allocate emissions data in activity and stationary emissions matrices are presented in section 4.4. The chapter ends with the conclusion in section 4.5.

4.1 Classification of accounts used in a SAM

A SAM describes all transactions and transfers in the economy, with intermediate inputs and primary factors used for production. These factors of production are contributed by institutional sectors that, in turn, receive factor payments. Apart from these income, institutions receive income from other institutional sectors. The income is spent for expenditure on goods and services, capital goods and services, or payment of taxes. The gap between income and expenditure is a saving for the future. In addition, the financial and capital flows among institutions are represented in the SAM.

A SAM is a square matrix. This is because economic transactions among agents are displayed in both column and row accounts. The SAM’s row account records each agent’s receipts and its column account show each agent's outlays. Thus, each cell in the SAM matrix represents simultaneously expenditure by an agent's column account and a source of income by other agent's row account, the total expenditure must be equal to the total income of each agent. Economic agents include industries, factors of production, households, enterprises, government and foreigners. Each agent has an account, thus there are many accounts used in a SAM matrix, including industry account, commodity account, factors of production accounts (labour, capital and land accounts), income account, financial account, and capital account. In the income, financial and capital accounts, there are five institution accounts: households, non-financial and financial corporations, government, and foreigners accounts.

Table 4.1 shows the basic structure of the SAM framework. There are some sub-matrices in the large matrix of the SAM, for example, sub-matrices, such as matrix A, B or C, is called the classification matrices, which are the cross-matrices among classifications. Each matrix A, B or C also contains sub-matrices, called the item matrices, which are cross-matrices among items. There are also some sub-matrices that are not labelled with name, because there is no transactions involved between classification in the column and classification in the row. The receipts and outlays of accounts used in the SAM are briefly presented as follows:

Inter-industry transactions are presented in matrix A. Industries, by column, use intermediate inputs, and pay for taxes on products as well as taxes on production, to produce commodities. Industries, by row, receive sales commodities. The payments of industries for factors of production are outlined in matrix B.

In the income account, the payments of institutions for their consumption are provided in matrix E, which include payments for goods and services, taxes on products based on their purchases as well as the subsidy of government to production of industries. The payments of institutions for primary factors are presented in matrix F, such as payments of foreigners to labour. Regarding the receipts of institutions, matrix C shows the income flows of recipients from taxes on products, taxes on productions, and imported commodities. Government receives taxes, while foreigners get sales of imported commodities. The income flows of recipients from their supply of primary factors are described in matrix D. Inter-institution transactions among institutions are provided in matrix G, which include receipts and outlays of institutional sectors regarding economic transactions and transfers among institutions. The gap between the total income and the total expenditure of an institution is allocated in matrix H, called the savings of an institution.

Table 4.1: Structure of a Social Accounting Matrix

Classification		Production Activities				Factors of production			Income Account					Financial Account					Capital Account					
	Items	Ind	Com	Tax on prods	Tax on prodt	Lab	Cap	Land	HH	C (nf)	C (f)	G	Fo	HH	C (nf)	C (f)	G	Fo	HH	C (nf)	C (f)	G	Fo	Total
Production Activities	Industry	A							E										J					
	Commodity																							
	Tax on products																							
	Tax on production																							
Factors of production	Labour	B							F															
	Capital																							
	Land																							
Income Account	Households	C				D			G															
	Corporations (nf)																							
	Corporations (f)																							
	Government																							
	Foreigners																							
Financial Account	Households													I										
	Corporations (nf)																							
	Corporations (f)																							
	Government																							
	Foreigners																							
Capital Account	Households								H										K					
	Corporations (nf)																							
	Corporations (f)																							
	Government																							
	Foreigners																							
	Total																							

Source: Pang, Meagher and Lim (2006)

Inter-institution transactions within the financial account are described in matrix I, which include receipts and outlays of institutional sectors regarding transactions on financial assets and liabilities. The gap of the total acquisition of financial assets and the total of incurrence of liabilities is accrued to change in the financial position. In a SAM, in the financial pattern, the total receipts of each institutional sector must be equal to the total payments, hence the change in the financial position is attributed to the value of non-flow items of each institutional sector.

In the capital account, the payments of institutions for purchasing capital goods and taxes on capital goods are provided in matrix J. Inter-institution transactions are reflected in matrix K, which includes capital transfers among institutions.

In conclusion, as shown in Table 4.1, there are various kinds of accounts, including production activities, factors of production, income, capital, or financial accounts. Rows indicate the receipts of accounts and columns show the outlays of accounts. The receipts and outlays are derived from different sources but the total value of receipts must be equal to the total value of payments of each account. The following sections present how to construct the SAM and how to disaggregate energy sectors, labour categories and households in the SAM.

4.2 Constructing the SAM

The SAM presents an aggregated perspective of the transactions in the economy. As shown in Table 4.1, the SAM elaborates the circular flows of incomes by production activities, factors of production, and institutional groups as well as the spending of these sectors and groups. This section describes how to collect data for and how to construct the SAM for Australia in the year 2009.

4.2.1 Sources of data for the SAM

The SAM requires data related to the sources of income as well as the expenditure of economic agents in the Australian economy. The economic agents include industries, factors of productions, household consumers, corporations, the government, and the rest of the world. Therefore, data for the SAM were collected from various sources, most of which were from the Input-Output (IO) tables, 2008-2009 (ABS, 2012c), and the Australian System of National Accounts (ASNA), 2010-2011 (ABS, 2011b) for the year 2009.

4.2.1.1 Input-Output tables, 2008-2009

There are many tables in IO tables 2008-2009, including Supply Table, Use Table, Import Table, Margin Tables, and Tax Tables. The data collected from these IO tables were used to construct the SAM.

The Use Table displays both domestic and imported commodity usage of industries and final consumers (including the margin values). To divide the values in the use matrix into those in the domestic matrix and imported matrix, the margin values were first deducted from the use matrix by subtracting the margin values out of the values of the 12 marginal commodities in the Use Table. The margin values of each marginal commodity were obtained from the row sum in its margin matrix. Then, the domestic matrix was derived by subtracting the import matrix from the use matrix without margins.

Table 4.2: Aggregate IO table, 2008-09 (A$m)

Categories	**Industry use**	**Final expenditure and gross fixed capital formation**				
		Households	**Government**	**Sum of capital account**	**Exports**	**Total**
Total intermediate input	1255894	623929	220597	328743	277350	2706513
+ Domestics	1024601	452750	215992	258972	256249	2208564
+ Imports	152788	64683	2902	49031	0	269405
+ Margins	78505	106496	1703	20740	21101	228544
Labour cost	596098	0	0	0	0	596098
Capital and land costs	536909	0	0	0	0	536909
Taxes less subsidies on products	12339	52285	0	19311	-592	83343
Taxes less subsidies on productions	35868	0	0	0	0	35868
Total Australian production	**2437108**	**676214**	**220597**	**348054**	**276758**	**3958731**

Source: Computed from the Input-Output tables, 2008-2009

Table 4.2 shows the aggregate IO table obtained from the Use Table, the Import Table, and the Margin Tables. These tables present the values of commodities supplied industries and final users in the economy in which all industries purchase the total values of A$1255894m (including A$1024601m of domestics, A$152788m of imports, and A$78505m of margins) as intermediate demand. The final users purchase the total value of A$1450619m, of which A$844526m is from final expenditure (households and government), A$328743m is from gross fixed capital formation, and A$ 277350m is from exports. These values include domestic, imported and margin values.

Column 2 in Table 4.2 presents the total costs paid to production, including intermediate cost (A$1255894m), labour cost (A$596098m), capital and land costs (A$536909m), taxes on products (A$12339m), and taxes on production (A$35868m). The total costs used to produce goods and services is equal to the total commodity output in the economy (A$2437108m) that is recorded in the Supply Table.

Some cells in the Use and Import Tables contain no data (n.p). The method used to fill data for n.p. cells are:

+ **For the Use Table**

In the Use Table, the ABS has not published data on the expenditure of the final users of the air and space transport commodity (code 4901) and the postal and courier pick-up and delivery services commodity (code 5101), as shown in Table 4.3. According to the Australian National Accounts: Input-Output Tables (Product Details) 2008-09 (ABS, 2012b), the supply of each sub-product of the commodity 4901 and of the commodity 5101 to the final users were as displayed in Table 4.4. Adding up all sub-commodities in Table 4.4, and then comparing them with Table 4.3, it was possible to construct Table 4.5. The households and export columns in Table 4.5 are marked n.p. The total supply of the commodity 4901 to households and exports is A$21624m (=21744-113-4-11+8), and the total supply of commodity 5101 to households and exports is A$688m. Thus the total supply of these two commodities to households and exports is A$22312m (=21624+688). The supply of commodity 4901 is A$13906.54m (=14349*21624/22312) to households, and A$7717.46m (=7963*21624/22312) to exports. Whereas the supply of commodity 5101 is A$442.46m (=14349*688/22312) to households and A$245.54m (=7963*688/22312) to exports.

Table 4.3: n.p. number in the Use Table

Commodity	Final consumption expenditure		Gross fixed capital formation			Change inventories	Exports	Final use
	Households	Government	Private enterprise	Public enterprise	General government			
4901	n.p	n.p	n.p	n.p	n.p	n.p	n.p	21744
5101	n.p	n.p	n.p	n.p	n.p	n.p	n.p	688
Total	14349	0	113	4	11	-8	7963	22432

Source: The Use Table, 2008-2009

Table 4.4: n.p. number in the IO Tables (product details), 2009-09 (A$m)

Commodity	Final consumption expenditure		Gross fixed capital formation			Change inventories	Exports
	Households	Government	Private enterprise	Public enterprise	General government		
49000020	0	0	0	0	0	0	0
49000030	n.p	0	0	0	0	0	n.p
49000040	n.p	0	0	0	0	0	n.p
49001600	149	0	113	4	11	-8	49
Total		**0**	**113**	**4**	**11**	**-8**	
51010010	n.p	0	0	0	0	0	n.p
51020010	n.p	0	0	0	0	0	n.p
51021980	0	0	0	0	0	0	0
Total		**0**	**0**	**0**	**0**	**0**	**0**

Source: The Input-Output Tables (Product Details), 2008-09

Table 4.5: Combination of Table 4.3 and Table 4.4 (A$m)

Commodity	Final consumption expenditure		Gross fixed capital formation			Change inventories	Exports	Final use
	Households	Government	Priv.enterprise	Pub. enterprise	Gen. govern			
4901	n.p	0	113	4	11	-8	n.p	21744
5101	n.p	0	0	0	0	0	n.p	688
Total	14349	0	113	4	11	-8	7963	22432

Source: The Input-Output Tables (Product Details), 2008-09

Table 4.6: n.p. number in the Import Table (A$m)

Commodity	Final consumption expenditure		Gross fixed capital formation			Change inventories	Exports	Final use
	Households	Government	Priv.enterprise	Pub. enterprise	Gen. govern			
4901	n.p	n.p	n.p	n.p	n.p	n.p	n.p	7431.84
5101	n.p	n.p	n.p	n.p	n.p	n.p	n.p	9.53
Total	7441.37	0	0	0	0	0	0	7441.37

Source: The Import Table, 2008-09

+ **The Import Table**

The same as for the Use Table, there are cells concerning the supplies of the commodity 4901 and the commodity 5101 to the final users in the Import Table, for which no data has been published, as shown in Table 4.6. It is apparent that the total supply of these two commodities to final users is almost zero, except for households. Therefore the supply of each commodity to these final users is zero also. For the household consumers, the total supply of the commodity 4901 to all final users is valued at A$7431.84m, while the total supply of the commodity 5101 is valued at A$9.53m. Thus, these values are assigned to the household column.

4.2.1.2 The Australian System of National Accounts, 2010-2011

A SAM portrays in detail transactions as circular flows of incomes and spending of each agent in the economy. The agents include not only industries and factors of production but also institutional sectors, such as households, the government, corporations, and the rest of the world (foreigners). The incomes and expenditures of these institutions are provided in detail in the Australina System of National Accounts (ASNA).[9] The ASNA shows the flows among institutional sectors in the economy regarding the income account, the financial account, and the capital account. To obtain consistent data with the IO tables, 2008-09, this study collected the data for institutions from the ASNA, 2010-2011 for the year 2009.[10]

4.2.2 Constructing data for the SAM

The SAM presents aggregate information about transmissions among economic agents by simultaneously showing the receipts of an agent corresponding to the outlays of other agents. The receipts are represented in rows and the expenditures are represented in columns.

4.2.2.1 Accounts in production activities

There are many accounts in production activities: industry account, commodity account, margin account, and tax account. The flows in each account are presented in detail as follows:

- **Industry account**

This account presents the receipts and outlays of industries in the economy. As seen in Table 4.7, the receipts are obtained from the sale of commodities (including the margin value) and

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[9] The Australian Bureau Statistics publishes the Australian System of National Accounts yearly from 1997-1998 until now.

[10] The Australian Bureau Statistics published the IO Tables, 2008-09 in September 2012, and ASNA, 2010-2011 in October 2011, the data related to institutions is consistent between these two sources.

the outlays consist of intermediate demand for domestic and imported commodities (including margin value), labour cost, capital cost, land cost, taxes on products and production taxes. The labour and land costs constitute income to households from labour and land, and capital cost makes up income for all institutions. The Use Table only records the gross operating surplus and mixed income that is divided to capital and land costs in the SAM.

The capital and land costs were calculated based on GTAP-E database 8.1 (base year 2007) for Australia, the capital value (excluding land) was US$266754.82m (= US$254315.7m for capital plus US$12430.12m for natural resources), the land value was US$4465.524m. It means that the capital value accounts for 98.35 per cent and the land value accounts for 1.65 per cent. Using these percentages the gross operating surplus and mixed income is divided into capital and land costs. A$536909m of total costs were divided into A$528069m (=536909*98.35%) to capital cost and A$8840m (=536909*1.65%) to land cost as shown in Table 4.7.

Table 4.7: Industry account (A$m)

Categories	Receipts	Categories	Outlays
Sale of domestic commodities	2208564	Intermediate Use	1255894
Margins	228544	+ Domestic	1024601
		+ Imported	152788
		+ Margins	78505
		Labour	596098
		Capital	528069
		Land	8840
		Taxes on products	12339
		Taxes on productions	35868
Total	**2437108**	**Total**	**2437108**

Source: Extracted from Table 4.2

- **Commodity account**

Commodity values include not only domestic and import values but also the margin values and tax on products. Thus, commodity accounts are disaggregated into domestic commodity account, imported commodity account, margin account and tax account.

+ *Domestic commodity account*

Table 4.8 displays the domestic commodity account with the receipts and outlays, in which the receipts include intermediate demand from the production activities (A$1024601m), and final expenditure demand from households (A$452750m), government (A$215992m), exports (A$256249m), and gross fixed capital formation (A$258972m), while the outlays represent the value of commodity sales by the industries. (A$2208564m). The total receipts are equal to the total outlays in this account.

Table 4.8: Domestic commodity account (A$m)

Categories	Receipts	Categories	Outlays
Domestic intermediate demand	1024601	Sales of domestic commodities	2208564
Household expenditure	452750		
Government spending	215992		
Exports	256249		
Formation of fixed capital	258972		
Total	**2208564**	**Total**	**2208564**

Source: Calculated by the author from the IO Tables, 2008-2009

+ *Imported commodity account*

The imported commodity account is shown in Table 4.9. The outlay is the sale of all imported commodities in the Australian economy with the value of A$277218m and the receipts are sourced from imported intermediate demand (A$152788m), final consumption on imports from households (A$64683m) and government (A$2902m), re-export (A$7813m), and formation of fixed capital (A$49031m). The total value of the receipts must be equal to the total value of the outlays in this account.

Table 4.9: Imported commodity account (A$m)

Categories	Receipts	Categories	Outlays
Imported intermediate demand	152788	Sales of imported commodities	277218
Household expenditure	64683		
Government spending	2902		
Re-exports	7813		
Formation of fixed capital	49031		
Total	**277218**	**Total**	**277218**

Source: Collected from the Import Table, 2008-2009

+ *Margin account*

The margin account is the addition of margin values from the 12 margin tables in the IO Tables, 2008-09. Table 4.10 shows the receipts and the outlays of the margin account. This account is recorded the same way as the domestic commodity account and imported commodity account. The receipts include intermediate demand (A$78505m), final consumption from households (A$106496m), from government (A$1703m), exports (A$21101m), and formation of fixed capital (A$20740m). The outlay represents the margin of commodity sales (A$228544m).

Table 4.10: Margin account (A$m)

Categories	Receipts	Categories	Outlays
Intermediate commodity margin	78505	Margin of sales of commodities	228544
Household spent commodity margin	106496		
Government spent commodity margin	1703		
Export margin	21101		
Margin of capital goods	20740		
Total	**228544**	**Total**	**228544**

Source: Collected from the aggregate Margin Table, 2008-2009

+ *Taxes on products account*

The receipts and outlays of the product tax account is shown in Table 4.11. All sectors and institutions have to pay indirect taxes on products to the government when purchasing goods and services. Thus, the receipts of product tax account are derived from the tax payment of these sectors and institutions, including from intermediate input demand (A$12339m), from households (A$52285m), and from foreigners (A$-592m). The outlays are payment to the government (A$83343m).

Table 4.11: Account for taxes on products (A$m)

Categories	Receipts	Categories	Outlays
Intermediate commodity tax	12339	Tax payment to government	83343
Household tax on commodities	52285		
Export tax on commodities	-592		
Tax on capital goods	19311		
Total	**83343**	**Total**	**83343**

Source: Collected from the Use Table, 2008-2009

- Taxes on production account

This account represents the receipts and outlays from taxes generated in the production. As shown in Table 4.12, the receipts include the other taxes, less subsidies on production, in the Use Table (A$35868m) and subsidies from the government on production given by the ASNA government account (A$17628m). Meanwhile the outlays of this account are the amount of taxes on production paid to the government (A$53496m). The total receipts are equal to the total outlays in this account.

Table 4.12: Account for production tax (A$m)

Categories	Receipts	Categories	Outlays
Production tax by industries	35868	Production tax payment to government	53496
Production subsidy by government	17628		
Total	**53496**	**Total**	**53496**

Source: Collected from the Use Table, 2008-2009 and the ASNA (2009), 2010-2011

4.2.2.2 Production factor accounts

In the SAM, there are three production factors: labour, capital, and land. Each factor has an account.

- **Labour account**

This account represents the receipts from and outlays to labour. As seen in Table 4.13, the receipts consist of the compensation of employees paid by industries and foreigners, while the outlays comprise labour cost paid to households and foreigners. The total value of the receipts must be equal to the total value of the outlays.

Table 4.13: Labour account (A$m)

Categories	Receipts	Categories	Outlays
Compensation of employee by industry	596098	Labour cost paid to households	594598
Compensation of employee by foreigners	1717	Labour cost paid to foreigners	3217
Total	**597815**	**Total**	**597815**

Source: Collected from the Use Table, 2008-2009 and the ASNA (2009), 2010-2011

- **Capital account**

The row of the capital account presents the capital receipts from the production process, and the column for this account presents payments to capital-owners as shown in Table 4.14. The capital cost is recorded in the Use Table, while the profits from capital to owners are recorded in the ASNA institution accounts. However, the ASNA household account only publishes household income from gross operating surplus and gross mixed income, instead of from capital and land separately. This study assumed that land cost appear in the product process and constitutes household income from land, which is A$8840m as represented in Table 4.7, therefore household income from capital is calculated by subtracting the land-sourced income from gross operating surplus and gross mixed income. The household income from capital is A$175291m (=83165+100966-8840).

Table 4.14: Capital account (A$m)

Categories	Receipts	Categories	Outlays
Capital used in the production	528069	Household received capital	175291
		Non-financial corps received capital	266949
		Financial corps received capital	59520
		Government received capital	26308
Total	**528069**	**Total**	**528069**

Source: Collected from the ASNA (2009), 2010-2011 and Table 4.7

- **Land account**

As seen in Table 4.7, the land cost of A$8840m in the production is equal to the household income from the land. Therefore, the receipt of this account presents the land cost in the production, while the outlays portray household income from the land.

4.2.2.3 Flows in the income account

Economic transactions between households (HH), non-financial corporations (Corps-nf), financial corporations (Corps-f), government (GOV), and foreigners (ROW) are derived from the respective ASNA institution accounts. The income and spending flows of each institution are a sum of interest flows, dividend flows, reinvested earning flows, rent on natural asset flows, social assistance benefit flows, non-life insurance flows, current transfer flows, and income tax flows. The procedure for calculating flows of each item among the institutions is as follows:

- **Interest flows**

Table 4.15 shows the total amounts of interest paid, and received, by each institution given by the ASNA institution accounts. In step 1, these numbers are assigned to the unallocated column and row. Households receive a total interest of A$91917m that consists of the property income receivable from interest (A$35156m) and the property income receivable from imputed interest (A$56761m). Meanwhile households pay the total interest of A$77080m, including the interest payable to dwellings (A$58714m), to consumer debt (A$11308m), and to unincorporated enterprises (A$7058m).

There are many assumptions made in stating step 2. First, households are assumed to pay interest only to non-financial and financial corporations, in which the interest payment to unincorporated enterprises of A$7058m is given to non-financial corporations and the other remaining payment of A$70022m (=77080-7058) is given to financial corporations. Second, non-financial corporations are assumed to pay interest only to financial corporations by the payment of A$48787m. Third, the government is assumed to pay interest to only financial corporations and foreigners, in which the interest payment of A$10132m on unfunded superannuation liabilities is made by the government to financial corporations and the other interest payment of A$6001m is given to foreigners, and the government is assumed to receive interest only from foreigners with the amount of A$6906m.

In step 3, the non-financial corporations are assumed to receive interest from financial corporations and households, thus the interest receipt of A$18081m (=25139-7058) is paid by financial corporations. Foreigners receive interests from financial corporations and general government, a residual receipt of A$36875m (=42876-6001) is made by financial corporations to foreigners. Financial corporations paid interests to households, non-financial corporations and foreigners, of which the interest payment of households is determined by a residual of A$88334m (=143290-18081-36875). The receipts to financial corporations from the foreigners is determined as a residual by the amount of A$2332m (=131273-70022-48784-10132).

Table 4.15: Interest flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							91917	91917
Corps-nf							25139	25139
Corps-f							131273	131273
GOV							6906	6906
ROW							42876	42876
Total							298111	298111
Unallocated	77080	48787	143290	16133	12821	298111		
Original	77080	48787	143290	16133	12821	298111		
Step 2								
HH			96109			96109	-4192	91917
Corps-nf	7058		47181			54239	-29100	25139
Corps-f	70022	48787		10132		128941	2332	131273
GOV					6906	6906	0	6906
ROW				6001		6001	36875	42876
Total	77080	48787	143290	16133	6906			
Unallocated	0	0	0	0	5915			
Original	77080	48787	143290	16133	12821			
Step 3								
HH			88334		3583	91917	0	91917
Corps-nf	7058		18081			25139	0	25139
Corps-f	70022	48787		10132	2332	131273	0	131273
GOV					6906	6906	0	6906
ROW			36875	6001		42876	0	42876
Total	77080	48787	143290	16133	12821			
Unallocated	0	0	0	0	0			
Original	77080	48787	143290	16133	12821			

Source: Computed from the ASNA (2009), 2010-2011

- **Dividend flows**

The receipts and payments for the dividend among institutions are presented in Table 4.16. This data is obtained from the property income receivable dividend and property income payable dividend in the institution accounts. The total receipts and outlays of each institution are displayed in the unallocated column and row respectively in step 1. As seen in Table 4.16, all institutions receive a dividend, but there is no dividends paid by households and the government.

In step 2, it is assumed that the dividend payments of non-financial corporations, financial corporations and foreigners are divided by the same proportion to the elements of unallocated columns in step 1. For example, financial corporations pay a dividend of A$16544m (= 27480*49064/81496) to households and the dividend of A$5415m (=8995*49064/81496) to the government. Foreigners, however, pay a dividend of A$88m (=834*8575/81469) to non-financial corporations and A$2806m (=26671*8575/81469) to financial corporations.

Table 4.16: Dividend flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							27,480	27,480
Corps-nf							834	834
Corps-f							26,671	26,671
GOV							8,995	8,995
ROW							17,516	17,516
Total							81,496	81,496
Unallocated	0	49,064	23,857	0	8,575	81,496		
Original	0	49,064	23,857	0	8,575	81,496		
Step 2								
HH		16,544	8,044	0	2,891	27,480	0	27,480
Corps-nf		502	244	0	88	834	0	834
Corps-f		16,057	7,808	0	2,806	26,671	0	26,671
GOV		5,415	2,633	0	946	8,995	0	8,995
ROW		10,545	5,128	0	1,843	17,516	0	17,516
Total	0	49,064	23,857	0	8,575			
Unallocated	0	0	0	0	0			
Original	0	49,064	23,857	0	8,575			

Source: Computed from the ASNA (2009), 2010-2011

- **Reinvested earnings flows**

The receipts and outlays of reinvested earnings of institutions are recorded in the unallocated column and row respectively as given in the ASNA institution accounts. As seen in step 1 in

Table 4.17, almost all institutions receive the reinvested earnings, but only non-financial corporations and foreigner record a positive reinvested earning, while other institutions obtain a negative reinvested earnings; these receipts to institutions are paid by only three institutions: non-financial corporations, financial corporations and foreigners.

It is assumed in step 2 that institutions which have positive total receipts would receive positive reinvested earnings from all institutions, and other institutions which have negative total receipts would receive negative reinvested earnings from all institutions. The calculation method of receipts and payments of each institution to reinvested earnings is similar to the calculation for dividends, being based on the proportion of payment of each institution.

Table 4.17: Reinvested earnings flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							-647	-647
Corps-nf							12144	12144
Corps-f							-1765	-1765
GOV							0	0
ROW							24971	24971
Total							34703	34703
Unallocated	0	14456	860	0	19387	34703		
Original	0	14456	860	0	19387	34703		
Step 2								
HH		-270	-16	0	-361	-647	0	-647
Corps-nf		5059	301	0	6784	12144	0	12144
Corps-f		-735	-44	0	-986	-1765	0	-1765
GOV		0	0	0	0	0	0	0
ROW		10402	619	0	13950	24971	0	24971
Total	0	14456	860	0	19387			
Unallocated	0	0	0	0	0			
Original	0	14456	860	0	19387			

Source: Computed from the ASNA (2009), 2010-2011

- Rent on natural assets flows

Table 4.18 sets out the allocation of rent on natural assets among the institutions. In step 1, the unallocated column and row display the total receipts and payments of each institution, in which the payment A$612m is from households and the payment A$8854m is from non-financial corporations, while the receipts are recorded in household account of A$19m, non-financial account of A$112m and government account of A$9335m. The total receipts is equal to the total outlays in this account in step 1.

It is assumed in step 2 that the rent on natural assets received by households and non-financial corporations is paid only by non-financial corporations. Whereas, the rent on natural assets paid by households is received only by the government. The government receives the rent on natural assets from both households and non-financial corporations, thus the payment of A$612m is paid by households to the government, and the residual receipt of the government is A$8723m (=9335-612) paid by non-financial corporations.

Table 4.18: Rent on natural assets flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							19	19
Corps-nf							112	112
Corps-f							0	0
GOV							9335	9335
ROW							0	0
Total							9466	9466
Unallocated	612	8854	0	0	0	9466		
Original	612	8854	0	0	0	9466		
Step 2								
HH		19				19	0	19
Corps-nf		112				112	0	112
Corps-f						0	0	0
GOV	612	8723				9335	0	9335
ROW								
Total	612	8854	0	0	0			
Unallocated	0	0	0	0	0			
Orignal	612	8854	0	0	0			

Source: Computed from the ASNA (2009), 2010-2011

- **Social assistance benefit flows**

The social assistance benefit transactions among institutions are shown in Table 4.19. As given in the ASNA institution accounts, the household account presents secondary income receivable of A$112820 million from social assistance benefits and the general government account shows secondary income payable of A$112820m as social assistance benefits in cash to residents. The allocation of social assistance benefit is straightforward as the government only pays this benefit to households, therefore, the benefit paid and the benefit received are equal.

Table 4.19: Social assistance benefit flows (A$m)

	HH	Corps -nf	Corps -f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							112820	112820
Corps-nf							0	0
Corps-f							0	0
GOV							0	0
ROW							0	0
Total							112820	112820
Unallocated	0	0	0	112820	0	112820		
Original	0	0	0	112820	0	112820		
Step 2								
HH				112820		112820	0	112820
Corps-nf						0	0	0
Corp-f						0	0	0
GOV						0	0	0
ROW						0	0	0
Total	0	0	0	112820	0			
Unallocated	0	0	0	0	0			
Original	0	0	0	112820	0			

Source: Computed from the ASNA (2009), 2010-2011

- **Non-life insurance claim flows**

The receipts and payments on non-life insurance claims between institutions is shown in Table 4.20. In step 1, the total receipts of A$33247m and A$4317m are collected from the ASNA institution accounts for households and non-financial corporations respectively, meanwhile the total payments of A$37564m is allocated to financial corporations. The total receipts is equal to the total payments in this account. It is clear that the receipt of households and non-financial corporations is paid by financial corporations. That is presented in step 2.

Table 4.20: Non-life insurance claim flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							33247	33247
Corps-nf							4317	4317
Corps-f							0	0
GOV							0	0
ROW							0	0
Total							37564	37564
Unallocated	0	0	37564	0	0	37564		
Original	0	0	37564	0	0	37564		

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 2								
HH			33247			33247	0	33247
Corps-nf			4317			4317	0	4317
Corps-f						0	0	0
GOV						0	0	0
ROW						0	0	0
Total	0	0	37564	0	0			
Unallocated	0	0	0	0	0			
Original	0	0	37564	0	0			

Source: Computed from the ASNA (2009), 2010-2011

- **Non-life insurance premium flows**

Table 4.21 shows the allocation of non-life insurance premiums among institutions. As seen in step 1, the paying institutions are households, non-financial corporations and foreigners, and the receiving institutions are financial corporations and foreigners. It is assumed in step 2 that non-life insurance premiums are paid by households, non-financial corporations and foreigners to financial corporations. A$6030m of the non-life insurance premiums is paid by non-financial corporations to financial corporations, foreigners pay A$1163m to financial corporation and the amount received by financial corporations from households is determined by the residual with the value of A$29775m (=36968-6030-1163). Foreigners are assumed to receive the non-life insurance premiums only from households with a value of A$1239m.

Table 4.21: Non-life insurance premium flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated	Original
Step 1								
HH							0	0
Corps-nf							0	0
Corps-f							36968	36968
GOV							0	0
ROW							1239	1239
Total							38207	38207
Unallocated	31014	6030	0	0	1163	38207		
Original	31014	6030	0	0	1163	38207		
Step 2								
HH						0	0	0
Corps-nf						0	0	0
Corps-f	29775	6030			1163	36968	0	36968
GOV						0	0	0
ROW	1239					1239	0	1239
Total	31014	6030	0	0	1163			
Unallocated	0	0	0	0	0			
Original	31014	6030	0	0	1163			

Source: Computed from the ASNA (2009), 2010-2011

- **Current transfer flows**

The allocations of current transfers among institutions are presented in Table 4.22. As seen in Step 1, the receipts and outlays of current transfers to each institution are recorded in the unallocated column and row. The paying institutions include all five institutions, while receiving institutions contain four out of the five institutions, except for financial corporations. It is assumed that the current transfers take place among all institutions, thus the current transfer paid by each institution to all institutions is calculated by the proportion of unallocated elements in the unallocated row in Step 1.

Step 2 presents the allocation of current transfers between institutions. In particular, the transfer paid by households to households is A$4023m (=25655*5426/34614), the transfer paid by households to foreigners is AS992m (=6331*5426/34614), transfer paid by government to non-financial corporations is A$381m (=552*23911/34614).

Table 4.22: Current transfer flows (A$m)

	HH	**Corps-nf**	**Corps-f**	**GOV**	**ROW**	**Total receipts**	**Unallocated**	**Original**
Step 1								
HH							25665	25665
Corps-nf							552	552
Corps-f							0	0
GOV							2066	2066
ROW							6331	6331
Total							34614	34614
Unallocated	5426	1953	197	23911	3127	34614		
Original	5426	1953	197	23911	3127	34614		
Step 2								
HH	4023	1448	146	17729	2319	25665	0	25665
Corps-nf	87	31	3	381	50	552	0	552
Corps-f	0	0	0	0	0	0	0	0
GOV	324	117	12	1427	187	2066	0	2066
ROW	992	357	36	4373	572	6331	0	6331
Total	5426	1953	197	23911	3127			
Unallocated	0	0	0	0	0			
Original	5426	1953	197	23911	3127			

Source: Computed from the ASNA (2009), 2010-2011

- **Income tax flows**

The allocation of income tax between institutions is recorded in Table 4.23 as provided in the ASNA institution accounts. It is clear that the receipt of income tax is displayed only in the government account, while the payment of income tax is presented in all other institution accounts. Therefore, general government is the only receiving institution, while all other institutions are paying institutions. The total income tax paid by the four institutions is equal to the total income received by the government.

Table 4.23: Income tax flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total receipts	Unallocated
HH						0	0
Corps-nf						0	0
Corps-f						0	0
GOV	136326	42270	16015	0	1916	196527	196527
ROW						0	0
Total	136326	42270	16015	0	1916		196527
Unallocated	136326	42270	16015	0	1916	196527	

Source: Computed from the ASNA (2009), 2010-2011

- **Total income flows**

Total income flows between institutions in the income account are recorded in the Table 4.24. This data is obtained by adding the income flows of nine categories: interest flows, dividend flows, reinvested earning flows, natural asset flows, social assistance benefit flows, non-life insurance claim flows, non-life insurance premium flows, current transfer flows, and income tax flows as described above.

Table 4.24: Total income flows (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW
HH	4023	17742	129755	130549	8432
Corps-nf	7145	5704	22946	381	6922
Corps-f	99797	70139	7764	10132	5315
GOV	137262	56525	18660	1427	9955
ROW	2231	21305	42657	10374	16365
Total outlays	**250458**	**171414**	**221783**	**152864**	**46989**
Total receipts	**290501**	**43098**	**193147**	**223829**	**92933**

Source: Sum up from Table 4.15 to Table 4.23

4.2.2.4 Flows in the financial account

A financial account records the net acquisition of financial assets as well as the net incurrence of liabilities for all institutional sectors by the types of financial assets. Such assets include currency and deposits, bills of exchange, one name paper, bonds, derivatives, loans and placements, shares and other equity, insurance technical reserves, other accounts payable, and non-flow items. A change in a financial position is attributed to the value of non-flow items of each institutional sector. The financial flow matrix presents the amount of such financial assets bought and sold by various institutions. In the financial pattern, the total of row sums is equal to the total of column sums for each financial asset, but in the case of some financial assets, this balance does not occur, so an adjustment needs to be made. The financial account of each institution to each type of financial asset is presented as follows:

- **Currency and deposits transactions**

The acquisition and incurrence of liability of currency and deposits to each institution are presented in the step 1 in Table 4.25 (expressed in millions of Australian dollars) as given in the ASNA institution accounts; the acquisitions are recorded as rows and the incurrence of liability are recorded as columns of each institution account. The total of the row sums is not equal to the total of the column sums; therefore, it is adjusted to meet this requirement. The difference (200) is assigned to the acquisition of currency and deposits to the external sector.

Table 4.25: Currency and deposits transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						74800
Corps-nf						42600
Corps-f						27600
GOV						1400
ROW						18900
Total	0	0	135000	200	30100	165300
Step 2						
HH			61089	91	13621	74800
Corps-nf			34791	52	7757	42600
Corps-f			22541	33	5026	27600
GOV			1143	2	255	1400
ROW			15436	23	3442	18900
Total	0	0	135000	200	30100	165300

Source: Computed from the ASNA (2009), 2010-2011

The transactions between institutions are presented in step 2. In particular, the acquisition of A$61089m to households from financial corporation is defined as 74800*135000/165300 and the acquisition of A$255m to government from external sector is computed as 1400*30100/165300.

- **Bills of exchange transactions**

The total acquisition of bills of exchange for each institution is presented in the total column and the total incurrence of liabilities is shown in the total row in Step 1 in Table 4.26 as given in the ASNA institution accounts. As there is a difference between total of column sums and total of row sums provided by the ASNA institution accounts, the acquisition of bills of exchange to the external sector is adjusted to be reduced by A$100m. In Step 2, A$400m is added to each cell of the matrix, except the non-financial corporations row and external sector column, thus A$1600m is added to each cell of the total column and of the total row, except the cells that have zero value.

Table 4.26: Bills of exchange transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HHH						-200
Corps-nf						0
Corps-f						8000
GOV						-100
ROW						-900
Total	1700	6000	-1200	300	0	6800
Step 2						
HH						1400
Corps-nf						0
Corps-f						9600
GOV						1500
ROW						700
Total	3300	7600	400	1900	0	13200
Step 3						
HH	350	806	42	202		1400
Corps-nf						0
Corps-f	2400	5527	291	1382		9600
GOV	375	864	45	216		1500
ROW	175	403	21	101		700
Total	3300	7600	400	1900	0	13200
Step 4						
HH	-50	406	-358	-198		-200
Corps-nf	0	0	0	0		0
Corps-f	2000	5127	-109	982		8000
GOV	-25	464	-355	-184		-100
ROW	-225	3	-379	-299		-900
Total	1700	6000	-1200	300	0	6800

Source: Computed from the ASNA (2009), 2010-2011

The bills of exchange transactions among institutions are calculated based on the proportion of total incurrence of liabilities of each institution. These transactions are presented in Step 3. For example, the bills of exchange A$806m received by households from non-financial corporations is computed from 1400*7600/13200, or the bills of exchange A$2400m paid by households to financial corporations is calculated as 9600*3300/13200. In Step 4, the value in each cell is deducted by A$400m from the value in Step 3.

- **Transactions of one name paper issued in Australia**

Table 4.27 shows the transactions of one name papers issued in Australia among institutions. The total receipts of each institution are displayed in the total column and the total outlays of each institution are presented in the total row in Step 1 as collected from the ASNA institution accounts. All numbers are expressed in millions of Australian dollars.

Table 4.27: Transactions of one name paper issued in Australia (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						-6000
Corps-nf						-19700
Corps-f						12800
GOV						300
ROW						1200
Total	0	-2500	-25600	16700	0	-11400
Step 2						
HH						15000
Corps-nf						1300
Corps-f						33800
GOV						21300
ROW						22200
Total		32500	9400	51700		93600
Step 3						
HH		5208	1506	8285		15000
Corps-nf		451	131	718		1300
Corps-f		11736	3394	18669		33800
GOV		7396	2139	11765		21300
ROW		7708	2229	12262		22200
Total	0	32500	9400	51700		93600
Step 4						
HH		-1792	-5494	1285		-6000
Corps-nf		-6549	-6869	-6282		-19700
Corps-f		4736	-3606	11669		12800
GOV		396	-4861	4765		300
ROW		708	-4771	5262		1200
Total	0	-2500	-25600	16700		-11400

Source: Computed from the ASNA (2009), 2010-2011

It is assumed that each cell in the matrix is added by A$7000m, except cells in households and external columns, thus A$35000m is added to each cell in total row in Step 2 from the values in Step 1, except the household total row and the external total row, while A$21000m is added to each cell in total column in Step 2 from value in Step 1. In Step 3, the one name paper paid by non-financial, financial corporations and the government to all five institutions is calculated based on the proportion of the total outlays of each institution. For example, the receipts of A$5208m to households from non-financial corporations is calculated as 15000*32500/93600, or the payment of A$18669m from government to financial corporation is calculated as 33800*51700/93600. In Step 4, the value in each cell in Step 3 is deducted by A$7000m that was added in Step 2. Therefore, the transaction of one name paper issued in Australia is presented in Step 4.

- **Transactions of one name paper issued offshore**

Some one name papers are issued in other countries and traded among institutions in Australia, the data of this financial asset is recorded in the ASNA institution accounts.

Table 4.28: Transactions of one name paper issued offshore (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						0
Corps-nf						0
Corps-f						-400
GOV						300
ROW						-47900
Total	0	-2500	-45400	0	-100	-48000
Step 2						
HH						0
Corps-nf						0
Corps-f						47600
GOV						48300
ROW						100
Total	0	45500	2600	0	47900	96000
Step 3						
HH						0
Corps-nf						0
Corps-f		22560	1289		23750	47600
GOV		22892	1308		24100	48300
ROW		47	3		50	100
Total	0	45500	2600	0	47900	96000
Step 4						
HH						0
Corps-nf						0
Corps-f		6560	-14711		7750	-400
GOV		6892	-14692		8100	300
ROW		-15953	-15997		-15950	-47900
Total	0	-2500	-45400	0	-100	-48000

Source: Computed from the ASNA (2009), 2010-2011

As seen in Step 1 in Table 4.28, the receiving institutions include financial corporations, the government, and the external sector, while the paying institutions incorporate non-financial, financial corporations, and the external sector. In Step 2, each cell in the matrix, except households and the government columns, and households and non-financial corporation rows, are added by A$16000m, thus each cell in the total column and in the total row is added by A$48000m, except for cells that have zero value. The method to calculate the transactions among institutions in Step 3 and Step 4 is similar to that in transactions of one name paper issued in Australia.

- **Transactions of bond issued in Australia.**

Similar to one name paper, bonds are issued in Australia and overseas. Table 4.29 shows the transactions of bonds issued in Australia among institutions. Data for the acquisition and incurrence of liabilities of bonds issued in Australia are collected from the ASNA institution accounts. To get the balance between the total acquisition and total incurrence of bonds, A$3100m is deducted from the incurrence of liability-bonds of the external account. The total bond acquisition and bond incurrence for each institution are presented in the total column and the total row in Step 1.

In Step 2, A$1000m is added to each cell in the matrix, except for cells in the household column. Thus each cell in the total row is increased by A$5000m, while each cell in the total column is increased by A$4000m, except for a cell that has a zero value. The method to calculate the transaction of bonds among institutions is similar to that in the one name paper. So, in Step 3 the value of each cell is increased up by A$1000m. To compute the real transactions among institutions, the value in each cell in Step 4 is decreased by A$1000m, compared to that in Step 3.

Table 4.29: Transactions of bond issued in Australia (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						-400
Corps-nf						4900
Corps-f						4500
GOV						13700
ROW						34500
Total	0	-3100	37200	27300	-4200	57200
Step 2						
HH						3600
Corps-nf						8900
Corps-f						8500
GOV						17700
ROW						38500
Total	0	1900	42200	32300	800	77200
Step 3						
HH		89	1968	1506	37	3600
Corps-nf		219	4865	3724	92	8900
Corps-f		209	4646	3556	88	8500
GOV		436	9675	7406	183	17700
ROW		948	21045	16108	399	38500
Total	0	1900	42200	32300	800	77200
Step 4						
HH		-911	968	506	-963	-400
Corps-nf		-781	3865	2724	-908	4900
Corps-f		-791	3646	2556	-912	4500
GOV		-564	8675	6406	-817	13700
ROW		-52	20045	15108	-601	34500
Total	0	-3100	37200	27300	-4200	57200

Source: Computed from the ASNA (2009), 2010-2011

- **Bond issued offshore transactions**

The bonds issued in other countries are traded among institutions as shown in Table 4.30. The acquisition and incurrence of liabilities of these bonds to each institution are collected from the ASNA institution accounts. It is clear that all institutions in Australia hold bonds issued offshore, but only households do not pay bonds to any institutions. To get the balance between the total acquisition of bonds and the total incurrence of bonds, A$100m is added to the acquisition of bonds to the external sector in Step 1.

Table 4.30: Bond issued offshore transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						100
Corps-nf						5100
Corps-f						-7900
GOV						5700
ROW						17000
Total	0	33600	-16800	100	3100	20000
Step 2						
HH						16100
Corps-nf						21100
Corps-f						8100
GOV						21700
ROW						33000
Total	0	53600	3200	20100	23100	100000
Step 3						
HH		8630	515	3236	3719	16100
Corps-nf		11310	675	4241	4874	21100
Corps-f		4342	259	1628	1871	8100
GOV		11631	694	4362	5013	21700
ROW		17688	1056	6633	7623	33000
Total	0	53600	3200	20100	23100	100000
Step 4						
HH		4630	-3485	-764	-281	100
Corps-nf		7310	-3325	241	874	5100
Corps-f		342	-3741	-2372	-2129	-7900
GOV		7631	-3306	362	1013	5700
ROW		13688	-2944	2633	3623	17000
Total	0	33600	-16800	100	3100	20000

Source: Computed from the ASNA (2009), 2010-2011

In Step 2, each cell in the matrix is increased by A$4000m, except cells in the household column; thus each cell in the total column is increased by A$16000m to its value in Step 1, while each cell in total row is increased by A$20000m to its value in Step 1, except a cell that has zero value. The transactions of bonds issued offshore among institutions are calculated by the same method as presented above for other financial assets. The value in each cell in Step 3 includes $4000m as increased in Step 2, while the amount in each cell in Step 4 is reduced by A$4000m.

- **Derivatives transactions**

Step 1 in Table 4.31 shows the total acquisitions and liabilities of derivatives to each institution as given in the ASNA institution accounts, and the amount is expressed in millions of dollars. In order to reach the equivalence between the assets and liabilities, A$100m is added to the acquisition of derivatives of the external sector. The derivatives transactions among institutions are calculated based on the proportion of the total payment on the financial asset of each institution, as shown in Step 2. For example, the amount that non-financial corporations paid in derivatives to financial corporations is –A$3919m (= (-39700)*(-8400)/(-85100), or the general government received derivatives from financial corporations is –A$1329m (=(-2900)*(-39000)/(-85100)).

Table 4.31: Derivatives transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						0
Corps-nf						-8000
Corps-f						-39700
GOV						-2900
ROW						-34500
Total	0	-8400	-39000	-7000	-30700	-85100
Step 2						
HH						0
Corps-nf		-790	-3666	-658	-2886	-8000
Corps-f		-3919	-18194	-3266	-14322	-39700
GOV		-286	-1329	-239	-1046	-2900
ROW		-3405	-15811	-2838	-12446	-34500
Total	0	-8400	-39000	-7000	-30700	-85100

Source: Computed from the ASNA (2009), 2010-2011

- **Loans and placements transactions**

The loans and placements transactions among the institutions are presented in Table 4.32. In Step 1, the total column represents the acquisition of loans and placements of each institution, while the total row shows the liabilities of loans and placements of each institution, as given by the ASNA institution accounts. The method to calculate the amount purchased and sold from each institution is similar to that for calculating the derivatives transaction.

Table 4.32: Loans and placements transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						0
Corps-nf						9200
Corps-f						104200
GOV						20500
ROW						29500
Total	65000	22000	42800	5900	27700	163400
Step 2						
HH	0	0	0	0	0	0
Corps-nf	3660	1239	2410	332	1560	9200
Corps-f	41450	14029	27294	3762	17664	104200
GOV	8155	2760	5370	740	3475	20500
ROW	11735	3972	7727	1065	5001	29500
Total	65000	22000	42800	5900	27700	163400

Source: Computed from the ASNA (2009), 2010-2011

- **Shares and other equities transactions**

The acquisition of shares and other equities of each institution is displayed in the total column and the liabilities of each institution is portrayed in the total row in Step 1 in Table 4.33. The total acquisition is equal to the total liabilities of this financial asset. To make positive the negative numbers in the total column in Step 1, A$4000m is added to each cell in the matrix in Step 2, except for the cells in households and general government columns that have zero value. Therefore, in Step 2, each cell in the total row is increased by A$20000m, while each cell in the total column is increased by A$12000m, compared to those in Step 1.

Table 4.33: Shares and other equities transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						-8600
Corps-nf						2400
Corps-f						51300
GOV						-11900
ROW						85200
Total	0	99700	1200	0	17500	118400

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 2						
HH						3400
Corps-nf						14400
Corps-f						63300
GOV						100
ROW						97200
Total		119700	21200		37500	178400
Step 3						
HH		2281	404		715	3400
Corps-nf		9662	1711		3027	14400
Corps-f		42472	7522		13306	63300
GOV		67	12		21	100
ROW		65218	11551		20432	97200
Total	0	119700	21200	0	37500	178400
Step 4						
HH		-1719	-3596		-3285	-8600
Corps-nf		5662	-2289		-973	2400
Corps-f		38472	3522		9306	51300
GOV		-3933	-3988		-3979	-11900
ROW		61218	7551		16432	85200
Total	0	99700	1200	0	17500	118400

Source: Computed from the ASNA (2009), 2010-2011

By applying the same method as for other financial assets to calculate the transactions among institutions, the amount of shares and other equities purchased and sold among institutions includes A$4000m in Step 3, but excludes A$4000m in Step 4. It is clear that households and the government do not pay for shares and other equities to any other institutions.

- **Insurance technical reserves transactions**

The acquisitions and liabilities of insurance technical reserves of each institution are presented in the total column and total row respectively in Step 1 in Table 4.34. The data is collected from the ASNA institution accounts. A$100m is deducted from the acquisition of this financial asset to the external sector to obtain the equivalence between the total acquisition and the total liabilities. All values are expressed in millions of Australian dollars. The method of calculation for the insurance technical reserves transactions among the institutions is similar to that for the loans and placements transaction.

Table 4.34: Insurance technical reserves transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						75900
Corps-nf						2000
Corps-f						0
GOV						0
ROW						100
Total	0	0	72800	4100	1100	78000
Step 2						
HH			70840	3990	1070	75900
Corps-nf			1867	105	28	2000
Corps-f			0	0	0	0
GOV			0	0	0	0
ROW			93	5	1	100
Total	0	0	72800	4100	1100	78000

Source: Computed from the ASNA (2009), 2010-2011

- **Other account payable transactions**

The total column and total row in Step 1 in Table 4.35 presents the receipts and payments for each institution to other accounts payable. Some acquisitions of this financial asset are adjusted compared to the data provided by the ASNA institution accounts to obtain the balance between the total column and the total row for each institution. In particular, the acquisition to non-financial corporations is increased by A$300m, and for financial corporations and the government, A$200m is deducted. Thus the total acquisition is equal to total liabilities of other accounts payable for all institutions.

There are negative numbers in the total receipts and payments of some institutions. To remove these negative numbers, A$4000m is added to each cell of the matrix. Therefore, each cell in the total column and in the total row in Step 2 is increased by A$20000m compared to that in Step 1. A similar method for calculating the transactions of other accounts payable among institutions is as presented above for other financial assets. A$4000m is removed from the value of each transition among the institutions in Step 4.

Table 4.35: Other account payable transactions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
Step 1						
HH						-3900
Corps-nf						32300
Corps-f						-5700
GOV						2700
ROW						-3600
Total	2000	2300	-19700	22700	14500	21800
Step 2						
HH						16100
Corps-nf						52300
Corps-f						14300
GOV						22700
ROW						16400
Total	22000	22300	300	42700	34500	121800
Step 3						
HH	2908	2948	40	5644	4560	16100
Corps-nf	9447	9575	129	18335	14814	52300
Corps-f	2583	2618	35	5013	4050	14300
GOV	4100	4156	56	7958	6430	22700
ROW	2962	3003	40	5749	4645	16400
Total	22000	22300	300	42700	34500	121800
Step 4						
HH	-1092	-1052	-3960	1644	560	-3900
Corps-nf	5447	5575	-3871	14335	10814	32300
Corps-f	-1417	-1382	-3965	1013	50	-5700
GOV	100	156	-3944	3958	2430	2700
ROW	-1038	-997	-3960	1749	645	-3600
Total	2000	2300	-19700	22700	14500	21800

Source: Computed from the ASNA (2009), 2010-2011

- **Change in financial position**

Change in financial position is the difference between the acquisition of total financial assets and the incurrence of liabilities for each institution. The change in financial position to all institutions is allocated in the non-flow item presented in the original row of Table 4.36. The data was collected from the ASNA institution accounts and is expressed in million dollars.

Table 4.36: Non-item flows (change in financial position) (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW
HH					
Corps-nf					
Corps-f					
GOV					
ROW					
Total					
Original	63000	-76300	13400	-40600	40500

Source: Computed from the ASNA (2009), 2010-2011

- **Total financial assets transactions**

Financial assets are disaggregated into categories, including currency and deposits, bills of exchange, one name paper, bonds, derivatives, loans and placements, shares and other equity, insurance technical reserves, and other accounts payable. The transactions of each item between institutions are shown above in Tables 4.25 to 4.35. Table 4.37 shows the transactions of all financial assets between institutions, being the sum of transactions from Tables 4.25 to 4.35. The data in Table 4.36 presents the non-flow items.

Table 4.37: Total financial assets transactions between institutions (A$m)

	HH	Corps-nf	Corps-f	GOV	ROW	Total
HH	-1142	-438	116005	6553	10722	131700
Corps-nf	9106	11666	22912	10849	16266	70800
Corps-f	42033	63175	12678	14379	22434	154700
GOV	8230	13515	-17286	15810	9431	29700
ROW	10472	59181	6991	22709	147	99500
Non-flow items	63000	-76300	13400	-40600	40500	
Total	**131700**	**70800**	**154700**	**29700**	**99500**	

Source: Sum up from Table 4.25 to Table 4.36

4.2.2.5 Flows in the capital account

A capital account records the income of institutions from net saving and capital transfers and their payments for fixed assets (including gross fixed capital formation and changes in inventory) and capital transfers.

- **Payments related to production**

Gross fixed capital formation shows the payment of each institution for fixed assets, including expenditure on new fixed assets, second-hand fixed assets, expenditure on repairs and maintenances of fixed assets. According to the Use Table, these payments were from private, public enterprises, and general government. Table 4.38 shows the fixed assets usage of private and public enterprises, general government, and change inventory demand for fixed assets that include sources constituted from domestic and imported supply, margins and tax on products. The data in Table 4.38 is collected from the IO Tables, 2008-09 and the author's calculations.

Table 4.38: Gross fixed capital formation and change in inventory in the Use Table (A$m)

	Private enterprise	Public enterprise	Private + public enterprises	Government	Change in inventory
Domestic use	204536	20801	225337	34173	-537
Imports	43307	1436	44743	6476	-2188
Margins	18418	659	19077	1931	-269
Tax on products	17714	208	17921	1454	-64
Total	283975	23104	307079	44033	-3058

Source: Calculated by the author from the IO Tables, 2008-09

This study disaggregates amounts into four institutional sectors: households, non-financial corporations, financial corporations and government. Thus, the data in both the private and public enterprises columns is disaggregated into the data of three columns in Table 4.39: household column, non-financial corporation column, and financial corporation column. The total payment for fixed assets is provided by the ASNA institution accounts, 2010-2011. Hence, the payment of each source of commodities is calculated based on the proportion of payment.

Table 4.39: Disaggregation of gross fixed capital formation to institutions (A$m)

	Households	Corporations (nf)	Corporations (f)	Government
Domestic commodity	81927	136688	6722	34173
Import commodity	16268	27141	1335	6476
Margins	6936	11572	569	1931
Tax on products	6516	10871	535	1454
Total	**111646**	**186272**	**9161**	**44033**

Source: Calculated by the author from the IO Tables, 2008-09

In particular, the payment of households on domestic use is A$81927m (=225337/307079*111646), the payment of non-financial corporations is A$136688m (=225337/307079*186272), and the expenditure of financial corporations is equivalent to A$6722m (=225337/307079*9161). This method is also applied to calculate the usage of imports, margins and tax on products for each institution. For the government, because of the same total number of payments for each published source in the IO Table and in the ASNA, 2010-2011, the numbers in the government column in Table 4.38 is the same as that in Table 4.39.

For change in inventory, the value of that change in Table 4.38 is divided among all four institutions: households, financial corporations, non-financial corporations and general government. Based on the ASNA institution account, the total of change inventory demand for each institution is shown in the total row in Table 4.40. The method to calculate the inventory demand of each institution for sources of commodities is similar to that in the gross fixed capital formation. For example, the inventory demand of households for domestic commodities is A$8m (=45*(-537)/(-3058)), or the change in inventory of imported commodities supplied to non-financial corporations is –A$2231m (= ((-3118)*(-2188)/(-3058), or the change in inventory of margins supplied to financial corporations is A$74m (=842*(-269)/(-3058), and the inventory demand of government for tax on products is –A$17m (= (-827)*(-64)/(-3058)). The results are shown in Table 4.40.

Table 4.40: Disaggregation of change in inventory for institutions (A$m)

	Households	Corporations (nf)	Corporations (f)	Government
Domestic commodity	8	-548	148	-145
Import commodity	32	-2231	602	-592
Margins	4	-274	74	-73
Tax on product	1	-65	18	-17
Total	**45**	**-3118**	**842**	**-827**

Source: Calculated by the author from the IO Tables, 2008-2009

Table 4.41 shows the sum up of Table 4.39 and Table 4.40 that is, combining the expenditure of institutions on gross fixed capital formation and on change in inventory, which, together, indicates the expenditure of each institution on commodities in the capital account.

Table 4.41: Combination of Table 4.39 and Table 4.40 (A$m)

	Households	Corporations (nf)	Corporations (f)	Government
Domestic commodity	81935	136140	6870	34027
Import commodity	16300	24910	1937	5884
Margins	6940	11298	643	1858
Tax les subsidy on product	6517	10806	552	1436
Total	**111691**	**183154**	**10003**	**43206**

Source: Calculated by the author from the IO Tables, 2008-2009

- **The receipts and payments of capital transfers between institutions**

The capital transfers between institutions are presented in the capital account. This data is collected from the ASNA institution accounts, 2010-2011 for the year 2009. As seen in Table 4.42, households receive and pay the capital transfer to only two institutions; namely, non-financial corporations and general government, while non-financial corporations also receive and pay capital transfers to only two institutions: households and general government. Financial corporations do not pay and receive the capital transfers to and from other institutions. Foreigners receive the capital transfers only from the government.

Table 4.42: Capital transfers transactions between institutions (A$m)

	Households	Corporations (nf)	Corporations (f)	Government	External	Total
Households		202		2132		2334
Corporations(nf)	373			4616		4989
Corporations (f)						0
Government	161	1449				1610
External				367		367
Total	534	1651	0	7115	0	

Source: Collected from the ASNA (2009), 2010-2011

In conclusion, the SAM represents the flows in the production and the transactions among institutions in the economy. In production, the SAM records the industry demand for intermediate inputs (including margins and tax values), primary factors as well as the demand of final users for commodities. In addition, the SAM records the transactions among institutions shown in the income account, financial account and capital account. There are many accounts in the SAM, in each account the total receipts is equal to the corresponding outlays. All data in the SAM is shown in Table 4.43.

Table 4.43: The SAM for Australia, 2009

Classification	Order	Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
			Production Activities						Factors of production			Income Account					Financial Account					Capital Account						
		Dimension	Industry	Commodity (domestic)	Commodity (imported)	Margins	Tax on products	Tax on production	Labour	Capital	Land	Households	Corporations (nf)	Corporations (f)	Government	Foreigners	Households	Corporations (nf)	Corporations (f)	Government	Foreigners	Households	Corporations (nf)	Corporations (f)	Government	Foreigners	non-flow items	Total
Production Activities	1	Industry		2220819		228544																						2449363
	2	Commodity (domestic)	1036363									453244			215992	256248						81935	136140	6870	34027			2220819
	3	Commodity (imported)	153282									64189			2902	7813						16300	24910	1937	5884			277218
	4	Margins	78505									106496			1703	21101						6940	11298	643	1858			228544
	5	Tax on products	12339									52285			0	-592						6517	10806	552	1436			83343
	6	Tax on production	35868												17628													53496
Factors of production	7	Labour	596098													1717												597815
	8	Capital	528069																									528069
	9	Land	8840																									8840
Income Account	10	Households							594598	175291	8840	4023	17742	129755	130549	8432												1069230
	11	Corporations (nf)								266949		7145	5704	22946	381	6922												310047
	12	Corporations (f)								59520		99797	70139	7764	10132	5315												252667
	13	Government					83343	53496		26308		137262	56525	18660	1427	9955												386976
	14	Foreigners			277218				3217			2231	21305	42657	10374	16365												373368
Financial Account	15	Households															-1142	-438	116005	6553	10722							131700
	16	Corporations (nf)															9106	11666	22912	10849	16266							70800
	17	Corporations (f)															42033	63175	12678	14379	22434							154700
	18	Government															8230	13515	-17286	15810	9431							29700
	19	Foreigners															10472	59181	6991	22709	147							99500
Capital Account	20	Households										142558											202		2132			144892
	21	Corporations (nf)											138633									373			4616			143622
	22	Corporations (f)												30884														30884
	23	Government													-4113							161	1449					-2503
	24	Foreigners														40090									367			40457
	25	non-flow items															63000	-76300	13400	-40600	40500	32666	-41183	20881	-52824	40457		
	26	Total	2449363	2220819	277218	228544	83343	53496	597815	528069	8840	1069230	310047	252667	386976	373368	131700	70800	154700	29700	99500	144891	143622	30884	-2503	40457		

Souce: Computed by the author from the Input-Output Tables, 2008-09 and the ASNA (2009), 2010-2011

4.3 Disaggregation and extension of the SAM

To achieve the objectives of this study, there is disaggregation on energy sectors, labour and households in the SAM. In particular, the four energy sectors are disaggregated into 24 sub-sectors, labour is categorised into 10 occupational groups, and households are divided into 20 household groups. The procedure of the disaggregation is presented in the following sections.

4.3.1 The input-output structure

An input-output table describes the flow of goods and services between all the individual sectors of a national economy over a stated period of time, a year (Leontief, 1986, pp. 19-20). The IO database is illustrated in Figure 4.1, including Absorption (Use) matrix, Make (Supply) matrix, and Tariff matrix. The Absorption matrix presents the commodity flows as well as the usage by producers of the primary factors, production tax and other costs in the production process. In this matrix, the column headings identify the demand categories:

+ Producers divided into i industries;

+ Investors divided into i industries;

+ Household divided into h household groups;

+ An aggregate foreign purchaser of exports;

+ Government demands; and

+ Changes in inventories.

The Absorption matrix contains both domestic and imported sources of commodities used as intermediate goods for production (V1BAS), capital formation (V2BAS), household consumption (V3BAS), government consumption (V5BAS) and changes in inventories (V6BAS). The V4BAS includes exports of domestically produced goods. Margins are divided into both domestic and imported goods that are used as intermediate goods (V1MAR) and final consumptions (V2MAR, V3MAR, V4MAR and V5MAR). There is no margin entry to change in inventories. Commodity taxes are paid by producers, investors, household and exporters. The indirect sales taxes are imposed on commodities supplied from both domestic and imported sources. The inventories account does not show the payment for indirect sale taxes.

		Absorption matrix					
		1	**2**	**3**	**4**	**5**	**6**
		Producers	**Investors**	**House-holds**	**Export**	**Government**	**Change in inventories**
	Size	**I**	**I**	**H**	**1**	**1**	**1**
Basic Flows	C*S	V1BAS	V2BAS	V3BAH	V4BAS	V5BAS	V6BAS
Margins	C*S*M	V1MAR	V2MAR	V3MAH	V4MAR	V5MAR	n/a
Taxes	C*S	V1TAX	V2TAX	V3TAH	V4TAX	V5TAX	n/a
Carbon emissions	C*S	EMI1 ETI1	0	EMC3 ETC3	0	0	0
Labor	O	V1LAB					
Capital	1	V1CAP					
Land	1	V1LND					
Production Tax	1	V1PTX					
Other costs	1	V1OCT					

I = Number of Industries
C = Number of Commodities
S = Domestic; Imported
O = Number of Occupation Types
M = Number of Commodities used as Margins

Make matrix

	Joint production matrix
Size	**I**
C	MAKE
C	Carbon emissions (EMO1, ETO1)

Tariff matrix

	Import Duty
Size	**1**
C	V0TAR

Figure 4.1: IO Database
Source: Horridge (2003)

For capital formation (V2BAS), the Absorption Table provided the gross fixed capital formation for each commodity by the total industries instead of for each industry; therefore, there is a need to disaggregate this data for each industry establishing the investment matrix that is consistent with the structure of the database. The disaggregation of this data for each industry is based on data reported in the Industry Performance by Industry Subdivision Table published by the Australian Bureau Statistics (ABS, 2010). This table provided the gross fixed capital formation of 95 industries. The values of those 95 industries are mapped to 131 industries in the Use Table using the output ratios of industries. Therefore, the investment matrix was constructed based on the gross fixed capital formation shares for each industry.

The carbon emissions matrices are incorporated into the SAM in order to measure the effects of the Australian emissions reduction strategies. The assumption is that emissions generated by industries or households are proportional to their usage of energy commodities. Emissions generations are divided into those generated from using domestic and imported commodities. The stationary emissions and the stationary emissions intensity from input usage by industries are given by the input emissions matrix (EMI1) and the input emissions intensity matrix (ETI1) respectively. The consumption emissions matrix (EMC3) and the consumption emissions intensity matrix (ETC3) present the carbon emissions and emissions intensity related to the household consumption. There are no carbon emissions and emissions intensity shown in government consumption, capital formation, exports and change in inventories columns.

Current production requires not only intermediate inputs but also the inputs of primary factors such as labour (V1LAB), capital (V1CAP) and land (V1LND), in which the labour cost paid by each industry is divided into 10 occupation groups. Thus data from one labour row in the Absorption Table is disaggregated into 10 labour category rows. The matrix V1LAB incorporates the wage bill of labour paid by each industry for the occupation groups. The matrices V1CAP, V1LND show the rental value of capital and of land paid by industries.

Each industry can produce one or more commodities. The value of a commodity output by each industry is presented in the Make matrix. In addition, the activity emissions and activity emissions intensity related to the production process are provided by the output emissions matrix (EMO1) and the output emissions intensity matrix (ETO1). Therefore, there is consistency between data in the Make matrix and output carbon emissions matrix because it is assumed that increased commodity output produced by industries results in increased emissions generated by the industries. The tariff on imported goods is presented in the tariff matrix. The following sections present, in detail, the methods of disaggregation of energy sectors, labour categories and household groups.

4.3.2 Disaggregating energy sectors

According to the original IO Tables, 2008-09 (ABS, 2012c) provided by the Australian Bureau Statistics, there are 111 industries corresponding to an equal number of commodities. In this research, the disaggregation produces 131 industries corresponding to 131 commodities in the IO Tables, in which four are in the energy sector: coal mining, oil and gas extraction, petroleum and coal product manufacturing, and electricity generation; these are disaggregated into 24 sub-sectors based on the IO Tables (Product Details), 2008-09 as follows:

+ Coal mining (code 0601) sector is disaggregated into two sub-sectors: black coal (code a1) and brown coal (code a2).

+ Oil and gas extraction (code 0701) sector is disaggregated into five sub-sectors: crude oil (code b1), condensate (code b2), liquefied natural gas (code b3), natural gas (code b4), and other gases (code b5).

+ Petroleum and coal product manufacturing (code 0801) sector is disaggregated into eight subsectors: automotive petrol; gasoline refining or blending; motor spirit (including aviation spirit) (code c1), kerosene (including kerosene type jet fuel) (code c2), gas oil and fuel oil (excluding motor spirit and kerosene) (code c3), petroleum bitumen; residues of petroleum oils and bituminous minerals; petroleum coke (code c4), liquefied petroleum gas produced at refineries (code c5), lubricating, heavy petroleum and bituminous oils; solvents; topped/enriched crude, refining products n.e.c (code c6), bituminous mixtures and other articles of asphalt (code c7), other petroleum and coal product (code c8).

+ Electricity generation (code 2601) sector is disaggregated into nine subsectors: electricity-black coal (code d1), electricity-brown coal (code d2), electricity-oil (code d3), electricity-gas (code d4), hydro-electricity (code d5), electricity-wind (code d6), electricity-solar (code d7), electricity-biomass (code d8), electricity-biogas (code d9).

4.3.2.1 Procedure for disaggregation in the Supply Table

In the Supply Table, the columns represent industries, while the rows represent commodities. The values in a row display the commodity outputs produced by industries. Disaggregation of the data from initial energy sectors into sub-energy sectors by row or column depends on the specific characteristics of those energy industries. The procedure for calculating data of sub-energy sectors by row and column is as follows:

- **Row commodity disaggregation in the Supply table**

The IO Tables (Product Details), 2008-09 (ABS, 2012b) provide the outputs of sub-energy commodities produced by industries. For example, the coal commodity is disaggregated into black coal and brown coal commodities, the outputs of black and brown coal commodities are shown in Table 4.44. To petroleum and coal product manufacturing commodity, the 21 sub-commodities in the IO Tables (Product Details), 2008-09, are aggregated into eight sub-commodities in this research, in which sub-commodities that have a value of under A$500m are grouped into the other petroleum and coal product commodity (code c8).

Table 4.44: Row disaggregation for coal mining commodities (A$m)

Commodity \ Industry	Black coal	Brown coal	Australian supply
Black coal	56423		56423
Brown coal		984	984

Source: Collected from the IO Tables (Product Details), 2008-09

Row commodities, including oil and gas extraction, and electricity generation are further disaggregated in this research, comparing to the IO Tables (Product Details), 2008-09. Therefore, this research is based on other sources to compile the data for row commodity disaggregation, in particular:

+ ***Oil and gas extraction commodity***

The IO Tables (Product Details), 2008-09 publish the total output of crude oil (incl. condensate) commodity of A$16151m, divided into crude oil and condensate commodities in this research. According to the data provided by the ABS (Australian Bureau Statistics (ABS), 2011a), the output of crude oil commodity in 2008-09 was A$11971m, while the output of condensate commodity was A$4132m. This means that crude oil accounts for 74.34 per cent of the total output of crude oil and condensate commodities, and condensate makes up about 25.66 per cent. Based on these proportions, A$16151m is divided into A$12007m (=16151*74.34%) for crude oil output and A$4144m (16151*25.66%) for condensate output. The output of each sub-oil and gas extraction commodity is shown in Table 4.45.

Table 4.45: Row disaggregation for oil and gas extraction commodities (A$m)

Commodity \ Industry	Crude oil	Condensate	LPG	Natural gas	Other gases	Australian supply
Crude oil	12007					12007
Condensate		4144				4144
LPG			7243			7243
Natural Gas				7751		7751
Other gases					1940	1940

Source: Computed from the IO Tables (Product Details), 2008-09 and the Australian Industry, 2008-09

+ ***Electricity generation commodity***

The outputs of three sub-electricity commodities are provided in the IO Tables (Product Details), 2008-09, including electricity generated from fossil fuels, hydro-electricity, and electricity generation n.e.c. These are further disaggregated into nine sub-sectors in this research. Thus, this research is based on other sources to do the disaggregation. The Bureau of Resources and Energy Economics (BREE, 2013) provided the total output of each electricity type produced by non-renewable and renewable sources in the seven states and territories in Australia, as shown in Table 4.46. According to the BREE, the output percentage of each electricity type produced in Australia is as calculated and shown in the last column of Table 4.46. This research uses these proportions to disaggregate the output of each electricity type.

For instance, A$13002m of the output of electricity generated from fossil fuel in the IO Tables (Product Details), 2008-09 is divided to into A$7430m (=13002*57.1%) from electricity-black coal, A$3235m (= 13002*24.9%) from electricity-brown coal, A$2108m (=13002*16.2%) from electricity-gas, A$229m (13002*1.8%) from electricity-oil. Meanwhile, A$287m of the output of electricity generated from renewable sources is divided into A$174m (=287*60.6%) from electricity-wind, A$66m (=287*22.9%) from electricity-biomass, A$40m (=287*14.1%) from electricity-biogas, and A$7m (=287*2.5%) from electricity-solar.

Table 4.46: Australian electricity generation by fuel type-physical unit

	NSW	VIC	QLD	WA	SA	TAS	NT	AU	%
Non-renewable	**70525.7**	**54475.9**	**62072.4**	**24182.7**	**12181.3**	**718.1**	**2900.4**	**227056.5**	**100.0**
Black coal	67 650.3		51 912.6	10 180.2				129743.1	57.1
Brown coal		51 975.9			4 517.1			56493.0	24.9
Natural gas	2 688.0	2 475.5	9 574.4	12 358.5	7 600.7	705.3	1 418.0	36820.4	16.2
Oil products	187.4	24.5	585.5	1 644.0	63.5	12.8	1 482.4	4000.1	1.8
Renewable	**774.4**	**1 041.5**	**1 296.6**	**582.8**	**2 178.7**	**403.0**	**9.3**	**6286.3**	**100.0**
Biomass	291.3		1 148.9					1440.2	22.9
Biogas	282.9	333.1	115.0	52.7	66.2	24.9	9.1	883.9	14.1
Wind	44.2	708.4	32.7	530.1	2 112.5	378.1	0.2	3806.2	60.6
Solar	156.0							156.0	2.5

Source: Collected and computed from the BREE (2013)

The Supply Table shows that electricity is produced by 13 industries, and it is assumed that in 11 out of these 13 industries, the electricity is produced by natural gas, with the exception of the electricity generation industry (code 2601) and Electricity Transmission, Distribution, On Selling and Electricity Market Operation industry (code 2605). In these two industries (codes 2601 and 2605), the electricity is produced from various sources; hence this research is based on the proportion of total output of electricity type to calculate the output of each electricity type produced by the industry 2605. The output of each electricity type produced by industry 2601 is determined by a residual.

As shown in Table 4.47, the output of electricity generation from fossil fuels (A$284m) is calculated from 13002/14335*313, the output of electricity generation n.e.c (A$6m) is computed from 287/14335*313. The output of electricity-black coal produced from the industry 2605 (A$162m) is defined as 7430/13002*284, the output of electricity-wind produced from the industry 2605 industry (A$4m) is computed from 174/287*6. The output of electricity types produced by electricity generation (2601) is the residual. For example, the output of electricity-black coal is A$7267m (=7430-162), the output of electricity-gas produced by 11 industries is A$965m, so the output of electricity-gas produced by electricity generation industry is A$1097m (=2108-46-965).

Table 4.47: Output of electricity type produced by industries (A$m)

		2601	**2605**	
	Other industries	**Electricity generation**	**Commercial electricity**	**Total**
Electricity generation		13057	313	14335
Electricity generation from fossil fuels	965	11753	284	13002
Electricity - black coal		7267	162	7430
Electricity - brown coal		3164	71	3235
Electricity - oil		224	5	229
Electricity - gas	965	1097	46	2108
Hydroelectricity		1023	23	1046
Electricity generation nec		281	6	287
Electricity - wind		170	4	174
Electricity - wolar		7	0	7
Electricity - biomass		64	1	66
Electricity - biogas		39	1	40

Source: Computed from the Supply Table, 2008-2009

- **Column industry disaggregation in the Supply table**

The four energy industries by columns are disaggregated into the 24 sub-energy industries corresponding to the 24 energy commodity rows. Columns in the Supply Table represent outputs of various commodities and sub-commodities being produced by industries and sub-industries.

Table 4.48: Disaggregated industries by column in the Supply Table (A$m)

Industry / Commodity	…..	Coal mining	k1=56423/57407 Black coal	k2=984/57407 Brown coal	……	Total Australian supply
……		a1	k1*a1	k2*a1		
Coal mining		57407				57407
Black coal			56423			56423
Brown coal				984		984
……						
Exploration mining support system		2908	2858	50		
…….		a_k	k1*a_k	k2*a_k		

Source: Computed from the Supply Table and the IO Tables (Product Details), 2008-09

As illustrated in Table 4.48, each disaggregated industry is assumed to produce its own commodity, while the production capacity of each disaggregated industry to other commodities is proportional to its production levels. For instance, A$2908m of exploration and mining support service produced by the coal mining industry is divided into A$2858m (=2908*56423/57407) produced by the black coal industry and A$50m (=2908*984/57407) produced by the brown coal industry.

4.3.2.2 Procedure for disaggregation in the Use Table

The Use Table describes intermediate use by industries and final use by final consumers to various commodities in the economy. A column represents an industry or final user, or total use category, while a row represents a commodity. Four energy commodities by rows and the four energy industries by columns in the original Use Table are disaggregated into 24 sub-energy commodities by rows and 24 sub-energy industries by columns in the Use Table in this research in the same way as in the Supply Table discussed in sub-section 4.3.2.1.

- **Row commodity disaggregation in the Use Table**

The rows in the Use Table present the values of commodities supply industries and final consumers. Most of these values of sub-energy commodities by row are collected from the IO Tables (Product Details), 2008-09, except for crude oil, condensate and electricity generation types. In the Use Table, disaggregation from crude oil (including condensate) to crude oil and condensate commodities is based on the ratios of the total supply value of each commodity to the total supply value of these two commodities. For example, the total crude oil supply accounts for 74.34 per cent of total crude oil (including condensate) (=12007/(12007+4144)*100%), while the total condensate supply constitutes 25.66 per cent.

Hence, A$2652m of the crude oil (including condensate) supplied to the whole trade industry is divided into A$1972m (=2652*74.34%) from crude oil and A$680m (=2652*25.66%) from condensate.

For electricity generation types, the procedure for disaggregation of commodities by row is based on the ratios of the total supply of each sub-electricity commodity to the total supply of its main commodity in the Supply Table. As illustrated in Table 4.49, the values supplied from fossil fuel-electricity generation commodity to industries are disaggregated into black coal, brown coal, oil and gas-electricity generation commodities, while electricity generation n.e.c commodity supply is disaggregated into wind, solar, biomass and biogas-electricity generation commodities by the same method of disaggregation.

Table 4.49: Row commodity disaggregation to fossil fuel-electricity generation (A$m)

Industry / Commodity	…	Construction services	Wholesale Trade	Retail Trade	...	Total industry use	Total Australian supply in Supply table
Fossil fuel-elec generation		90	396	445		8679	13002
Black coal-elec		90*k1	396*k1	445*k1		8679*k1	7430 (k1=7430/13002)
Brown coal-elec		90*k2	396*k2	445*k2		8679*k2	3235 (k2=3235/13002)
Oil-elec		90*k3	396*k3	445*k3		8679*k3	229 (k3= 229/13002)
Gas-elec		90*k4	396*k4	445*k4		8679*k4	2108 (k4=2108/13002)

Source: Computed from the IO Tables (Product Details), 2008-09 and Table 4.47

- **Column industry disaggregation in the Use Table**

The columns present the usage of industries and the final users to commodities. Based on an assumption that the more output an industry produces the more input this industry uses, this research is based on the ratios of the total supply value of each sub-energy commodity to its aggregated energy commodity supply in order to disaggregate the values of energy industries into their sub-energy industries.

To the matrix intersected between disaggregated industries and disaggregated commodities, there is a difference between the energy sectors in their supply and demand. In particular, in the matrix intersection between sub-coal mining industries and sub-petroleum industries, black coal supplies three out of eight sub-petroleum industries: the sub-industry c4, the sub-industry c7, and the sub-industry c8, and brown coal supplies only one sub-industry, c8. In the matrix intersection between coal mining and electricity generation, black coal supplies electricity generated from black coal, and brown coal supplies to electricity generated from brown coal.

In the matrix intersection between sub-sectors of oil and gas extraction commodity and sub-sectors of petroleum and coal product manufacturing industry, crude oil and condensate supply to all sub-petroleum industries. Natural gas only supplies two sub-petroleum industries: the sub-industry c1 and the sub-industry c8. Other gases supply to three sub-petroleum industries: the sub-industry c1, the sub-industry c5 and the sub-industry c8. In the intersected matrix between sub-sectors of oil and gas extraction commodity and sub-sectors of electricity generation industry, natural gas only supplies to electricity generated from gas. In the matrix intersection between sub-sectors of petroleum and coal product manufacturing commodity and sub-sectors of electricity generation industry, the gas oil or fuel oil commodity only supplies the electricity generated by oil, while other sub-commodities of petroleum and coal product manufacturing supply all sub-electricity generation industries based on their output ratio in the Supply Table.

4.3.2.3 The procedure for disaggregation in the Import Table

In the Import Table, the four energy commodities and industries are disaggregated into 24 sub-sectors similarly to those in the Use Table and the Supply Table. The Use Table shows the values of commodities supplied to industries, including domestic and imported values. Therefore, the procedures of disaggregation for sub-energy commodities and sub-energy industries in the Use Table are applied consistently with those in the Import Table.

4.3.2.4 The procedure for disaggregation in the Margin, Tax and Subsidy Tables

There are 12 margin tables in the IO Tables: wholesale, retail, restaurant, road transport, rail transport, pipeline transport, water, air transport, port handling, marine insurance, gas, and electricity margins. Tax and Subsidy Tables include the goods and services tax (GST), Import duty, taxes on products NEI (not elsewhere identified), and Subsidy Tables. The procedure of disaggregation for sub-energy commodities and sub-energy industries in the Use Tables are similarly applied in these tables.

4.3.3 The procedure for labour disaggregation

Labour is categorized into ten occupational groups in the extension of the SAM based on the data in the Household Expenditure Survey, 2009-2010 (ABS, 2012a). These ten occupations are: managers and administrators; professionals; technicians and trade workers; community and personal service workers; clerical and administrative workers; sales workers; machinery operators and drivers; labourers; foreigners; and others. The flows of receipts and payments for each category are provided in more detail. The receipts are from industries and foreigners, while payments are given to households and foreigners of each category.

The original Use Table provides the aggregate labour costs paid by 111 industries; these aggregate labour costs paid by the four energy industries are disaggregated into sub-energy industries based on the ratios of the output supply of each sub-energy industry to the total output supply of its energy industry. Moreover, the labour costs paid by industries and sub-industries are disaggregated into 10 occupational categories in this research. To do that, the 131 industries are aggregated into the 45 industries, then the labour costs paid by the 45 industries are disaggregated into each category. The procedure of labour disaggregation is based on the data provided by the Australian Bureau Statistics (ABS, 2011c), in which the ratios of each occupational category costs paid by each industry are computed and the 20 industries provided by this ABS source is mapped into 45 industries in the research.

4.3.4 The procedure for household disaggregation

This research disaggregates all Australian households into 20 household groups based on their income level, in which group 1 is the lowest income household group and group 20 is the highest income household group. One household column (or row) in the SAM is divided into 20 household columns (or rows). The household receipts and payments in the SAM are divided into 20 household groups. The following sections present the specific procedures used to divide each item of these household receipts and payments.

4.3.4.1 Household receipts

Households are one of five institutions that exist in the income account, the financial account and the capital account. Households receive income from various sources.

- **Receipts in the income account**

Household receipts in the income account include incomes from labour, capital and land as well as from economic transactions among institutions. The procedures used to divide these household incomes into 20 household groups are varied, based on the data in the HES, 2009-10, that is provided by the Australian Bureau Statistics (ABS, 2012a). In particular, Column 2 in Table 4.50 shows that the total household income of A$1069230m published in the Use Table, 2008-09, is shared to 20 household groups based on the total household income ratios of each household group to the sum of these 20 groups. Household income sourced from labour, social assistance benefits, non-life insurance claims and current transfers, as shown in columns

3, 4, 5 and 6, is based on the ratios presented in Appendix A1.1, which are used to divide the total household income to each group.

Column 7 in Table 4.50 displays the income residual of each household group. The division of household income from all other remaining sources is based on the residual ratios as shown in column 8 in Table 4.50. This is because the remaining sources, including income sourced from capital, land, interest, dividends, re-invested earnings and rent on natural assets, has similar characteristics to household investment.

Table 4.50: Household income disaggregation by group and source (A$m and %)

Group	**Total**	**Labour**	**Social Assistant Benefit**	**Non-life insurance claims**	**Current Transfer**	**Residual ($)**	**Residual (%)**
1	2	3	4	5	6	7 =2-3-4-5-6	8
Group 1	7418	672	3523	170	649	2405	0.79%
Group 2	13390	231	6685	0	1083	5391	1.78%
Group 3	14316	136	7271	0	1178	5730	1.89%
Group 4	15797	348	7084	0	1414	6951	2.29%
Group 5	18773	840	7678	0	1707	8548	2.82%
Group 6	21102	741	9915	0	1808	8638	2.85%
Group 7	22796	1432	9547	302	1896	9619	3.18%
Group 8	25029	2164	10082	297	2257	10228	3.38%
Group 9	28008	3994	9590	567	2277	11581	3.82%
Group 10	31462	6369	9572	1310	2251	11960	3.95%
Group 11	35703	11485	7918	1106	1945	13249	4.37%
Group 12	41776	17640	6976	1428	1740	13992	4.62%
Group 13	49007	25636	4977	3670	1340	13384	4.42%
Group 14	57036	35665	3742	1810	1033	14786	4.88%
Group 15	66119	44860	2119	2901	663	15576	5.14%
Group 16	76454	53331	2426	6323	741	13632	4.50%
Group 17	89033	66021	1408	709	467	20428	6.74%
Group 18	105288	79851	963	4387	441	19645	6.49%
Group 19	131290	97622	689	1468	318	31192	10.30%
Group 20	219436	145560	656	6798	457	65966	21.78%
TOTAL	**1069230**	**594598**	**112820**	**33247**	**25665**	**302900**	**100.00%**

Source: Computed from the Use Table, 2008-09, based on the HES 2009-10

- **Receipts in the financial account**

In the financial account, households receive items through transmissions in financial assets among institutions. These financial assets include: currency and deposits; bills of exchange; one name paper; bonds; shares and other equity; insurance technical reserves and other accounts payable. For each item of financial assets, this research has a specific ratio with the different variables used to calculate the ratio of income obtained by each household group (see in the Appendix A1.2).

- **Receipts in the capital account**.

Household receipts in the capital account include savings and capital transfers. The savings of each household group is the difference between household receipts and payments of each group. This saving is allocated in the diagonal in the matrix intersected between income account and capital account. Meanwhile, the household receipts on capital transfers to each household group is computed as the ratio of each household group's receipts from different variables in the capital account (see in the Appendix A1.3).

4.3.4.2 Household payments

Household payments incorporate the household consumption on goods and services, and expenditure paid to institutions in the income account, the financial account and the capital account.

- **Expenditure in the income account.**

Household expenditure in the income account includes household consumption on goods and services and household expenditure paid to institutions as shown in the SAM in Table 4.43. These consumptions and expenditures are divided to 20 household groups in the extension of the SAM, as illustrated in Table 4.51. The division is based on various ratios that are calculated from household expenditure data in the HES, 2009-10. In particular, household consumption on domestic and imported commodities are divided to each group based on the ratios of consumption of each household group for each goods and service while household payments for taxes on products is based on the ratios of payment of each household group on the goods and services tax.

In addition, household outlays include their expenditure for interests; rents on natural assets; non-life insurance premium; current transfers and income tax to institutions. The ratios used to disaggregate these expenditures are presented in detail in Appendix A2.1. The margin is defined as the residual in the Table 4.51.

Table 4.51: Household expenditure disaggregation by group and item (A$m)

Group	Commodity (domestic)	Commodity (imported)	Margin	Tax on products	Income tax	Other sources	Total expenditure
Group 1	13346	1800	2932	1372	0	2564	22013
Group 2	9922	1209	3452	935	0	965	16483
Group 3	9733	1312	1612	907	0	894	14458
Group 4	11163	1416	673	960	0	1190	15403
Group 5	13152	1909	2949	1339	0	1608	20956
Group 6	14043	1995	2414	1450	16	1736	21654
Group 7	14594	2160	3173	1564	13	1517	23022
Group 8	15573	2138	4126	1643	29	1781	25292
Group 9	16363	2219	2342	1879	207	1862	24872
Group 10	17501	2382	3907	1937	538	2643	28909
Group 11	19727	2737	4475	2312	1200	3553	34004
Group 12	20935	2825	5152	2610	2467	4595	38585
Group 13	22368	3166	5130	2683	4047	5550	42945
Group 14	26301	3640	7473	3208	5823	7179	53623
Group 15	26387	3887	6594	3466	8215	8513	57063
Group 16	29666	4202	7038	3686	10292	9752	64636
Group 17	34799	5106	7381	4143	13569	11003	76002
Group 18	36724	5537	8115	4704	17291	13564	85935
Group 19	44298	6191	6763	5075	23737	15072	101135
Group 20	56649	8356	20794	6412	48881	18590	159683
Total	**453244**	**64189**	**106496**	**52285**	**136326**	**114132**	**926672**

Source: Computed from the Use table, 2008-09, the ASNA (2009), 2010-11, based on the HES 2009-10

- **Expenditure in the financial account**

In the financial account as shown in the SAM, households paid financial assets for institutions. With each financial asset, this study used various variables to calculate the ratios used to compute the amount of payment of each household group, as seen in the Appendix A2.2.

- **Expenditure in the capital account.**

Household payments in the capital account include expenditures on fixed assets, such as dwellings, non-dwelling construction, machinery, equipment, intellectual property product, and payments on capital transfers to institutions. To calculate the expenditure of each household group on fixed assets, this study used the ratios of total household expenditure in order to split household expenditure into each household group. The payments on tax are based on the ratios of the GST of each household group. The current transfer payments of households are based on the ratios of some variables (see in Appendix A2.3).

In conclusion, all flows and transactions in the Australian economy are described in the SAM table, in which the economic flows of 111 sectors and transactions among five institutions are presented in the SAM. There is a disaggregation of energy sectors, labour categories and household groups; thus, there are the flows and transactions of 131 sectors, 10 occupational categories and 20 household groups in the extension of SAM in the Australian economy. These 131 sectors were finally aggregated into 45 sectors in this research.

4.4 Constructing carbon emissions matrices

The National Greenhouse Gas Inventory (Department of the Environment, 2013c) classified greenhouse gas emissions into five sectors in Australia under the *Kyoto Protocol* framework, including:

+ Energy (combustion of fuels and fugitive emissions from fuels).
+ Industrial processes,
+ Agriculture,
+ Waste,
+ Land use, land-use change and forestry.

GHG emissions include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and synthetic gases (including HFCs, SF6, CF4, and C2F6). All emissions are standardised by being expressed as a carbon dioxide equivalent (CO_2-e). The emissions data was obtained in November 2013 for the year 2009 from the National Greenhouse Gas Inventory – Kyoto Protocol Classifications (Department of the Environment, 2013c). These emissions are a result of human activities, in particular related to the production and consumption of energy commodities and other commodities. Thus, there is a relationship between these emissions and production and consumption of goods and services in the IO tables. In particular, consuming commodities by industries and final users in the Use Table is able to generate emissions, while producing commodities by industries in the Supply Table also generate emissions. Therefore, in allocating emissions consistently, emissions generated from combusting fuels and using Halocarbons and Sulphur Hexafluoride in the production processes are allocated in the stationary emissions matrix, while emissions generated from the remaining sources are incorporated in the activity emissions matrix.

4.4.1 Activity emissions matrix

The activity emissions matrix includes emissions generated from fugitive emissions, industrial processes, agriculture, waste, land use, land-use change and forestry.

+ Fugitive emissions

Fugitive emissions occur during the extraction, processing and delivery of fossil fuels to the point of final use. The National Greenhouse Gas Inventory (NGGI) provides data on fugitive emissions from coal mining, and oil and gas extraction in the process of their production, storage and transport. Based on the disaggregation of these industries in the Supply Table, the fugitive emissions are also allocated to disaggregated industries according to the output ratios of each sub-industry (see Appendix B.2).

+ Industrial processes

The emissions generated from industrial processes that are not directly a result of energy consumed during the production processes, thus these emissions are allocated in the activity emissions matrix. For instance, the emissions generated from the transformation of raw materials, or produced from the production processes of iron and steel, coke, cement and lime, and aluminium. However, the emissions generated from the consumption of halocarbons and hexafluoride in the industrial processes is allocated to the stationary emissions matrix. The emissions from industrial processes is incorporated into the activity emissions matrix of each disaggregated industry based on its output ratio in the Supply Table (see Appendix B.3).

+ Agriculture

In the agricultural sector, agricultural land and activities produce emissions into the atmosphere as a result of natural and human-induce processes. Particularly, the emissions result in the decay, burning of biomass, fermentative digestion by ruminant livestock, stored animal manures, nitrogen fertilizer, and crop residues returned to the soil. Based on the total emissions generated by each industry, it is divided into each commodity produced by industry because of the ratios of commodity output produced by industry (see Appendix B.4).

+ Waste

Some emissions are, such as carbon dioxide, methane and nitrous oxide that are generated from the decomposition of organic materials from solid waste disposal in a landfill, sewage, incineration of waste, and the treatment processes of waste. The NGGI classified emissions from waste management into four categories: solid waste disposal on land, wastewater handling, waste incineration, and others. The emissions generated from wastewater handling is assigned to the water supply, sewage and drainage service industry (code 2801) and emissions from the other three categories are assigned to waste collection, treatment and disposal service industry (code 2901) (see Appendix B.5).

+ Land use, land-use change and forestry.

The land sector creates the change of emissions into the atmosphere through activities such as forest management and land management. In particular, afforestation/reforestation (or land converted to forest land) results in the decline of emitted emissions, while deforestation (land converted to crop land or grass land) leads to an increase in generated emissions. The emissions emitted by land use, land-use change and forestry are allocated in all agricultural industries based on the output produced by each industry.

4.4.2 Stationary emissions matrix

The fuel combustion emissions and emissions from using halocarbons and hexafluoride in the industrial processes are allocated to the stationary emissions matrix.

+ The fuel combustion emissions

The emissions from the combustion of fuel for energy are mainly CO_2; the quantity of CO_2 depends on the carbon content of the fuel and degree of combusted fuels (fully or partially). The methane and nitrous oxide emissions are quite small, depending on the combustion conditions such as combustion temperature, level of oxygen and reaction of nitrogen and oxygen. All GHG emissions are calculated together as CO2 equivalent (CO_2-e).

There are many types of fuels, such as solid fuels (black and brown coal), liquid fuels (crude oil, fuel oil, kerosene, liquefied petroleum gas, diesel/gas oil, other oil and other petroleum products), and gaseous fuels (natural gas, coal gas and liquefied natural gas). These fuel types are categorised into 15 energy commodities in this study, including commodities a1, a2, b1 to b5, and c1 to c8. The industries and final consumers use these energy commodities to combust in the production and consumption generated emissions into the atmosphere, thus these emissions are allocated in the stationary emissions matrix.

The energy sectors are disaggregated in the stationary emissions matrix in the same way as in the Use Table. It is assumed in the stationary emissions matrix that the amount of emissions generated by each industry, or sub-industry depends on their usage of energy products and the content of carbon in the energy products. Thus, the emissions generated by each industry in the stationary emissions matrix are consistent with its use of energy commodities in the Use Table. In addition, the emissions generated by industries depend on the emissions intensity of each energy commodity.

The NGGI provides emissions generated by fuel type corresponding to industry categories: energy industries, manufacturing industries, construction industries, transport industries, and other industries. These emissions are categorised into 131 industries in the stationary emissions matrix (see Appendix B.1). For each industry, its emissions generated was calculated based on its energy usage ratio. The emissions in the stationary emissions matrix are from both domestic and imported commodities, thus to obtain these emissions generated separately from domestics and imports, the author based on the emissions intensity between domestic and imported fuel types that were provided by the GTAP-E database (version 8, base year 2007) to calculate emissions of each industry from using both domestic and imported energy commodities.

+ Emissions from consuming halocarbons & sulphur hexafluoride

Emissions generated from the consumption of halocarbons and sulphur hexafluoride were allocated into the stationary emissions matrix because these emissions were emitted in their use in refrigeration, air conditioning equipment, fire extinguishers and medical equipment by industries and consumers. Refrigeration and air-conditioners are popularly used in the domestic, commercial and transport sectors. According to the IO Tables (Product Details) 2008-09, domestic refrigeration and air conditioners belong to the Domestic Appliance Manufacturing Commodity (2404), while commercial and transport refrigeration and air-conditioners are in the Specialized and other Machinery and Equipment Manufacturing Commodity (2405). The emissions generated from the usage of domestic refrigeration and air-conditioners were assigned to household consumers, while emissions generated from the usage of commercial and transport refrigeration and air-conditioners were assigned to industries based on the amount of these commodities supplied to industries. These amounts are provided by the IO Tables (Product details), 2008-2009.

The emissions generated from foam blowing, fire extinguishers, aerosol/metered dose inhalers, and electric equipment were treated in a different way. For example, foam blowing, fire extinguishers, and metered dose inhalers belong to the commodity 2405, electric equipment is included in both the Professional, Scientific, Computer and

Electronic Equipment Manufacturing Commodity (2401), and the Electrical Equipment Manufacturing Commodity (2403). Thus, these emissions were allocated to these commodities corresponding industries based on the supply ratio.

4.5 Conclusion

The main purpose of this chapter was to construct the SAM, with disaggregation on energy sectors, labour categories and household groups, as well as to allocate emissions to the activity emissions matrix and stationary emissions matrix. If the SAM describes the aggregated flows or transactions among economic agents in the Australian economy, disaggregation and extensiton of the SAM provides more detail on disaggregated flows and transactions, with the disaggregation of energy sectors into 24 sub-energy sectors to get the total sector of 131, of labour into 10 occupational groups and of households into 20 household groups. Thus, the extension of the SAM describes a highly disaggregated SAM at sectoral, occupational and household levels. In this study, 131 sectors are finally aggregated into 45 sectors for modelling purposes.

Constructing the SAM was based on the database that was collected from the IO Tables, 2008-2009, and the ASNA, 2010-2011 for the year 2009. To disaggregate the data of energy sectors, labour and households, this study used the database that was collected from the IO Tables (Product details), 2008-09, and Household Expenditure Survey, 2009-2010. The objective of this study is to measure the effects of an emissions trading scheme on distribution and welfare, thus this chapter adds one more section on the construction of emissions consistent with the IO Tables. The emissions data were collected from the National Greenhouse Gas Inventory.

CHAPTER 5: THE COMPUTABLE GENERAL EQUILIBRIUM MODEL OF THE AUSTRALIAN ECONOMY

As discussed in Chapter 2, CGE modelling has been used widely as a tool for analysing the effects of policy changes on all aspects of the economy. The structure of the database for the CGE model is presented in Chapter 4. In this chapter, the theoretical structure of the CGE model designed to assess the effects of an Emissions Trading Scheme (ETS) on the Australian economy is outlined in detail. This chapter is organised as follows: section 5.1 presents the theoretical structure of the CGE model, consisting of the equations describing: (1) demand for intermediate inputs and primary factors by industries; (2) investment demand; (3) household demand; (4) export, and government demands and inventory; (5) carbon emissions accounts; (6) price system and zero profit conditions; (7) market clearing equations; and (8) household, corporation, government and foreigner accounts. Elasticity compilation play a significant role in the CGE model because the values of the substitution elasticities in equations affect largely the impacts of policy changes, therefore, this chapter adds section 5.2 to describe how to collect the elasticity parameters used in this CGE model. The chapter ends with the conclusion in section 5.3.

5.1 The model structure

A CGE model describes the motivation and behaviour of all producers and consumers in an economy and the linkages among them. The CGE model includes a system of equations such as behavioural and identity equations. The behavioural equations describe the economic behaviour of producers, consumers and other agents in the economy. For example, the behavioural equations represent how firms minimise the costs of inputs to produce a specific level of outputs given the prices and technological constraints in their production process, or represent how consumers maximise their utility given the commodity prices and their budget. The identity equations are defined as mathematical functions, describing constraints in a CGE model to ensure that the market clearing constraints are solved, for example the total saving equals to the total investment or the aggregate supply equals to the aggregate demand for each factor.

There are exogenous and endogenous variables in equations in a CGE model. Exogenous variables have fixed values that do not change in the model, and endogenous variables are determined by the equations in the model. In a CGE model, the number of endogenous variables equals the number of equations and the choice of which variables are endogenous and which

variables are exogenous is very important because these affect the model results. All the equations in the model are solved simultaneously to find an economy wide equilibrium, in which, for some sets of prices, the quantities of supply and demand are equal in every market.
A CGE model incorporates exogenously given parameters that have constant values. There are many types of elasticities that depend on the types of production and utility functions assumed in the model, including factor substitution elasticity, factor mobility elasticity, income elasticity of demand, own- and cross-price substitution elasticity and export demand elasticity. The size of the elasticity value assumed in the model can affect the model results. Exogenous parameters also include shift parameters and share parameters that show the types of supply and demand functions used in a CGE model. The following sections describe in detail the CGE model applied in this study.

5.1.1 An overview of the CGE model in this study

The CGE model used in this thesis is based on the ORANI-G model (Horridge, 2003). The ORANI-G model incorporates a system of equations that describe the behaviour of producers and consumers in an economy for a given time period. There are a number of assumptions in the model, for example, agents are assumed to be price-takers (a perfect competition), and demand and supply equations for private-sector agents are derived from the solutions to the optimisation problems (cost minimisation or profit maximisation for producers, and utility maximisation for consumers). The model consists of equations describing the economy as follows:

+ Producers' demands for intermediate inputs and primary factors;

+ Producers' supplies of commodities;

+ Demands for inputs to capital formation;

+ Household demands for commodities;

+ Government demands for commodities;

+ Export demands;

+ The relationship of basic values to production costs and to purchasers' prices;

+ Market-clearing conditions for commodities and primary factors; and

+ Numerous macroeconomic variables and price indices.

In developing the model for this thesis, there have been modifications, compared to ORANI-G with the inclusion of detailed energy sectors, detailed electricity generation sectors, disaggregated households and detailed emissions in the Australian economy. These modifications include:

(i) The ORANI-G model treats energy commodities as intermediate inputs under the Leontief function. Hence, it does not allow substitution among energy commodities in the production process. However, to create a shift from high carbon intensive commodities to low carbon intensive commodities in response to reduced carbon emissions, this CGE model allows substitution between energy commodities, and treats energy and non-energy commodities separately. Moreover, this CGE model allows substitution between capital and energy composite under the primary factor part to complete the carbon emissions reduction strategies as proposed by the government.

(ii) This CGE model allows substitution among electricity generated by different sources. There are nine types of sources used to produce electricity in the model, including electricity produced from black coal, brown coal, oil, gas, hydro, wind, solar, biomass, and biogas.

(iii) This CGE model incorporates carbon emissions accounting.

(iv) The ORANI-G model has only one single household, but there are 20 household groups ranked by household income level in this present CGE model.

(v) The ORANI-G model is mostly based on the IO tables. In order to assess the distributional and welfare effects of the Australian emissions reduction strategies, this thesis requires more information on households that is only derived from a Social Accounting Matrix (SAM) as presented in Chapter 4. Thus, this CGE model is based on a SAM database.

The equations in the CGE model are presented as a series of linear equations relating to percentage changes in model variables. The functions applied in the CGE model include the Constant Elasticity of Substitution (CES) function and the Leontief function. Thus, most functions are represented as linearised equations with the variables of percentage changes. All equations in the model are contained in the TABLO file. The TABLO language in which the file is written is, essentially, conventional algebra, with names for variables and coefficients chosen to be suggestive of their economic interpretation.

It is customary that a lower case letter is used to express a percentage change variable and an upper case letter is used to express a level, or ordinary change variable. Commodity and Industry are assigned as _c and _i respectively, and domestic and imported commodities are assigned s=1 and s=2, respectively. The names of variables and coefficients are systemised into the following patterns:

First, a letter or letters indicating the type of variables.

a	technical change
del	ordinary (rather than percentage) change
f	shift variable
H	indexing parameter
p	price, local currency
pf	price, foreign currency
S	share
σ	elasticity of substitution
t	tax
V	levels value, local currency
w	percentage change value, local currency
x	quantity

Second, one of the digits between 0 and 6 identifies the users

1	current production
2	investment
3	consumption
4	export
5	government
6	inventories
0	all users, or user distinction irrelevant

5.1.2 The structure of production

Similar to the ORANI-G model, the production structure allows each industry to produce several commodities using intermediate inputs, primary factors, and other costs. Commodities used to export are distinguished from those consumed in the local market. This multi-input, multi-output production specification is managed by a series of assumptions. The generalised production function under these assumptions for each industry can be written as:

$$G\ (\text{inputs}) = X1TOT = H\ (\text{outputs}) \qquad (5.1)$$

Where X1TOT is an index of industry activity. The function H of output is obtained from two nested Constant Elasticity of Transformation (CET) aggregate functions. The function G is derived from a sequence of nested production functions. These functions are explained by some combined levels between inputs and primary factors, or among inputs themselves and among primary factors themselves.

The input demand of the production function consists of a five layer nested Leontief and the CES functions, as shown in Figure 5.1. The same as the ORANI-G model, at the top level, intermediate input bundles, energy-primary factor bundles and other costs are combined using a Leontief production function, it means that they are used in fixed proportions to produce their level of output; all other bottom levels are nested by various CES functions. In particular, the intermediate inputs are CES combinations of domestic and imported goods. Energy-primary factors are CES combinations of energy-capital composite, labour and land. This is expressed in the second level. Some studies disaggregated the electricity generation into subsectors based on the fuel used, but the electricity generation types are treated as other intermediate input by using the Leontief function as the same top level (Adams, Parmenter, & Horridge, 2000). However, the difference between this CGE model and the ORANI-G model is the approach used to treat electricity generation and energy inputs in the production function. This treatment is the same as found in studies by Sajeewani et al. (2013).

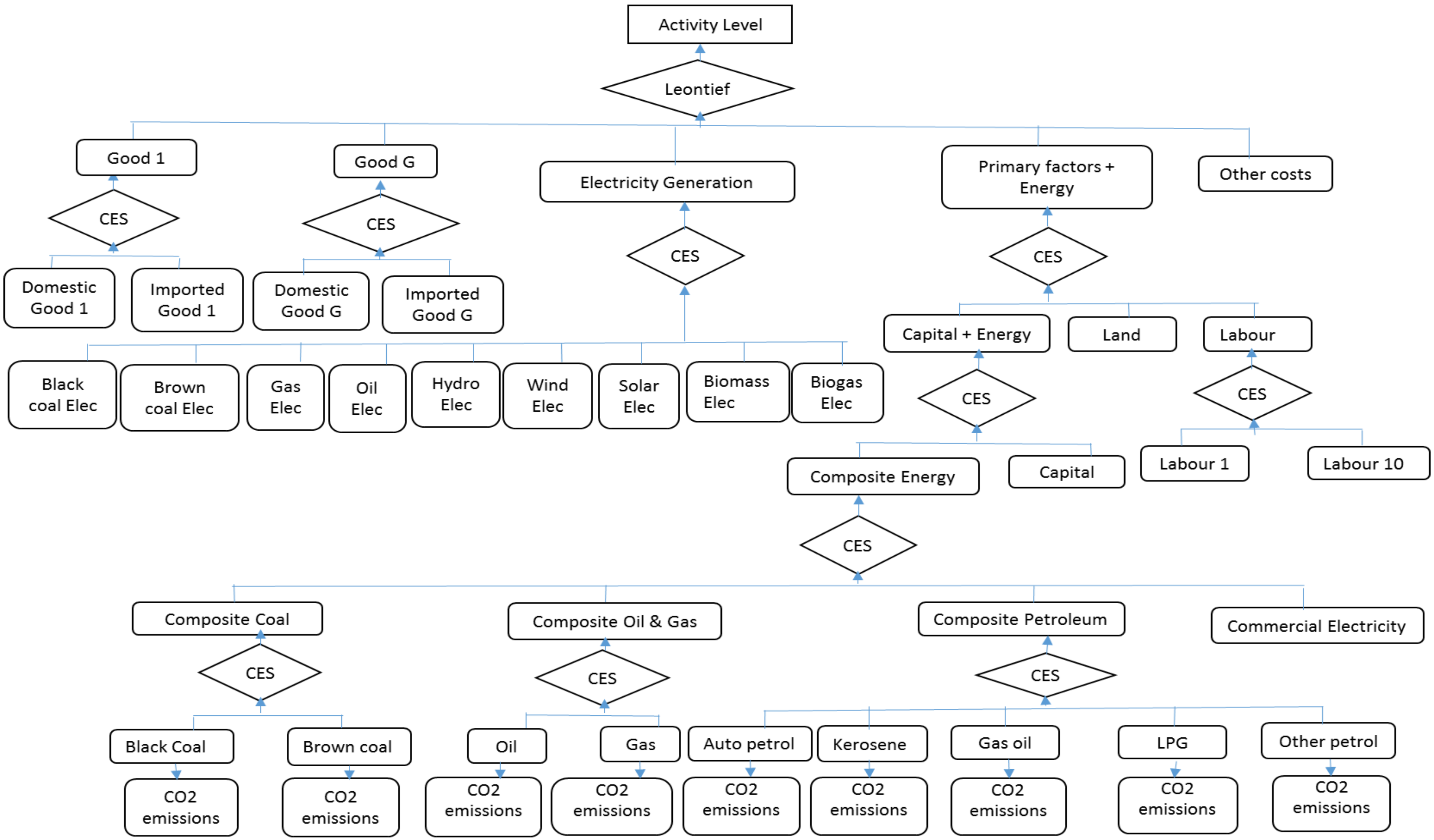

Figure 5.1: The structure of production
Source: Adapted from Horridge (2003)

Electricity generation, based on the type of energy sources used, is disaggregated into nine power-generating categories: electricity generated from black coal; brown coal; oil; gas; and renewable energy sources, namely electricity generated from hydro, wind, solar, biomass and biogas. Differing from the treatment of electricity generation type as a Leontief function that is expressed in the top level, this CGE model allows for substitution between electricity generated from different sources. This is expressed using a CES function, thus leading to a shift from high carbon emissions generators to low carbon emissions generators. This structure assumes that electricity generated by various sources is sold directly to the commercial electricity sector.

The model treats energy and non-energy inputs separately. In particular, the third level is a CES combination of energy inputs and capital. The substitution between energy inputs and capital shows the flexibility of the Australian economy's ability to adopt and utilise energy saving technology because the energy input costs are affected by the application of the carbon price mechanism. The elasticity of substitution between energy and capital is small (Okagawa & Ban, 2008; Truong, Kemfert, & Burniaux, 2007). The model allows the labour substitution between 10 occupational categories and substitution among these 10 occupational groups is expressed using a CES function

The fourth level describes the substitutability of energy inputs in the economy through the CES function. The demand for composite energy is obtained from composite coal, composite oil and gas, composite petroleum and commercial electricity. In each composite energy, the model presents the availability of substitution among sub-energy sectors, such as the substitutability between black and brown coal in composite coal, between oil and gas in composite oil and gas, between auto petrol, kerosene, gas/fuel oil, liquefied petroleum gas and other petroleum in the composite petroleum that is described in the bottom level by the CES function.

In order to assess the effects of an ETS, the model incorporates the carbon emissions accounts. The carbon emissions, that were generated from fuel combustion, fugitive emissions, industrial processes, agriculture, waste and land use, land-use change and forestry were aggregated into three main sources: carbon emissions from stationary sources (input emissions), from production activities (output emissions), and from household consumption (consumption emissions). The carbon emissions from all sources were disaggregated into emissions from domestic and imported products. Carbon emissions in the model were treated as proportional to energy inputs used for the level of activity. Therefore, under the ETS, the quantity of emissions generation is fixed and the price of emissions permits is endogenously determined in the model.

5.1.2.1 Industry demand for intermediate inputs

In the production process, industries use intermediate inputs from both domestic and imported sources. According to the Armington assumption, there is imperfect substitution between domestic and imported commodities, the total cost of imported and domestic commodities determines the import/domestic composition in the production process of each industry, in which the total cost of production is minimised subject to a CES production function. The demand for intermediate inputs by industry is given by:

$$x^1_{csi} - a^1_{csi} = x^{1\_s}_{ci} - \sigma^1_c *[p^1_{csi} + a^1_{csi} - p^{1\_s}_{ci}], \quad (5.2)$$

where x^1_{csi} is the demand for commodity c by industry i from source s, a^1_{csi} is the technical change of commodity c, by industry i from source s, $x^{1\_s}_{ci}$ is the demand for import/domestic composite commodity c, by industry i, p^1_{csi} is the purchaser price of commodity c from source s to industry i, $p^{1\_s}_{ci}$ is the price of import/domestic composite commodity c to industry i, σ^1_c is the Armington substitution elasticity between domestic and imported commodity c.

The effective price of the commodity composite is given as:

$$p^{1\_s}_{ci} = \sum_{s \in SRC} S^1_{csi} * [p^1_{csi} + a^1_{csi}], \quad (5.3)$$

where S^1_{csi} is the share of industry i of purchasing domestic or imported commodity c. The Tablo code is given in Appendix C, Excerpt 5.6.

There is a different treatment in electricity generation and energy inputs in the production function, compared to the ORANI-G model, thus leading to an addition of equations expressing the demand of industries for electricity generation and energy commodities in the model as follows:

- **Industry demand for composite electricity generation**

Electricity generated from non-renewable sources includes black coal, brown coal, oil and gas. Electricity generated from renewable sources includes hydro, wind, solar, biomass and biogas. Thus, there are nine electricity-generating plants in this CGE model. Electricity generation is assumed to supply electricity for the commercial electricity sector. The model allows for the substitutions between electricity generated by various sources. Thus, the industry demand for electricity generation type is expressed using a CES production function in Equation (5.4). The elasticity of substitution (σ) in Equation (5.4) illustrates substitutability between electricity generated by different sources.

$$x_{ci}^{1\_elcg} = x_i^{1elcg} - \sigma_i^{1elcg} * [p_{ci}^{1\_elcg} + a_{ci}^{1\_elcg} - p_i^{1elcg}], \qquad (5.4)$$

where $x_{ci}^{1\_elcg}$ is the demand for electricity generation c by industry i, x_i^{1elcg} is the electricity generation composite demand in industry i, σ_i^{1elcg} is the elasticity of substitution between different electricity generation types in industry i, $p_{ci}^{1\_elcg}$ is the price of electricity generation c in industry i, $a_{ci}^{1\_elcg}$ is the technical change of electricity generation c in industry i, p_i^{1elcg} is the price of composite electricity generation to industry i.

The effective price of composite electricity generation is obtained from:

$$[\text{TINY} + V_i^{1elcg}] * p_i^{1elcg} = \sum_{c \in ELCG} V_{ci}^{1elcg\_s} * p_{ci}^{1\_elcg}, \qquad (5.5)$$

where V_i^{1elcg} is the value of composite electricity generation used by industry i, $V_{ci}^{1elcg\_s}$ is the purchase value of domestic and imported electricity generation type c, used by industry i.

For an industry which does not use electricity generations, $V_{ci}^{1elcg\_s}$ would contain only zeros, so that p_i^{1elcg} would be undefined. To prevent this, the coefficient TINY[11] is added to the left hand side of Equation (5.5). If $V_{ci}^{1elcg\_s}$ are all zero, p_i^{1elcg} would be zero. The Tablo code is given in Appendix C, Excerpt 5.7.

5.1.2.2 Industry demand for energy inputs

As shown in Figure 5.1, the bottom level presents the usage of energy commodities in the production function by each industry through the CES function. It means that substitution among different energy commodities is allowed in the production process. The energy inputs include coal, oil-gas, petroleum and commercial electricity, in which coal, oil-gas and petroleum are disaggregated into subsectors that are either imported or produced domestically. The following sections present industry demand for different types of energy inputs.

- Industry demand for composite coal energy

Coal is disaggregated into black and brown coal. The optimal choice of black and brown coal in the production function by industry is to minimise the total cost of composite coal energy.

[11] The coefficient TINY is very small number that is used to prevent zerodivides or singular matrix, TINY is equal to 0.000000000001 (or 10^{-12}) due to the ORANI-G: A Generic Single-Country Computable General Equilibrium model.

Equation (5.6) presents the industry demand for black coal and brown coal in the percentage change form:

$$x_{ci}^{1\_col} = x_i^{1col} - \sigma_i^{1col}{}_{i} * [p_{ci}^{1\_col} - p_i^{1col}], \qquad (5.6)$$

where $x_{ci}^{1\_col}$ is the intermediate use of black and brown coal in industry i, x_i^{1col} is the demand of industry i for composite coal, σ_i^{1col} is the substitution elasticity between black and brown coal in industry i, $p_{ci}^{1_col}$is the price of black and brown coal to industry i, p_i^{1col} is the price of composite coal to industry i.

The effective price of the composite coal is obtained from:

$$[\text{TINY} + V_i^{1col}]* p_i^{1col} = \sum_{c\epsilon COAL} V_{ci}^{1col\_s} * p_{ci}^{1\_col} \;, \qquad (5.7)$$

where V_i^{1col} is the value of the composite coal used by industry i, $V_{ci}^{1col\_s}$ is the purchase values of black and brown coal supplied to industry i. The same as for equation (5.5), the coefficient TINY is added to the left-hand side of Equation (5.7) to prevent the case of $V_{ci}^{1col\_s}$ all zero. The Tablo code is given in Appendix C, Excerpt 5.8.

- **Industry demand for composite oil-gas energy**

In the production process, an industry can substitute between oil and gas with the purpose of minimising the cost of composite oil-gas. The demand for intermediate inputs of oil and gas by industry is presented in equation (5.8) formed by the percentage change:

$$x_{ci}^{1\_oig} = x_i^{1oig} - \sigma_i^{1oig} * [p_{ci}^{1\_oig} - p_i^{1oig}], \qquad (5.8)$$

where $x_{ci}^{1\_oig}$ is the oil and gas demand by industry i, x_i^{1oig} is the demand for the composite oil-gas by industry i, σ_i^{1oig} is the substitution of elasticity between oil and gas in industry i, $p_{ci}^{1_oig}$is the price of oil and gas to industry i, p_i^{1oig} is the price of composite oil-gas to industry i.

The effective price of composite oil-gas energy is derived from:

$$[\text{TINY} + V_i^{1oig}]* p_i^{1oig} = \sum_{c\epsilon OILG} V_{ci}^{1oig\_s} * p_{ci}^{1\_oig} \;, \qquad (5.9)$$

where $V_i^{1oig}$is the value of composite oil-gas supplied to industry i, $V_{ci}^{1oig\_s}$ is the purchaser value of oil and gas usage by industry i. The coefficient TINY is added to equation (5.9) to avoid the infinity of p_i^{1oig} as all $V_{ci}^{1oig\_s}$ are zero values. The Tablo code is shown in Appendix C, Excerpt 5.9.

- **Industry demand for composite petroleum energy**

The petroleum sector is disaggregated into five subsectors namely automotive petroleum, kerosene, gas/fuel oil, liquefied petroleum gas, and other petroleum products. The industry demand for composite petroleum energy is modelled as a CES aggregation among these five petroleum products and is given by:

$$x_{ci}^{1\_ptr} = x_{i}^{1ptr} - \sigma_{i}^{1ptr} * [p_{ci}^{1\_ptr} - p_{i}^{1ptr}], \quad (5.10)$$

where $x_{ci}^{1\_ptr}$ is the intermediate demand of industry i for petroleum commodity, c, x_{i}^{1ptr} is the demand for composite petroleum by industry i, σ_{i}^{1ptr} is the substitution elasticity between different petroleum products in industry i, $p_{ci}^{1\_ptr}$ is the price of petroleum product c to industry i, p_{i}^{1ptr} is the price of composite petroleum to industry i.

Equation (5.11) presents the effective price of composite petroleum:

$$[\text{TINY} + V_{i}^{1ptr}] * p_{i}^{1ptr} = \sum_{c \epsilon PETR} V_{ci}^{1ptr\_s} * p_{ci}^{1\_ptr} \quad (5.11)$$

where V_{i}^{1ptr} is the value of composite petroleum supplied to industry i, $V_{ci}^{1ptr\_s}$ is the value of petroleum product c used by industry i. Equation (5.11) adds the coefficient TINY to avoid the infinity of p_{i}^{1ptr} as all $V_{ci}^{1ptr\_s}$ are zero values (See Tablo code in Appendix C, Excerpt 5.10).

- **Industry demand for composite energy inputs**

The demand of industry for composite energy inputs is modelled as a CES combination of composite coal, composite oil-gas, composite petroleum and commercial electricity. The energy commodities are combined in the production process of each industry in response to minimise the production cost, as seen in the following equations:

$$x_{i}^{1col} - a_{i}^{1col} = x_{i}^{1eng} - \sigma_{i}^{1eng} * [p_{i}^{1col} + a_{i}^{1col} - p_{i}^{1eng}], \quad (5.12)$$

$$x_{i}^{1oig} - a_{i}^{1oig} = x_{i}^{1eng} - \sigma_{i}^{1eng} * [p_{i}^{1oig} + a_{i}^{1oig} - p_{i}^{1eng}], \quad (5.13)$$

$$x_{i}^{1ptr} - a_{i}^{1ptr} = x_{i}^{1eng} - \sigma_{i}^{1eng} * [p_{i}^{1ptr} + a_{i}^{1ptr} - p_{i}^{1eng}], \quad (5.14)$$

$$x_{i}^{1ele} - a_{i}^{1ele} = x_{i}^{1eng} - \sigma_{i}^{1eng} * [p_{i}^{1ele} + a_{i}^{1ele} - p_{i}^{1eng}], \quad (5.15)$$

where x_{i}^{1eng} is the intermediate demand of industry i for composite energy, a_{i}^{1col}, a_{i}^{1oig}, a_{i}^{1ptr} and a_{i}^{1ele} are the augmentation of coal, oil and gas, petroleum products and commercial electricity technical change in the industry i, σ_{i}^{1eng} is the substitution of elasticity between different energy commodities in industry i, p_i^{1eng} is the effective price of composite energy to industry i.

The effective price of composite energy is derived from:

$$V_i^{1eng}*p_i^{1eng}=V_i^{1col}*[p_i^{1col}+a_i^{1col}] + V_i^{1oig}*[p_i^{1oig}+a_i^{1oig}] + V_i^{1ptr}*[p_i^{1ptr}+a_i^{1ptr}]+V_i^{1ele}*[p_i^{1ele}+a_i^{1ele}], \quad (5.16)$$

where V_i^{1eng} is the total value of composite energy inputs that is used by industry i, V_i^{1ele} is the value of commercial electricity used by industry i. The Tablo code is shown in Appendix C, Excerpt 5.11.

5.1.2.3 Industry demand for composite energy- capital

The substitution between capital and energy has been incorporated in many previous studies. It seems that energy and capital are complements in the short term and substitutes in the long term (Burniaux, Nicoletti, & Oliveira-Martins, 1992). The model in this study allows substitution between capital and composite energy through a CES production function. In order to minimise the cost, producers determine optimal composition of the capital-energy composite as shown in equations (5.17) and (5.18).

$$x_i^{1eng} - a_i^{1eng} = x_i^{1enc} - \sigma_i^{1enc}*[p_i^{1eng}+a_i^{1eng} - p_i^{1enc}], \quad (5.17)$$

$$x_i^{1cap} - a_i^{1cap} = x_i^{1enc} - \sigma_i^{1enc}*[p_i^{1cap}+a_i^{1cap} - p_i^{1enc}], \quad (5.18)$$

where x_i^{1enc} is the intermediate demand for the composite capital-energy in industry i, x_i^{1cap} is the industry demand for capital in industry i, a_i^{1eng} is the energy-augmenting technical change in industry i, $a_i^{1cap}$is the capital-augmenting technical change in industry i, σ_i^{1enc} is the substitution elasticity between composite energy and capital in industry i, p_i^{1enc} is the effective price of capital-energy composite to industry i.

The effective price of capital-energy composite is derived from:

$$V_i^{1enc}*p_i^{1enc}=V_i^{1eng}*[p_i^{1eng}+a_i^{1eng}] + V_i^{1cap}*[p_i^{1cap}+a_i^{1cap}], \quad (5.19)$$

where V_i^{1enc} is the total cost of capital and energy in industry i, V_i^{1cap} is the value of capital cost in industry i. The Tablo code is shown in Appendix C, Excerpt 5.12.

5.1.2.4 Industry demand for labour

Labour in the model is disaggregated into ten occupational categories. In order to minimise the total production cost, firms in each industry can employ different combinations of occupational categories. Therefore, a CES combination of ten occupational groups is applied in the model. Equation (5.20) depicts the demand of each industry i for labour type o. Equation (5.21) shows the effective price of labour in each industry:

$$x_{io}^{1lab} = x_{i}^{1lab\_o} - \sigma_{i}^{1lab} * [p_{io}^{1lab} - p_{i}^{1lab\_o}], \tag{5.20}$$

$$[\text{TINY} + V_{i}^{1lab\_o}] * p_{i}^{1lab\_o} = \sum_{c \epsilon OCC} V_{io}^{1lab} * p_{io}^{1lab} \quad , \tag{5.21}$$

where x_{io}^{1lab} is the demand for occupation type o, by industry i, $x_{i}^{1lab\_o}$ is the demand for composite labour by industry i, σ_{i}^{1lab} is the elasticity of substitution among ten occupations in industry i, p_{io}^{1lab} is the price of occupation type o to industry i, $p_{i}^{1lab\_o}$ is the effective price of labour to industry i, V_{io}^{1lab} is the labour demand for the occupation type o, by industry i, $V_{i}^{1lab\_o}$ is the total labour bill in industry i. The coefficient TINY is added to the left hand side of Equation (5.21) to prevent the infinity of $p_{i}^{1lab\_o}$ as all V_{io}^{1lab} are zero values. The Tablo code is shown in Appendix C, Excerpt 5.13.

5.1.2.5 Industry demand for primary factors

In the production process, not only the cost of intermediate input but also the cost of primary factors needs to be minimised. Industry demand for the primary factors is modelled using a CES function and allowing substitution between composite energy-capital, composite labour and land with the purpose of minimisation of total primary factor cost. The equations of the demand for primary factors are expressed in percentage change form as follows:

Industry demand for effective labour is given as:

$$x_{i}^{1lab\_o} - a_{i}^{1lab\_o} = x_{i}^{1prim} - \sigma_{i}^{1prim} * [p_{i}^{1lab\_o} + a_{i}^{1lab\_o} - p_{i}^{1prim}]. \tag{5.22}$$

Industry demand for composite energy-capital is given as:

$$x_{i}^{1enc} - a_{i}^{1enc} = x_{i}^{1prim} - \sigma_{i}^{1prim} * [p_{i}^{1enc} + a_{i}^{1enc} - p_{i}^{1prim}]. \tag{5.23}$$

Industry demand for land is given as:

$$x_{i}^{1lnd} - a_{i}^{1lnd} = x_{i}^{1prim} - \sigma_{i}^{1prim} * [p_{i}^{1lnd} + a_{i}^{1lnd} - p_{i}^{1prim}], \tag{5.24}$$

where x_i^{1prim} is the industry demand for primary factor composite, x_i^{1lnd} is the demand for land by industry i, $a_i^{1lab\_o}$, a_i^{1enc} and a_i^{1lnd} are labour, energy-capital, and land-augmenting technical changes in industry i respectively, σ_i^{1prim} is the substitution elasticity between primary factors in industry i, p_i^{1prim} is the effective price of primary factor composite to industry i.The effective price of primary factor composite is derived from:

$$V_i^{1prim} * p_i^{1prim} = V_i^{1lab\_o} * [p_i^{1lab\_o} + a_i^{1lab\_o}] + V_i^{1enc} * [p_i^{1enc} + a_i^{1enc}] + V_i^{1lnd} * [p_i^{1lnd} + a_i^{1lnd}], \quad (5.25)$$

where V_i^{1prim} is the total value of primary factor inputs to industry i, V_i^{1lnd} is the value of land demand from industry i. The Tablo code is shown in Appendix C, Excerpt 5.14.

5.1.2.6 Top nest of production structure

At the top level of production structure, the electricity generating commodity composite, intermediate non-energy commodity composite, primary factor-energy composite and other cost tickets are combined through a Leontief production function. The substitution elasticity is set to zero at this level and the demand equations lack the price terms. The equations of the demand for intermediate inputs, primary factor-energy composite and other cost tickets are expressed in percentage change form:

Industry demand for non-energy commodity composite:

$$x_{ci}^{1\_s} - [a_{ci}^{1\_s} + a_i^{1tot}] = x_i^{1tot}. \quad (5.26)$$

Industry demand for electricity generation composite:

$$x_i^{1elcg} - [a_i^{1elcg} + a_i^{1tot}] = x_i^{1tot}. \quad (5.27)$$

Industry demand for primary factor composite:

$$x_i^{1prim} - [a_i^{1prim} + a_i^{1tot}] = x_i^{1tot}. \quad (5.28)$$

Industry demand for other cost tickets:

$$x_i^{1oct} - [a_i^{1oct} + a_i^{1tot}] = x_i^{1tot}, \quad (5.29)$$

where x_i^{1tot} is the total output produced by industry i, $x_i^{1oct}$is the demand of industry i for other cost , a_i^{1tot} is all input-augmenting technical change in industry i, a_i^{1oct} is the other cost ticket augmenting technical change in industry i. See Tablo code in Appendix C, Excerpt 5.15.

5.1.2.7 Industry costs and production taxes

The total industry costs (excluding taxes) incorporate the cost of intermediate inputs, primary factor-energy composite, and other costs. The taxes related to the production process are taxes on production. The output emissions permit revenue which firms pay to the government for buying their generated emissions cap is considered as a production cost. Therefore, the permit revenue related to emissions generated from production processes is incorporated in the production costs. The levels and level changes in the total cost of production are presented as follows:

$$100*\Delta V_i^{1cst}= V_i^{1cap}*[p_i^{1cap}+x_i^{1cap}]+V_i^{1lnd}*[p_i^{1lnd}+x_i^{1lnd}]+\sum_{c\,\epsilon OCC} V_{io}^{1lab}*[p_{io}^{1lab}+x_{io}^{1lab}]+\sum_{c\epsilon COM}\sum_{s\epsilon SRC} V_{csi}^{1pur}*[p_{csi}^{1}+x_{csi}^{1}]+V_i^{1oct}*[p_i^{1oct}+x_i^{1oct}], \quad (5.30)$$

$$\Delta V_i^{1tot}=\Delta V_i^{1cst}+\Delta V_i^{1ptx}+\sum_{c\in COM}\Delta TX1CO_{ci}, \quad (5.31)$$

$$V_i^{1tot}*[p_i^{1tot}+x_i^{1tot}] = 100*\Delta V_i^{1tot}, \quad (5.32)$$

where ΔV_i^{1tot} is the change in the total cost of industry i, including production tax, ΔV_i^{1cst} is the change in the total cost of industry i , excluding production tax, $\Delta V_i^{1ptx}$is the change in production tax of industry i, $\Delta TX1CO_{ci}$ is the change in output emissions permit revenue from commodity c, by industry i.

Defined as the percentage change in the unit cost of production for industry i, p_i^{1tot} is the percentage change in marginal cost, given the constant returns to scale. In order to satisfy the competitive zero pure profits condition, p_i^{1tot} are assumed to be equal to the average price received by each industry. See the Tablo code in Appendix C, Excerpt 5.16.

5.1.2.8 Industry output mix

Each industry in the model is allowed to produce a mixture of all commodities, the total revenue from all outputs is maximised, subject to the Constant Elasticity of Transformation (CET) function. The CET aggregation function is identical to the CES function, but the transformation parameter in the CET function has the opposite sign to the substitution parameter in the CES function. For each industry, the variety of a mixture of all the commodities is determined by the relative prices of commodities. Equation (5.33) presents the commodity supply of industry i:

$$q_{ci}^{1} = x_i^{1tot} + \sigma_i^{1out}*[p_c^{0com} - p_i^{1tot}], \quad (5.33)$$

where q_{ci}^{1} is the supply of commodity c, by industry i, σ_i^{1out} is the elasticity transformation of industry i, p_c^{0com} is the general output price of locally-produced commodity c, p_i^{1tot} is the average price received by industry i.

The average price p_i^{1tot} is given as:

$$p_i^{1tot} = \sum_{c\epsilon COM}\left[\frac{V_{ci}^{make}}{V_i^{make\_c}}\right] * p_{ci}^{q1}, \quad (5.34)$$

where V_{ci}^{make} is a matrix records the value of commodity c produced by industry i, $V_i^{make_c}$is the total production by industry i, p_{ci}^{q1} is the price of commodity c, produced by industry i.

Equation (5.35) depicts the total output of commodity.

$$x_c^{0com} = \sum_{i\epsilon IND}\left[\frac{V_{ci}^{make}}{V_c^{make\_i}}\right] * q_{ci}^{1}. \quad (5.35)$$

The output price of locally-produced commodity c is given in Equation (5.36).

$$V_c^{make\_i} * p_c^{0com} = \sum_{i\epsilon IND} V_{ci}^{make} * p_{ci}^{q1} . \quad (5.36)$$

(See Tablo code in Appendix C, Excerpt 5.17)

5.1.2.9 Output for local and export markets

The CET determines the destination of commodities for the local and export markets. If the inverse of transformation, (τ_c), was zero, the values of p^{0com}, p^{0dom} and p^{e} would be all equal.

The supply of commodities to export market:

$$\tau_c * [x_c^{0dom} - x_c^{4}] = p_c^{0dom} - p_c^{e}, \quad (5.37)$$

where τ_c is the inverse of the elasticity of transformation between exportable and locally used commodity c, x_c^{0dom} and x_c^{4} are the quantity of commodity c supplied to the local and export markets, p_c^{0dom} and p_c^{e} are the price of locally produced and exportable commodity c.

The supply of commodities to the domestic market is expressed as:

$$x_c^{0com} = [1-S_c^{exp}]* x_c^{0dom} + S_c^{exp}* x_c^{4} . \quad (5.38)$$

The zero pure profits in transformation is given as:

$$p_c^{0com} = [1-S_c^{exp}]* p_c^{0dom} + S_c^{exp}* p_c^{e} , \quad (5.39)$$

where S_c^{exp} is the share of commodity c sold in the export market. The Tablo code is given in Appendix C, Excerpt 5.18.

5.1.3 Investment demands

The structure of investment demand is similar to the structure of intermediate input demand. Capital is assumed to be produced with inputs from domestic and imported sources. There are no primary factors and other costs used directly as inputs to capital formation. Thus, the structure of the investment demand incorporates two levels. At the bottom level, the total cost of imported and domestic commodity c is minimised subject to the CES function, while at the top level the total cost of commodity composite is minimised subject to the Leontief function. Therefore, the investment demand equations are expressed as follows:

Equation (5.40) represents the demand for investment goods c.

$$x_{csi}^2 - a_{csi}^2 - x_{ci}^{2\_s} = -\sigma_c^2 * [p_{csi}^2 - a_{csi}^2 - p_{ci}^{2\_s}], \qquad (5.40)$$

where x_{csi}^2 is the demand for investment goods c, from source s by industry i, $x_{ci}^{2\_s}$ is the investment use of commodity composite c in industry i, a_{csi}^2 is investment basic technical change in goods c, from source s, by industry i, σ_c^2 is the substitution elasticity between domestic and imported commodity c, $p_{ci}^{2\_s}$ is the effective price of commodity composite c by industry i.

The effective price of commodity composite is given as:

$$p_{ci}^{2\_s} = \sum_{s \in SRC} S_{csi}^2 * [p_{csi}^2 + a_{csi}^2], \qquad (5.41)$$

where S_{csi}^2 is investment share of goods c from source s in industry i.

The demand for commodity composite by industry is given as:

$$x_{ci}^{2\_s} - [a_{ci}^{2\_s} + a_i^{2tot}] = x_i^{2tot} . \qquad (5.42)$$

The cost of unit of capital is expressed in Equation (5.43):

$$p_i^{2tot} = \sum_{c \in COM} \frac{V_{ci}^{2pur\_s}}{IDO1[V_i^{2tot}]} * \left[p_{ci}^{2\_s} + a_{ci}^{2\_s} + a_i^{2tot}\right], \qquad (5.43)$$

where x_i^{2tot} is the total output for investment in industry i, $a_{ci}^{2\_s}$ is the technical change of investment import-domestic composite from commodity c, by industry i, a_i^{2tot} is the neutral technical change–investment in industry i, $V_{ci}^{2pur\_s}$ is the purchaser value of the import-domestic composite of investment for commodity c, by industry i, V_i^{2tot} is the total purchaser of industry i, p_i^{2tot} is the cost of unit of capital of industry i. The Tablo code is given in Appendix C, Excerpt 5.19.

5.1.4 Household demands

Figure 5.2 shows the nesting structure for household demands. It can be seen that the structure for household demands is different from investment demands and for intermediate input demands at the top level, but similar to those at the lower levels. In particular, the nesting structure for household demands is aggregated by a Klein-Rubin at the top level, rather than a Leontief function in the intermediate input demands and investment demands, leading to the linear expenditure system. The equations for the lower levels are similar to the corresponding equations for those as aggregation by a CES function. The domestic and imported commodity composite is modelled by using the Armington aggregation. Households in the model are disaggregated into 20 household groups. In each household group, they are assumed to choose commodity c, from source s to minimise the cost of commodity composite subject to a nested CES function.

The function of household demands is given as:

$$x_{csh}^{3h} - a_{csh}^{3h} = x_{ch}^{3\_sh} - \sigma_c^3 * [p_{cs}^3 + a_{cs}^3 - p_c^{3\_s}]. \qquad (5.44)$$

The effective price of commodity composite is given as:

$$p_c^{3\_s} = \sum_{s \in SRC} S_{cs}^3 * [p_{cs}^3 + a_{cs}^3], \qquad (5.45)$$

where x_{csh}^{3h} is the demand of household h for commodity c, from source s, $x_{ch}^{3\_sh}$ is the demand of household h for commodity composite c, a_{csh}^{3h} is the household h's basic taste change from source s of commodity c, $\sigma_c^3$is the household Armington elasticity for commodity c, p_{cs}^3 is the price of commodity c, from source c, $p_c^{3\_s}$ is the effective price of the commodity composite c, S_{cs}^3 is the share of value of household expenditure on commodity c from source s.

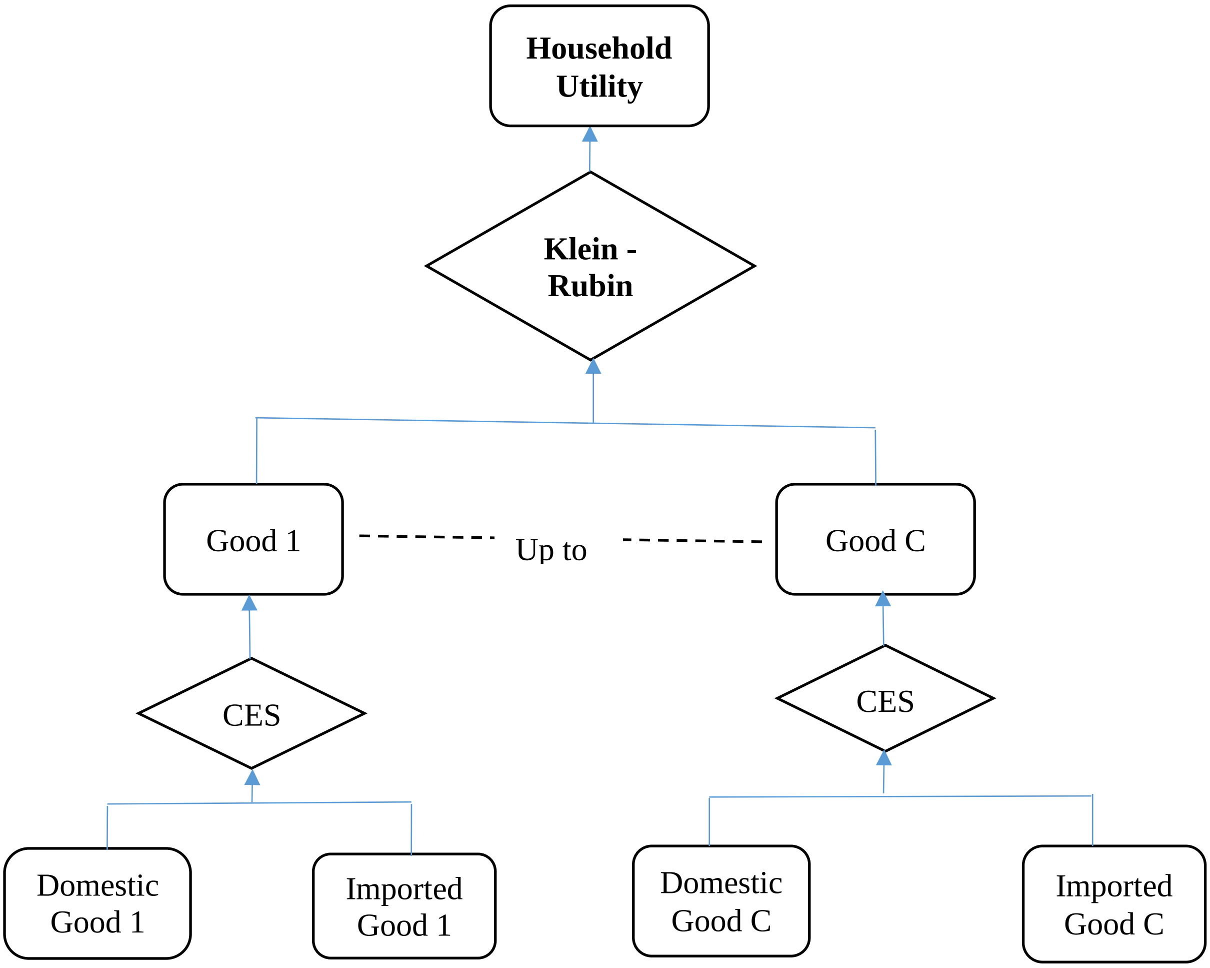

Figure 5.2: Demand function for each household group

Source: Horridge (2003)

The household demand at the top level is obtained from the Klein-Rubin utility function with the purpose of maximising the household utility subject to the household budget constraints.

$$\text{Utility per household} = \frac{1}{Q} * \prod_c (X_c^{3_s} - X_c^{3sub})^{S_c^{3lux}} \quad \text{Subject to } \sum_c X_{ch}^{3\_s} * P_{ch}^{3\_s} = V^{3tot} \quad , \quad (5.46)$$

where $X_c^{3\_s}$ is the household consumption of composite commodity c, X_c^{3sub} is the subsistence of commodity c, purchased regardless of price, S_c^{3lux} is the share of luxury commodity c, or marginal budget share.

The linear expenditure function of household demand is expressed as:

$$X_c^{3\_s} = X_c^{3sub} + X_c^{3lux} \quad (5.47)$$

where X_c^{3lux} is the household demand for the luxury commodity c. The demands for commodity c are presented as follows:

$$X_c^{3sub} = Q{*}A_c^{3sub} \text{ ,} \tag{5.48}$$

$$X_c^{3lux}{*}P_c^{3\_s} = S_c^{3lux}{*}\, V^{3lux\_c} \text{ ,} \tag{5.49}$$

$$\text{Or } X_c^{3\_s} = X_c^{3sub} + S_c^{3lux}{*}\, V^{3lux\_c}/P_c^{3\_s} \text{ ,} \tag{5.50}$$

where A_c^{3sub} is the individual subsistence demand for commodity c, Q is the number of households, V^{3lux_c} is the remains of the household budget after reducing subsistence expenditure, $P_c^{3\_s}$ is consumer price of composite commodity c.

In the percentage change form, Equations (5.48), (5.49) and (5.50) are presented as follows:

$$x_{ch}^{3sub} = q_h + a_{ch}^{3sub} \text{ ,} \tag{5.51}$$

$$x_{ch}^{3lux} + p_c^{3\_s} = w_h^{3luxh} + a_h^{3lux} \text{ ,} \tag{5.52}$$

$$x_{ch}^{3\_sh} = B_{ch}^{3lux}{*}x_{ch}^{3lux} + [1\text{-}B_{ch}^{3lux}]{*}\, x_{ch}^{3sub} \text{ ,} \tag{5.53}$$

where $B3LUX_{ch}$ is the ratio of luxury expenditure to the total household expenditure.

Household demand is disaggregated into subsistence demand and luxury demand, the subsistence demand is a necessary expenditure regardless of price, so the change in household utility depends on the luxury expenditure.

$$Utility_h + q_h = \sum_{c \in COM} S_{ch}^{3lux} * x_{ch}^{3lux}. \tag{5.54}$$

Real household consumption of household groups is given as:

$$x_h^{3tot} = \sum_{c \in COM} S_{ch}^{3\_s} * x_{ch}^{3\_s}. \tag{5.55}$$

The consumer price to household groups is given as:

$$p_h^{3tot} = \sum_{c \in COM} S_{ch}^{3\_s} * p_c^{3\_s}. \tag{5.56}$$

Total real consumption of household is expressed as:

$$x^{3tot} = \sum_{c \in COM} \sum_{h \in HOU} S_{ch}^{3\_s} * x_{ch}^{3\_s}. \tag{5.57}$$

The consumer price index is given as:

$$p^{3tot} = \sum_{c \in COM} \sum_{h \in HOU} S_{ch}^{3\_s} * p_c^{3\_s}. \tag{5.58}$$

The household budget constraint is defined as:

$$w^{3tot} = x^{3tot} + p^{3tot}, \tag{5.59}$$

where x_h^{3tot} is percentage change in real consumption of household group h, p_h^{3tot} is the percentage change in consumer price to household group h, x^{3tot} is percentage change in real household consumption, p^{3tot} is percentage change in consumer price index, w^{3tot} is percentage change in nominal total household consumption. The Tablo code is given in Appendix C, Excerpt 5.20.

5.1.5 Export, government and inventory demands

5.1.5.1 Export demands

Export commodities in the model are divided into two groups: individual export commodities and collective export commodities. For individual export commodities, foreign demand is inversely related to that commodity's price. For collective export commodities, foreign demand is inversely related to the average price of all collective export commodities. Therefore, there are two sets of export demand functions for each group.

The individual export commodity demand function is a downward-sloping foreign demand, represented in the percentage form as follows:

$$x_c^4 - f_c^{4q} = -\text{ABS}\,[\sigma_c]*[p_c^4 - \varphi - f_c^{4p}], \tag{5.60}$$

where x_c^4 is the export volume of commodity c, p_c^4 is the price of export commodity c, σ_c is the constant elasticity of export demand for commodity c, φ is the exchange rate that converts local to foreign currency units, f_c^{4q} and f_c^{4p} are quantity and price shift variables of commodity c.

The export demand function for the collective export commodity is given as:

$$x_c^4 - f_c^{4q} = x^{4\_ntrad} , \tag{5.61}$$

where x^{4_ntrad} is the collective export aggregate quantity. The Tablo code is given in Appendix C, Excerpt 5.21.

5.1.5.2 Government demands

The government demands for imported and domestically produced commodities can be defined as follows:

$$x_{cs}^5 = f_{cs}^5 + f^{5tot} , \tag{5.62}$$

$$f^{5tot} = x^{3tot} + f^{5tot2} , \tag{5.63}$$

where f_{cs}^{5} and f^{5tot} are shift variables and both are exogenous, government consumption is exogenously determined, f^{5tot2} is introduced as an endogenous variable in the model, and by endogenising f^{5tot} and exogenising f^{5tot2}, aggregate government consumption moves with real aggregate household consumption, x^{3tot}. See Tablo code in Appendix C, Excerpt 5.21.

5.1.5.3 Inventory demands

The change in the volume of goods going to inventories is defined in Equation (5.64).

$$100*P_{cs}^{0}*\ delx_{cs}^{6} = V_{cs}^{6BAS}*x_{c}^{0com} + fx_{cs}^{6}\ , \tag{5.64}$$

where P_{cs}^{0} (level basic prices) is the arbitrary setting for commodity c, source s, $delx_{cs}^{6}$ is the change in the volume of goods c from source s going to inventories, fx_{cs}^{6} is the shifter on rule for stocks.

In the model, $fx_{cs}^{6}$is an exogenous variable, in the short run, $delx_{cs}^{6}$ can be swapped to fx_{cs}^{6} to become an exogenous variable, and $fx_{cs}^{6}$is an endogenous variable. The Tablo code is given in Appendix C, Excerpt 5.21.

5.1.6 Demands for margins

The margin values are included in the purchasers' prices, which are calculated for producers, investors, households, exporters and government. Thus, the margin demands are defined under each user.

The margin demand is defined to producers in Equation (5.65):

$$x_{csim}^{1mar} = x_{csi}^{1} + a_{csim}^{1mar}. \tag{5.65}$$

The margin demand is defined to investors in Equation (5.66):

$$x_{csim}^{2mar} = x_{csi}^{2} + a_{csim}^{2mar}. \tag{5.66}$$

The margin demand is defined to households in Equation (5.67):

$$x_{cshm}^{3mar} = x_{csh}^{3} + a_{cshm}^{3mar}. \tag{5.67}$$

The margin demand is defined to exports in Equation (5.68):

$$x_{cm}^{4mar} = x_{c}^{4} + a_{cm}^{4mar}. \tag{5.68}$$

The margin demand is defined to government in Equation (5.69):

$$x_{csm}^{5mar} = x_{cs}^{1} + a_{csm}^{5mar}\ , \tag{5.69}$$

where a_{csim}^{1mar} and a_{csim}^{2mar} are the intermediate and investment technical change in margins usage, a_{cshm}^{3mar} is the household margin technical change, a_{cm}^{4mar} and a_{csm}^{5mar} are the exporters and government technical change in margin usage. See Tablo code in the Appendix C, excerpt 5.22.

5.1.7 Carbon emissions account

In order to analyse the effects of emission reduction strategies, the model incorporates the carbon emission accounts as well as the emission pricing mechanism. The model includes the carbon emissions generated from fuel combustion, fugitive emissions from fuels, industrial processes, agriculture, waste, and land use, land-used change and forestry. Such carbon emissions are divided into three main sources, including carbon emissions from stationary sources (input emissions), from production activities (output emissions), and from household consumption (consumption emissions). The carbon emissions data is divided into emissions generated from imported commodities and from domestic commodities. See the Tablo code in Appendix C, Excerpt 5.23.

5.1.7.1 Carbon emission intensity

The carbon emissions data is presented in the emissions matrix. The input emissions and consumption emissions are illustrated in the stationary emissions matrix, and output emissions are shown in the activity emissions matrix. Input and output carbon emissions intensities are calculated by commodity c sourced s for industry i, and consumption carbon emission intensity is accounted for household groups.

Input carbon emissions intensity:

$$ET_{csi}^{1I} = EM_{csi}^{1I}/X_{csi}^{1} , \tag{5.70}$$

where ET_{csi}^{1I} is the input carbon emissions intensity of industry i for using commodity c, from source s, EM_{csi}^{1I} is the input carbon emissions in industry i for using commodity c from source s, X_{csi}^{1} is the value of commodity c, from source s, usage by industry i.

Output emissions intensity:

$$ET_{ci}^{1O} = EM_{ci}^{1O}/X_{ci}^{0}, \tag{5.71}$$

where ET_{ci}^{1O} is the output emissions intensity from using commodity c, by industry i, EM_{ci}^{1O} is the carbon emissions in industry i from using commodity c, X_{ci}^{0} is the value of commodity c produced by industry i.

Consumption emissions intensity:

$$ET^{3C}_{csh} = EM^{3C}_{csh}/X^{3}_{csh}, \tag{5.72}$$

where ET^{3C}_{csh} is the consumption emissions intensity by household group h from using commodity c, sourced s, EM^{3C}_{csh} is the consumption emissions by household group h from using commodity c, sourced s, X^{3}_{csh} is the value of household consumption to commodity c from source s.

5.1.7.2 Change in carbon emissions resulting from an ETS

Under an ETS, the government issues the fixed emissions cap that each emitter is allowed to generate and the emissions price is endogenously determined by the market. The emitters must pay the cost for their emissions generation. This emissions cost is included in the production costs. Therefore, in order to reduce the production cost from the emissions generated, emitters related to the ETS must change their behaviour in production and consumption to minimise the emissions generated. Thus, this leads to changes in the emissions generation sourced from all input, output and consumption.

Change in input carbon emissions:

$$\Delta X^{1ci}_{csi} = 0.01 * ET^{1I}_{csi} * X^{1}_{csi} * x^{1}_{csi}\ , \tag{5.73}$$

where ΔX^{1ci}_{csi} is the change in input carbon emissions by industry i from using commodity c sourced s, x^{1}_{csi} is the percentage change in the demand for commodity c from source s by industry i.

Change in output carbon emissions:

$$\Delta X^{1co}_{ci} = 0.01 * ET^{1O}_{ci} * X^{0}_{ci} * q^{1}_{ci}\ , \tag{5.74}$$

where ΔX^{1co}_{ci} is the change in output carbon emissions by industry i from using commodity c, q^{1}_{ci} is the percentage change in output c from industry i.

Change in consumption carbon emissions:

$$\Delta X^{3cc}_{csh} = 0.01 * ET^{3c}_{csh} * X^{3}_{csh} * x^{3h}_{csh}\ , \tag{5.75}$$

where ΔX^{3cc}_{csh} is the change in consumption carbon emissions by household group h from using commodity c sourced s, x^{3h}_{csh} is the percentage change in household group h’s demand for commodity c from source s, X^{3}_{csh} is the value of household group h's consumption to commodity c from source s.

Total change in input, output carbon emissions by industry is given in Equation (5.76).

$$\Delta\text{EMIT} = \sum_{c\in COM}\sum_{i\in IND}[\Delta X^{1co}_{ci} + \sum_{s\in SRC}\Delta X^{1ci}_{csi}]. \quad (5.76)$$

The percentage change in total carbon emissions is defined in Equation (5.77).

$$\text{EMIT}^{*}\, x^{coit} = 100{*}\Delta\text{EMIT}, \quad (5.77)$$

where EMIT is the total carbon emissions generated by industries, x^{coit} is the percentage change in carbon emissions generated by industries, ΔEMIT is the change in the carbon emissions generated by industries.

5.1.7.3 The emission trading among industries in Australia

The model assumes that the ETS will occur among all industries in the Australian economy. To do that, the model sets a block of industries and a block of households related to the ETS, and a block of industries and a block of household unrelated to the ETS. Under this ETS, all industries are assumed to participate in the ETS, while all household are excluded from the ETS. Therefore all industries are grouped into a block of industries related to the ETS and all households are in a block of households unrelated to the ETS.

+ Emissions reduction target to industries

In order to achieve the total emission reduction target, the Australian Government must set emissions caps for industries related to the ETS, based on their emissions in a previous year or in a previous period. The government does not set the emissions allowance to industries and households that are unrelated to the ETS. Because of the imposition of a price on carbon emissions, producers and consumers are expected to change their production and consumption behaviours, thus leading to a reduction in emissions generation. The change in emissions of industry i is presented in Equation (5.78) and the change in emissions of household h is presented in Equation (5.79):

$$\Delta COIQ_i = 0.01{*}COIQ_i * x^{coiq}_{i}, \quad (5.78)$$

$$\Delta COHQ_h = 0.01{*}COHQ_h * x^{cohq}_{h}, \quad (5.79)$$

where $COIQ_i$ is the carbon emissions generated by industry i, $COHQ_h$ is the carbon emissions generated by household h, x_i^{coiq} is the percentage change in carbon emissions generated by industry i, x_h^{cohq} is the percentage change in carbon emissions generated by household h.

For industries and households unrelated to the ETS, x_i^{coiq} and x_h^{cohq} are set to zero.

The industries in the ETS are set in a block named BLOCI. The percentage change in the total emissions generated by these industries is given by Equation (5.80).

$$\text{COIQ\_I}*x^{coiq\_I}= \sum_{i\in BLOCI} COIQ_i * x_i^{coiq}, \qquad (5.80)$$

The households in the ETS are set in a block named BLOCH. The percentage change in the total emissions generated by these households is given in Equation (5.81).

$$\text{COHQ\_H}*x^{cohq\_H}= \sum_{h\in BLOCH} COHQ_h * x_h^{cohq}, \qquad (5.81)$$

The percentage change in the total emissions in industries and households related to the ETS is expressed in Equation (5.82).

$$\text{COTQ}*x^{cotq} = \text{COIQ\_I}*x^{coiq\_I} + \text{COHQ\_H}*x^{cohq\_H}, \qquad (5.82)$$

where COIQ_I is the total carbon emissions generated by industries in the ETS, COHQ_H is the total carbon emissions generated by households in the ETS, COTQ is the total carbon emissions generated by industries and households in the ETS, x^{cotq} is the percentage change in total emissions generated by industries and households in the ETS.

Under the ETS, the government sets the fixed quantity of carbon emissions reduction (cap) for each of the industries in response to the carbon emissions reduction target. Therefore, there is a relationship between the percentage change in carbon emissions generated in the economy and carbon emissions generated by industries and households related to the ETS. This is expressed in Equation (5.83)

$$x^{empp} = x^{coit}-x^{cotq}, \qquad (5.83)$$

In the model, the emisisons price is an exogenous variable. However, under the ETS the emissions is determined by the market, the quantity of emissions reduction for each industry and households related to the ETS is fixed by the government, therefore, x^{empp} is swapped by an emission price to an exogenous variable. The actual percentage change (x^{coit}) in emissions generated in the economy is determined by the percentage change (x^{cotq}) in emisisons generated by the industries and households related to the ETS.

+ The emissions permit price and emissions trading among industries

The emissions permit price appears in the industry and households related to the ETS blocks, but for industries and households unrelated to the ETS, the emissions permit price is set to be zero. The emissions permit price is equal to all industries and to all household groups related to the ETS. The selling emissions or buying emissions is calculated for each industry as follows:

$$COIQemi_i = COIQ_i - X_i^{1ci\_sc} - X_i^{1co\_c} , \qquad (5.84)$$

where $COIQemi_i$is the gap between emissions generation target of industry i and the change in emissions of industry i, $X_i^{1ci_sc}$and $X_i^{1co_c}$are the change in input and output emissions of industry i.

Equation (5.84) shows that industry i sells its excessive emissions to other industries if industry i actually generates less emissions than its emissions generation target, and vice versa. Industry i buys its deficient emissions from other industries if it actually generates more emissions than its emissions generation target. Therefore, the permit revenue of each industry is likely to be positive or negative. It is positive when industry i sells the carbon emissions permits. Conversely, it is negative when the industry i buys the carbon emissions permits. The permit revenue by industry i is expressed in Equation (5.85).

$$COIQrvn_i = \text{PCTAX} * COIQemi_i , \qquad (5.85)$$

where PCTAX is the price of an emissions permit.

+ Government revenue from the ETS

The permit revenue obtained from the ETS is calculated as:

$$1000*\Delta GREV = COIQ\_I*\Delta PCTAX + PCTAX*\Delta COIQ\_I , \qquad (5.86)$$

where ΔGREV is the permit revenue that is obtained by the government, COIQ_I is the total emissions generated from industries related to the ETS, ΔCOIQ_I is the change in total emissions generation from all industries related to the ETS, ΔPCTAX is the change in the emissions permit price.

5.1.8 Price system and zero pure profit conditions

The price system includes basic prices and purchaser prices. The basic prices are the producers' prices, which include intermediate input costs, the cost of primary factors and other production costs. The purchasers' prices include basic prices, sales taxes and margins. Sales taxes are treated as ad valorem on basic prices with the sales-tax variables t in the linearised model being percentage change in the powers of taxes. To obtain zero pure profits, each equation indicates that the output price must equal the input price. The purchasers' prices are applied to users, such as producers, households, government, investors and exports (See the Tablo code in Appendix C, Excerpt 5.24).

5.1.8.1 Percentage change in purchasers' prices to producers

Producers who emit into the atmosphere must pay for their pollution. This cost is added into the purchasers' prices. Purchasers' prices paid by producers are accounted for in both domestic and imported commodities in percentage form as follows:

$$[X_{csi}^{1pur}+\text{TINY}]*p_{csi}^{1}=[X_{csi}^{1bas}+X_{csi}^{1tax}]*[p_{cs}^{0}+t_{csi}^{1}]+\sum_{m\in MAR}X_{csim}^{1mar}*[p_{m}^{0dom}+a_{csim}^{1mar}]$$
$$+100*\Delta TX1CI_{csi}-TX1CI_{csi}*x_{csi}^{1}\ . \qquad (5.87)$$

5.1.8.2 Percentage change in purchasers' prices to investors

The purchasers' prices paid by investors include basic prices, taxes and the cost of the margin. The percentage change in purchasers' prices to investors is given as:

$$[X_{csi}^{2pur}+\text{TINY}]*p_{csi}^{2}=[X_{csi}^{2bas}+X_{csi}^{2tax}]*[p_{cs}^{0}+t_{csi}^{2}]+\sum_{m\in MAR}X_{csim}^{2mar}*[p_{m}^{0dom}+a_{csim}^{2mar}]. \qquad (5.88)$$

5.1.8.3 Percentage change in purchasers' prices to households

Similar to producers, the purchasers' prices to households include basic prices, taxes, marginal costs, and carbon emissions charges that households must pay for emissions generated during their consumption. The percentage change in purchasers' prices to households is given as:

$$[X_{cs}^{3pur}+\text{TINY}]*p_{cs}^{3}=[X_{cs}^{3bas}+X_{cs}^{3tax}]*[p_{cs}^{0}+t_{cs}^{3}]+\sum_{m\in MAR}\sum_{h\in HOU}X_{cshm}^{3mah}*[p_{m}^{0dom}+a_{cshm}^{3mah}]+$$
$$\sum_{h\in HOU}[100*\Delta TX3CC_{csh}-TX3CC_{csh}*x_{csh}^{3h}]. \qquad (5.89)$$

5.1.8.4 Percentage change in purchasers' prices to export commodities

The purchasers' prices include the basic price of export commodities, taxes on exports and the cost of margin to export commodities. The percentage change in purchasers' prices to export commodities is given as:

$$[X_c^{4pur}+\text{TINY}]*p_c^4=[X_c^{4bas}+X_c^{4tax}]*[p_c^e+t_c^4] + \sum_{m\in MAR} X_{cm}^{4mar} * [p_m^{0dom} + a_{cm}^{4mar}]. \quad (5.90)$$

5.1.8.5 Percentage change in purchasers' prices to government

The purchasers' prices of commodities to government include the basic price plus tax on commodities and the cost of margins. It is expressed as:

$$[X_{cs}^{5pur}+\text{TINY}]*p_{cs}^5=[X_{cs}^{5bas}+X_{cs}^{5tax}]*[p_{cs}^0+t_{cs}^5]+\sum_{m\in MAR} X_{csm}^{5mar} * [p_m^{0dom} + a_{csm}^{5mar}]. \quad (5.91)$$

5.1.9 Market clearing equations

Market clearing equations ensure that the economy is in equilibrium, in which demand is equal to supply, and prices are endogenously determined. There is no excess demand and no excess supply in the economy. The total supply incorporates a sum of all industry output, while the total demand includes demand for intermediate inputs to current production, demand for capital inputs, household demand, government demand, export demand, margins and inventories. The value changes in margins for the marginal commodities are defined by equation (5.92).

$$\Delta sale_m^{mar}= \sum_{c\epsilon COM}[V_{cm}^{4mar} * x_{cm}^{4mar} + [\sum_{s\epsilon SRC}[\sum_{h\epsilon HOU} V_{cshm}^{3mar} * x_{cshm}^{3mar}] + V_{csm}^{5mar} * x_{csm}^{5mar}+\sum_{i\epsilon IND}[V_{csim}^{1mar} * x_{csim}^{1mar} + V_{csim}^{2mar} * x_{csim}^{2mar}]]]. \quad (5.92)$$

For commodities, if they are not included in the marginal commodity group, $\Delta sale_m^{mar}$ are zero; if they are in the marginal commodity group but they are imported, $\Delta sale_m^{mar}$ is also zero.

Market clearing equations for domestically produced commodities, defined in percentage form, are presented in equation (5.93). The left-hand side of equation (5.93) shows a sum of commodity c produced by all industries in the economy, and the right-hand side of the equation presents the total demand constituted from intermediate input demand, capital input demand, household demand, government demand, export demand, margins and changes in inventories.

$$[\text{TINY}+sales_c^{dom}]*x_c^{0dom} = [\sum_{i\epsilon IND}[V_{c,dom,i}^{1bas} * x_{c,dom,i}^{1bas} + V_{c,dom,i}^{2bas} * x_{c,dom,i}^{2bas}]]+ [\sum_{h\epsilon HOU} V_{c,dom,h}^{3bas} * x_{c,dom,h}^{3}] + V_c^{4bas} * x_c^4 + V_{c,dom}^{5bas} * x_{c,dom}^5 + 100*LEV_{c,dom}^{P0} * \Delta X_{c,dom}^6+ 100* \Delta sale_m^{mar} \;, \quad (5.93)$$

where $sales_c^{dom}$ is the total sales of commodity c in the local market, x_c^{0dom} is the percentage change in output of commodity c produced in the local market, $LEV_{c,dom}^{P0}$ is the level of the basic price to commodity c in the local market, $\Delta X^{6}_{c,dom}$ is the change in inventory to commodity c in the local market.

For imported commodity c, the supply is equal to the total demand for imported commodity c. The market clearing equations for imported commodity c are presented in Equation (5.94). The demand components are expressed in the right-hand side of equation (5.94), and the supply is expressed in the left-hand side of this equation.

$$[\text{TINY}+V^{0imp}_{c}]*x^{0imp}_{c} = \sum_{i\epsilon IND}[V^{1bas}_{c,imp,i} * x^{1bas}_{c,imp,i} + V^{2bas}_{c,imp,i} * x^{2bas}_{c,imp,i}]+[\sum_{h\epsilon HOU} V^{3bas}_{c,imp,h} * x^{3}_{c,imp,h}] + V^{5bas}_{c,imp} * x^{5}_{c,imp} + 100*LEV^{P0}_{c,imp} * \Delta X^{6}_{c,imp} \quad (5.94)$$

(See the Tablo code in Appendix C, Excerpt 5.25).

5.1.10 Household, corporation, government and ROW accounts

The ORANI-G model is predominantly based on the IO database; the model in this study is mostly based on the SAM database. The income, expenditure and savings of each of the institutions are provided in detail in the model. See Tablo code in Appendix C, Excerpt 5.26.

5.1.10.1 Household income, expenditure and saving

- Household income

There are 20 household groups in the model and each household group receives income from various sources. The sources of income are: labour income, income from land ownership, from capital ownership, transfers from government, corporations and the rest of the world (ROW). Household income is presented through the following equation:

$$HINC_{h}*x^{HINC}_{h} = \sum_{o\epsilon OCCD} 100 * \Delta HHL_{ho} + 100*\Delta HHK_{h} + 100*\Delta HHLD_{h} + \sum_{n\epsilon HOU} HTH_{hn} * x^{HTH}_{hn} + NFTH_{h}*x^{NFTH}_{h} + FTH_{h}*x^{FTH}_{h} + GTH_{h}*x^{GTH}_{h} + RWTH_{h}*x^{RWTH}_{h}. \quad (5.95)$$

where $HINC_{h}$ and x^{HINC}_{h} are the value and percentage changes of household group h's income, ΔHHL_{ho} is the change in labour income from occupation o; ΔHHK_{h} and $\Delta HHLD_{h}$ are the changes in capital and land income by household group h respectively, HTH_{hn} and x^{HTH}_{hn} are the value and percentage changes of transfer income from household group n to household group h, $NFTH_{h}$ and x^{NFTH}_{h}; FTH_{h} and x^{FTH}_{h}; GTH_{h} and x^{GTH}_{h}; $RWTH_{h}$ and x^{RWTH}_{h} are the value and percentage changes of transfer received from non-financial corporations, financial corporations, government and the rest of the world by household group h.

- ***Household expenditure***

Household expenditure includes final household consumption, all transfers to other households and all other institutions. The equations representing household expenditure is given as:

$$HEXP_h * x_h^{HEXP} = V_h^{3tot} * x_h^{3toth} + \sum_{n \epsilon HOU} HTH_{nh} * x_{nh}^{HTH} + HTNF_h * x_h^{HTNF} +$$
$$HTF_h * x_h^{HTF} + HTG_h * x_h^{HTG} + HTRW_h * x_h^{HTRW} , \quad (5.96)$$

where $HEXP_h$ and x_h^{HEXP} are the value and percentage changes of the total expenditure of household group h, V_h^{3tot} and x_h^{3toth} are the value and percentage changes of the total household consumption of household group h, HTH_{nh} and x_{nh}^{HTH} are the value and percentage changes of transfers from household group n to household group h, $HTNF_h$ and x_h^{HTNF}, HTF_h and x_h^{HTF}, HTG_h and x_h^{HTG}, $HTRW_h$ and x_h^{HTRW} are the values and percentage changes respectively of transfers paid to non-financial corporations, financial corporations, government and the rest of the world by household group h respectively.

- ***Household savings***

In the case of household savings, the model assumes that the household savings share is fixed. This means that household income and expenditure change proportionally. Household savings is presented as follows:

$$\Delta HHSV_h = S_h^{HHSV} * \Delta HINC_h , \quad (5.97)$$

where $\Delta HHSV_h$ is the change in saving of household group h, $\Delta HINC_h$ is the change in income of household group h, S_h^{HHSV} is the household savings share of household group h.

5.1.10.2 Corporation income, expenditure and savings

- Corporation income

Income to non-financial and financial corporations sourced from capital income and transfers received from all institutions, including households, other non-financial and financial corporations, government, and the rest of the world.

+ Non-financial corporation income

$$\text{NINC} * x^{NINC} = 100 * \Delta\text{NFK} + \sum_{n \epsilon HOU} HTNF_h * x_h^{HTNF} + \text{NTNF} * x^{NTNF} +$$
$$\text{FTNF} * x^{FTNF} + \text{GTNF} * x^{GTNF} + \text{RWNF} * x^{RWNF} , \quad (5.98)$$

where NINC and x^{NINC} are the value and percentage change in income of non-financial corporations, ΔNFK is the change in capital income of non-financial corporations, $HTNF_h$ and x_h^{HTNF}, NTNF and x^{NTNF}, FTNF and x^{FTNF}, GTNF and x^{GTNF}, RWNF and x^{RWNF} are the values and percentage changes in transfers from household group h, other non-financial corporations, financial corporations, government and foreigners, respectively, to non-financial corporations.

+ Financial corporation income

$$\text{FINC}*x^{FINC}=100*\Delta\text{FFK}+\sum_{n\epsilon HOU} HTF_h * x_h^{HTF}+\text{NFTF}*x^{NFTF}+$$
$$\text{FTF}*x^{FTF}+\text{GTF}*x^{GTF}+\text{RWTF}*x^{RWTF}\ , \quad (5.99)$$

where FINC and x^{FINC} are the value and percentage change in income of financial corporations, ΔFFK is the change in capital income of financial corporations, HTF_h and x_h^{HTF}, NFTF and x^{NFTF}, FTF and x^{FTF}, GTF and x^{GTF}, RWTF and x^{RWTF} are the values and percentage changes in transfers from household group h, non-financial corporations, other financial corporations, government and foreigners, respectively, to financial corporations.

- Corporation expenditure

Expenditure of non-financial and financial corporations constitutes transfers paid to all institutions, including households, other non-financial and financial corporations, government and the rest of the world.

+ Non-financial corporation expenditure

$$\text{NEXP}*x^{NEXP}=\sum_{n\epsilon HOU} NFTH_h * x_h^{NFTH}+\text{NFTN}*x^{NFTN}+\text{NFTF}*x^{NFTF}+$$
$$\text{NFTG}*x^{NFTG}+\text{NFRW}*x^{NFRW}\ , \quad (5.100)$$

where NEXP and x^{NEXP} are the value and percentage change in expenditure of non-financial corporations, $NFTH_h$ and x_h^{NFTH}, NFTN and x^{NFTN}, NFTF and x^{NFTF}, NFTG and x^{NFTG} , NFRW and x^{NFRW} are values and percentage changes in transfers from non-financial corporations to household group h, other non-financial corporations, financial corporations, government, and foreigners respectively.

+ Financial corporation expenditure

$$\text{FEXP}*x^{FEXP}=\sum_{n\epsilon HOU} FTH_h * x_h^{FTH}+\text{FTNF}*x^{FTNF}+\text{FTF}*x^{FTF}+$$
$$\text{FTG}*x^{FTG}+\text{FTRW}*x^{FTRW} \quad (5.101)$$

where FEXP and x^{FEXP} are the value and percentage change in expenditure of financial corporations, FTH_h and x_h^{FTH}, FTNF and x^{FTNF}, FTF and x^{FTF}, FTG and x^{FTG} , FTRW and x^{FTRW} are values and percentage changes in transfers from financial corporations to household group h, non-financial corporations, other financial corporations, government and foreigners respectively.

- Corporation savings

Savings to non-financial and financial corporations is defined as the gap between their income and their expenditure.

+ Non-financial corporation savings

$$\text{NFSV}*x^{NFSV} = \text{NINC}*x^{NINC} - \text{NEXP}*x^{NEXP} \quad , \qquad (5.102)$$

where NFSV is the value of non-financial corporations savings, x^{NFSV} is the percentage change in savings of non-financial corporations.

+ Financial corporation savings

$$\text{FSV}*x^{FSV} = \text{FINC}*x^{FINC}\text{-FEXP}*x^{NEXP} \ , \qquad (5.103)$$

where FSV is the value of financial corporation savings, x^{FSV} is the percentage change in savings of financial corporations.

5.1.10.3 Government income, expenditure and savings

- Government income

Income to the government includes all taxation revenue, income from capital ownership and transfers from all institutions. Moreover, government income incorporates the revenue derived from the sales of emissions permit.

$$\begin{aligned}\Delta\text{GINC}= \ & [\textstyle\sum_{i\epsilon IND}[\sum_{c\epsilon COM}[\sum_{s\epsilon SRC} \Delta V_{csi}^{1tax} + \Delta V_{csi}^{2tax} + \Delta TX1CI_{csi}] + \Delta TX1CO_{ci}] + \Delta V_i^{1ptx}] + \\ & \Delta\text{V0TAR\_C} + \textstyle\sum_{c\in COM}\sum_{h\in HOU}\sum_{s\in SRC}[\Delta V_{csh}^{3tah} + \Delta TX3CC_{csh}] + \Delta\text{GGK} + \\ & 0.01* \textstyle\sum_{h\epsilon HOU} HTG_h * x_h^{HTG} + \text{NFTG}*x^{NFTG} + \text{FTG}*x^{FTG} + \\ & \text{GTG}*x^{GTG} + \text{RWTG}*x^{RWTG} \ , \qquad (5.104)\end{aligned}$$

where ΔGINC is the change in government income, ΔV_{csi}^{1tax} is the change in taxes on intermediate input by industry i to commodity c, sourced s, ΔV_{csi}^{2tax} is the change in taxes on investment by industry i to commodity c, sourced s, ΔV_{csh}^{3tah} is the change in taxes on commodity c sourced s to household group h, ΔV_i^{1ptx} is the change in production tax to industry i, ΔV0TAR_C is the change in the total tariff revenue, ΔGGK is the change in government income sourced from capital, HTG_h and x_h^{HTG}, NFTG and x^{NFTG}, FTG and x^{FTG}, GTG and x^{GTG}, RWTG and x^{RWTG} are the values and percentage changes of transfers received by government from household group h, non-financial corporations, financial corporations, government, and foreigners respectively.

- Government expenditure

Government expenditure incorporates government consumption on goods and services, subsidy payments and transfers made to all institutions.

$$GEXP*x^{GEXP} = V5TOT*x^{5tot} + \sum_{h \epsilon HOU} GTH_h * x_h^{GTH} + GTNF*x^{GTNF} + GTF*x^{GTF} + GTG*x^{GTG} + GTRW*x^{GTRW} + SUBG*x^{SUBG} , \quad (5.105)$$

where GEXP and x^{GEXP} are the value and percentage change in government expenditure, V5TOT and x^{5tot} are the value and percentage change in government consumption on goods and services, GTH_h and x_h^{GTH}, GTNF and x^{GTNF}, GTF and x^{GTF}, GTG and x^{GTG}, GTRW and x^{GTRW}, SUBG and x^{SUBG} are the values and percentage changes in transfers paid to household group h, non-financial corporations, financial corporations, government, foreigners, and subsidies respectively.

- Government savings

Government savings is the difference between government income and government expenditure:

$$GSV*x^{GSV} = GINC*x^{GINC} - GEXP*x^{GEXP} , \quad (5.106)$$

where GSV and x^{GSV} are the value and percentage change respectively of government savings.

5.1.10.4 ROW income, expenditure and savings

- ROW income

The link between domestic institutions and the rest of the world is shown by the ROW income and expenditure in the ROW account. ROW income includes the value of imported goods and services, wages paid to foreign labour, and transfers from all domestic institutions to foreigners:

$$RINC*x^{RINC} = \sum_{c \epsilon COM}[\sum_{i \epsilon IND}[V_{c,imp,i}^{1bas}*x_{c,imp,i}^{1}+V_{c,imp,i}^{2bas}*x_{c,imp,i}^{2}]]+\sum_{h \in HOU} V_{c,imp,h}^{3bas}* x_{c,imp,h}^{3}+V_{c,imp}^{5bas}* x_{c,imp}^{5}+ \Delta X_{c,imp}^{6}] +100*\Delta LTRW +$$

$$\sum_{h\in HOU} HTRW_h * x_h^{HTRW} + \text{NTRW}*x^{NTRW} + \text{FTRW}*x^{FTRW} + \text{GTRW}*x^{GTRW} + \text{RWRW}*x^{RWRW}, \quad (5.107)$$

where RINC and x^{RINC} are the value and percentage change in income of external sector, $\Delta LTRW$ is the change in income of external sector sourced from labour, $HTRW_h$ and x_h^{HTRW}, NTRW and x^{NTRW}, FTRW and x^{FTRW}, GTRW and x^{GTRW}, RWRW and x^{RWRW} are the values and percentage changes in transfers received by the external sector from household group h, non-financial corporations, financial corporations, government, and foreigners respectively.

- ROW expenditure

ROW expenditure incorporates the value of exported goods and services, the wages paid to offshore labourers, and transfers from the rest of the world to all domestic institutions:

$$\text{REXP}*x^{REXP} = V^{4tot}*x^{4tot} + 100*\Delta\text{RWTL} + \sum_{h\epsilon HOU} RWTH_h * x_h^{RWTH} + \text{RWTN}*x^{RWTN} + \text{RWTF}*x^{RWTF} + \text{RWTG}*x^{RWTG} + \text{RWRW}*x^{RWRW}, \quad (5.108)$$

where REXP and x^{REXP} are the value and percentage change in expenditure of the external sector, $\Delta RWTL$ is the change in labour wages paid by the external sector, $RWTH_h$ and x_h^{RWTH}, RWTN and x^{RWTN}, RWTF and x^{RWTF}, RWTG and x^{RWTG}, RWRW and x^{RWRW} are the values and percentage changes in transfers paid by the external sector to household group h, non-financial corporations, financial corporations, government, and foreigners respectively.

- ROW savings

The ROW savings is determined residually by ROW income and expenditure:

$$\text{RWSV}*x^{RWSV} = \text{RINC}*x^{RINC} - \text{REXP}*x^{REXP}, \quad (5.109)$$

where RWRW and x^{RWSV} are the value and percentage change, respectively, in savings of the external sector.

5.2 Elasticity parameters

Behavioural responses of agents to economic changes (mainly prices) are explained by the elasticity parameters. There are various parameters in this research, including Armington elasticities between domestic and imported commodities, elasticity of substitution among occupational categories, elasticity of substitution among primary factors, elasticity of substitution among energy commodities and between energy and capital, household expenditure elasticity. The values of the elasticity parameters are estimated or borrowed from the existing literature or other models. The following sections explain how to collect these substitution elasticities.

5.2.1 The elasticity of substitution between domestic and imported commodities

The elasticity of substitution in demand between domestically produced commodities and imported commodities explains the degree of substitutability between them; the higher the value of elasticity substitution the closer the degree of substitution. If an elasticity parameter between two products is low, the two products are dissimilar or are weak substitutes, if they are identical, the value of the elasticity parameter are infinite. The degree of similarity, or differentiation, between these two sources of supply is captured by the Armington elasticity. The Armington elasticity plays an important role in the CGE model, including Armingon elasticities of intermediate use (σ_1), investment use (σ_2) and household consumption (σ_3). The Armington elasticities are borrowed from the Centre of Policy Studies (2003) as shown in Table 5.1.

Table 5.1: Armington elasticities in the model

	Commodities	**σ_1**	**σ_2**	**σ_3**
1	Agriculture, Forestry & Fishing	1.42	1.58	1.43
2	Black coal	1.73	2	1.71
3	Brown coal	1.73	2	1.71
4	Oil	1.73	2	1.71
5	Gas	1.73	2	1.71
6	Mining	1.73	2	1.71
7	Food, beverages & tobacco	2.36	1.88	1.74
8	Textile, clothing & footwear	3.37	2.83	2.92
9	Wood, paper & printing	1.76	1.75	1.71
10	Automotive petrol	0.4	0.4	0.4
11	Kerosene	0.4	0.4	0.4
12	Gas oil or fuel oil	0.4	0.4	0.4
13	Liquefied petroleum gas	0.4	0.4	0.4
14	Other petroleum & coal products	0.4	0.4	0.4
15	Chemical products	1.99	1.95	1.89
16	Iron & Steel	0.871	0.9	1
17	Other metal products	1.73	1.64	1.87
18	Furniture & equipment	1.21	1.12	1.08
19	Other manufacturing	2.42	2.6	2.85
20	Electricity-Black coal	0	0	0
21	Electricity-Brown coal	0	0	0

	Commodities	σ_1	σ_2	σ_3
22	Electricity-Oil	0	0	0
23	Electricity-Gas	0	0	0
24	Electricity-Hydro	0	0	0
25	Electricity-Wind	0	0	0
26	Electricity-Solar	0	0	0
27	Electricity-Biomass	0	0	0
28	Electricity-Biogas	0	0	0
29	Commercial Electricity	0	0	0
30	Gas supply	0	0	0
31	Water & sewerage services	0	0	0
32	Construction services	0	0	0
33	Wholesale trade	0	0	0
34	Retail trade	0	0	0
35	Accommodation and restaurant	0	0	0
36	Road transport	0.804	2	1.19
37	Other transports	0.804	2	0
38	Communication services	0	0	0
39	Finance and Insurance	0	0	0
40	Property and business services	0	0	0
41	Public services	0	0	0
42	Education and training	0	0	0
43	Health and community services	0	0	0
44	Art and recreation services	0	0	0
45	Other services	0	0	0

Source: Collected from Centre of Policy Studies (2003)

5.2.2 The elasticity of substitution among electricity generation types and among energy inputs

The substitution elasticity among different form of electricity generation produced by different types of fuels is identically assigned to 5.0, which is similar to the MMRF-Green model (Pezzey & Lambie, 2001). The sub-energy inputs seem to have a relatively high similarity, thus the elasticity of substitution between black coal and brown coal, between oil and gas, and between petroleum products are all assigned the same elasticity value of 0.8.

The elasticity of substitution between composite coal, composite oil and gas, composite petroleum is assigned at 0.6 in this research. According to Shahiduzzaman and Alam (2014), there is weak substitutability between all of the energy types of coal, oil, gas. The elasticity of substitution between coal and oil was estimated at 0.616 for the period 1990-2008.

5.2.3 The elasticity of substitution among labour categories, between energy and capital and among primary factors

There are ten occupational categories and these labour groups are allowed to substitute in the model through the CES function. The elasticity of substitution among occupational groups is borrowed from the Centre of Policy Studies (2003), in which the value of elasticity is set at 0.5 for all industries. In the ORANI-G model the elasticity of substitution among labour, capital and land is set at 0.5 for all industries. In this study, the elasticity of substitution between composite labour, capital-energy composite, and land is assigned the value of 0.5.

For the substitution between energy and capital, the value of substitution elasticity reflects the adoption of energy-saving technologies in the economy aimed at reducing energy consumption, thus leading to the emissions reduction. There have been many empirical studies conducted to estimate substitution elasticity between capital and energy. For example, Costantini and Paglialunga (2014) estimated the elasticity of substitution between capital and energy of 0.27 for aggregate manufacturing industry in 21 OECD countries from 1975 to 2008. In the GTAP-E database, the value of substitution elasticity between capital and energy is assumed to be 0.5 to most industries (Truong et al., 2007). Okagawa and Ban (2008) estimated the substitution elasticities in two main structures, the KE-L and KL-E forms, using data from 14 countries and 19 industries from 1990 to 2004. They concluded that the capital-energy elasticity in the KE-L ranged from 0.04 to 0.45, and that there is a higher KE elasticities for energy-intensive industries, as shown in Table 5.2. In this study, the elasticity of substitution between energy and capital is identically assigned to industries at 0.25.

Table 5.2: The elasticity of substitution between capital and energy

Industries	KE elasticity
Chemical	0.04
Other Non-metallic Mineral	0.35
Iron & Steel	0.29
Machinery	0.12
Electricity equipment	0.25
Transport equipment	0.09
Transport	0.45
Food	0.39
Basic metals	0.29
Pulp and Paper	0.37
Textiles	0.17

Source: Collected from Okagawa & Ban (2008)

5.2.4 Household expenditure elasticity

There are 45 commodities and 20 household groups in this model, in order to estimate the expenditure elasticity and Frisch parameters for 45 commodities by 20 household groups, this study used the research of Cornwell & Creedy (1997, pp. 61-82). For Frisch parameters, Cornwell and Creedy presented three different equations in order to produce a range of Frisch values; this study is based on one of those three equations, as shown in Equation (5.110):

$$\text{Log}(\xi) = 16389\text{-}1.405\log(m+10222.89) \qquad (5.110)$$

Where ξ is the Frisch parameter and m is the household expenditure.

The value of Frisch parameters of each household group is shown in Table 5.3.

Table 5.3: Frisch parameters

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**	**Group 10**
Frisch parameters	-11.478	-18.045	-17.368	-15.576	-11.956	-11.592	-10.773	-10.290	-9.444	-8.762
	Group 11	**Group 12**	**Group 13**	**Group 14**	**Group 15**	**Group 16**	**Group 17**	**Group 18**	**Group 19**	**Group 20**
Frisch parameters	-7.615	-6.641	-6.157	-4.983	-4.777	-4.291	-3.677	-3.261	-2.784	-2.000

Source: Author's calculation

Cornwell and Creedy (1997) empirically estimated household expenditure elasticities for 30 household income groups to 14 commodities in Australia, using the cross-sectional budget data of consumer expenditure for the year 1984. These 30 household groups were further aggregated into 20 household groups by grouping two consecutive household groups into one household group, and 14 commodities were mapped into 45 commodities, as seen in Table 5.4

The next step was to calculate the marginal budget share of each household group to 45 commodities; the marginal budget share is computed by Equation (5.111).

$$S_{ch}^{3lux} = \frac{X_{ch}^{3\_s}}{\sum_{c \epsilon COM} X_{ch}^{3\_s}} * EPS_{ch} \;, \qquad (5.111)$$

where S_{ch}^{3lux} is the marginal budget share of household group h for commodity c, and $X_{ch}^{3\_s}$ is the expenditure of household group h to both domestic and imported commodity c (this is purchasers' values) , EPS_{ch} is the estimated expenditure elasticity of household group h for commodity c.

The sum of marginal household expenditure share (S_{ch}^{3lux}) is equal to the average Engle elasticity that should be equal to 1 for each household group. However, the average Engle elasticity for each household group was not equal to 1, thus expenditure elasticities were recalculated in response to the equivalent 1 of the average Engle elasticity by Equation (5.112):

$$EPS'_{ch} = \frac{EPS_{ch}}{\sum S_{ch}} \tag{5.112}$$

Using EPS'_{ch} instead of EPS_{ch} satisfies the condition that the average Engle elasticity for each household group is equal to 1. The household expenditure elasticity is shown in Table 5.5.

Table 5.4: Average expenditure elasticities

Commodity	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
Agriculture, Forestry & Fishing	0.957	0.905	0.758	0.690	0.605	0.599	0.592	0.589	0.584	0.584
Black coal	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Brown coal	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Oil	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Gas	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Mining	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Food, beverages & tobacco	0.957	0.905	0.758	0.690	0.605	0.599	0.592	0.589	0.584	0.584
Textile, clothing & footwear	1.083	1.141	1.194	1.200	1.229	1.252	1.230	1.217	1.241	1.239
Wood, paper & printing	1.323	1.490	1.577	1.508	1.484	1.517	1.410	1.349	1.369	1.361
Automotive petrol	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Kerosene	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Gas oil or fuel oil	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Liquefied petroleum gas	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Other petroleum & coal products	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Chemical products	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Iron & Steel	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Other metal products	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Furniture & equipment	1.323	1.490	1.577	1.508	1.484	1.517	1.410	1.349	1.369	1.361
Other manufacturing	1.133	1.317	1.366	1.253	1.276	1.303	1.217	1.239	1.216	1.217
Electricity-Black coal	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Brown coal	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Oil	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Gas	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Hydro	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385

Commodity	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
Electricity-Wind	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Solar	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Biomass	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Electricity-Biogas	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Commercial Electricity	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Gas supply	0.928	0.843	0.589	0.433	0.173	0.207	0.308	0.332	0.368	0.385
Water & sewerage services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Construction services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Wholesale trade	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Retail trade	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Accommodation and restaurant	1.069	1.125	1.173	1.159	1.200	1.222	1.274	1.301	1.355	1.318
Road transport	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Other transports	1.189	1.311	1.435	1.485	1.490	1.361	1.269	1.259	1.286	1.263
Communication services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Finance and Insurance	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Property and business services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Public services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Education and training	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468
Health and community services	0.972	0.937	0.837	0.827	0.794	0.722	0.682	0.640	0.547	0.507
Art and recreation services	1.069	1.125	1.173	1.159	1.200	1.222	1.274	1.301	1.355	1.318
Other services	0.947	0.884	0.696	0.603	0.472	0.460	0.465	0.470	0.468	0.468

Table 5.4: Average expenditure elasticities (continued)

Commodity	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18	Group 19	Group 20
Agriculture, Forestry & Fishing	0.579	0.576	0.577	0.573	0.573	0.575	0.571	0.566	0.579	0.522
Black coal	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Brown coal	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Oil	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Gas	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Mining	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Food, beverages & tobacco	0.579	0.576	0.577	0.573	0.573	0.575	0.571	0.566	0.579	0.522
Textile, clothing & footwear	1.206	1.185	1.216	1.225	1.241	1.238	1.196	1.195	1.122	1.080
Wood, paper & printing	1.283	1.261	1.276	1.189	1.142	1.149	1.129	1.111	1.056	1.036
Automotive petrol	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Kerosene	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Gas oil or fuel oil	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Liquefied petroleum gas	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Other petroleum & coal products	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Chemical products	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Iron & Steel	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Other metal products	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Furniture & equipment	1.283	1.261	1.276	1.189	1.142	1.149	1.129	1.111	1.056	1.036
Other manufacturing	1.215	1.199	1.210	1.166	1.132	1.135	1.149	1.141	1.047	1.014
Electricity-Black coal	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Brown coal	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Oil	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Gas	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421

Commodity	**Group 11**	**Group 12**	**Group 13**	**Group 14**	**Group 15**	**Group 16**	**Group 17**	**Group 18**	**Group 19**	**Group 20**
Electricity-Hydro	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Wind	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Solar	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Biomass	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Electricity-Biogas	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Commercial Electricity	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Gas supply	0.400	0.405	0.450	0.433	0.442	0.462	0.463	0.464	0.493	0.421
Water & sewerage services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Construction services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Wholesale trade	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Retail trade	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Accommodation and restaurant	1.264	1.260	1.291	1.292	1.373	1.377	1.353	1.337	1.239	1.142
Road transport	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Other transports	1.126	1.118	1.089	0.993	0.900	0.876	0.656	0.500	0.336	0.220
Communication services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Finance and Insurance	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Property and business services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Public services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Education and training	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416
Health and community services	0.288	0.417	0.546	0.547	0.564	0.564	0.535	0.520	0.523	0.453
Art and recreation services	1.264	1.260	1.291	1.292	1.373	1.377	1.353	1.337	1.239	1.142
Other services	0.477	0.469	0.471	0.464	0.463	0.467	0.489	0.478	0.498	0.416

Source: Computed from Cornwell and Creedy (1997)

Table 5.5: Household expenditure elasticities

Commodity	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
Agriculture, Forestry & Fishing	0.939	0.893	0.829	0.832	0.765	0.778	0.770	0.773	0.777	0.779
Black coal	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Brown coal	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Oil	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Gas	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Mining	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Food, beverages & tobacco	0.939	0.893	0.829	0.832	0.765	0.778	0.770	0.773	0.777	0.779
Textile, clothing & footwear	1.063	1.126	1.305	1.448	1.554	1.625	1.600	1.599	1.651	1.653
Wood, paper & printing	1.299	1.471	1.723	1.820	1.878	1.969	1.834	1.773	1.821	1.815
Automotive petrol	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Kerosene	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Gas oil or fuel oil	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Liquefied petroleum gas	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Other petroleum & coal products	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Chemical products	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Iron & Steel	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Other metal products	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Furniture & equipment	1.299	1.471	1.723	1.820	1.878	1.969	1.834	1.773	1.821	1.815
Other manufacturing	1.112	1.300	1.493	1.512	1.614	1.691	1.583	1.628	1.618	1.623
Electricity-Black coal	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Brown coal	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Oil	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Gas	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Hydro	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513

Commodity	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10
Electricity-Wind	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Solar	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Biomass	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Electricity-Biogas	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Commercial Electricity	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Gas supply	0.911	0.832	0.644	0.523	0.218	0.269	0.400	0.436	0.489	0.513
Water & sewerage services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Construction services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Wholesale trade	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Retail trade	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Accommodation and restaurant	1.050	1.110	1.282	1.398	1.518	1.586	1.658	1.709	1.802	1.758
Road transport	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Other transports	1.167	1.294	1.569	1.792	1.884	1.767	1.651	1.655	1.711	1.685
Communication services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Finance and Insurance	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Property and business services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Public services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Education and training	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624
Health and community services	0.954	0.925	0.914	0.998	1.005	0.937	0.887	0.840	0.727	0.676
Art and recreation services	1.050	1.110	1.282	1.398	1.518	1.586	1.658	1.709	1.802	1.758
Other services	0.929	0.873	0.761	0.727	0.597	0.597	0.605	0.617	0.622	0.624

Table 5.5 Household expenditure elasticities (continued)

Commodity	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18	Group 19	Group 20
Agriculture, Forestry & Fishing	0.796	0.801	0.782	0.795	0.789	0.796	0.798	0.811	0.871	0.851
Black coal	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Brown coal	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Oil	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Gas	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Mining	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Food, beverages & tobacco	0.796	0.801	0.782	0.795	0.789	0.796	0.798	0.811	0.871	0.851
Textile, clothing & footwear	1.658	1.649	1.648	1.699	1.711	1.713	1.673	1.714	1.687	1.759
Wood, paper & printing	1.765	1.754	1.729	1.650	1.574	1.589	1.579	1.594	1.587	1.687
Automotive petrol	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Kerosene	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Gas oil or fuel oil	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Liquefied petroleum gas	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Other petroleum & coal products	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Chemical products	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Iron & Steel	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Other metal products	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Furniture & equipment	1.765	1.754	1.729	1.650	1.574	1.589	1.579	1.594	1.587	1.687
Other manufacturing	1.671	1.668	1.640	1.618	1.560	1.570	1.607	1.636	1.575	1.652
Electricity-Black coal	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Brown coal	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Oil	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Gas	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685

Commodity	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18	Group 19	Group 20
Electricity-Hydro	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Wind	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Solar	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Biomass	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Electricity-Biogas	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Commercial Electricity	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Gas supply	0.550	0.563	0.610	0.600	0.609	0.639	0.648	0.665	0.741	0.685
Water & sewerage services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Construction services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Wholesale trade	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Retail trade	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Accommodation and restaurant	1.739	1.753	1.750	1.793	1.893	1.906	1.893	1.918	1.863	1.861
Road transport	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Other transports	1.548	1.555	1.476	1.378	1.240	1.212	0.917	0.717	0.505	0.358
Communication services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Finance and Insurance	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Property and business services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Public services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Education and training	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678
Health and community services	0.395	0.580	0.740	0.759	0.778	0.780	0.748	0.745	0.787	0.738
Art and recreation services	1.739	1.753	1.750	1.793	1.893	1.906	1.893	1.918	1.863	1.861
Other services	0.655	0.652	0.638	0.644	0.638	0.646	0.683	0.686	0.748	0.678

Source: Author’s calculation

5.3 Conclusion

This chapter described the theoretical structure of the CGE model developed to analyse the effects of an ETS. The model incorporates a system of equations, in which equations explaining intermediate input demand functions of various energy commodities and capital-energy composite input demand functions are outlined in details. Furthermore, to measure the effects of fixed quantities of emissions to industries, the model included equations defining the emissions trading mechanism among industries in the Australian economy. Purchaser price equation incorporated the emissions permit price; therefore, the explicit carbon emissions quantity shocks will change the equilibrium level of quantities and prices in the economy. Moreover, to measure the distributional and welfare effects, the model contained sets of behavioural equations explaining the income and expenditure of all institutions in the economy. This allows an evaluation and comparison of the effects of various compensation policies of households.

The model requires various parameters that illustrate the behaviour of producers and consumers in the economy to economic changes. The values of the elasticity parameters show substitutability between domestic and imported commodities in production and consumption as well as substitutability between energy inputs and primary factors in production to price changes when the government imposes the emissions cap to industries. Therefore, the values of these elasticity parameters played an important role in determining the effects of carbon emissions reduction policies. This chapter presented in detail the approaches for collecting and estimating the values of these elasticity parameters.

CHAPTER 6: IMPACTS OF THE AUSTRALIAN EMISSIONS TRADING SCHEME AND REVENUE RECYCLING POLICIES

The purpose of this chapter is to compare and contrast the macroeconomic, sectoral, distributional, and welfare effects of different scenarios of revenue recycling under the domestic ETS in Australia. In order to achieve the Kyoto emissions reduction target of five per cent below 2000 levels by 2020, the Australian Government is assumed to fix a quantity of emissions generated in the whole economy, then allocate this emissions quantity to each polluting industry based on their previous amounts of emissions. Under the ETS, industries can purchase their emissions quota from the government or other industries, which have excessive emissions, by paying an emissions permit price that is determined endogenously by the market. The government accrues the amount of revenue. In this study, it is assumed that half of the auction revenue is used to compensate household groups through various compensation policies, and the other half of the revenue is kept in the government budget. The impacts of these policies on disaggregated energy sectors, occupational categories, and household groups will be presented in detail in this chapter.

The chapter is organised as follows. The model setting is outlined in section 6.1. The impacts of the ETS plus the various compensation policies on the macroeconomic variables are presented in section 6.2 and the impacts on industries are discussed in section 6.3. Section 6.4 analyses those impacts on household groups: that is, on household income, household consumption, household utility, and household welfare. A sensitivity analysis is presented in section 6.5, and the chapter ends with the conclusion in section 6.6.

6.1 Model setting

The ETS applies to industries in the Australian economy with the objective to achieve the emissions reduction target. To measure the effects of the ETS as well as the various compensation policies, the model setting needs to be established.

6.1.1 Closure to the model

The closure of the model is the split of the set of variables into exogenous and endogenous categories. To make a closure valid, the number of endogenous variables must be equal to the number of equations.[12] This is the standard requirement for closing the model. To specific

[12] GEMPACK manual searched from website: file:///C:/GP/gpmanual.htm#gpd3.5.1a

research questions, ‘swap’ statements allow for setting the previously exogenous variables to endogenous variables or the previous endogenous variables to exogenous variables in the closure. A choice of closure reflects two different types of considerations: first, the closure is associated with the simulation timescale, such as a short-run simulation or a long-run simulation; second, the choice of closure depends on a particular simulation (Horridge, 2003).

A timescale assumption affects factor markets after the policy shock. This study examines the effects of the policy shocks in the short run framework. The length of a short run is thought to be between one and three years; that is the time period needed for economic variables to adjust to a new equilibrium. The short-run closure allows for rigidities in the capital and labour markets. The short-run closure fixes the capital stocks and the rates of return on capital are affected by the policy shock. Labour market rigidities are implemented by fixing real wages, while aggregate employment and employment levels of various occupational categories are affected by the policy shock. The variables that need to be set as exogenous are:

+ technical change variables, mostly beginning with ‘a’;

+ shift variables, mostly beginning with ‘f’;

+ some change variables, beginning with ‘del’;

+ percentage change in transfers between institutions, beginning with ‘x’;

+ land endowments ‘x1lnd’, the number of households ‘qh’, and industry capital stock ‘x1cap’; investment ‘x2tot’;

+ foreign prices ‘pf0cif’; and the investment slack variable ‘invslack’; power of tariff ‘t0imp’;

+ the exchange rate ‘phi’, which could serve as numeraire;

+ percentage change in quantity of emissions generated by industries related to the ETS ‘xcoiq_B’ and ‘xcoiq_M’, and by households related to the ETS ‘xcohq_H’.

This research analyses the effects of fixed quantities of emissions to polluting industries on the Australian economy. So a percentage change in emissions generated by each industry is determined exogenously and an emissions permit price becomes an endogenous variable. Thus, there is a ‘swap’ statement between the emissions permit price and the percentage change in emissions. The percentage changes in emissions generated by industries are set to be shocks in the closure. In addition, in order to measure the effects of various compensation policies on

Australian households, the changes in transfers from government to households are swapped to become endogenous variables, while certain selected shift variables are swapped to become exogenous variables. To carry out simulations in the short run, there are many swaps in the model:

+ exogenising ‘realwage’ instead ‘f1lab_io’;

+ exogenising ‘delx6’ instead ‘fx6’;

+ exogenising ‘x5tot’ instead ‘f5tot2’;

+ exogenising ‘x^{empp}’ instead ‘delPCTAX’.

6.1.2 Emissions reduction target

The total emissions generated in 2000 was 586 Mt CO_2-e. In order to achieve the emissions reduction target of 5 per cent below 2000 levels by 2020, the 2020 emissions target was set at 555 Mt CO_2-e (Department of the Environment, 2013a). The emissions data in this research is 2009 with the total emissions of 575.679 Mt CO_2-e as stated by the National Greenhouse Gas Inventory (NGGI).[13] In this research, it is assumed that the average annual emissions growth rate in the period 2009-2020 would be the same as the average annual emissions growth rate in the period 2005-2010 (including Land Use, Land-Use Change and Forestry (LULUF)). According to the United Nations Framework Convention on Climate Change (UNFCCC),[14] the average annual emissions growth rate for the period 2005-2010 is calculated at 0.72 per cent.[15]

Given an average annual emissions growth rate of 0.72 per cent in the period 2009-2020, the emissions reduction target in 2009 should be reduced by 63.489 Mt CO_2-e to achieve an emissions target of 555Mt CO_2-e by 2020. Under the ETS, the trading scheme is assumed to take place between polluting industries within the Australian economy. The Australian Government sets emissions reduction targets for industries related to the ETS in response to the total emissions reduction target of 63.489 Mt CO_2-e. Because of their high emissions level, the electricity-black coal and electricity-brown coal industries are set to reduce their emissions by 27.442 per cent from baseline emissions; each remaining industry affected by the ETS is required to reduce emissions by 3.366 per cent from their baseline emissions. If industries generate less emissions than their emissions allowance, they can sell their excess emissions

[13] The emissions data was compiled for the year 2009 from website http://ageis.climatechange.gov.au/

[14] http://unfccc.int/di/DetailedByParty/Event.do?event=go

[15] Based on http://unfccc.int/di/DetailedByParty/Event.do?event=go, the emissions (excluding LULUCF) in 2002 and in 2012 were 503.585Mt CO2-e, and 543.648Mt CO2-e

abatements to other industries who generate more emissions than their allowance in the emissions auctions and vice versa. In such an ETS, the emissions permit price is determined by the market.

6.1.3 Simulation scenarios

Under the ETS, the government fixes an amount of emissions permits equivalent to the total emissions target and then sells them to polluting industries. It is assumed that the emissions permits are only traded between Australian industries. Emitters from other countries are not allowed to purchase these emissions permits. Furthermore, the Australian Government does not give emissions permits free to any polluters. Therefore, the Government accrues the revenue from auctions that is equal to the emissions permit price multiplied by the quantity of emissions permits. Half of the auction revenue is assumed to compensate households according to various policies. This thesis compares the results of simulations from various scenarios of revenue recycling.

In the first scenario, the ETS is implemented without revenue recycling (called the Non-Revenue Recycling (NRR) policy). It means that all revenue raised from the ETS is accrued to increase government revenue, which might create a budget surplus. The effects on the Australian economy come entirely from the ETS only. The following scenarios describe the ETS plus various types of revenue recycling. It is assumed that half of the auction revenue is used to compensate all household groups in different ways, the remaining 50 per cent is kept in the government budget.

In the second scenario, the auction revenue is used to return to household groups by reducing the Goods and Services Tax (GST) (called the GST policy). The GST is reduced in the uniform general ad valorem sales tax rate for all commodities. To do so, the uniform percentage change in the power of tax on household usage would be endogenous while the change in the government income from the GST would be swapped to exogenous.

The revenue is recycled to all household groups in the form of reducing income tax in the next scenario. This is expressed in the third scenario and is known as the INT policy. All income tax rates are reduced in equal proportions (or an equal decrease in marginal income tax rate to all individuals). Because of different income tax rates, the household groups would receive various benefits from this policy. As measured by the dollar value, higher income households would receive more benefits than lower income households in this case.

The fourth scenario offers compensation to all household groups, based on the ratios of their receipts from the government pensions and allowances (called the GOT policy). The Household Expenditure Survey 2009-2010 shows that household income from the government is one of five sources constituting total household income. The poor receive more payments from the government than the rich. In the fifth scenario, all household groups receive the same compensation from the revenue policy (called the equal lump-sum transfer (ELS) policy).

The carbon tax was implemented for two years, from July 2012 to July 2014. In that time, the government changed its personal income tax rates through increasing the threshold and changing marginal rates, mainly for individuals whose income is below $80,000 per year (Robson, 2014). In the sixth scenario, this thesis simulates revenue recycling by redistribution to low and middle income households, in particular to the 12 poorest out of 20 household groups (called the lump-sum transfer to poor and middle household groups (MLS) policy).

In summary, there are six scenarios, of which the first is only the ETS with no revenue recycling (NRR policy), followed by five scenarios of revenue recycling. The revenue is returned indirectly through the reduction of taxes, such as the goods and services tax cut (GST policy) or the income tax reduction (INT policy). The revenue is distributed directly to all household groups through lump-sum transfers, such as increasing payments from the government (GOT policy), or an equal lump-sum transfer to all household groups (ELS policy), and or an equal lump-sum transfer to the 12 poorest household groups (MLS policy).

6.2 Macro-economic impacts

Polluting industries have to pay for the emissions they generate. As a result, there is an extra cost to the cost of production. The question is then raised: who will bear this cost? Will producers or consumers bear all the cost, or will it be divided between producers and consumers? The answer to this question depends on the elasticities of supply and demand. In general, producers tend to pass this cost forward to consumers through higher prices for commodities, or they pass it backward to investors (through lower returns on investment earnings) or workers (through lower wages). This section discusses the impact of the ETS on macro-economic variables under various revenue recycling options.

6.2.1 Impacts on macro-economic variables

Table 6.1 displays the impacts of the ETS on macro-economic variables under a variety of revenue recycling options. These variables are categorised into environmental variables, quantity variables and price variables. To achieve the emissions reduction of 63.489 Mt CO_2-e, the emissions permit price is projected to be at A$20.608/t$CO_2$-e under the NRR policy. This permit price increases slightly in all compensation scenarios, with the highest permit price of A$21.025/t$CO_2$-e under the GST policy, followed by A$20.619/t$CO_2$-e under the INT policy and A$20.614/t$CO_2$-e under the GOT policy. When compared to other compensation policies the permit emissions price is higher under the GST policy because it seems that the reduction in goods and services taxes results in a higher household consumption of goods and services, which in turn results in a higher production of output for industries. Therefore, more carbon emissions are generated under the GST policy than other revenue recycling options, and consequently the permit price increases in value under the former, rather than the latter. The auction revenue is calculated by multiplying the emissions price and the quantity of emissions generated by industries. The auction revenue is highest, at A$10,488 million in the GST policy. It is A$10,286 million in the INT policy and A$10,280 million in the NRR policy.

Table 6.1: Impacts of the ETS on macro-economic variables

Variables	**NRR**	**GST**	**INT**	**GOT**	**ELS**	**MLS**
Environmental variables						
Emissions price($)	20.608	21.025	20.619	20.614	20.616	20.615
Emissions reduction (Mt)	-63.489	-63.489	-63.489	-63.489	-63.489	-63.489
Permit revenue($ million)	10280	10488	10286	10283	10284	10284
Quantity variables (%)						
Nominal GDP	0.056	-0.594	0.186	0.116	0.137	0.116
Real GDP	-0.298	0.022	-0.277	-0.288	-0.285	-0.288
Nominal GNE	0.238	-0.620	0.445	0.334	0.367	0.334
Real GNE	-0.091	0.002	0.011	-0.043	-0.027	-0.043
Real household consumption	-0.168	0.003	0.020	-0.079	-0.050	-0.079
Aggregate employment	-0.440	0.196	-0.418	-0.430	-0.426	-0.430
Export volume	-1.245	-0.041	-1.546	-1.386	-1.434	-1.387
Import volume	-0.314	-0.138	-0.242	-0.278	-0.268	-0.279
Price variables (%)						
CPI index	0.358	-0.899	0.475	0.411	0.430	0.412
GDP price index	0.355	-0.616	0.465	0.405	0.423	0.406
GNE price index	0.330	-0.622	0.434	0.377	0.394	0.377
Price of exports	0.127	0.002	0.158	0.142	0.147	0.142
Price of imports	0.000	0.000	0.000	0.000	0.000	0.000
Terms of trade	0.127	0.002	0.158	0.142	0.147	0.142

Source: Simulation from the model

For the quantity variables, the ETS leads to an increase in nominal GDP of nearly 0.056 per cent under the NRR policy. This can be explained from both supply and demand sides. On the supply side, the emissions price increases the cost of production factors, thus leading to a reduction in usage of these factors in the production process. In the short-run, labour wages are indexed to the CPI, thus the increase in the CPI leads to higher wages. On the demand side, because of increased prices of goods and services, real household consumption decreases by 0.168 per cent, export volume decreases by 1.245 per cent, and import volume decrease by 0.314 per cent, together leading to a reduction in real GDP of 0.298 per cent. Both nominal and real GNE are less affected by the emissions price, compared to the GDP. This is because the GNE index does not include exports and imports. Thus, nominal GNE increases at 0.238 per cent and real GNE decreases at only 0.091 per cent.

The increased production costs caused by the imposition of a price on carbon emissions resulted in increases in the price indices. In particular, the CPI increases by 0.358 per cent under the ETS without a compensation policy, while export prices increase by 0.127 per cent and import prices are fixed by assumption. Together, these increases lead to an increase of the GDP price index by 0.355 per cent and the GNE price index by 0.330 per cent. In the model, because of the fixed import prices, the terms of trade is fully reflected by the change in export prices in all scenarios.

If the auction revenue is distributed to households in the forms of direct compensation, the results shown in Table 6.1 illustrate that the macroeconomic variables improved most under the INT policy. Some macroeconomic variables increase to the highest percentage, other variables decrease to the lowest percentage when compared to other compensation policies. Furthermore, under the INT policy, real household consumption increases by 0.02 per cent, compared to 0.003 per cent under the GST scenario. This means that the ETS plus an income tax reduction creates more economic efficiency than other compensation policies. Meanwhile, under the GST scenario, the GST cut is sufficient to offset the increased prices caused by the ETS, thus leading to a decrease in the CPI as well as GDP and GNI price indices. Normally, a decrease in prices of goods and services result in an increase in quantity consumed, hence the real GDP increases by 0.022 per cent under the GST scenario. However, the decrease in the GDP price is much higher than the increase in real GDP, thus leading to a decrease of a high nominal GDP of 0.594 per cent.

Concerning the labour market, the real wage is assumed to be fixed and the nominal wage is indexed by the CPI in the short-run. Therefore, under the GST policy, a reduction in the CPI induces a decrease in the nominal wage. As seen in Table 6.1, aggregate employment increases by 0.196 per cent, while aggregate employment decreases under all other compensation policies. Furthermore, the decreases in prices of goods and services are likely to make Australian commodities more competitive in the international market under the GST scenario than under other compensation policies, thus leading to an export volume increase in the former compared to that in the latter. In particular, the GST scenario results in the smallest decrease of export volume of 0.041 per cent; this is because of the smallest increase in the export price of 0.002 per cent.

If household groups receive the auction revenue through lump-sum transfers or a government payment increase, the trend of impacts of these policies on macro-economic variables are similar to the case of the ETS without compensation. However, the positive effects under the compensation policies are higher and negative effects under the compensation policies are smaller when compared to those in the no compensation policy, except for the export volume. Moreover, the ETS plus an equal lump-sum transfer to all household groups creates a better improvement in most macroeconomic indices than under the GOT and MLS policies. The effects of ETS plus a government payment increase or plus a lump-sum transfer to the 12 lowest income household groups on all macro-economic variables are quite similar. This is because government payments are mainly obtained by low and middle income household groups. In fact, according to the HES, 2009-2010, the total income, which sourced from government payments to the 12 lowest income household groups, accounts for about 85 per cent of the total income of all households.

6.2.2 Impacts on prices of consumption goods and services

Table 6.2 shows the percentage changes in the prices of goods and services under the six scenarios. The results illustrate that in five out of the six scenarios, the prices of most goods and services will increase at various rates; the price of electricity increases by the highest percentage under all scenarios. For example, it is 13.528 per cent under the NRR policy, and then continues to increase in most compensation scenarios, except the GST policy. The electricity prices reach its highest level of 13.663 per cent under the INT policy, followed by the ELS policy with an increase of 13.614 per cent. Under the GST policy the electricity price increases the least amount at 12.908 per cent, but it remains the highest price increase compared to those of other goods and services.

Table 6.2: Impacts of the ETS on prices of commodities (% change)

	Commodities	NRR	GST	INT	GOT	ELS	MLS
1	Agriculture, forestry, fishing	0.488	-0.293	0.594	0.535	0.552	0.534
2	Black coal	-0.106	-1.076	-0.105	-0.105	-0.105	-0.105
3	Brown coal	-31.010	-31.650	-31.062	-31.035	-31.044	-31.036
4	Gas	-0.080	-0.884	-0.054	-0.067	-0.063	-0.067
5	Mining	0.821	0.092	0.854	0.837	0.843	0.838
6	Food, beverages, tobacco	0.234	-0.755	0.339	0.281	0.297	0.280
7	Textile, clothing, footwear	0.148	-0.764	0.290	0.210	0.232	0.209
8	Wood, paper, printing	0.232	-0.803	0.359	0.289	0.308	0.288
9	Automotive petrol	0.142	-0.847	0.185	0.179	0.182	0.180
10	Kerosene	0.221	-0.662	0.231	0.226	0.228	0.226
11	Gas oil or fuel oil	0.046	-0.931	0.063	0.057	0.059	0.058
12	Liquefied petroleum gas	0.169	-0.722	0.193	0.183	0.186	0.183
13	Other petroleum, coal products	0.511	-0.418	0.593	0.548	0.560	0.548
14	Chemical products	0.168	-0.714	0.261	0.209	0.224	0.209
15	Other metal products	0.150	-0.761	0.233	0.187	0.200	0.187
16	Furniture, equipment	0.161	-0.824	0.259	0.205	0.220	0.204
17	Other manufacturing	0.202	-0.724	0.311	0.251	0.268	0.250
18	Electricity	13.528	12.908	13.663	13.591	13.614	13.595
19	Gas supply	-0.644	-1.940	-0.519	-0.585	-0.564	-0.582
20	Water, sewerage services	0.737	-0.642	0.918	0.829	0.861	0.836
21	Construction services	0.465	-1.199	0.558	0.507	0.522	0.507
22	Wholesale trade	-0.046	-1.540	0.031	-0.011	0.001	-0.011
23	Accommodation, restaurant	0.210	-1.142	0.323	0.261	0.279	0.260
24	Road transport	1.827	0.574	1.885	1.856	1.865	1.856
25	Other transports	0.077	-1.033	0.101	0.090	0.093	0.090
26	Communication services	0.009	-1.137	0.143	0.072	0.094	0.074
27	Finance and insurance	-0.043	-1.630	0.140	0.028	0.060	0.027
28	Property, business services	0.039	-1.311	0.159	0.097	0.117	0.099
29	Public services	0.297	-1.559	0.406	0.347	0.365	0.348
30	Education and training	0.261	-1.537	0.358	0.306	0.322	0.307
31	Health, community services	0.312	-1.596	0.427	0.366	0.384	0.367
32	Art, recreation services	0.123	-1.258	0.302	0.198	0.228	0.194
33	Other services	0.563	-1.079	0.677	0.616	0.635	0.617
	Consumer price index	**0.358**	**-0.899**	**0.475**	**0.411**	**0.430**	**0.412**

Source: Simulation from the model

The largest increase in the price of electricity is because coal is the largest source of electricity generation in Australia. The World Bank (2014a) notes that about 70 per cent of electricity production in Australia is sourced from coal. Furthermore, as a high carbon intensive source of energy, coal is most affected by the emissions permit price. In particular, as estimated in this model, the price of black coal in the electricity-black coal industry increases about 112 per cent and the price of brown coal in the electricity-brown coal industry increases approximately 132 per cent under the ETS without revenue recycling. These increases of black and brown coal prices in the electricity generation industry lead to a rise in the electricity production costs, which, in turn, results in higher electricity prices for consumers. The next highest electricity price increase is for the road transport price, with an increase estimated at around 1.827 per cent under the NRR policy. Meanwhile, increases in the prices of other goods and services to households are tiny, being less than 1 per cent under the NRR policy.

In contrast to most goods and services, the prices of some other goods and services experience a decline at various degrees in all scenarios. The price of brown coal is estimated to be most affected by the highest decline of 31.010 per cent under the NRR policy. Moreover, it continues to decrease under other ETS plus compensation policies. This shows a shift from high emissions intensity products to low emissions intensity products. The highest decline in brown coal price might be explained by a high decrease in the demand for brown coal in the electricity generation sector. According to the Use Table in the IO Tables, 2008-2009 published by the ABS, over 90 per cent of brown coal output was supplied to produce electricity, a decreased demand for the electricity-brown coal caused by the ETS results in a high decrease in the demand for brown coal in this electricity sector, thus leading to the highest decrease in brown coal price.

Table 6.2 shows that prices decrease for most goods and services under the GST scenario except for prices of electricity, road transport and mining products. This indicates that the decreases in prices of most goods and services caused by the GST are sufficient to offset the increases in their prices caused by the ETS, thus leading to a decrease of the CPI index by 0.899 per cent under the GST policy. By contrast, under all other compensation policies, prices of most goods and services are estimated to increase at higher percentages, compared to the ETS without compensation. The ETS plus the income tax reduction results in the highest price increase of most commodities, followed by the ETS with an equal lump-sum transfer to all household groups. The CPI for the former is 0.475 per cent, while that for the latter is 0.430 per cent. The price increases of most commodities are quite for the GOT policy and the MLS policy. Their CPI is 0.411 per cent and 0.412 per cent respectively, which is higher than the CPI of 0.358 per cent under the ETS without the compensation.

The converse trend of prices increased for most commodities under the income tax reduction or lump-sum transfers, prices of black coal, brown coal, gas, and gas supply are projected to decrease at different percentages. In particular, under the INT policy, the decrease in brown coal price is highest, while the decreases in prices of gas and gas supply show a smaller percentage, compared to other compensation policies. For black coal, the price is estimated to reduce at the same percentage of 0.105 per cent under all four compensation policies. This means that consumers would change their consumption behaviour from high carbon intensive energy commodities to low carbon intensive commodities.

6.2.3 Impacts on prices of primary factors

In order to minimise production cost under the emissions permit price, polluting producers tend to adjust their use of primary factors, thus affecting the price of primary factors, such as returns on capital and land, and labour. In this analysis, the nominal wage is fully indexed to the consumer price index, and therefore, the change in nominal wage is the same as the CPI change. The real wage is assumed fixed, hence the percentage change of real wage is set to zero. The producers' demand for capital and land are fixed, hence their percentage changes are also set to zero as well.

The imposition of a price on carbon emissions results in higher prices of most goods and services, thus leading to a decrease in the demand of producers and consumers for these goods and services. As a result, there is a general contraction in the Australian economy. This contraction affects primary factors such as capital, land and labour. As can be seen in Figure 6.1, the emissions permit price leads to declines in returns on capital and land in all scenarios. Moreover, the highest reductions occur for the NRR policy. In particular, the returns on capital and land are estimated to decrease at about 1.703 per cent and 1.009 per cent, respectively. Reflecting the CPI, the nominal wage increases at 0.358 per cent.

The compensation policies implemented through direct and indirect payments to households lead to an increase in household disposable income for household groups, which, in turn, raises households' demands for goods and services. Thus, the compensation policies assist in the recovery in production, thus leading to an improvement in the demand for production factors, compared to the ETS without a compensation policy. However, as illustrated in Figure 6.1, the percentage change of capital and land rentals are negative under all compensation scenarios. This means that the percentage increases of capital and rent returns associated with the compensation policies are not sufficient to offset the decrease caused by the emissions permit price. In particular, the GST cuts induce declines in capital and land rentals by 1.477 per cent and 0.798 per cent respectively, followed by an INT policy with 1.594 per cent and 0.900 per cent respectively. The decreases in capital and land rentals are similar under the GOT policy and the MLS policy.

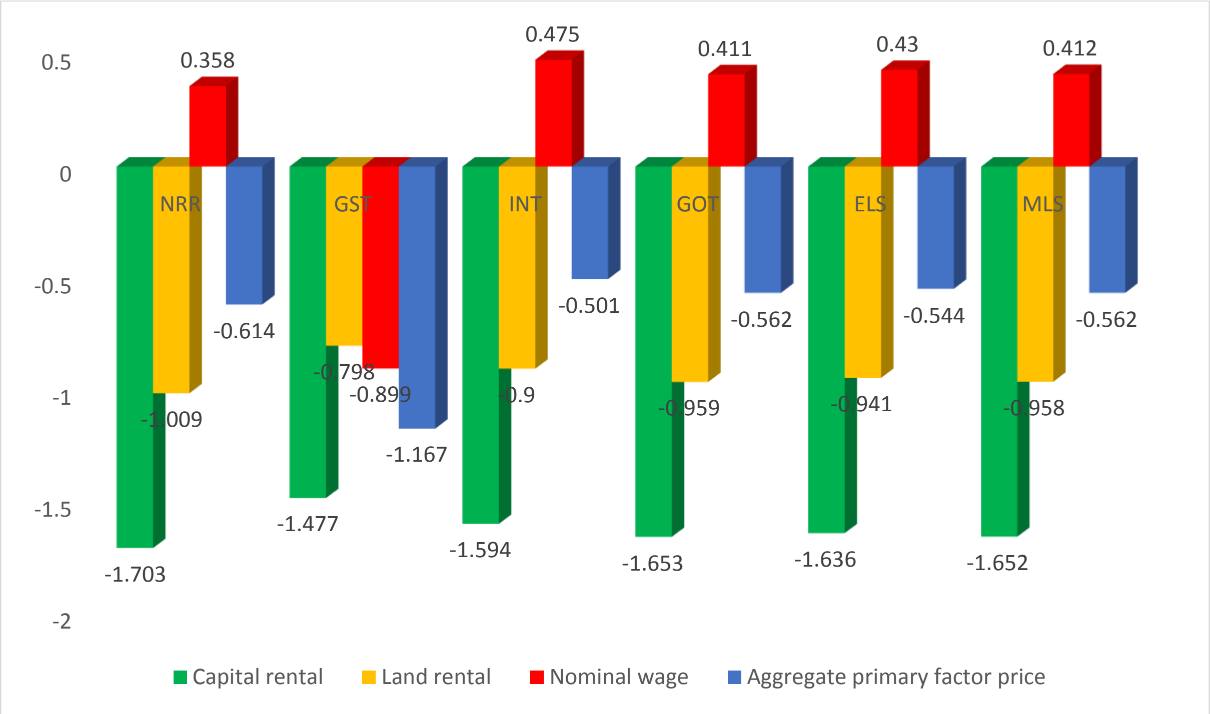

Figure 6.1: Impacts of the ETS on prices of production factors (% change)
Source: Simulations from the model

The nominal wage is indexed to the CPI, thus reflecting the same change as the CPI in each compensation policy. In contrast to an increase in the CPI for all other scenarios, the GST reduction policy results in a decrease in the CPI, thus leading to a decline in nominal wage by 0.899 per cent. Therefore, the GST policy leads to the highest price decrease of aggregate primary factors by 1.167 per cent. Meanwhile, all other compensation policies result in price decreases of aggregate primary factors by around 0.5 per cent. For all household groups, income from capital, land and labour constitutes the main sources of the total household income. Thus, the changes in payment for production factors would create changes in the income of all household groups, thus affecting distributional income and welfare of all household groups.

In conclusion, the ETS designed to achieve the emissions reduction target affects the Australian economy negatively. However, the revenue raised from the auctions can be used to compensate households in different ways, which can improve macro-economic variables. Compensation policies through direct payments, such as the income tax reduction or the lower GST, lead to more economic efficiency than those provided through indirect payments, such as lump-sum transfers or government payment increases.

6.3 Impacts of the ETS on industries

Under this ETS, the government fixes the quantity of emissions to be generated by each industry. If emitters generate more emissions than their allowance, they need to cover their deficiency by buying from other emitters who have produced fewer emissions than their allowance. In this study, no emissions are given away for free to any polluting industries. Hence, all industries have to buy their generated emissions quota at the market emissions price. The imposition of a price on emissions generally results in an increase in the production costs of most industries, thus, finally, affecting their emissions reduction, their output, as well as their employment levels. All these effects are discussed in following subsections.

6.3.1 Emissions reduction by sectors

In this analysis, all industries (45 industries) in the Australian economy are assumed to participate in the ETS. The industries are: agriculture (1), disaggregated energy industries (9), mining industry (1), electricity generating industries (9), commercial electricity (1), manufacturing industries (8), transport industries (2), services and other industries (14). As high emission intensity sectors, the electricity-black coal and electricity-brown coal industries are responsible for 80 per cent of the total emissions reduction target, therefore, each of these two electricity sectors is set to reduce their emissions level by 27.442 per cent from their baseline emissions, while all other industries in the ETS are set to reduce equally their baseline emissions by 3.366 per cent; thus, together, leading to a reduction in emissions for the whole economy in response to achieving the emission reduction target of 63.489 Mt CO_2-e.

Table 6.3 shows emissions level by industry under the ETS without compensation policy. All 45 industries participating in the ETS are presented in Column 1. Column 2 outlines the actual emissions generated by these industries in the baseline year. It is apparent that emissions generated from four energy sectors (including coal, oil and gas, petroleum and electricity generation) contributed nearly half of the total emissions generated by all industries. For the electricity generation sector, the highest number of 115.928 Mt CO_2-e comes from the electricity-black coal sector, followed by the electricity-brown coal sector of 69.157 Mt CO_2-e, and the electricity-gas sector of 22.011 Mt CO_2-e. All of these electricity sectors make up 36.8 per cent out of 37.3 per cent of the total emissions generated by all electricity generation types. The emissions generated from the agriculture sector contributed about 20.8 per cent of the total emissions emitted by all industries, compared to around 15.1 per cent from the transport sector and nearly 10 per cent from the manufacturing sector.

Table 6.3: The emissions by industries in the no compensation policy (1,000 tCO_2-e)

	Industries	Actual generated emissions	Reduced emissions by each industry	Purchased/ Sold Emissions	Emissions Reduction Target
	1	**2**	**3**	**4**[16]	**5**
1	Agriculture, forestry, fishing	117190	-2087	-1858	-3945
2	Black coal	32750	-153	-950	-1102
3	Brown coal	586	-73	53	-20
4	Oil	1730	-4	-54	-58
5	Gas	23017	-650	-124	-775
6	Mining	4429	-34	-115	-149
7	Food, beverages, tobacco	3270	-415	305	-110
8	Textiles, clothing, footwear	408	-83	69	-14
9	Wood, paper, printing	1700	-162	105	-57
10	Automotive petrol	2351	-141	62	-79
11	Kerosene	665	-41	18	-22
12	Gas oil or fuel oil	1693	-104	47	-57
13	Liquefied petroleum gas	342	-42	30	-12
14	Other petroleum, coal products	2124	-449	378	-71
15	Chemical products	11092	-643	270	-373
16	Iron and steel	9740	-269	-59	-328
17	Other metal products	16456	-1022	468	-554
18	Furniture and equipment	486	-8	-8	-16
19	Other manufacturing	12839	-970	538	-432
20	Electricity -black coal	115928	-28608	-3205	-31813
21	Electricity -brown coal	69157	-16703	-2275	-18978
22	Electricity-oil	2656	-297	208	-89
23	Electricity- gas	22011	385	-1126	-741
24	Hydro-electricity	0	0	0	0
25	Electricity -wind	0	0	0	0
26	Electricity-solar	0	0	0	0
27	Electricity-biomass	165	15	-21	-6
28	Electricity-biogas	59	3	-5	-2
29	Commercial electricity	52	-9	7	-2
30	Gas supply	3021	-43	-59	-102
31	Water, sewerage services	3005	-6	-95	-101
32	Construction services	2924	-32	-66	-98
33	Wholesale trade	670	-7	-16	-23
34	Retail trade	505	0	-17	-17
35	Accommodation, restaurant	755	1	-27	-25
36	Road transport	72964	-10625	8170	-2456
37	Other transports	12158	-160	-249	-409
38	Communication services	342	0	-11	-12
39	Finance and insurance	63	-1	-1	-2
40	Property, business services	771	0	-26	-26
41	Public services	808	-1	-27	-27
42	Education and training	147	1	-6	-5
43	Health, community services	360	0	-12	-12
44	Art, recreation services	123	0	-4	-4
45	Other services	10825	-51	-313	-364
	Total	**562336**	**-63489**	**0**	**-63489**

Source: Simulation from the model

[16] In column 4, minus figures indicate purchase of permits and plus figures indicate sale of permits.

Column 5 in Table 6.3 presents the levels of emissions reduction targets for each industry, in which electricity-black coal and electricity-brown coal industries are set to reduce by about 31.813 Mt CO_2-e and 18.978 Mt CO_2-e, respectively, thus, together, leading to a reduction of 50.891 Mt CO_2-e, equivalent to around 80 per cent of the total emissions reduction target. The model allows for substitution between energy commodities, substitution between capital and energy composite, and substitution between electricity produced by different sources. Hence, to reduce emissions generated, the polluting industries can adjust their production processes by way of either reducing output of carbon intensive products or using more low carbon intensive products. As a result, high emission intensity sectors are likely to reduce their emissions by a large percentage.

Column 3 shows the emissions quantity reduced by each industry because of the emissions permit price. This is because the highest emissions intensity sectors, the electricity-black coal and electricity-brown coal sectors, can reduce the highest emissions of 28.608 Mt CO_2-e (or 45.1 per cent of the total emissions reduction target) and 16.703Mt CO_2-e (or 26.3 per cent of the total emissions reduction target) respectively. That is, together, these electricity sectors can achieve around 71.4 per cent of the total emissions reduction target. The road transport sector reduces by 10.625 Mt CO_2-e (16.7 per cent of the total emissions reduction target). Meanwhile, by generating the highest amount of carbon emissions, the agricultural sector can reduce only 3.3 per cent of the total emissions reduction target.

Under the ETS, emitters buy emissions permits from the government. Emitters who generate more emissions than their allowance can buy their deficient emissions from other emitters who generate less emissions than their allowance. Column 4 presents the purchased, or sold, emissions by each industry. The negative number represents the emissions quantity (permits) purchased by industries and the positive number shows the emissions quantity (permits) sold by industries. As seen in column 4, there are 15 permit sellers and 27 permit buyers. In particular, the electricity-black coal and electricity-brown coal sectors become the largest buyers with 3.205 Mt CO_2-e and 2.275 Mt CO_2-e worth of permits respectively, followed by the agricultural sector and electricity-gas sector with 1.858 Mt CO_2-e and 1.126 Mt CO_2-e respectively. The energy sectors, comprising black coal, oil, and gas sectors, are also permit buyers. Meanwhile, the road transport sector becomes the largest seller with 8.170 Mt CO_2-e worth of permits, this is due to its higher capacity to reduce emissions through the application of the emissions permits, which is greater than its emissions reduction percentage target. In particular, the road transport sector sets the goal to reduce emissions by 3.366 per cent from its baseline emissions. With a decrease of 14.56 per cent from its baseline emissions, the road transport sector experienced the third largest emissions reduction of CO_2-e emissions. If all other sectors, except for the electricity-black coal and electricity-brown coal sectors, are targeted to reduce an equal emissions percentage, most manufacturing sectors and petroleum and brown coal sectors become sellers, while most services sectors are likely to become buyers. This is because there is a high emissions intensity in the former and low emissions intensity in the latter.

6.3.2 Impacts on sectoral outputs

Under the ETS, polluting industries, even being permit sellers or buyers, have to pay for their generated emissions. The payment for emissions generation results in higher costs of production, thus affecting the output of polluting industries. The emissions permit price directly impacts the energy sectors: black coal, brown coal, oil and gas, petroleum and electricity. It also affects indirectly other sectors which use energy products as intermediate inputs in their production. Thus, the emissions permit price would affect the output of all industries in the economy. Moreover, in order to achieve the emissions reduction target, each industry will adjust their production by reducing its output or replacing high emissions intensive products with low emissions intensive products. Table 6.4 presents the percentage changes of sectoral output relative to the baseline value under the ETS with and without a compensation policy.

Table 6.4 illustrates that most industries are likely to experience a loss of output because of the emissions permit price. It is obvious that the emissions permit price results in higher production costs to sectors with high intensity emissions, thus leading to higher relative prices of emissions intensive products. Therefore, both producers and consumers will seek to reduce their production and consumption of these products. With the highest emissions intensity (or the highest ratio of CO_2-e generated to sector output) the electricity generating sectors using black and brown coal, suffering the highest output reduction of 9.504 per cent and 13.322 per cent respectively in the NRR policy. The output reduction in the electricity-brown coal industry creates a decrease in the output of the brown coal industry by 4.801 per cent because the main use of brown coal in Australia is for electricity generation.

Table 6.4: Sectoral outputs under various compensation options (% change)

	Industries	NRR	GST	INT	GOT	ELS	MLS
1	Agriculture, forestry, fishing	-1.657	-1.394	-1.686	-1.671	-1.675	-1.671
2	Black coal	-0.223	-0.147	-0.232	-0.227	-0.229	-0.227
3	Brown coal	-4.801	-4.693	-4.827	-4.813	-4.818	-4.813
4	Oil	-0.050	0.003	-0.055	-0.052	-0.053	-0.052
5	Gas	-0.893	-0.839	-0.902	-0.897	-0.899	-0.897
6	Mining	-0.182	0.064	-0.212	-0.196	-0.201	-0.196
7	Food, beverages, tobacco	-0.813	-0.162	-0.851	-0.830	-0.836	-0.830
8	Textiles, clothing, footwear	-0.435	0.215	-0.467	-0.454	-0.459	-0.455
9	Wood, paper, printing	-0.540	0.020	-0.567	-0.553	-0.557	-0.553
10	Automotive petrol	-0.746	-0.670	-0.696	-0.676	-0.676	-0.673
11	Kerosene	-0.988	-0.770	-1.024	-1.005	-1.011	-1.005
12	Gas oil or fuel oil	-1.014	-0.923	-1.014	-1.005	-1.007	-1.005
13	Liquefied petroleum gas	-3.345	-3.169	-3.372	-3.348	-3.354	-3.347
14	Other petroleum, coal products	-1.549	-1.455	-1.566	-1.555	-1.558	-1.555
15	Chemical products	-1.268	-0.774	-1.333	-1.298	-1.309	-1.298
16	Iron and steel	-1.737	-1.184	-1.798	-1.765	-1.775	-1.766
17	Other metal products	-1.281	-0.812	-1.334	-1.305	-1.314	-1.305
18	Furniture and equipment	-0.548	0.268	-0.594	-0.569	-0.578	-0.570
19	Other manufacturing	-1.238	-0.694	-1.286	-1.261	-1.268	-1.261
20	Electricity -black coal	-9.505	-9.531	-9.493	-9.499	-9.497	-9.499
21	Electricity -brown coal	-13.322	-13.600	-13.299	-13.312	-13.308	-13.312
22	Electricity-oil	-2.849	-2.784	-2.837	-2.844	-2.842	-2.843
23	Electricity- gas	2.753	2.837	2.774	2.763	2.766	2.764
24	Hydro-electricity	5.399	5.635	5.392	5.396	5.395	5.397
25	Electricity -wind	5.409	5.644	5.401	5.405	5.404	5.406
26	Electricity-solar	5.688	5.930	5.680	5.684	5.683	5.685
27	Electricity-biomass	9.182	9.461	9.179	9.181	9.180	9.181
28	Electricity-biogas	4.929	5.169	4.921	4.926	4.925	4.926
29	Commercial electricity	-3.971	-3.927	-3.951	-3.962	-3.958	-3.961
30	Gas supply	-1.430	-1.298	-1.420	-1.425	-1.422	-1.423
31	Water, sewerage services	-0.214	0.021	-0.168	-0.187	-0.178	-0.184
32	Construction services	0.111	0.168	0.108	0.110	0.109	0.110
33	Wholesale trade	-0.533	-0.037	-0.550	-0.541	-0.544	-0.542
34	Retail trade	-0.211	-0.073	0.020	-0.112	-0.078	-0.116
35	Accommodation, restaurant	-0.533	0.222	-0.447	-0.495	-0.482	-0.500
36	Road transport	-1.875	-1.433	-1.900	-1.884	-1.889	-1.885
37	Other transports	-0.527	-0.029	-0.575	-0.547	-0.555	-0.548
38	Communication services	-0.194	0.112	-0.181	-0.186	-0.184	-0.185
39	Finance and insurance	-0.207	0.110	-0.169	-0.196	-0.189	-0.197
40	Property, business services	-0.170	0.168	-0.166	-0.166	-0.165	-0.165
41	Public services	-0.051	0.004	-0.050	-0.050	-0.050	-0.050
42	Education and training	-0.275	0.499	-0.310	-0.288	-0.293	-0.286
43	Health, community services	-0.063	0.069	-0.021	-0.039	-0.032	-0.036
44	Art, recreation services	-0.236	0.215	-0.095	-0.183	-0.159	-0.191
45	Other services	-0.455	-0.172	-0.417	-0.436	-0.429	-0.434

Source: Simulation from the model

However, the electricity-gas and the electricity-renewable industries will expand their output significantly. This is because of their low emissions intensity (or their low ratio of CO_2-e generated to sector output); the production costs of electricity produced by gas and renewable sources is smaller relative to the electricity generated by black and brown coal after the shock. In addition, there is high substitutability between electricity produced by different sources, thereby leading to a significant decrease in output in electricity-black coal and electricity-brown coal industries. This in turn releases production factors that result in lower production costs in the electricity-gas and electricity-renewable industries, providing incentives to increase their production. Indeed, the electricity-gas sector increases its output by 2.753 per cent, while the electricity generated from renewable sources increases their average output by over 6 per cent. It could be concluded that the Australian economy will experience a shift in production and consumption from high carbon emissions intensive activities to low emissions intensive activities.

In the analysis, it is assumed that all generating plants sell their electricity output to the commercial electricity sector. Therefore, changes in the output of electricity generated by fossil fuels and renewable sources affect the output of the commercial electricity sector. In Australia, most electricity is generated using coal and electricity generated using gas and renewable resources account for a small percentage of the total electricity output, thus a high output reduction of electricity produced by coal results in a reduction in the output of the commercial electricity sector by 3.971 per cent under the NRR policy.

Among other energy sectors, the liquefied petroleum gas industry experiences the highest output loss, while the black coal sector records the smallest output loss. The reason is due to the difference in the output value in the baseline of these two sectors. It is small for the former and large for the latter. Moreover, over 90 per cent of black coal is exported, with only a small percentage, of around 3.5 per cent of black coal output, supplied to the electricity generation sector, so the emissions permit price slightly affects the output of the black coal sector. Among the non-energy sectors, the road transport sector is mostly affected by the emissions permit price by its output reduction of 1.875 per cent. This is due to the high energy consumption of the road transport industry; BREE (2014) stated that the transport sector is the second largest net energy consumer in 2012-2013, accounting for 26 per cent of total energy consumption. Thus, higher prices of energy commodities lead to an increase in price of road transport products. Since most industries use services of road transport in their production and the emissions permit price results in a contraction in the output of these industries, a reduction in the demand for road transport services occurs.

The manufacturing sectors are the third largest net energy consumer with 22 per cent of the total, in 2012-2013, after the electricity sector and the transport sector (BREE, 2014). The output loss of these sectors caused by the ETS is about 1 per cent. In particular, iron and steel and other metal manufacturing industries bear a high output percentage reduction, with 1.737 per cent and 1.281 per cent respectively. The output of food, beverage, and tobacco industries is reduced by 0.813 per cent, while other industries decrease their output by around 0.5 per cent.

Compensation policies result in various percentage changes in sectoral outputs. Particularly under the GST policy, almost all industries improve their output relative to the NRR policy. Moreover, three manufacturing sectors and about two-thirds of the service sectors will experience an output expansion compared to the baseline value. It means that the GST reduction policy results in decreases in the prices of goods and services, thus leading to the increase in demand for these goods and services. As a result, production will recover because of a reduction in the GST. However, even if there is a reduction in the GST, the electricity produced by black and brown coal will continue to face a higher output loss relative to the NRR policy. This is because of a higher emissions permit price under the GST policy. A higher price causes a higher cost of production in these two electricity sectors, hence leading to a reduction in output.

When auction revenue is used to reduce income tax or provide lump-sum transfers, some industries, such as agriculture, energy industries (except the electricity industry) and manufacturing industries, experience more contraction in their output relative to the NRR policy. This contraction is the highest in the INT policy, followed by the ELS policy. This contraction is quite similar in the GOT policy and in the MLS policy. However other industries, including the electricity industry and service industries, have an expansion in their output, compared to the NRR policy. This expansion is the largest in the INT policy, followed by the ELS policy, then by the GOT policy and finally the MLS policy.

As seen in Table 6.4 the auction revenue recycled to all household groups by various compensation methods results in disparate benefits to output of each industry. If the revenue is returned to reduce the income tax, the rich receive more benefits from this policy than the poor. When receiving a higher disposable income, the rich tend to increase their consumption of luxury goods and services, thus leading to an increase of the output of service industries. Therefore, the INT policy brings more benefit to the services industries. If the auction revenue is recycled to households by giving more compensation to poor households, the manufacturing sectors, agricultural sector, and energy sectors (excluding the electricity industry) gain the benefits compared to other revenue recycling options. By contrast, the GST policy results in the highest percentage reduction in the output of the electricity generated by black and brown coal, but create the highest percentage increase in the output of all other industries compared to all other scenarios.

6.3.3 Employment impacts

The effects of an ETS on employment demand by industry and occupational categories are presented in detail in this section. In this research, there are ten occupational groups, made up of nine domestic occupations and one foreign occupation group. The first impression of Table 6.5 is that the ETS affects negatively all occupational categories under most scenarios, except for the GST policy. This may be because of the contraction of almost all industries in the Australian economy, as discussed in subsection 6.3.2. All occupations experience the highest percentage reduction in the NRR policy when compared to other scenarios of compensation policies. The most affected occupational category is managers and administrators, with its employment reduction of 0.666 per cent, followed by the machinery operators and drivers, and labourers of 0.606 per cent and 0.567 per cent, respectively. These groups are mainly related to the energy and transport sectors. Thus when the ETS is imposed, these sectors will experience significant contractions, thus leading to the dismissal of many employees. Moreover, the employment loss for machinery operators and drivers continues to increase when the government compensates households by providing income tax reduction or lump-sum transfers. This is because of the continued reductions in the output of the transport sector under these compensation packages, as seen in Table 6.4. It is apparent that the constant return to scale (SRC) assumption used in the model reflects a relationship between output changes by industry and employment changes by respective industries.

The service sectors are less affected by the ETS than the energy and manufacturing sectors. Therefore, there is a smaller employment loss of service workers under the NRR policy. In particular, employment opportunity reduces about 0.277 per cent for community and personal service workers and demand for technicians and trade workers or clerical and administrative worker declines by 0.383 per cent for each occupational group. When the auction revenue is recycled to household groups by reducing income tax or increasing government payments or lump-sum transfers, there will be an increase in demand for labour. However, the employment expansion caused by the compensation policies is not sufficient to offset the employment contraction caused by the emissions permit price. Therefore, all occupations still face negative percentage changes in employment.

Table 6.5: Employment impacts by occupational categories (% change)

	Occupations	NRR	GST	INT	GOT	ELS	MLS
1	Managers and administrators	-0.666	0.006	-0.633	-0.652	-0.647	-0.653
2	Professionals	-0.337	0.291	-0.322	-0.329	-0.327	-0.328
3	Technicians and trades workers	-0.383	0.205	-0.382	-0.382	-0.382	-0.382
4	Community and personal service workers	-0.227	0.237	-0.185	-0.206	-0.200	-0.206
5	Clerical and administrative workers	-0.383	0.229	-0.361	-0.374	-0.370	-0.374
6	Sales workers	-0.409	0.135	-0.246	-0.339	-0.315	-0.342
7	Machinery operators and drivers	-0.606	0.235	-0.648	-0.624	-0.631	-0.624
8	Labourers	-0.567	0.146	-0.552	-0.559	-0.557	-0.560
9	Foreign workers	-0.440	0.196	-0.418	-0.430	-0.426	-0.430
10	Others	-0.446	0.185	-0.431	-0.440	-0.438	-0.440

Source: Simulation from the model

All occupations benefit from the GST policy because they experience a positive percentage change in employment levels to various degrees. The GST policy results in an increase in the aggregate employment of 0.196 per cent, with the community and personal service workers category obtaining the highest percentage increase of 0.237 per cent, followed by clerical and administrative workers category of 0.229 per cent. Managers and administrators have the smallest percentage increase in employment. Under the GST policy, job opportunities for all occupational categories are explained by the recovery of production of most industries in the Australian economy; some industries expand their output when the government reduces the GST, thus leading to an increase in labour demand in those industries.

The percentage changes in employment by sector are shown in Table 6.6. It is apparent that employment changes by industries follow a similar magnitude to output changes by respective industries. This research simulates the effects of the ETS in the short run, with no change in technology and capital stock, thus the output change is mainly due to changes in the labour demand. The percentage changes in employment are greater than the changes in sectoral output. For example, under the NRR policy, the employment change in the brown coal sector is estimated to reduce by 27.668 per cent whereas output is estimated to decrease by 4.801 per cent.

Table 6.6: Employment impacts by sectors

	Industries	NRR	GST	INT	GOT	ELS	MLS
1	Agriculture, forestry, fishing	-5.121	-4.130	-5.223	-5.168	-5.185	-5.169
2	Black coal	-1.168	-0.440	-1.245	-1.203	-1.216	-1.203
3	Brown coal	-27.668	-27.079	-27.790	-27.724	-27.744	-27.725
4	Oil	-0.363	0.324	-0.426	-0.390	-0.401	-0.390
5	Gas	-1.535	-0.852	-1.603	-1.566	-1.577	-1.566
6	Mining	-0.263	0.705	-0.372	-0.313	-0.330	-0.313
7	Food, beverages, tobacco	-1.141	-0.028	-1.205	-1.169	-1.180	-1.170
8	Textiles, clothing, footwear	-0.700	0.509	-0.758	-0.735	-0.744	-0.738
9	Wood, paper, printing	-0.641	0.373	-0.688	-0.662	-0.671	-0.663
10	Automotive petrol	-0.861	-0.155	-0.851	-0.797	-0.806	-0.793
11	Kerosene	-1.172	-0.288	-1.273	-1.218	-1.234	-1.219
12	Gas oil or fuel oil	-1.206	-0.483	-1.260	-1.219	-1.230	-1.218
13	Liquefied petroleum gas	-3.592	-2.773	-3.676	-3.619	-3.635	-3.618
14	Other petroleum, coal products	-1.361	-0.627	-1.436	-1.393	-1.406	-1.393
15	Chemical products	-1.763	-0.606	-1.897	-1.825	-1.846	-1.825
16	Iron and steel	-2.066	-0.931	-2.182	-2.119	-2.138	-2.120
17	Other metal products	-1.252	-0.204	-1.358	-1.301	-1.318	-1.301
18	Furniture and equipment	-0.682	0.528	-0.750	-0.714	-0.726	-0.715
19	Other manufacturing	-1.477	-0.439	-1.564	-1.517	-1.531	-1.518
20	Electricity -black coal	5.078	5.936	5.071	5.076	5.075	5.078
21	Electricity -brown coal	1.085	1.643	1.091	1.088	1.090	1.090
22	Electricity-oil	11.854	12.861	11.847	11.852	11.851	11.854
23	Electricity- gas	14.227	15.179	14.225	14.227	14.227	14.229
24	Hydro-electricity	21.450	22.744	21.419	21.438	21.433	21.440
25	Electricity -wind	21.478	22.774	21.448	21.466	21.462	21.468
26	Electricity-solar	22.617	23.959	22.586	22.605	22.600	22.607
27	Electricity-biomass	38.206	39.990	38.191	38.202	38.201	38.206
28	Electricity-biogas	19.604	20.887	19.573	19.592	19.587	19.594
29	Commercial electricity	-3.794	-3.316	-3.758	-3.777	-3.770	-3.775
30	Gas supply	-6.018	-5.442	-5.978	-5.996	-5.988	-5.991
31	Water, sewerage services	-0.248	0.395	-0.135	-0.182	-0.160	-0.173
32	Construction services	0.286	0.441	0.277	0.283	0.281	0.283
33	Wholesale trade	-0.744	0.061	-0.773	-0.757	-0.763	-0.758
34	Retail trade	-0.232	-0.015	0.106	-0.087	-0.037	-0.093
35	Accommodation, restaurant	-0.579	0.529	-0.456	-0.524	-0.507	-0.532
36	Road transport	-0.133	0.845	-0.188	-0.153	-0.163	-0.154
37	Other transports	-0.659	0.447	-0.762	-0.702	-0.719	-0.703
38	Communication services	-0.469	0.417	-0.433	-0.449	-0.443	-0.446
39	Finance and insurance	-0.414	0.225	-0.339	-0.393	-0.378	-0.394
40	Property, business services	-0.357	0.453	-0.349	-0.348	-0.347	-0.345
41	Public services	-0.035	0.042	-0.034	-0.034	-0.034	-0.034
42	Education and training	-0.296	0.607	-0.336	-0.311	-0.317	-0.309
43	Health, community services	-0.049	0.114	0.001	-0.020	-0.013	-0.017
44	Art, recreation services	-0.361	0.437	-0.116	-0.268	-0.227	-0.283
45	Other services	-0.574	-0.147	-0.521	-0.547	-0.538	-0.545

Source: Simulation from the model

In contrast, there have been employment gains in the electricity generation sector. In particular, electricity-black coal and electricity-brown coal industries increase their labour force by a small proportion of 5.078 per cent and 1.085 per cent respectively, compared to over 10 per cent of electricity-gas and electricity-oil industries and over 20 per cent of electricity-renewable industries. The employment increases by electricity-gas and electricity-renewable sources are explained by the expansion in the output of these industries, while the reason for increased demand of electricity-black coal, -brown coal and-oil industries for labour is because of the substitution between labour, land and capital-energy composite in the primary factor usage.

When the auction revenue is returned to household groups via various compensation policies, there are various changes occurring in industry employment. The trend of changes in employment by industry is quite similar to that in output by respective industries. In particular, under the GST policy, expansions in output of some industries result in the increases in employment of those industries. Moreover the employment increase in such industries can offset the employment decrease of other industries, thus leading to an increase in the aggregate employment of 0.196 per cent. There are contractions in employment in industries that are high emissions-intensive sectors, such as energy sectors, transport sectors and manufacturing sectors, under the other compensation policies. There is a shift in employment from high emissions-intensive production activities to low emissions-intensive ones.

6.4 Impacts of the ETS on households

Producers initially bear the increases in the costs of production that is due to the emissions permit price. However, producers tend to pass these costs to customers as much as possible in order to maximise their profit. Indeed, households, which are considered as final consumers, finally bear these costs through increases in the prices of goods and services, thus leading to a reduction in household consumption. Producers also tend to pass backward these costs to investors and employees in the form of lower returns on primary factors. Household income is predominantly sourced from labour, capital and land. Therefore, the emissions price affects the distribution of income and welfare of all household groups. In this research, all households are disaggregated into 20 household groups based on the household income rank. The following sections present more details about these effects in the ETS plus various revenue recycling options.

6.4.1 Impacts of the ETS on household income

According to the HES 2009-2010, household income derives from five sources: investments, unincorporated business, government payments, employee income, and other sources. The contribution of each source to the total household income of each household group is quite different. For example, in the poorest household group, around 90.5 per cent of total income is sourced from government payments, about 10.5 per cent of total income is sourced from employee income, about 1.6 per cent is obtained from investments, 7.5 per cent is lost from unincorporated business, and 4.9 per cent of the total income is sourced from other sources. Income of the richest households comprise: 0.6 per cent from government payment, over 77.8 per cent from employee income, 11.8 per cent and 2.8 per cent respectively from investments and other sources, and about 7.0 per cent is obtained from unincorporated businesses. This results in differential impacts of the ETS with or without revenue recycling on all 20 household groups.

Figure 6.2 shows the percentage changes in income for the 20 household groups under the ETS plus various compensation policies. The first impression is that all household groups suffer a reduction in income under the NRR policy. In particular, low-income household groups suffer a greater percentage of income reduction than high-income household groups. However, the difference in the income reduction percentage between household groups is quite small; hence there is moderately regressive effect under the NRR policy. The various percentage changes in income of the 20 household groups are explained by the changes in returns on primary factors and the contribution of income sourced from primary factors to the total household income of each household group.

When the auction revenue is distributed to all household groups in the forms of reducing income tax and decreasing the GST, the effects of revenue recycling options are quite different among household groups. Under the GST reduction, it is apparent that all household groups still experience a decline in income, but there are smaller percentage reductions for low-income households, and higher reductions for middle- and high-income households, compared to the NRR policy. This is because under the GST, the reduction in the CPI is reflected in a decrease in the nominal wages and labour income contributes a high proportion to the income of rich household groups. Therefore, the GST policy is progressive. However, under the INT policy, the effects are opposite, all household groups still face income reductions relative to the baseline value, but these reductions are smaller than under the NRR policy. With a reduction in marginal income tax rates, high-income households receive more benefits than low-income households;

hence, rich household groups have lower percentages of income reduction than poor household groups. That makes the INT policy more regressive.

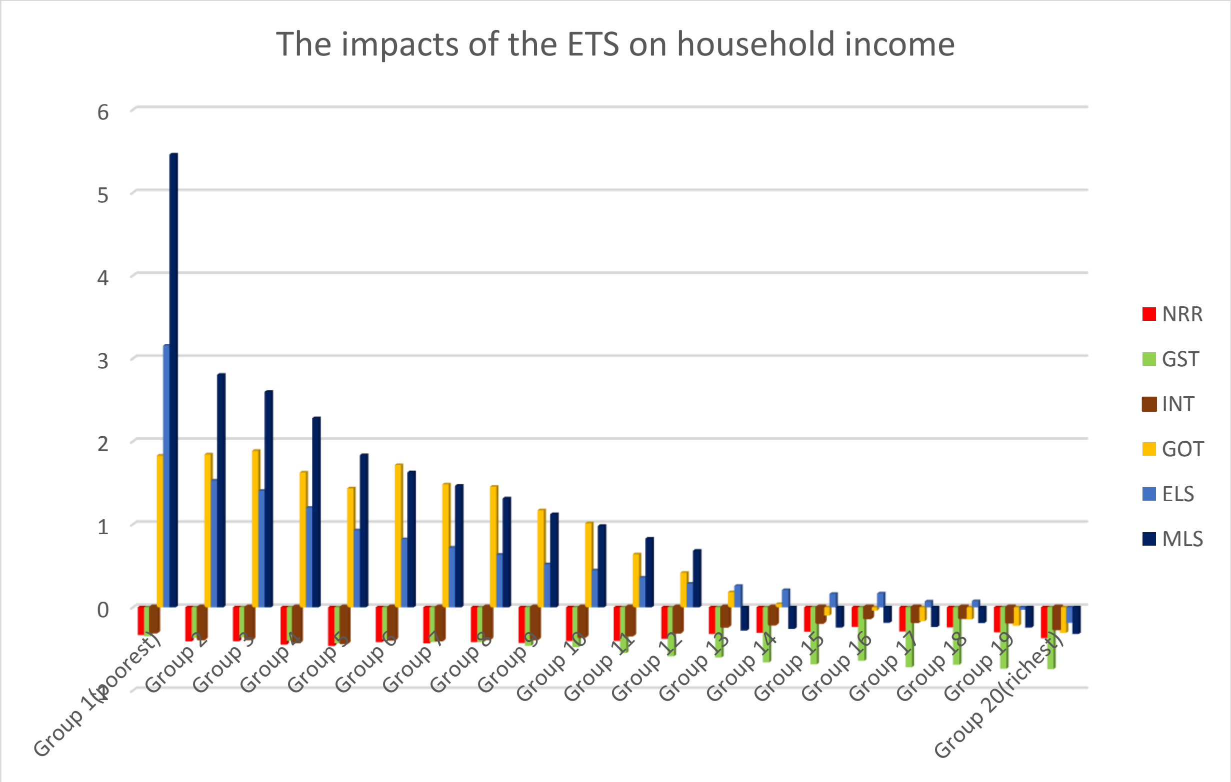

Figure 6.2: Impacts of the ETS on household income (% change)
Source: Simulation from the model

In contrast, if the auction revenue is returned to households in the form of providing lump-sum transfers, all household groups obtain benefits from these policies with positive changes in income for low and middle-income household groups and smaller negative changes in income for high income household groups, compared to the NRR policy. As can be seen in Figure 6.2, the ELS policy brings benefits to the highest number of household groups. For example, 18 out of 20 household groups receive an increase in their income compared to the baseline value, with the poorest household group increasing their income by 3.154 per cent under the ELS policy, compared to a reduction of 0.333 per cent under NRR policy, and the third richest group increases their income by 0.075 per cent under the ELS policy, compared to the reduction of 0.241 per cent under the NRR policy. Only the two richest household groups still experience negative percentage changes in their income of 0.029 per cent for the second richest household group and of 0.186 per cent for the richest household group, compared to a reduction of 0.299 per cent and 0.371 per cent respectively under the NRR policy.

When the auction revenue is recycled to all household groups based on the government payment ratios, or compensated equally to the 12 poorest household groups, these policies generally provide more benefits to low- and middle-income households. In particular, 14 poor household groups increase their income under the GOT policy, compared to positive percentage changes in income of 12 poor household groups under the MLS policy. It means that, under the GOT policy, the increase in percentage income change caused by the increased government payment for the six richest household groups is not sufficient to offset the reduction in their income caused by the ETS. Therefore, their income continues to be less compared to the baseline value under the GOT policy.

In conclusion, the ETS reduced the income of all household groups, however their income improved when revenue is recycled. In particular, all household groups suffer decreases in their income under the compensation policies through tax reductions, but income tax reduction brings more benefits to wealthy household groups. GST cuts results in more income reduction for rich household groups than the NRR policy. By contrast, the revenue that is returned as lump-sum transfers to household groups create increases in income for low and middle income household groups, and a lesser decline in the income of high income household groups. Noticeably, the equal lump-sum transfer results in the highest number of household groups whose income increases compared to the baseline value.

6.4.2 Impacts of the ETS on household consumption

As seen in Table 6.7, there is a decrease in the household consumption of most goods and services under a no compensation policy, in which household consumption of electricity decreases at the highest proportion of 1.763 per cent, followed by the household consumption of road transport products by 0.457 per cent. The highest reduction in consumption of these two products is due to the highest percentage increase in their prices, as shown in Table 6.2. Household consumption of manufacturing products, service products and agricultural products decreases slightly at below 0.3 per cent. By contrast, households increase their consumption of brown coal by 5.749 per cent from its baseline under the NRR policy. This increase is explained by the highest decrease in the brown coal price. However, the increase in brown coal consumption by households does not result in more emissions into the atmosphere because of the very small proportion of brown coal products consumed by households, at just less than 2 per cent of the total value of brown coal products.

Table 6.7: Household consumption by commodities (% change)

	Commodities	NRR	GST	INT	GOT	ELS	MLS
1	Agriculture, forestry, fishing	-0.185	-0.127	-0.015	-0.114	-0.086	-0.113
2	Black coal	-0.042	0.023	0.069	0.024	0.044	0.034
3	Brown coal	5.749	5.835	5.931	5.849	5.882	5.862
4	Gas	-0.050	-0.005	0.075	0.011	0.034	0.018
5	Mining	-0.194	-0.160	-0.048	-0.140	-0.112	-0.137
6	Food, beverages, tobacco	-0.128	-0.032	0.029	-0.054	-0.029	-0.052
7	Textile, clothing, footwear	-0.255	-0.078	0.108	-0.128	-0.072	-0.143
8	Wood, paper, printing	-0.268	-0.048	0.054	-0.120	-0.076	-0.127
9	Automotive petrol	-0.113	0.011	0.004	0.040	0.041	0.047
10	Kerosene	-0.127	-0.024	-0.007	0.037	0.036	0.048
11	Gas oil or fuel oil	-0.093	0.030	0.025	0.071	0.070	0.081
12	Liquefied petroleum gas	-0.117	-0.013	0.002	0.042	0.042	0.052
13	Other petroleum, coal products	-0.185	-0.076	-0.073	-0.037	-0.036	-0.029
14	Chemical products	-0.100	-0.036	0.041	-0.039	-0.015	-0.036
15	Other metal products	-0.096	-0.027	0.045	-0.034	-0.010	-0.031
16	Furniture and equipment	-0.241	-0.040	0.096	-0.089	-0.042	-0.095
17	Other manufacturing	-0.252	-0.081	0.078	-0.114	-0.065	-0.123
18	Electricity	-1.763	-1.756	-1.658	-1.716	-1.697	-1.712
19	Gas supply	0.026	0.133	0.119	0.085	0.102	0.095
20	Water, sewerage services	-0.173	-0.039	-0.069	-0.114	-0.094	-0.107
21	Construction services	-0.136	0.044	-0.013	-0.071	-0.050	-0.065
22	Wholesale trade	-0.062	0.099	0.073	0.001	0.025	0.005
23	Retail trade	-0.049	-0.093	0.031	0.041	0.049	0.061
24	Accommodation, restaurant	-0.266	0.092	0.070	-0.115	-0.064	-0.126
25	Road transport	-0.457	-0.293	-0.315	-0.341	-0.324	-0.345
26	Other transports	-0.103	0.038	0.048	0.019	0.036	0.015
27	Communication services	-0.069	0.034	0.051	-0.007	0.013	-0.002
28	Finance and insurance	-0.073	0.124	0.077	-0.026	0.002	-0.029
29	Property, business services	-0.072	0.061	0.047	-0.009	0.011	-0.003
31	Public services	-0.111	0.100	0.010	-0.047	-0.027	-0.041
31	Education and training	-0.105	0.096	0.017	-0.040	-0.020	-0.034
32	Health, community services	-0.126	0.118	0.006	-0.051	-0.031	-0.044
33	Art, recreation services	-0.243	0.143	0.093	-0.111	-0.055	-0.128
34	Other services	-0.157	0.025	-0.029	-0.098	-0.075	-0.095

Source: Simulation from the model

The results in Table 6.7 show that when households receive the rebate from government revenue raised from selling emissions permits, households increase their consumption of almost all goods and services compared to no revenue recycling. In particular, households increase their consumption of most service products from the baseline value when the government implements the compensation policies through reducing taxes. Moreover, if the revenue is recycled to households by reducing income tax, households increase their consumption of not only service products but also manufacturing products. However, household consumption of some products, such as agricultural products, mining, kerosene, other petroleum and coal products, electricity, water and sewerage services, and road transport, are still reduced under the tax reduction policies. It seems that the lower GST policy does not affect household consumption on agricultural products and electricity as much as other compensation policies; thus household consumption on these products decreases at the highest percentage compared to other revenue recycling options. Meanwhile, the income tax reduction policy creates greater improvements in household consumption on agricultural products and electricity when compared to all other compensation policies.

When government compensates households through lump-sum transfers, there is an improvement in household consumption of goods and services when compared to the no revenue recycling scenario. But quantities of commodities consumed by households still experience negative percentage changes except for energy commodities such as black coal, brown coal, gas and petroleum products. It means that compensation through lump-sum transfers are not sufficient to offset the negative effects caused by the ETS to these commodities. The results in Table 6.7 show that an equal lump-sum transfer to all household groups creates greater household consumption on most goods and services than the GOT and MLS policies.

Comparing household consumption of goods and services between household groups, Figure 6.3 shows that the emissions permit price induces a reduction in consumption of all household groups, of which wealthy household groups suffer a higher percentage reduction than poor household groups. For example, the poorest household group reduce by about 0.076 per cent of their consumption, compared to 0.413 per cent for the richest household group. As seen in Figure 6.3 household consumption of the poorest household group is reduced more than that of the seven richer groups; this is because households are ranked based on their income level. The first household groups had losses in their own-unincorporated business income, thus they become the poorest household group, but their consumption is higher than the four richer groups. Moreover, according to the HES 2008-09, the consumption cost of the poorest household group on housing is higher than that of the eight richer groups.

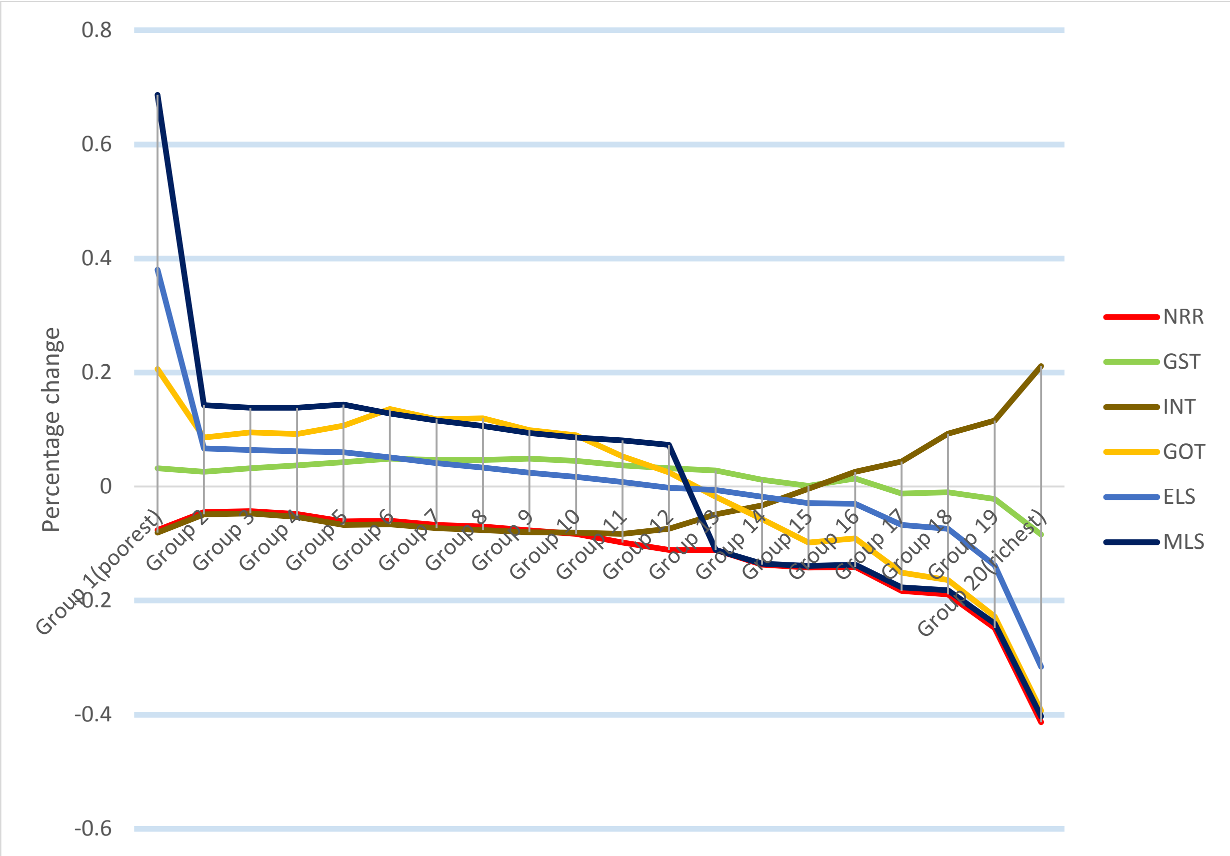

Figure 6.3: Impacts on household consumption (% change)
Source: Simulation from the model

The first impression from Figure 6.3 is that the consumption of all household groups has improved, to different degrees, due to various compensation policies. The revenue recycling option chosen depends on the purpose of the policy. If the auction revenue is recycled to reduce income tax, this policy provides higher benefit to wealthy household groups, thus leading to positive percentage changes in the household consumption of the five richest groups. Meanwhile the declines in household consumption of the nine lowest income groups are higher than those under the NRR policy. If the auction revenue is returned to reduce the GST, this policy generally creates equal benefits to all household groups. In particular, the GST policy creates an increase in household consumption of the first 16 household groups when compared to their baseline values. Only the four highest income household groups experience a negative percentage change in their consumption, but this percentage is much smaller than under the NRR policy.

When the auction revenue is returned to all household groups through increasing government payments to all household groups as well as providing lump-sum transfers, the lowest income household groups gain the most benefits because their consumption increases relative to the baseline value. However, higher income household groups still experience a negative percentage change in their consumption. Comparing among lump-sum transfer scenarios, the ELS policy results in a lower consumption increase to poor household groups than the MLS policy, but a greater consumption increase than under the GOT policy. The percentage change in the consumption of the poorest household group is 0.380 per cent under the ELS policy, 0.687 per cent under the MLS policy and 0.206 per cent under the GOT policy. However, the ELS policy also results in a decrease in household consumption by 0.316 per cent for the richest household group, compared to 0.393 per cent under the GOT policy and of 0.403 per cent under the MLS policy.

Table 6.8 presents the percentage changes in energy consumption of all 20 household groups under the no compensation scenario. It is apparent that all household groups decrease their consumption on energy commodities by various degrees. The results in Table 6.8 show that rich household groups tend to reduce their consumption of energy commodities by a greater percentage than poor household groups. The poorest household group reduces their consumption ratio on energy commodities more than some higher income household groups. This is because they suffered losses in their own unincorporated business income that caused them to become the poorest household group but the ratio of consumption of energy commodities is higher than that of the richer groups.

Rich household groups reduce their consumption ratio on energy products more than poor household groups because poor households tend to spend a greater proportion of their income on energy-intensive products than high-income households. For instance, in the database for this model, the poorest household groups spends 13.6 per cent of their disposal income on petroleum products, 6.6 per cent on electricity, 2.5 per cent on oil and gas, which together totals 22.8 per cent for energy products. Meanwhile, these proportions for the richest household group are 1.2 per cent, 0.9 per cent, 0.3 per cent, respectively, which together totals 2.3 per cent on energy products. Therefore, it is seemingly more difficult to reduce the percentage of household income spent on energy products in the low-income household groups than in the high-income household groups. As seen in Table 6.8, the richest household groups can cut 4.244 per cent of their electricity consumption, 0.157 per cent of their oil and gas consumption, and 0.121 per cent of their petroleum consumption; that is, 1.719 per cent of their total energy consumption.

The proportions of the poorest household group of these electricity consumption sources are just 0.981 per cent, 0.034 per cent, 0.066 per cent, and 0.338 per cent, respectively.

Table 6.8: Energy consumption under the no compensation policy (% change)

Group	Electricity Consumption	Oil & Gas Consumption	Petroleum Consumption	Energy Consumption	Real Consumption
Group 1(poorest)	-0.981	-0.034	-0.066	-0.338	-0.076
Group 2	-0.567	-0.017	-0.041	-0.217	-0.045
Group 3	-0.456	-0.013	-0.052	-0.164	-0.043
Group 4	-0.414	-0.014	-0.071	-0.155	-0.048
Group 5	-0.226	-0.008	-0.101	-0.129	-0.061
Group 6	-0.285	-0.009	-0.090	-0.137	-0.060
Group 7	-0.458	-0.014	-0.092	-0.192	-0.067
Group 8	-0.521	-0.016	-0.094	-0.217	-0.070
Group 9	-0.638	-0.020	-0.108	-0.244	-0.077
Group 10	-0.721	-0.022	-0.113	-0.283	-0.083
Group 11	-0.889	-0.028	-0.122	-0.338	-0.098
Group 12	-1.045	-0.032	-0.139	-0.392	-0.111
Group 13	-1.216	-0.032	-0.128	-0.443	-0.111
Group 14	-1.478	-0.038	-0.148	-0.556	-0.137
Group 15	-1.563	-0.040	-0.137	-0.556	-0.142
Group 16	-1.817	-0.035	-0.128	-0.639	-0.141
Group 17	-2.161	-0.056	-0.134	-0.748	-0.183
Group 18	-2.491	-0.053	-0.105	-0.850	-0.189
Group 19	-3.270	-0.092	-0.102	-1.042	-0.248
Group 20(richest)	-4.244	-0.157	-0.121	-1.719	-0.413

Source: Simulation from the model

Among energy products, the highest increase in the price of electricity results in the highest percentage reduction of electricity consumption in all household groups. The consumption of oil and gas, and petroleum in all households accounts for a fairly small percentage, just less than 0.2 per cent. The reductions in the consumption of energy products lead to a real consumption decrease by various degrees in all household groups. It is obvious that all households experience a reduction in real consumption with a higher percentage decline for rich groups. In order to improve this consumption reduction in all household groups, revenue recycling is provided to all household groups by various compensation policies.

6.4.3 Impacts of the ETS on household utility

In this model, household demand is featured by a linear expenditure system (LES), hence the change in household consumption is largely realised through the change in supernumerary (luxury) consumption. Household utility is measured by the level of luxury consumption. Figure 6.4 presents the percentage change in utility per household for the household groups under all scenarios. It is apparent that the percentage change in household utility is linked with the change in household income and household consumption, as presented in Figures 6.2 and 6.3 respectively. A higher increase in household income leads to a higher increase in household consumption, thus leading to an increase in supernumerary consumption, that is, in household utility.

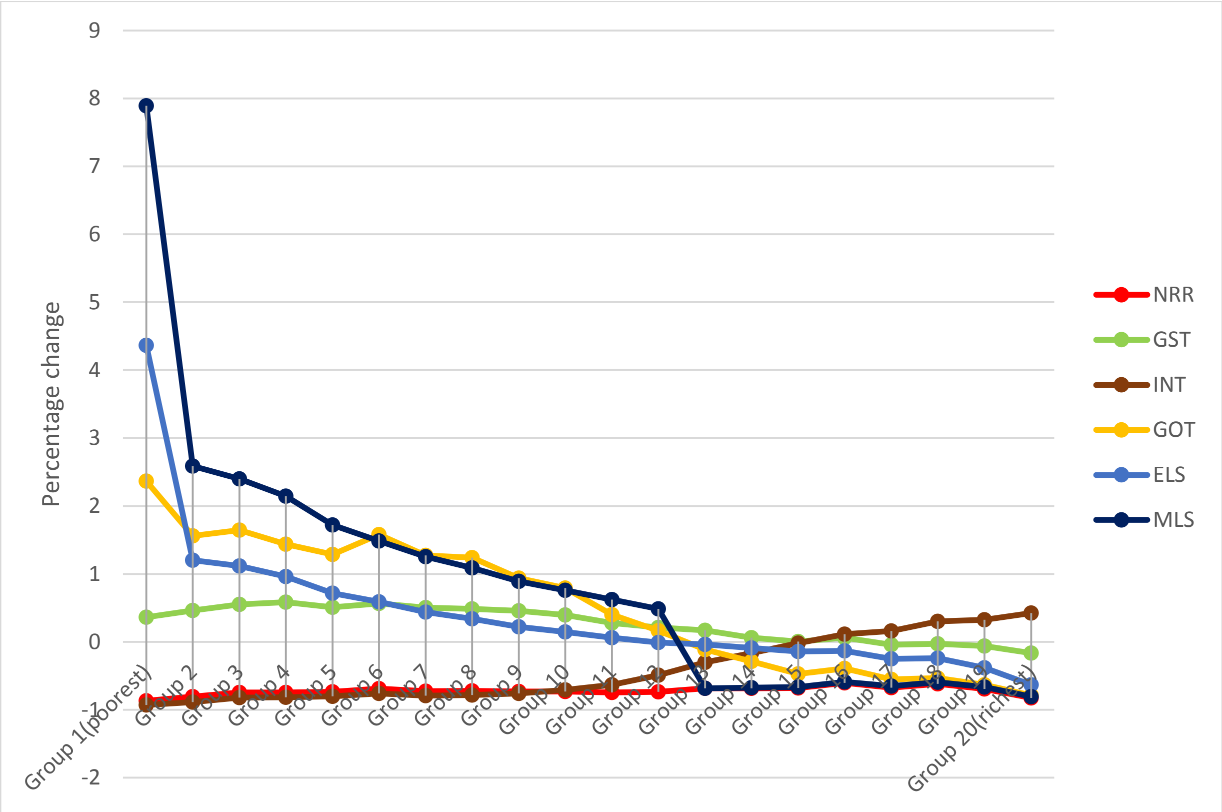

Figure 6.4: Impacts of the ETS on household utility (% change)
Source: Simulation from the model

Under the NRR policy, the percentage changes in utility of all household groups in Figure 6.4 are similar to the percentage changes in their income in Figure 6.2. However, the percentage change in utility is much greater than the percentage change in income, this is because households use a proportion of their income for luxury consumption, and a smaller base of luxury consumption leads to a larger percentage change in luxury consumption, thus resulting in a greater percentage change in household utility than the percentage change in income. All household groups experience a decline in utility with a slightly increased percentage reduction for poor household groups. In order to reduce the negative percentage change in utility of all household groups, various forms of compensation to households are provided.

The first impression is that all households groups are better off under all compensation policies compared to the no revenue recycling policy. As shown in Table 6.7, households increase their consumption of luxury goods, compared to the baseline values, if the government implements tax reduction policies rather than lump-sum transfer policies. The benefits obtained from the reductions in the GST or in income tax are quite different between household groups, thus leading to various changes in utility between household groups. Comparing the INT and GST policies, it is found that the lower income households are worse off under the INT policy but better off under the GST policy. In particular, the first 16 household groups increase their utility because of the GST reduction while the top four groups continue to face a reduction in their utility but this reduction is at a lesser percentage rate when compared to other scenarios. By contrast, under the INT policy, the first 15 poor groups experience a decrease in their utility. Moreover, this reduction for the first nine poor groups is higher than under the no compensation policy, while the five richest household groups increase their utility in line with the high positive percentage change.

If the revenue is recycled to household groups by increasing the government payment, or providing a lump-sum transfer, either to all household groups or to low and middle income households, the trend in the percentage changes in utility is similar to that in income and consumption. However, the change in utility is higher than the change in income, and much higher than the change in consumption. All these policies bring the most benefits to poor household groups, with their highest percentage increase in utility under the MLS policy, followed by the ELS policy and the GOT policy. By contrast, rich households receive more benefits under the ELS policy and fewer benefits under the MLS policy.

6.4.4 Impacts of the ETS on household welfare

Equivalent Variation (EV) is a monetary measure of the welfare effects brought about by price changes. EV measures the change in utility in terms of dollar value and indicates the amount of money needed to achieve a new level of utility at the initial price level or the maximum amount that a consumer would be willing to pay to avoid a price change. A negative value of the EV shows a welfare loss and a positive value for EV represents a welfare gain. The first impression from Table 6.9 is that the poorest household groups suffer a welfare loss under the NRR and the INT policies but obtain a welfare gain under the other policies.

Table 6.9: Impacts of the ETS on Equivalent Variation (A$m)

Group	NRR	GST	INT	GOT	ELS	MLS
Group 1(poorest)	-14.640	6.122	-15.667	39.990	73.731	133.245
Group 2	-6.931	3.956	-7.614	13.398	10.335	22.237
Group 3	-5.799	4.289	-6.417	12.836	8.712	18.742
Group 4	-6.773	5.296	-7.453	13.093	8.768	19.520
Group 5	-11.861	8.216	-12.942	20.751	11.567	27.806
Group 6	-11.854	9.714	-13.051	27.078	10.106	25.464
Group 7	-14.443	10.044	-15.771	25.354	8.741	24.986
Group 8	-16.468	11.021	-17.892	28.235	7.761	24.795
Group 9	-17.605	11.081	-18.297	22.681	5.362	21.489
Group 10	-21.402	11.660	-20.818	23.281	4.262	22.240
Group 11	-28.636	10.741	-24.230	15.383	2.416	23.803
Group 12	-35.050	10.111	-23.198	7.843	-0.525	22.968
Group 13	-37.146	9.212	-16.287	-6.091	-1.959	-37.142
Group 14	-55.622	4.852	-13.557	-23.337	-7.196	-54.831
Group 15	-57.347	0.405	-1.768	-39.659	-11.795	-55.998
Group 16	-62.818	6.230	11.645	-40.689	-13.596	-61.250
Group 17	-94.184	-6.153	22.630	-77.555	-34.714	-91.218
Group 18	-104.065	-5.246	51.238	-90.188	-40.945	-100.225
Group 19	-154.893	-13.590	72.259	-142.033	-85.801	-149.476
Group 20(richest)	-381.288	-77.166	194.918	-362.867	-291.391	-371.835
Total	**-1138.825**	**20.795**	**137.728**	**-532.496**	**-336.161**	**-534.680**

Source: Simulation from the model

As shown in Table 6.9, the results show that all household groups experience a welfare loss by different degrees under the NRR policy. It is clear that poor household groups suffer a lesser welfare loss than rich household groups. In particular, the absolute welfare loss is about $14.64 million for the lowest income household group compared to $381.288 million for the highest income household group. On average, all Australian households experience an aggregate loss of $1138.825 million. This aggregate loss is offset by the compensation policies used to reduce the GST and income tax. In particular, the income tax reduction policy results in an aggregate gain of $137.728 million to all Australian households, compared to $20.795 million under the GST policy. However, the distribution of welfare is quite different between household groups under each policy. Under the GST policy, middle-income groups obtain the highest welfare increase while rich income household groups experience a welfare loss, but with smaller numbers than other scenarios. By contrast, the INT policy results in a welfare gain to rich household groups, while it makes poor household groups lose more of their welfare than under the no compensation policy.

Compared to tax reduction scenarios, the lump-sum transfer scenarios result in an aggregate loss in all Australian households, in particular the equal lump-sum transfer induces the smallest aggregate loss of $336.161 million under the ELS policy compared to over $532.496 million under the GOT policy and $534.680 million under the MLS policy. Seemingly, the ELS policy is the optimal choice for all household groups because this policy provides equal benefits to all household groups. Lower income household groups obtain more welfare gain under the ELS policy rather than under the GOT policy, while wealthy household groups suffer less welfare loss under the ELS than under both the GOT and MLS policies.

6.5 Sensitivity analysis

The results of the economic simulations rely on the values for key exogenous parameters. Thus, the values assigned to parameters play an important role in the accuracy of the model's results. However, the values of these parameters are often not precisely known. In particular, the elasticity parameters in this study were obtained from the ORANI-G database and other literature. Therefore, it is crucial to find out how variations in the values of these parameters affect the model results. A Systematic Sensitivity Analysis[17] (SSA) is a consistent way to test the sensitivity of all parameters at once. The SSA is implemented through a Gaussian Quadrature, which is an optimization method. Given the distributions of M exogenous variables (parameters), the Gaussian Quadrature estimates the means and standard deviations of all endogenous variables by choosing the best possible N simulations. All parameters are assumed to have a triangle distribution and the optimum number of simulations is determined using the Stroud Quadrature.[18]

Table 6.10 presents the mean, standard deviation, and confidence interval[19] of the selected variables under the SSA for the NRR policy (the ETS without revenue recycling). All elasticity parameters were varied by 50 per cent variation from their mean.

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[17] The results of SSA is collected from running the model in the RunGEM programme of the GEMPACK software.

[18] Gaussian Quadrature include Strouds quadrature and Lius quadrature. The model is solved 2N times with Strouds quadrature and 4N times with Lius quadrature.

[19] The confidence interval is calculated using the Chebyshevs inequality, which states that whatever the distribution of the variable in question, for each positive real number k, the probability that the values of Y

Table 6.10: SSA of the ETS without compensation, 50% variation in parameters

			Confidence Interval (95%)	
Variable (percentage change)	**Mean**	**Standard dev**	**Lower**	**Upper**
Real GDP	-0.29879	0.01435	-0.36292	-0.23467
Real GNE	-0.09197	0.00519	-0.11514	-0.06879
Real Household Consumption	-0.16933	0.00955	-0.21200	-0.12665
Aggregate employment	-0.44094	0.02042	-0.53219	-0.34968
Export volume	-1.24617	0.06405	-1.53247	-0.95986
Import volume	-0.31316	0.02766	-0.43679	-0.18954
Consumer price index	0.35853	0.01513	0.29092	0.42614
Industry output				
Agriculture, forestry, fishing	-1.66663	0.13440	-2.26739	-1.06586
Black coal	-0.22415	0.02519	-0.33673	-0.11157
Brown coal	-4.80896	0.43686	-6.76172	-2.85621
Oil	-0.04975	0.00510	-0.07253	-0.02697
Gas	-0.89771	0.16874	-1.65195	-0.14346
Mining	-0.18205	0.03076	-0.31953	-0.04458
Food, beverages, tobacco	-0.81500	0.05305	-1.05212	-0.57788
Textiles, clothing, footwear	-0.43580	0.02527	-0.54875	-0.32285
Wood, paper, printing	-0.53978	0.04566	-0.74388	-0.33568
Automotive petrol	-0.74075	0.07594	-1.08021	-0.40130
Kerosene	-0.98024	0.15473	-1.67188	-0.28859
Gas oil or fuel oil	-0.99995	0.20312	-1.90790	-0.09200
Liquefied petroleum gas	-3.32666	0.43034	-5.25027	-1.40305
Other petroleum, coal products	-1.54132	0.21556	-2.50486	-0.57778
Chemical products	-1.26795	0.16288	-1.99602	-0.53987
Iron and steel	-1.73501	0.16573	-2.47581	-0.99420
Other metal products	-1.27905	0.19498	-2.15063	-0.40748
Furniture and equipment	-0.54732	0.03387	-0.69871	-0.39592
Other manufacturing	-1.23881	0.12506	-1.79781	-0.67981
Electricity -black coal	-9.44235	1.18753	-14.75060	-4.13410
Electricity -brown coal	-13.39194	2.22969	-23.35865	-3.42524
Electricity-oil	-2.87723	1.05107	-7.57551	1.82104
Electricity- gas	2.70133	0.86599	-1.16966	6.57233
Hydro-electricity	5.42041	0.57108	2.86768	7.97314
Electricity -wind	5.43047	0.57971	2.83917	8.02176
Electricity-solar	5.71059	0.61380	2.96689	8.45429
Electricity-biomass	9.21160	1.02501	4.62982	13.79338
Electricity-biogas	4.94557	0.53352	2.56073	7.33041

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does not lie within k standard deviations of the mean, M, is no more than 1/(k^2). If k = 4.47 the confidence interval is 95 per cent.

			Confidence Interval (95%)	
Variable (percentage change)	**Mean**	**Standard dev**	**Lower**	**Upper**
Commercial electricity	-3.94086	0.47312	-6.05568	-1.82603
Gas supply	-1.44633	0.25587	-2.59007	-0.30258
Water, sewerage services	-0.21433	0.01881	-0.29841	-0.13024
Construction services	0.11097	0.01125	0.06070	0.16125
Wholesale trade	-0.53336	0.02723	-0.65507	-0.41165
Retail trade	-0.21246	0.01354	-0.27300	-0.15192
Accommodation, restaurant	-0.53392	0.03700	-0.69931	-0.36852
Road transport	-1.86829	0.17197	-2.63700	-1.09957
Other transports	-0.52751	0.06208	-0.80498	-0.25003
Communication services	-0.19379	0.00853	-0.23191	-0.15568
Finance and insurance	-0.20692	0.00924	-0.24824	-0.16560
Property, business services	-0.16983	0.00724	-0.20219	-0.13746
Public services	-0.05065	0.00240	-0.06139	-0.03992
Education and training	-0.27549	0.01136	-0.32626	-0.22472
Health, community services	-0.06364	0.00296	-0.07685	-0.05043
Art, recreation services	-0.23714	0.01119	-0.28715	-0.18714
Other services	-0.45550	0.02491	-0.56683	-0.34416
Household consumption by groups				
Group 1(poorest)	-0.07593	0.00362	-0.09210	-0.48763
Group 2	-0.04494	0.00203	-0.05403	-0.28644
Group 3	-0.04297	0.00201	-0.05194	-0.27512
Group 4	-0.04801	0.00239	-0.05869	-0.31037
Group 5	-0.06176	0.00321	-0.07612	-0.40201
Group 6	-0.05986	0.00302	-0.07335	-0.38774
Group 7	-0.06755	0.00335	-0.08251	-0.43637
Group 8	-0.07048	0.00347	-0.08597	-0.45478
Group 9	-0.07761	0.00389	-0.09499	-0.50222
Group 10	-0.08360	0.00415	-0.10217	-0.54030
Group 11	-0.09840	0.00507	-0.12104	-0.63942
Group 12	-0.11174	0.00587	-0.13798	-0.72853
Group 13	-0.11191	0.00592	-0.13836	-0.73037
Group 14	-0.13758	0.00763	-0.17170	-0.90509
Group 15	-0.14284	0.00812	-0.17916	-0.94367
Group 16	-0.14146	0.00794	-0.17693	-0.93235
Group 17	-0.18403	0.01093	-0.23286	-1.22494
Group 18	-0.18980	0.01129	-0.24024	-1.26370
Group 19	-0.24983	0.01496	-0.31671	-1.66551
Group 20(richest)	-0.41564	0.02409	-0.52332	-2.75490

Source: Simulations from the model

Results show that the percentage change in endogenous variables is robust to variation in parameters because of the low standard deviation of almost all endogenous variables and the SSA mean values are not significantly different to the original simulation results. As can be seen from Table 6.10, with 95 per cent confidence, the results are robust with respect to the 50 per cent parameter variation. For example, with 95 per cent confidence, by negative value of upper bound, it can be concluded that real GDP, real GNE, real household consumption, aggregate employment and exports will decrease. However, by the positive value of lower bound, the CPI will increase.

6.6 Conclusion

This research measured the effects of the ETS on macro-economic variables, industries and household groups under the no revenue recycling options as well as for compensation policies. Under the ETS, the government imposes about 80 per cent of the emissions reduction target that is implemented by the electricity-black coal and electricity-brown coal industries, and the remaining target is carried out by all other industries. The payments for emissions generated by industries affect all aspects of the Australian economy.

The emissions permit price is estimated at \$20.608/tCO_2-e under the ETS without a compensation policy. The imposition of an emissions price results in increases in the prices of most goods and services. As emissions-intensive products, and energy commodities experience the larger percentage change, with electricity price estimated to increase by the highest percentage of over 13.528 per cent, and brown coal estimated to decrease by the highest percentage of over 31.010 per cent. The highest reduction in the brown coal price is caused by a large reduction in demand for brown coal in the electricity generation sector. In addition, the returns on capital, land and labour change because of the ETS; together they affect household income, consumption and utility.

To offset these undesirable effects of the emissions price, the government can introduce revenue recycling policies. This chapter compares the effects of various revenue recycling policies which use 50 per cent of the total auction revenue to compensate households. Results show that there is likely to be a trade-off between efficiency and equity. The income tax reduction policy results in more efficiency in the Australian economy than other compensation policies through a higher GDP and household consumption. However, this policy induces inequity by providing more benefits to higher income household groups and fewer benefits for lower income household groups. By contrast, the equal lump-sum transfer to all household groups creates equity between household groups, with over compensation to the poor and the rich who lose less of their income, consumption and welfare compared to other compensation policies.

The payment for emissions generation directly affects sectoral output and employment. Results indicate that all industries experience output loss and employment reduction in various degrees, with the electricity-black coal and electricity-brown coal suffering the highest sectoral output loss, and labourers in the brown coal sector bearing the highest percentage of job losses. However, the compensation policies bring an improvement in sectoral outputs as well as in sectoral employment. While the tax reduction policies create more benefits for the services sectors, lump sum transfer policies result in relatively equal benefits to all industries.

CHAPTER 7: CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

7.1 Introduction

This thesis applied a CGE model to measure the distributional and welfare effects of an ETS in Australia. Under the ETS, the government sells a fixed quantity of permits to polluting industries to achieve an emissions reduction target of five per cent below 2000 levels by 2020. Emitters can purchase deficient emissions permits (or sell excessive emissions permits) from (to) other emitters at an emissions permit price that is endogenously determined by the market. Generally, an ETS results in an improvement in environmental quality but it might create regressive effects on the Australian economy. To mitigate undesirable implications, the government can use the revenue raised from selling emissions permits to compensate households through various revenue recycling policies.

Six of the chapters of this thesis explained the research approach taken to investigate the effects of an ETS and the various compensatory options. Chapter 1 introduced the research problem, the objectives of the research, the methodology used and the contribution of the research. Chapter 2 surveyed the literature on instruments used to reduce emissions, with a predominant focus on carbon pricing mechanisms, such as a carbon tax and an ETS. A carbon pricing policy is the most efficient and effective instrument for reducing carbon emissions. The distributional and welfare effects of a carbon pricing policy were analysed in both theoretical and empirical reviews. The economic theories show that the burden of placing a price on carbon emissions is shared between producers and consumers, depending on the elasticity of supply and demand, and the government raises revenues from imposing a carbon price. The variety of ways for using these revenues to compensate vulnerable populations was examined through the use empirical studies. Chapter 2 reviewed the empirical studies, such studies applied CGE models to assess distributional and welfare effects of a carbon pricing policy in Australia and other countries.

Chapter 3 provided an overview of the Australian environmental policies with the purpose of achieving the Australia's *Kyoto Protocol* commitment. Many carbon emissions reduction strategies have been proposed or implemented by the Australian Government in recent years. A carbon pricing mechanism was implemented from July 2012 for two years. It had the effect on carbon emissions but also impacted the Australian economy. Chapter 3 also explained the compensation packages accompanying the implemented carbon pricing mechanism. The compensation policy was implemented to assist producers and consumers to cope with the extra costs caused by the carbon pricing policy.

Analysis of distributional and welfare effects of an ETS in a CGE modelling framework can be implemented by a model using a Social Accounting Matrix (SAM). Chapter 4 presented the procedures used to construct the SAM for the Australian economy for 2009. The aggregate transactions or flows among agents in the economy are presented in the SAM. In order to measure the distributional and welfare effects of an ETS, some accounts in the SAM are disaggregated to provide more detail about circular flows of income and spending in the economy. In this study, there is disaggregation of energy sectors, electricity generating sector, labour and households. In all, 131 sectors, 10 occupational categories, and 20 household groups were analysed. The 131 sectors were aggregated into 45 sectors for this study. To measure the effects of an ETS, the methods used for allocating emissions to industries and consumers were explained in detail in this chapter.

Chapter 5 developed the static CGE model applied in this study through a system of equations. There are modifications in the treatment of energy commodities in the production structure, compared to the ORANI-G model (Horridge, 2003) on which the present model was based. For example, this CGE model allows for substitutions among energy products, between electricity generated from different sources, and between energy composites and capital. These substitutions are described by using the CES function. They allow for a shift from high carbon intensive production activities to low carbon intensive production activities, thus leading to a reduction in carbon emissions. To measure the distributional and welfare effects of an ETS, equations describe the emissions permit price and the emissions trading mechanism among emitters under the ETS. The quantities of emissions reduction to emitters, which are fixed by the government, are set to be shocks in the model. This CGE model also incorporated equations describing income and expenditure for 20 household groups, corporations, government and the rest of the world, thus allowing for analysis of distributional and welfare effects. In addition, Chapter 5 explained the compilation methods of various elasticity parameters in the CGE model.

The effects of an ETS on macro-economic variables, sectoral and household levels were analysed in Chapter 6. The ETS is undertaken with the purpose of achieving the emissions reduction target of five per cent below the 2000 level by 2020. As the highest emissions intensity sectors, the electricity-black coal and electricity-brown coal industries are responsible for about 80 per cent of the total emissions reduction target. To do that, the government is assumed to set the emission reduction target of 27.442 per cent from the baseline emissions to electricity-black coal and electricity-brown coal industries, and the government imposes an equal emissions reduction target of 3.366 per cent to all other industries in the Australian economy. The government obtains the revenues from selling emissions permits to industries. In this study, 50 per cent of the revenues is used to compensate households to offset negative effects of an ETS, and the other 50 per cent is kept as government revenue. Chapter 6 compared and contrasted the effects of an ETS with and without revenue recycling policies. The compensation policies included an income tax reduction (INT), goods and services tax reduction (GST), government transfer increase (GOT), an equal lump-sum transfer to all household groups (ELS), or an equal lump-sum transfer to the 12 lowest household income groups (MLS). The chapter ended with the sensitivity analysis on different values of elasticity parameters to test the robustness of the results generated by the model.

The remainder of this chapter is organised as follows: section 7.2 provides the summary of major findings and policy implcations; section 7.3 presents the contribution of the research; limitations of the research are discussed in section 7.4; and suggestions for further study are outlined in the final section.

7.2 Summary of major findings and policy implications

This section summarises the major findings and policy implcations related to macroeconomic effects, sectoral effects, and household effects of an ETS in the cases of with and without a compensation policy as discussed in Chapter 6.

First, in order to achieve the emissions reduction target of 5 per cent below the 2000 levels by 2020, the emissions permit price is estimated at around A\$20.608/tCO_2-e and the auction revenue is predicted to be around A\$10.280 billion under the ETS without a compensation policy. About 50 per cent of this revenue is assumed to return to households in various forms of compensation such as lowering GST rate, an income tax reduction, a government transfer increase, an equal lump-sum transfer to all household groups, or an equal lump-sum transfer to the 12 lowest income household groups. The results of this study indicate that the emissions permit price will increase slightly under all compensation policies, with the GST policy predicted to increase the price of emissions permit to the highest amount of A\$21.025/tCO_2-e.

Second, the emissions permit price results in changes in macro-economic levels to varying degrees, including an increase in the CPI by 0.358 per cent, a decrease in real GDP by around

0.298 per cent and in real household consumption by 0.168 per cent under the ETS without compensation. All revenue recycling policies create an improvement in macro-economic variables in the Australian economy, when compared to the ETS without compensation. Economic efficiency is achieved by positive change to real household consumption under the GST and INT policies. Under the GST policy, real GDP and aggregate employment improves. For other compensation policies, there are still decreases in these macro-economic variables but by lower percentages when compared to the no compensation policy. Thus, it can be concluded that the ETS plus a tax reduction may result in both better environmental quality and economic efficiency, thus leading to a 'double dividend'.

Third, the prices of most goods and services experience changes due to the emissions permit price, especially the price of energy commodities. Particularly, the electricity price is estimated to increase at the highest amount of around 13 per cent, followed by the second highest increase of nearly 2 per cent for the road transport services. Brown coal is estimated to decrease by the largest percentage of around 31 per cent. Under the scenarios of the compensation policies, except for the GST policy, prices of electricity and road transport continue to increase, while the price of brown coal continues to decrease. The prices of goods and services increases at a higher percentage under the INT policy than under the GOT and MLS policies; therefore there is a CPI increase of 0.475 for the former and 0.411 and 0.412 respectively for the latter.

Fourth, imposing a price on carbon emissions leads to a decrease in emissions in the Australian environment. The emissions reduction is mainly due to a decrease in sectoral output in the short-run when technological changes are assumed to be fixed. In particular, with the emissions permit price of \$20.608/tCO_2-e, the electricity-black coal and electricity-brown coal industries experience about 45.311 Mt CO_2-e reduction, which is equivalent to 71.4 per cent of the total emissions reduction target. Therefore, these two electricity industries will become the biggest emissions buyers if the government imposes them to reduce about 80 per cent of the total emissions reduction target. As high emissions intensive production activities, energy sectors, such as black coal, oil and, gas, are also emissions permit buyers. By contrast, a high emissions permit price results in a large emissions reduction in road transport sector, thus if the government imposes emissions reduction of 3.366 per cent from its baseline emissions, the road transport sector will become the biggest permit seller.

High emissions reductions are due to large reductions in output in the energy sectors. In particular, the output of electricity-black coal and electricity-brown coal sectors will decline about 9.505 per cent and 13.322 per cent respectively, followed by the brown coal sector with 4.801 per cent of output reduction. The output of the road transport sector decreases about 1.875 per cent. Under all compensation policies, the declines in the output of these sectors are still high, when compared to other sectors. The decrease in sectoral output results in a corresponding decline in sectoral employment, in particular the brown coal sector experiences the largest decrease in employment of over 27 per cent and continues to decrease under the compensation policies, except in the GST policy. In contrast to the employment reduction in most industries, the electricity generation sectors experiences an increase in employment, especially in the area of electricity generated from renewable sources. This is explained by the substitution between labour, and capital-energy composite that is allowed for in the model. For occupational categories, the highest reductions are in the numbers of managers and administrators, and machinery operators, drivers and labourers.

Fifth, households, as final consumers and primary factor suppliers, bear the extra cost caused by the emissions permit price through changes in their income and expenditure. The results reveal that all household groups experience a decrease in both income and expenditure under the ETS without compensation. The emissions permit price is a moderately regressive policy when poor- and middle-income household groups experience a higher rate of income reduction when compared to rich household income groups. When the auction revenue is partially recycled to all household groups in various compensation policies, the ETS plus INT policy is still regressive, whereas the ETS plus other compensation policies is quite progressive.

The ETS plus the income tax reduction appears favourable towards wealthy household groups, whereas the ETS plus an equal lump-sum transfer to the 12 lowest income household groups is seen to be favourable to poor and middle income household groups. However, the ETS plus an increase in government transfers would bring benefits to middle-income groups such as groups 7, 8, 9 and 10. Under the ETS plus equal lump-sum transfer to all household groups, the benefits are distributed quite equally among all household groups. Welfare effect is measured by the Equivalent Variation (EV). The results indicate that all households groups experienced a welfare loss under the ETS without a compensation policy. The various compensation policies make difference in welfare loss and welfare gains for household groups. On average, the ETS plus the income tax reduction or the GST cut results in welfare gains to Australian households. Five of the richest household groups obtained welfare gains under the INT policy, while the lower GST brings welfare gains to 16 poor household groups. By contrast, creating welfare loss to Australian households on average, the ETS plus lump-sum transfers will bring welfare gains to low and middle income household groups, in which groups 6,7,8, 9 and 10 receive higher welfare gains under the GOT policy than under the ELS and MLS policies.

7.3 Expected contribution of the research

Applying the CGE model to analyse the effect of the ETS on distribution and welfare in Australia, this thesis has contributed to academic literature in this field in several ways:

First, this thesis contributes to the methodology of CGE modelling for emissions trading policy analysis. Differing from CGE models currently being used in modelling a fixed carbon price in the Australian economy, the CGE model in this study simulated domestic emissions trading among Australian industries in which the emissions permit price is endogenously determined but the quantity of emissions generated by each industry is fixed and set to be shocks in the model. The changes in carbon emissions caused by the ETS are reflected by changes in the production of commodities by taking emissions intensities into consideration in the model. These changes, in turn, affect the price of primary factors in the economy. The emissions permit price is included in the purchaser price equations to producers and consumers, thus leading to an adjustment in the production and consumption of high emissions intensive products. Changes in the prices of goods and services are reflected in the expenditure of institutions, and changes in prices of primary factors are expressed in the income of institutions. Hence, the model incorporates equations describing the income and expenditure of all institutions in the economy, enabling an analysis of the distributional and welfare effects of the ETS. The model also explains various compensation policies under the ETS.

Second, this thesis contributed by constructing the SAM framework for the Australian economy. The SAM describes the economic transactions and transfers in the Australian economy. In addition, disaggreagtion on the energy and electricity generation sectors, occupational categories, and households are incorporated in the SAM. Particularly, the electricity generation sector is disaggregated into nine sub-sectors and totally, four energy sectors are disaggregated into 24 sub-sectors, labour is divided into ten occupational groups, and households are disaggregated into 20 household groups. The data to construct the SAM was collected from various sources, mainly from the Input-Output Tables, 2008-09, and the ASNA, 2010-2011. To disaggregate the values in the SAM, the thesis used data from the IO tables (Product Details), 2008-09, for the energy industries, and the Household Expenditure Survey for Labour and Households. The emissions data were mostly compiled from the National Greenhouse Gas Inventory for 2009.

This study also contributes by comparing the impacts of the ETS with and without compensation policies, as well as the ETS with various scenarios of compensation policies on macro-economic, sectoral and household levels, with a primary focus on the distribution of income and welfare effects. It seems that there is a trade-off between efficiency and equity. The compensation policies could bring about a recovery to the Australian economy. In particular, the income tax reduction policy would result in economic efficiency, but inequality because this policy provides financial benefit to wealthy household groups, thus resulting in the ETS policy being regressive. The equal lump-sum transfer to all household groups brings equality to the economy but does not create economic efficiency in the same way that an income tax reduction policy does. This explains why the Australian Government implemented the carbon tax with the income tax reduction policy that applied only to individuals who are in the low- and middle-income bracket, and whose income was lower than A$80,000 per year.

7.4 Limitations of the research

There are many significant weaknesses related to the application of a static CGE model and household data disaggregation in the SAM.

Applying a static CGE model leads to limitations in this research. First, such a static model does not allow for implementing banking and borrowing emissions permits. However, under the ETS, Chapter 2 discussed that the permit price is volatile and implementing banking and borrowing of emissions permits can bring a reduction in the volatility of the emissions permit price. Second, a static CGE model only measures the effects of the ETS in the short run. Such a static model does not track variables over time; hence, this does not reflect the capital accumulation and investment decision. Such capital accumulation and investment decision may cause producers to adopt low carbon emissions technologies.

For household data disaggregation, as discussed in Chapter 4, household income constitutes from various sources, the amount of income from each source is disaggregated into 20 household groups in this study. Therefore, to do that, this research used various ratios as presented in detail in Appendix A to disaggregate these income amounts into each household group. However, the HES, 2009-2010 provided some sources of the household income, hence it is not sufficient information to disaggregate the household incomes in the SAM. Therefore, a ratio was used to disaggregate the household incomes from different souces. For example, to divide household income from land and capital into 20 household groups, this research used the residual ratios in column 8 Table 4.50. This is a limitation of this research because in reality the ratios of household income from capital and land may be different.

7.5 Suggestions for further study

This thesis focuses on assessing the distributional and welfare effects of an ETS in achieving the emissions reduction target in the Australian economy. These objectives alrealdy have been addressed in this study. However, there are still have many limitations regarding the application of a static CGE model and database, thus it is important in further research to extend the model and update database.

+ Improving methodology

The application of a static CGE model results in limitations to this research. Future research should be undertaken by extending the model to make it dynamic, thus allowing for an analysis of the effect of the ETS over time. This would also allow for the inclusion of the banking and borrowing of emissions permits in the model, hence leading to a reduction of the emissions price volatility. Moreover, a dynamic CGE model would trace each variable through time periods, thus reflecting the changes in the economy and, thereby, providing a more realistic observation of the effects of the ETS on distribution and welfare.

To examine the distributional and welfare effects of the ETS, households are disaggregated into 20 household groups based on their annual income rank. In a further study, households could be disaggregated based on their annual expenditure rank, thereby permitting a comparison of the effects of the ETS in two cases of household disaggregation based on income level and expenditure level. Moreover, a further study could combine this CGE model with a microsimulation model providing details about the household level or individual level, thus leading to an examination of the distribution and welfare effects of the ETS across various categories of households, such as urban and rural, or different household types (couples, couples with children, single parent).

The current model has incorporated sectoral projections for only 45 sectors. Whereas, there are 111 sectors in the original IO tables, 2008-09, four energy sectors in the IO tables are disaggregated into 24 sectors. Therefore, there are 131 sectors in the IO tables in this research. Because of the lack of data for all 131 sectors, all these sectors are aggregated into 45 sectors in this research. If it were possile to obtain the data for all 131 sectors the effects on specific sectors could be obtained.

+ Improving data

This research obtained the data from IO Tables 2008-09, ASNA 2010-11 to construct the SAM. In order to disaggregate household incomes and expenditures to 20 household groups, this research used the HES data of the year 2009-2010. These were the latest databases available at the time of model implementation. However, recently, the ABS published IO Table 2009-2010 and IO Table 2012-2013, ASNA 2014-2015, hence another study could utilise this more recent data to update the SAM.

The CGE model applied in this study contained many elasticity parameters. Some parameters were collected from the ORANI-G database. Other parameters were borrowed from similar studies with adjustment to suit with some modification in this study. The simulation results are sensitive to the parameter values, thus a further study could improve results by using parameters that are estimated by some econometric model for the Australian economy in which these parameters are validated.

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APPENDICES

Appendix A: Procedure to disaggregate household receipts and payments

The ratios used to disaggregate the receipts and the payments of households are based on the data provided in the Household Expenditure Survey (HES) 2009-10.

Section A1: Household receipts

A1.1 Household receipts in the income account

+ Household receipts from labour (HHRL)

The total employee income (or compensation to employee) is defined as the sum of current weekly employee income including overtime, salary sacrifice bonus and STRP (IWSSUCP8), current weekly income from workers' compensation lump sum (CWINCLS) and current weekly income from regular workers' compensation (IRWCCP).

R1= $\frac{HHRL\ of\ each\ household\ group}{HHRL\ of\ all\ househod\ group}$

+ Household receipts from social assistant benefits (HHRSAB)

The social assistant benefit is a payment from the government to households in order to meet the same needs as social insurance benefits. They may be payable in cash or in kind. So, this is defined as weekly household total social assistant benefits in cash or kind (TBEN).

R2 = $\frac{HHRSAB\ of\ each\ household\ group}{HHRSAB\ of\ all\ househod\ group}$

+ Household receipts from non-life insurance claims (HHRNLI).

Non-life insurance claim is a payment by financial corporations to households in settlement of damages or loss in the current account period. This is defined as the sum of current weekly income from accident compensation and sickness insurance (IACSICP) and current weekly income from workers' compensation (IRWCCP)

R3 = $\frac{HHRNLI\ of\ each\ household\ group}{HHRNLI\ of\ all\ househod\ group}$

+ Household receipts from current transfers (HHRCT)

(1) Households receive current transfers from other households (HHRCTHH)

This is classified in the form of other family support, child support/maintenance, parenting support. It is defined as the sum of current weekly income from family members not living in the households (CWIFNIH), current weekly income from child support/maintenance (ICHLDSCP) and current weekly income from parenting payment (IPARENCP)

R4 = $\frac{HHRCTHHof\ each\ household\ group}{HHRCTHH\ of\ all\ househod\ group}$

(2) Households receive current transfers from corporations (HHRCTC)

Households receive current transfers from non-financial and financial corporations in the form of charities, workers' compensation, accident/sickness insurance, superannuation pension and annuities and scholarships. It is defined as the sum of current weekly income from superannuation/annuity/private pension (ISUPERCP), current weekly income from regular workers' compensation (IRWCCP), current weekly income from accident compensation and sickness insurance (IACSICP) and current weekly income from scholarships (ISCHOLCP).

R5 = $\frac{HHRCTCof\ each\ household\ group}{HHRCTC\ of\ all\ househod\ group}$

(3) Households receive current transfers from the government (HHRCTG)

The current transfers from government to households is defined as the social assistant benefits in cash or kind (TBEN)

R6 = $\frac{HHRCTGof\ each\ household\ group}{HHRCTG\ of\ all\ househod\ group}$

(4) Households receive current transfers from foreigners (HHRCTF)

Households can receive transfers from individuals, non-profit institution, or governments from other countries and is based on the current weekly income from oversea pension and benefits (IOSEASCP) to calculate household receipts to current transfers from foreigners

R7 = $\frac{HHRCTFof\ each\ household\ group}{HHRCTF\ of\ all\ househod\ group}$

A1.2 Household receipts in the financial account

+ Currency, deposits receipts.

Financial transactions in currency and deposits consist of addition to, or disposal of currency and incrementing deposits or making withdrawals from it. In the case of deposits, the interest is first recorded the distribution of the primary income account, and recorded in the financial account as a new deposit. So, the increase in the value of the deposit may be due to the payment of interest earned. The increase on deposits may correspond to the decrease in currency, and vice versa.

(1) Currency, deposite receipts from financial corporations and foreigners (HHRCDFF)

These receipts are defined as the total of current weekly employee income from bonuses (IWSBUCP) and current weekly cash income from their own unincorporated business (IOBTCP)

R8 = $\frac{HHRCDFF of\ each\ household\ group}{HHRCDFF\ of\ all\ househod\ group}$

(2) Currency, deposit receipts from the government (HHRCDG)

These receipts are defined as the current weekly employee income from bonuses (IWSBUCP)

R9 = $\frac{HHRCDG of\ each\ household\ group}{HHRCDG\ of\ all\ househod\ group}$

+ Bills of exchange receipts (HHRBE)

This research is based on total financial assets to calculate ratios for each group.

R10 = $\frac{HHRBE of\ each\ household\ group}{HHRBE\ of\ all\ househod\ group}$

+ One name paper receipts (HHRONPA)

This study is based on the total financial assets to calculate ratios for each group.

+ Bonds receipts (HHRB)

This study is based on the value of debentures and bonds to calculate the ratio for each household group

R11 = $\frac{HHRB of\ each\ household\ group}{HHRB\ of\ all\ househod\ group}$

+ Shares and other equity receipts (HHRSE)

These receipts are defined as the total value of shares-household level (VSHARCH) and value of silent partnerships-household level (VSIPCH)

R12 = $\frac{HHRSE of\ each\ household\ group}{HHRSE\ of\ all\ househod\ group}$

+ Insurance technical reserves receipts (HHRITR)

These insurance technical reserves receipts are defined as the total household weekly expenditure on medical care and health expenses (EXP09) plus household weekly expenditure on transport (EXP10) plus household weekly expenditure on superannuation and life insurance (EXP17)

R13 = $\frac{HHRITRof\ each\ household\ group}{HHRITR\ of\ all\ househod\ group}$

+ Other account receipts (HHROA)

Other account receipts are defined as the ratio of total financial assets.

A1.3 Household receipts in the capital account.

The capital transfers households receive from non-financial corporations is the acquisition of assets without payments by households such as the irregular winnings from lotteries or other gambling, payments received on life insurance policies, lump sum compensation for injuries, casualty claims, and legal damages. Based on the HES, 2009-2010, the capital transfers of each household group is calculated due to some variables as follows and it is defined as the total of all the following variables

+ Personal irregular receipts from superannuation payments over the last 2 years (I40SUP)

+ Personal irregular receipts from life insurance payments over the last 2 years (I41LIP)

+ Personal irregular receipts from accident compensation over the last 2 years (I43ACPAC)

+ Personal irregular receipts from legal damages over the last 2 years (I43ACPLD)

+ Personal irregular receipts from matrimonial settlement over the last 2 years (I46MPP)

+ Personal receipts from windfall gains/winning over the last 2 years (I49WGP)

+ Personal irregular receipts from other sources over the last 2 years (I53OLP)

R14 = $\frac{HHRCT\ of\ each\ household\ group}{HHRCT\ of\ all\ househod\ group}$

Section A2: Household payments

A2.1 Household payments in the income account

In the income account, household payments include the expenditure on goods & services and goods and services tax (GST). The HES, 2009-2010 provided the household expenditure on 10 commodity categories and one category of total expenditure on goods and services, these categories were mapped into 131 commodities in the Use table. The ratios are used as shown in the following calculations:

+ Payment for goods and services consumption (EXTLCSER)

$$P1 = \frac{HHPGS\ of\ each\ household\ group}{HHPGS\ of\ all\ househod\ group}$$

+ Payment for the goods and services tax (TOTGST)

$$P2 = \frac{HHPT\ of\ each\ household\ group}{HHPT\ of\ all\ househod\ group}$$

In addition, there are payments to institutions including interests, rents on natural assets, non-life insurance, current transfer and tax. The ratios used to disaggregate payments is calculated as follows:

+ Interest payments

(1) Interest payment to non-financial corporations (HHPINFC)

The total weekly mortgage repayments to purchase/build (TRPAY1CH) and weekly mortgage repayments for alterations/additions (TRPAY2CH) is used to calculate interest paid by households to non-financial corporations.

$$P3 = \frac{HHPINFCof\ each\ household\ group}{HHPINFC\ of\ all\ househod\ group}$$

(2) Interest payment to financial corporations (HHPIFC)

That is defined as the sum of weekly mortgage repayments to purchase/build (TRPAY1CH), weekly mortgage repayments for alterations/additions (TRPAY2CH), weekly repayments on unsecured loans for housing purposes (TRPAY4CH) and current weekly interest paid on money borrowed to purchase shares or units (LINVCP)-person level.

$$P4 = \frac{HHPIFCof\ each\ household\ group}{HHPIFC\ of\ all\ househod\ group}$$

+ Payment for rent on natural assets

This is a payment of households to government for renting natural assets for their production such as land, minerals, forest and so on, thus it is defined as weekly rent payments (WKRENTCH).

$$P5 = \frac{HHPRNAof\ each\ household\ group}{HHPRNA\ of\ all\ househod\ group}$$

+ Payment on non-life insurance premium

This is the amount of money that households prepay to insurance companies (financial corporations and foreigners) in order to cover the loss of non-life assets, the damage, or the accidents happening in the future. There are expenditures by households on their health, cars, building, machinery, and so on. Therefore, it is defined as the sum of household weekly expenditure on medical care and health expenses (EXP09) and household weekly expenditure on transport (EXP10).

P6= $\frac{HHPNLIof\ each\ household\ group}{HHPNLI\ of\ all\ househod\ group}$

+ Payment on current transfers

(1) Current transfers to other households (HHPCTHH)

These transfers are defined as the sum of current weekly financial support provided to family members not in the household (CWFINSPP) and current weekly payments for child support/spousal maintenance (KSUPPCP)

P7 = $\frac{HHPCTHHof\ each\ household\ group}{HHPCTHH\ of\ all\ househod\ group}$

(2) Current transfers to non-financial corporations, government, and foreigners

This study is based on the total household income to define these current transfers paid by households to these institutions. An assumption is made that high-income households pay more to charities than poor households.

+ Payment of income tax (HHPTG)

This is defined as the current weekly expenditure on income tax (EXP14)

P8 = $\frac{HHPTGof\ each\ household\ group}{HHPTG\ of\ all\ househod\ group}$

A2.2 Household payments in the financial account

+ Payment on bill of exchange (HHPBE)

There is no data related to bills of exchange provided by the Household Expenditure Survey, 2009-2010, so this study is based on total financial assets of each household group in ordet to disaggregate.

The financial assets of households include:

+ Value of shares-household level (VSHARCH)

+ Value of own incorporated business (net liabilities)-household level (VIBUSCH)

+ Value of own unincorporated business (net liabilities)-household level (VUBUSH)

+ Value of silent partnerships-household level (VSIPCH)

+ Value of private trust-household level (VPRTCH)

+ Value of debentures and bonds-household level (VDEBCH)

+ Value of loans to persons not in the same household-household level (VPLNCH)

+ Value of other financial investments-household level (VINVOTCH)

+ Value of public unit trusts-household level (VPUTCH)

+ Value of children's assets (VCHASSCH)

P9 = $\frac{HHPBEof\ each\ household\ group}{HHPBE\ of\ all\ househod\ group}$

+ Payment on loans and placements (HHPLP)

Payments on loans and placements are defined as the sum of of weekly mortgage repayments to purchase/build (TRPAY1CH), weekly mortgage repayments for alterations/additions (TRPAY2CH), weekly mortgage repayments other purposes (TRPA3ACH) and weekly repayments on unsecured loans for housing purposes (TRPAY4CH).

P10 = $\frac{HHPLPof\ each\ household\ group}{HHPLP\ of\ all\ househod\ group}$

+ Payment on other account

This study based on the total financial assets of each household to disaggregated the ratio for each household as the same in household payments in bills of exchange.

A2.3 Household payments in the capital account

These payments include the expenditure on fixed assets and the payments in capital transfers to other institutions.

+ Household expenditure on fixed assets

This expenditure is defined as the total goods and services expenditure (EXPTL)

P11 = $\frac{HHPCF\ of\ each\ household\ group}{HHPCF\ of\ all\ househod\ group}$

+ Capital transfers payments (HHPCT)

The capital transfers that households give to non-financial corporation and government are defined as the transfer of ownership of an assets of households to private institutions or government. This asset is a non-financial asset. It is assumed that the more assets households have the more donation they make. So, the thesis is based on the total value of non-financial assets to calculate the ratio of each household group.

The value of non-financial assets of household includes:

+ Value of non-residential property (VNRPRCH)

+ Value of content of selected dwelling (VCONTCH)

+ Value of residential property (excluding selected dwelling) (VRPRCH)

+ Value of own unincorporated business (net liabilities) (VUBUSCH)

+ Value of assets n.e.c (VOTASSCH)

+ Value of vehicle (VVEHICH)

P12 = $\frac{HHPCT\ of\ each\ household\ group}{HHPCT\ of\ all\ househod\ group}$

Appendix B: Carbon emissions data

Emissions collected from the National Greenhouse Gas Inventory are categorized into 5 sources such as energy combustion; fugitive; industrial process; agriculture; waste; and land use, land-used change and forestry. These emissions are linked to the IO tables to define the emissions generated by industries with assumption that combustion emissions are modelled as being directly proportional to fuel usage and non-combustion emissions (activity related) emissions are generally modelled as directly proportional to the output of the related industries.

Appendix B.1

Table B.1: Emissions from fuel combustion

I-O table code	Category	Gas	Gg(1000 tonnes)
	1. Energy (Fuel combustion)		**382,064.18**
	1.1. Energy industries		237,011.04
2601	1.1.1. Public electricity and heat production	All fuel	209,913.97
1701	1.1.2. Petroleum Refining	All fuel	5,169.90
1701	1.1.3. Manufacture of Solid fuel	All fuel	1,136.24
	1.1.4. Other energy industries	All fuel	20,790.93
0601	Coal mining	All fuel	4,429.64
2701	Gas Production and Distribution	All fuel	137.39
2701	Oil & Gas extraction	All fuel	15,289.32
0701 (b4)	Natural gas	All fuel	934.58
	1.2. Manufacturing Industries and Construction	All fuel	39,318.92
2101+2201	1.2.1. Iron & Steel	All fuel	3,434.56
2101	1.2.2. Non-Ferrous Metal	All fuel	12,803.63
	1.2.3. Chemicals	All fuel	5,231.57
1701	1.2.3.1. Petroleum and coal product manufacturing	All fuel	468.96
1803	1.2.3.2. Basic Chemical Manufacturing	All fuel	4,762.59
1501+1502+1601	1.2.4. Pulp, Paper, and Print	All fuel	1,678.12
1101 to 1205	1.2.5. Food Processing, Beverages and Tobacco	All fuel	3,085.64
	1.2.6. Others	All fuel	13,085.40
0801+0802+0901	1.2.6.1. Mining (Non- Energy)	All fuel	4,099.09
	1.2.6.2. Non Metallic Mineral Products	All fuel	6,221.69
2003+2004	Cement, Lime, Plaster and Concrete Manufacturing	All fuel	4,219.60
2002+2001	Ceramic Manufacturing	All fuel	1,150.42
2001	Glass and glass product manufacturing	All fuel	565.86

I-O table code	Category	Gas	Gg(1000 tonnes)
2005	Non-Metallic Mineral product manufacturing(n.e.c)	All fuel	285.83
	1.2.6.3. All other manufacturing	All fuel	1,008.53
2301 to 2405	Machinery & Equipment	All fuel	381.19
1401+1402+1801 +1802+ 1804+1901+1902	Other Manufacturing	All fuel	82.42
2202+2203+2204	Other Metal Manufacturing	All fuel	139.48
1301 t0 1306	Textile, Clothing, Footwear and Leather Manufacturing	All fuel	405.45
3001+3002+3101	1.2.6.4. Construction	All fuel	1,756.09
	1.3. Transport	All fuel	84,638.76
4901	1.3.1. Civil Aviation	All fuel	6,002.75
4601	1.3.2. Road transportation	All fuel	72,923.28
4701	1.3.3. Railway transport	All fuel	2,385.86
4801	1.3.4. Navigation	All fuel	3,283.73
4801	1.3.5. Other transport	All fuel	43.15
	1.4. Other sectors	All fuel	19,674.07
1001, 2605 to 2901, 3201 to 4501, 5101 to 9502.	1.4.1. Commercial & Institutional	All fuel	4,537.75
Households	1.4.2. Residential	All fuel	9,219.52
0101 to 0501	1.4.3. Agriculture, Forestry and Fishing		5,916.80
	1.5. Other (not elsewhere classified)		1,421.39
1701	Lubricants and Greases	All fuel	479.88
7601	Military transport	All fuel	941.51

Appendix B.2

Table B.2: Fugitive emissions

I-O table code	Category	Gas	Gg(1000 tonnes)
	2. Fugitive emissions from fuels		**40211.89**
	2.1. Solid Fuel	CO2-e	28822.9
0601(a1+a2)	2.1.1. Coal Mining	CO2-e	27164.14
0601(a1+a2)	2.1.2. Other	CO2-e	1658.76
	2.2. Oil & Natural gas	CO2-e	11388.99
0701(b1+b2)	2.2.1. Oil	CO2-e	377.65
0701(b3+b4+b5)	2.2.2. Natural gas	CO2-e	3801.21
0701(b3+b4+b5)	Production Process	CO2-e	67.64
2701	Distribution	CO2-e	3014.9
0701(b3+b4+b5)	Transmission	CO2-e	237.94
0701(b3+b4+b5)	Exploration	CO2-e	480.73
	2.2.3. Venting and Flaring	CO2-e	7210.13
	Venting	CO2-e	4254.68
0701(b3+b4+b5)	Gas	CO2-e	4254.68
	Flaring	CO2-e	2955.45
0701(b3+b4+b5)	Gas	CO2-e	1728.26
0701(b1+b2)	Oil	CO2-e	1227.18

Appendix B.3

Table B.3: Emissions from industrial processes

I-O table code	Category	Gas	Gg(1000 tonnes)
	3. Industrial Processes		**22749.35**
2003	**3.1. Mineral Products**	CO2-e	6535.57
1803	**3.2. Chemical Industry**	CO2-e	6313.71
	3.3. Metal Products	CO2-e	9738.67
2101+2201	Iron and steel production	CO2-e	6294.53
2202	Aluminium production	CO2-e	3444.14
	3.4. Other Production	CO2-e	161.4
1101 to 1205	Food and Drink	CO2-e	161.4

Appendix B.4

Table B.4: Emissions from agriculture

I-O table code	Category	Gas	Gg(1000 tonnes
	4. Agriculture		**83860.11**
	4.1. Enteric Fermentation	CO2-e	54592.74
101	Cattle	CO2-e	43816.68
102	Other livestock	CO2-e	36.34
102	Buffalo	CO2-e	7.04
101	Sheep	CO2-e	10496.83
101	Goat	CO2-e	65.23
102	Camels & Llamas	CO2-e	2.01
102	Horse	CO2-e	97.65
102	Mules & Asses	CO2-e	0.12
102	Swine	CO2-e	70.84
	4.2. Manure Management		3293.4
101	Cattle	CO2-e	1541.09
102	Other livestock	CO2-e	0.01
102	Buffalo	CO2-e	0.01
101	Sheep	CO2-e	2.78
101	Goat	CO2-e	0.03
102	Horse	CO2-e	0.15
102	Swine	CO2-e	1154.11
102	Poultry	CO2-e	595.22
	4.3. Rice Cultivation	CO2-e	46.28
101	Irrigated	CO2-e	46.28
	4.4. Agricultural soils		14271.6
	4.4.1. Direct soil emissions	CO2-e	4875.86
103	Synthetic Fertilisers	CO2-e	2698.65
	Animal waste applied to soils		661.29
101	Cattle	CO2-e	401.03
102	Poultry	CO2-e	169.62
102	Swine	CO2-e	90.64
103	Nitrogen Fixing Crops	CO2-e	611.31
103	Crop Residue	CO2-e	845.96
103	Cultivation of Histosols	CO2-e	15.59
103	Sewage sludge applied to	CO2-e	43.05
	4.4.2. Animal production		3631.74
	Nitrogen Excretion on Pasture	CO2-e	3631.74

I-O table code	Category	Gas	Gg(1000 tonnes
	Urine		2426.47
102	Buffalo	CO2-e	0.33
102	Camels & Llamas	CO2-e	0.11
101	Cattle	CO2-e	1662.65
101	Goats	CO2-e	6.02
102	Horse	CO2-e	14.12
102	Mules & Asses	CO2-e	0.01
101	Sheep	CO2-e	741.04
102	Other	CO2-e	2.19
	Faeces		1205.28
102	Buffalo		0.17
102	Camels & Llamas		0.06
101	Cattle		876.34
101	Goats		3.07
102	Horses		7.21
102	Mules & Asses		0.01
101	Sheep		312.64
102	Poultry		4.66
102	Other		1.12
	4.4.3. Indirect		5764
	Atmospheric Deposition		3351.47
103	Fertiliser		433
	Manure		2042.03
102	Buffalo		0.23
102	Camels & Llamas		0.08
101	Cattle		1355.94
101	Goats		4.24
102	Horses		9.94
102	Mules & Asses		0.01
102	Other		1.54
102	Poultry		127.82
101	Sheep		495.57
102	Swine		46.65
103	Other		876.44
	Nitrogen Leaching and Run-off		2412.53
103	Fertiliser		744.35
	Manure		1650.24
102	Buffalo		0.3

I-O table code	Category	Gas	Gg(1000 tonnes
102	Camels & Llamas		0.1
101	Cattle		1154
101	Goats		3
102	Horses		6.99
102	Mules & Asses		0
102	Other		1.57
102	Poultry		30.9
101	Sheep		439.1
102	Swine		14.27
	Other		17.94
103	Sewage sludge applied to		17.94
	4.5. Prescribe Burning of Savanas		11342.1
103	Savanas Grassland		572.15
103	Savanas Woodland		10720.95
103	Temperate Grassland		49
	4.6. Field Burning of Agricultural Residues		313.99
101	Cereals		238.22
103	Pulse		30.11
103	Sugar cane		39.76
103	Other crops		5.91

Appendix B.5

Table B.5: Emissions from waste

I-O table code	Category	Gas	Gg(1000 tonnes)
	5. Waste		13277.67
2901	**5.1. Solid waste disposal on land**	Net	10296.08
2801	**5.2. Wastewater handling**	Net	2880.43
	Industrial wastewater	Net	1196.88
	Domestic & Commercial Wastewater	Net	1683.54
2901	**5.3. Waste Incineration**	Net	29.91
	Plastics and other non-biogenic waste	Net	29.91
2901	**5.4. Other**	Net	71.25
	Biological treatment of solid waste	Net	71.25

Appendix C: Tablo code excerpts

There are 45 industries corresponding to 45 commodities named as IND and COM in the SET statement. Subsets of commodities are named as GCOM, COAL, OILG, PETR, and ELEC. The commodities are obtained from two sources, domestic and import named as SRC. There are some margin commodities known as MAR statement and MAR is subset of COM. Labour category named as OCC is disaggregated into 9 domestic occupational group named as OCCD and one foreigner group. OCCD is subset of OCC. There are 20 household groups in the set HOU.

Exerpt 5.1 Files, Sets and Subsets in the model

```
File
BASEDATA# Input data file #;
SUMMARY  # Output for summary and checking data #;
Set
 COM # Commodities# read elements from file BASEDATA header "COM";! c !
 SRC # Source of commodities # (dom,imp);                    ! s !
 IND # Industries # read elements from file BASEDATA header "IND";! i !
 OCC # Occupations # read elements from file BASEDATA header "OCC";! o !
 MAR # Margin commodities # read elements from file BASEDATA header "MAR";! m !
NONMAR   # Non-margin commodities # = COM - MAR;
HOU # Households # read elements from file BASEDATA header "HOU";
Set
GCOM # non energy commodities # read elements from file BASEDATA header "GCOM";
COAL # black and brown coal # read elements from file BASEDATA header "COAL";
OILG # oil and gas commodities# read elements from file BASEDATA header "OILG";
PETR # petroleum commodities# read elements from file BASEDATA header "PETR";
ELEC # electricity commodities# read elements from file BASEDATA header "ELEC";
ELCG # electricity generation# read elements from file BASEDATA header "ELCG";
GNCOM # non-electricity generation commodities# = GCOM-ELCG
Subset
MAR is subset of COM;
GCOM is subset of COM;
COAL is subset of COM;
OILG is subset of COM;
PETR is subset of COM;
ELEC is subset of COM;
ELCG is subset of GCOM;
```

Coefficients and Variables

The coefficients appear in upper-case characters while variables appear in lower-case characters

Except 5.2 Data coefficients and variables relating to basic commodity flows

Coefficient*! Basic flows of commodities (excluding margin demands)!*
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND) V1BAS(c,s,i)*# Intermediate basic flows #*;
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND) V2BAS(c,s,i) *# Investment basic flows #*;
(**all**,c,COM)(**all**,s,SRC) V3BAS(c,s) *# Household basic flows #*;
(**all**,c,COM)(**all**,s,SRC)(**all**, h, HOU) V3BAH(c,s,h) *# Household basic flows#*;
(**all**,c,COM) V4BAS(c) *# Export basic flows #*;
(**all**,c,COM)(**all**,s,SRC) V5BAS(c,s) *# Government basic flows #*;
(**all**,c,COM)(**all**,s,SRC) V6BAS(c,s) *# Inventories basic flows #*;
Read
V1BAS **from file** BASEDATA **header** *"1BAS"*;
V2BAS **from file** BASEDATA **header** *"2BAS"*;
V3BAH **from file** BASEDATA **header** *"3BAH"*;
V4BAS **from file** BASEDATA **header** *"4BAS"*;
V5BAS **from file** BASEDATA **header** *"5BAS"*;
V6BAS **from file** BASEDATA **header** *"6BAS"*;
Variable *!Variables used to update above flows!*
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND) x1(c,s,i) *# Intermediate basic demands #*;
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND)x2(c,s,i) *# Investment basic demands #*;
(**all**,c,COM)(**all**,s,SRC) x3(c,s) *# Household basic demands #*;
(**all**,c,COM)(**all**,s,SRC)(**all**, h,HOU) x3h(c,s,h) *# Household basic flows#*;
(**all**,c,COM)(**all**,s,SRC)(**all**, h,HOU) a3h(c,s,h) *# Household taste by group#*;
(**all**,c,COM) x4(c) *# Export basic demands #*;
(**all**,c,COM)(**all**,s,SRC) x5(c,s) *# Government basic demands #*;
(**change**) (**all**,c,COM)(**all**,s,SRC) delx6(c,s) *# Inventories demands #*;
(**all**,c,COM)(**all**,s,SRC) p0(c,s) *# Basic prices for local users #*;
(**all**,c,COM) pe(c) *# Basic price of exportables #*;
(**change**)(**all**,c,COM)(**all**,s,SRC) delV6(c,s) *# Value of inventories #*;
Update
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND) V1BAS(c,s,i) = p0(c,s)*x1(c,s,i);
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND) V2BAS(c,s,i) = p0(c,s)*x2(c,s,i);
(**all**,c,COM)(**all**,s,SRC)(**all**, h,HOU) V3BAH(c,s,h) = p0(c,s)*x3h(c,s,h);
(**all**,c,COM) V4BAS(c) = pe(c)*x4(c);
(**all**,c,COM)(**all**,s,SRC) V5BAS(c,s) = p0(c,s)*x5(c,s);
(**change**)(**all**,c,COM)(**all**,s,SRC) V6BAS(c,s) = delV6(c,s);
Formula
(**all**,c,COM)(**all**,s,SRC) V3BAS(c,s)=**sum**(h,HOU,V3BAH(c,s,h));

Excerpt 5.3 Data coefficients and variables relating to margin flows

```
Coefficient
(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR) V1MAR(c,s,i,m)#Intermediate margins #;
(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR) V2MAR(c,s,i,m)  # Investment margins #;
(all,c,COM)(all,s,SRC)(all,m,MAR) V3MAR(c,s,m) # Households margins#;
(all,c,COM)(all,s,SRC)(all,h,HOU)(all,m,MAR) V3MAH(c,s,h,m) # Households  margins #;
(all,c,COM)(all,m,MAR)        V4MAR(c,m)      # Export margins #;
(all,c,COM)(all,s,SRC)(all,m,MAR) V5MAR(c,s,m)    # Government margins #;
Read
 V1MAR from file BASEDATA header "1MAR";
 V2MAR from file BASEDATA header "2MAR";
 V3MAH from file BASEDATA header "3MAH";
 V4MAR from file BASEDATA header "4MAR";
 V5MAR from file BASEDATA header "5MAR";
Formula
 (all,c,COM)(all,s,SRC)(all,m,MAR)V3MAR(c,s,m)=sum(h,HOU,V3MAH(c,s,h,m));
 Variable !Variables used to update above flows!
 (all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR) x1mar(c,s,i,m) # Intermediate margin demand
#;
 (all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR) x2mar(c,s,i,m)# Investment margin demands #;
(all,c,COM)(all,s,SRC)(all,h,HOU)(all,m,MAR)x3mah(c,s,h,m)#Householdsmargins#;
(all,c,COM)(all,m,MAR)       x4mar(c,m)    # Export margin demands #;
(all,c,COM)(all,s,SRC)(all,m,MAR) x5mar(c,s,m)# Government margin demands #;
 (all,c,COM)      p0dom(c) # Basic price of domestic goods = p0(c,"dom") #;
Update
(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
              V1MAR(c,s,i,m)  = p0dom(m)*x1mar(c,s,i,m);
(all,c,COM)(all,s,SRC)(all,i,IND)(all,m,MAR)
              V2MAR(c,s,i,m)  = p0dom(m)*x2mar(c,s,i,m);
(all,c,COM)(all,s,SRC)(all,h,HOU)(all,m,MAR)
              V3MAH(c,s,h,m) = p0dom(m)*x3mah(c,s,h,m);
(all,c,COM)(all,m,MAR)   V4MAR(c,m) = p0dom(m)*x4mar(c,m);
 (all,c,COM)(all,s,SRC)(all,m,MAR) V5MAR(c,s,m) = p0dom(m)*x5mar(c,s,m);
```

Excerpt 5.4 Data coefficients and variables relating to commodity taxes

```
Coefficient ! Taxes on Basic Flows!
 (all,c,COM)(all,s,SRC)(all,i,IND) V1TAX(c,s,i) # Taxes on intermediate #;
 (all,c,COM)(all,s,SRC)(all,i,IND)  V2TAX(c,s,i) # Taxes on investment #;
 (all,c,COM)(all,s,SRC)            V3TAX(c,s)   # Taxes on households #;
 (all,c,COM)(all,s,SRC)(all,h,HOU)  V3TAH(c,s,h) #  households tax #;
 (all,c,COM)                    V4TAX(c)     # Taxes on export #;
 (all,c,COM)(all,s,SRC)            V5TAX(c,s)   # Taxes on government #;
Read
 V1TAX from file BASEDATA header "1TAX";
 V2TAX from file BASEDATA header "2TAX";
 V3TAH from file BASEDATA header "3TAH";
 V4TAX from file BASEDATA header "4TAX";
 V5TAX from file BASEDATA header "5TAX";
Formula
 (all,c,COM)(all,s,SRC)V3TAX(c,s)=sum(h,HOU,V3TAH(c,s,h));
Variable
 (change)(all,c,COM)(all,s,SRC)(all,i,IND)  delV1TAX(c,s,i) # Interm tax revenue #;
 (change)(all,c,COM)(all,s,SRC)(all,i,IND) delV2TAX(c,s,i) # Invest tax revenue #;
 (change)(all,c,COM)(all,s,SRC)(all,h,HOU) delV3TAH(c,s,h)   # H'hold tax revenue #;
 (change)(all,c,COM)         delV4TAX(c)     # Export tax revenue #;
 (change)(all,c,COM)(all,s,SRC)    delV5TAX(c,s)   # Govmnt tax revenue #;
Update
 (change)(all,c,COM)(all,s,SRC)(all,i,IND)  V1TAX(c,s,i) = delV1TAX(c,s,i);
 (change)(all,c,COM)(all,s,SRC)(all,i,IND)  V2TAX(c,s,i) = delV2TAX(c,s,i);
 (change)(all,c,COM)(all,s,SRC)(all,h,HOU)  V3TAH(c,s,h) = delV3TAH(c,s,h);
 (change)(all,c,COM)                     V4TAX(c)     = delV4TAX(c);
 (change)(all,c,COM)(all,s,SRC)            V5TAX(c,s)   = delV5TAX(c,s);
```

Excerpt 5.5 Data coefficients for primary factor flows, other industry costs and tariffs

```
Coefficient
 (all,i,IND)(all,o,OCC)  V1LAB(i,o)  # Wage bill matrix #;
 (all,i,IND)             V1CAP(i)    # Capital rentals #;
 (all,i,IND)             V1LND(i)    # Land rentals #;
 (all,i,IND)             V1PTX(i)    # Production tax #;
 (all,i,IND)             V1OCT(i)    # Other cost tickets #;
Read
 V1LAB from file BASEDATA header "1LAB";
 V1CAP from file BASEDATA header "1CAP";
 V1LND from file BASEDATA header "1LND";
 V1PTX from file BASEDATA header "1PTX";
 V1OCT from file BASEDATA header "1OCT";
Variable
 (all,i,IND)(all,o,OCC)  x1lab(i,o)  # Employment by industry and occupation #;
 (all,i,IND)(all,o,OCC) p1lab(i,o)  # Wages by industry and occupation #;
 (all,i,IND)  x1cap(i)       # Current capital stock #;
 (all,i,IND)  p1cap(i)       # Rental price of capital #;
 (all,i,IND)  x1lnd(i)       # Use of land #;
 (all,i,IND)  p1lnd(i)       # Rental price of land #;
 (change)(all,i,IND) delV1PTX(i) # Ordinary change in production tax revenue #;
 (all,i,IND)  x1oct(i)       # Demand for "other cost" tickets #;
 (all,i,IND)  p1oct(i)       # Price of "other cost" tickets #;
Update
 (all,i,IND)(all,o,OCC)  V1LAB(i,o)  = p1lab(i,o)*x1lab(i,o);
 (all,i,IND)             V1CAP(i)    = p1cap(i)*x1cap(i);
 (all,i,IND)             V1LND(i)    = p1lnd(i)*x1lnd(i);
(change)(all,i,IND)      V1PTX(i)    = delV1PTX(i);
 (all,i,IND)             V1OCT(i)    = p1oct(i)*x1oct(i);
! Data coefficients relating to import duties!
Coefficient (all,c,COM) V0TAR(c)  # Tariff revenue #;
Read V0TAR from file BASEDATA header "0TAR";
Variable (all,c,COM) (change) delV0TAR(c) # Ordinary change in tariff revenue #;
Update (change)  (all,c,COM) V0TAR(c) = delV0TAR(c);
```

Excerpt 5.6 Import/domestic composition of intermediate demands

```
Variable
 (all,c,COM)(all,s,SRC)(all,i,IND) a1(c,s,i) # Intermediate basic tech change #;
 (all,c,COM)(all,i,IND) x1_s(c,i) # Intermediate use of imp/dom composite#;
 (all,c,COM)(all,i,IND) p1_s(c,i) # Price, intermediate imp/dom composite#;
 (all,i,IND)          p1mat(i)   # Intermediate cost price index #;
 (all,i,IND)           p1var(i)  # Short-run variable cost price index #;
Coefficient
 (parameter)(all,c,COM) SIGMA1(c) # Armington elasticities: intermediate #;
 (all,c,COM)(all,i,IND) V1PUR_S(c,i) # Dom+imp intermediate purch. value #;
 (all,c,COM)(all,s,SRC)(all,i,IND) S1(c,s,i) # Intermediate source shares#;
 (all,i,IND)           V1MAT(i # Total intermediate cost for industry i #;
 (all,i,IND)       V1VAR(i) # Short-run variable cost for industry i #;
Read SIGMA1 from file BASEDATA header "1ARM";
Zerodivide default 0.5;
Formula
 (all,c,COM)(all,i,IND)    V1PUR_S(c,i) = sum{s,SRC, V1PUR(c,s,i)};
 (all,c,COM)(all,s,SRC)(all,i,IND) S1(c,s,i) = V1PUR(c,s,i) / V1PUR_S(c,i);
 (all,i,IND)                 V1MAT(i)     = sum{c,COM, V1PUR_S(c,i)};
 (all,i,IND)                 V1VAR(i)     = V1MAT(i) + V1LAB_O(i);
Zerodivide off;
Equation E_x1  # Source-specific commodity demands #
 (all,c,COM)(all,s,SRC)(all,i,IND)
  x1(c,s,i)-a1(c,s,i) = x1_s(c,i) -SIGMA1(c)*[p1(c,s,i) +a1(c,s,i) -p1_s(c,i)];
Equation E_p1_s  # Effective price of commodity composite #
 (all,c,COM)(all,i,IND)
  p1_s(c,i) = sum{s,SRC, S1(c,s,i)*[p1(c,s,i) + a1(c,s,i)]};
Equation E_p1mat  # Intermediate cost price index #
 (all,i,IND)
          p1mat(i) = sum{c,COM, sum{s,SRC,(V1PUR(c,s,i)/ID01[V1MAT(i)])*p1(c,s,i)}};
Equation E_p1var  # Short-run variable cost price index #
 (all,i,IND) p1var(i) = [1/V1VAR(i)]*[V1MAT(i)*p1mat(i) + V1LAB_O(i)*p1lab_o(i)];
```

Excerpt 5.7 Industry demand for electricity generation

```
Coefficient
(parameter)(all,i,IND) SIGMA1elcg(i) # CES substitution, electricity generation #;
Read SIGMA1elcg from file BASEDATA header "SELC";
Coefficient (all,i,IND) V1ELCG(i) #Total electr-generation input to industry I #;
Formula     (all,i,IND) V1ELCG(i) = sum{c,ELCG, V1PUR_S(c,i)};
Variable
 (all,i,IND)  p1elcg(i)       # electricity generation price #;
 (all,i,IND)  x1elcg(i)       # electricity generation quantity #;
 (all,i,IND)  a1elcg(i)       # electricity generation tech-efficiency#;
 (all,c,COM)(all,i,IND) a1_s(c,i) # Tech change, int'mdiate imp/dom composite #;
Equation
E_x1_sE (all,c,ELCG)(all,i,IND)
x1_s(c,i)=x1elcg(i)-SIGMA1elcg(i)*[p1_s(c,i)+a1_s(c,i)-p1elcg(i)];
E_p1elcg
(all,i,IND)[TINY+V1ELCG(i)]*p1elcg(i)=sum{c,ELCG, V1PUR_S(c,i)*p1_s(c,i)};
```

Excerpt 5.8 Industry demand for coal

```
Coefficient
 (parameter)(all,i,IND) SIGMA1COL(i) # CES substitution between black and brown #;
 (all,i,IND) V1COL(i) # Total coal usage in industry i #;
Read SIGMA1COL from file BASEDATA header "SCOL";
Formula
 (all,i,IND) V1COL(i) = sum{c,COAL, V1PUR_S(c,i)};
Variable
 (all,c,COAL)(all,i,IND) x1_col(c,i)  # Intermediate use of imp/dom composite #;
 (all,i,IND) p1col(i) # Price of coal composite in each industry #;
 (all,i,IND) x1col(i) # coal composite inputs in each industry  #;
Equation
  E_x1_sA   # Demand for composite coal #
  (all,c,COAL)(all,i,IND) x1_s(c,i) = x1_col(c,i);
  E_x1_col   # Demand for black and brown coal #
  (all,c,COAL)(all,i,IND)
   x1_col(c,i) = x1col(i) - SIGMA1COL(i)*[p1_s(c,i) - p1col(i)];
 E_p1col # Price of coal composite #
  (all,i,IND) [TINY+V1COL(i)]*p1col(i) = sum{c,COAL, V1PUR_S(c,i)*p1_s(c,i)};
```

Excerpt 5.9 Industry demand for oil and gas

```
Coefficient
 (parameter)(all,i,IND) SIGMA1OIG(i) # CES substitution between oil and gas #;
 (all,i,IND) V1OIG(i)   # Total oil-gas usage in industry i #;
Read SIGMA1OIG from file BASEDATA header "SOIG";
Formula
 (all,i,IND) V1OIG(i) = sum{c,OILG, V1PUR_S(c,i)};
Variable
 (all,c,OILG)(all,i,IND) x1_oig(c,i)  # Intermediate use of imp/dom composite #;
 (all,i,IND) p1oig(i) # Price of oil-gas composite in each industry#;
 (all,i,IND) x1oig(i) # oil-gas composite inputs in each industry #;
Equation
  E_x1_sB   # Demand for oil and gas commodities #
  (all,c,OILG)(all,i,IND) x1_s(c,i) = x1_oig(c,i);
  E_x1_oig   # Demand for oil and gas #
  (all,c,OILG)(all,i,IND)
   x1_oig(c,i) = x1oig(i) - SIGMA1OIG(i)*[p1_s(c,i) - p1oig(i)];
 E_p1oig # Price of oil-gas composite #
  (all,i,IND) [TINY+V1OIG(i)]*p1oig(i) = sum{c,OILG, V1PUR_S(c,i)*p1_s(c,i)};
```

Excerpt 5.10 Industry demand for petroleum

```
Coefficient
 (parameter)(all,i,IND) SIGMA1PTR(i) # CES substitution between petroes #;
 (all,i,IND) V1PTR(i)   # Total petro usage in industry i #;
Read SIGMA1PTR from file BASEDATA header "SPTR";
Formula
 (all,i,IND) V1PTR(i) = sum{c,PETR, V1PUR_S(c,i)};
Variable
 (all,c,PETR)(all,i,IND) x1_ptr(c,i)  # Intermediate use of imp/dom composite #;
 (all,i,IND) p1ptr(i) # Price of petro composite in each industry #;
 (all,i,IND) x1ptr(i) # Petro composite inputs in each industry  #;
Equation
  E_x1_sC   # Demand for composite petroleum commodity#
  (all,c,PETR)(all,i,IND) x1_s(c,i) = x1_ptr(c,i);
  E_x1_ptr   # Demand for composite petroleum #
  (all,c,PETR)(all,i,IND)
   x1_ptr(c,i) = x1ptr(i) - SIGMA1PTR(i)*[p1_s(c,i) - p1ptr(i)];
 E_p1ptr # Price of petro composite #
  (all,i,IND) [TINY+V1PTR(i)]*p1ptr(i) = sum{c,PETR, V1PUR_S(c,i)*p1_s(c,i)};
```

Excerpt 5.11 Industry demand for composite energy

```
Coefficient
(parameter)(all,i,IND) SIGMA1ENG(i) # CES substitution between composite energy #;
Read SIGMA1ENG from file BASEDATA header "SENG";
Coefficient
 (all,i,IND) V1ELE(i) # Total electricity input to industry i #;
 (all,i,IND) V1ENG(i) # Total energy input to industry i #;
Formula
 (all,i,IND) V1ELE(i) = sum{c,ELEC, V1PUR_S(c,i)};
 (all,i,IND) V1ENG(i) = V1COL(i)+ V1OIG(i) + V1PTR(i) + V1ELE(i);
Variable
 (all,i,IND) p1eng(i)  # Effective price of energy composite #;
 (all,i,IND) x1eng(i)  # Energy composite #;
 (all,i,IND) p1ele(i)  # Price of comercial electricity #;
 (all,i,IND) x1ele(i)  # Commercial electricity usage by industry #;
 (all,c,ELEC)(all,i,IND) x1_ele(c,i)  # Intermediate use of imp/dom composite #;
 (all,i,IND) a1col(i) # Coal-augmenting technical change #;
 (all,i,IND) a1oig(i) # Oil-gas-augmenting technical change #;
 (all,i,IND) a1ptr(i) # Petrol-augmenting technical change #;
 (all,i,IND) a1ele(i) # Electricity-augmenting technical change #;
Equation
 E_x1_sD   # Demand for composite electriciy commodities #
  (all,c,ELEC)(all,i,IND) x1_s(c,i) = x1_ele(c,i);
E_x1_ele   # Demand for commercial electricity #
  (all,c,ELEC)(all,i,IND) x1_ele(c,i) = x1ele(i) - 0.5*[p1_s(c,i) - p1ele(i)];
 E_p1ele # Price of petroleum composite #
 (all,i,IND) [TINY+V1ELE(i)]*p1ele(i) = sum{c,ELEC,V1PUR_S(c,i)*p1_s(c,i)};
 E_x1col  # Industry demands for coal composite #
  (all,i,IND)  x1col(i) - a1col(i) =
   x1eng(i) - SIGMA1eng(i)*[p1col(i) + a1col(i) - p1eng(i)];
 E_x1oig  # Industry demands for oil-gas composite #
  (all,i,IND)  x1oig(i) - a1oig(i) =x1eng(i) - SIGMA1eng(i)*[p1oig(i) + a1oig(i) - p1eng(i)];
 E_x1ptr  # Industry demands for petroleum composite #
  (all,i,IND)  x1ptr(i) - a1ptr(i) =x1eng(i) - SIGMA1eng(i)*[p1ptr(i) + a1ptr(i) - p1eng(i)];
 E_x1ele  # Industry demands for commercial electricity #
  (all,i,IND)  x1ele(i) - a1ele(i) =x1eng(i) - SIGMA1eng(i)*[p1ele(i) + a1ele(i) - p1eng(i)];
 E_p1eng  # Effective price for energy #
  (all,i,IND)  V1ENG(i)*p1eng(i) = V1COL(i)*[p1col(i) + a1col(i)] + V1OIG(i)*[p1oig(i) +
a1oig(i)] + V1PTR(i)*[p1ptr(i) + a1ptr(i)] + V1ELE(i)*[p1ele(i) + a1ele(i)];
```

Excerpt 5.12 Industry demand for composite energy-capital

```
Coefficient
(parameter)(all,i,IND) SIGMA1ENC(i) # CES substitution between capital and energy #;
Read SIGMA1ENC from file BASEDATA header "SENC";
Coefficient
(all,i,IND) V1ENC(i) # Total cap-energy input to industry i #;
Formula
(all,i,IND) V1ENC(i) = V1ENG(i)+ V1CAP(i);
Variable
 (all,i,IND) p1enc(i) # Effective price of capital-energy composite#;
 (all,i,IND) x1enc(i)  # Capital-energy composite #;
 (all,i,IND) a1eng(i) # Energy-augmenting technical change #;
 (all,i,IND) a1cap(i) # Capital-augmenting technical change #;
Equation
 E_x1eng  # Industry demands for effective energy composite #
  (all,i,IND)  x1eng(i) - a1eng(i) = x1enc(i) - SIGMA1enc(i)*[p1eng(i) + a1eng(i) - p1enc(i)];
 E_p1cap  # Industry demands for capital #
  (all,i,IND)  x1cap(i) - a1cap(i) = x1enc(i) - SIGMA1enc(i)*[p1cap(i) + a1cap(i) - p1enc(i)];
 E_p1enc  # Effective price of cap-energy composite #
  (all,i,IND)  V1ENC(i)*p1enc(i) = V1ENG(i)*[p1eng(i) + a1eng(i)]
    + V1CAP(i)*[p1cap(i) + a1cap(i)];
```

Excerpt 5.13 Industry demand for labour

```
Coefficient
 (parameter)(all,i,IND) SIGMA1LAB(i) # CES substitution between occupational groups #;
 (all,i,IND) V1LAB_O(i)   # Total labour bill in industry i #;
  TINY    # Small number to prevent zerodivides or singular matrix #;
Read SIGMA1LAB from file BASEDATA header "SLAB";
Formula
 (all,i,IND) V1LAB_O(i) = sum{o,OCC, V1LAB(i,o)};
            TINY       = 0.000000000001;
Variable
 (all,i,IND) p1lab_o(i) # Price to each industry of labour composite #;
 (all,i,IND) x1lab_o(i) # Effective labour inputs #;
Equation
 E_x1lab   # Demand for labour by industry and skill group #
  (all,i,IND)(all,o,OCC)
   x1lab(i,o) = x1lab_o(i) - SIGMA1LAB(i)*[p1lab(i,o) - p1lab_o(i)];
 E_p1lab_o # Price to each industry of labour composite #
  (all,i,IND) [TINY+V1LAB_O(i)]*p1lab_o(i) = sum{o,OCC, V1LAB(i,o)*p1lab(i,o)};
```

Excerpt 5.14 Industry demand for primary factors

```
Coefficient
(parameter)(all,i,IND) SIGMA1PRIM(i) # CES substitution among primary factors #;
Read SIGMA1PRIM from file BASEDATA header "P028";
Coefficient
(all,i,IND) V1PRIM(i) # Total factor input to industry i #;
Formula
(all,i,IND) V1PRIM(i) = V1LAB_O(i)+ V1ENC(i) + V1LND(i);
Variable
 (all,i,IND) p1prim(i) # Effective price of primary factor composite #;
 (all,i,IND) x1prim(i)  # Primary factor composite #;
 (all,i,IND) a1lab_o(i) # Labor-augmenting technical change #;
 (all,i,IND) a1enc(i)   # Capital-augmenting technical change #;
 (all,i,IND) a1lnd(i)   # Land-augmenting technical change #;
(change)(all,i,IND) delV1PRIM(i)# Ordinary change in cost of primary factors #;
Equation
 E_x1lab_o  # Industry demands for effective labour #
  (all,i,IND)  x1lab_o(i) - a1lab_o(i) = x1prim(i) - SIGMA1PRIM(i)*[p1lab_o(i) + a1lab_o(i) -
p1prim(i)];
 E_x1enc  # Industry demands for capital #
  (all,i,IND)  x1enc(i) - a1enc(i) = x1prim(i) - SIGMA1PRIM(i)*[p1enc(i) + a1enc(i) -
p1prim(i)];
 E_p1lnd  # Industry demands for land #
  (all,i,IND)  x1lnd(i) - a1lnd(i) = x1prim(i) - SIGMA1PRIM(i)*[p1lnd(i) + a1lnd(i) -
p1prim(i)];
 E_p1prim  # Effective price term for factor demand equations #
  (all,i,IND)  V1PRIM(i)*p1prim(i) = V1LAB_O(i)*[p1lab_o(i) + a1lab_o(i)]
    + V1ENC(i)*[p1enc(i) + a1enc(i)] + V1LND(i)*[p1lnd(i) + a1lnd(i)];
 E_delV1PRIM  # Ordinary change in total cost of primary factors #
  (all,i,IND) 100*delV1PRIM(i) = V1ENC(i)  * [p1enc(i) + x1enc(i)]
                          +  V1LND(i)  * [p1lnd(i) + x1lnd(i)]
                  + sum{o,OCC, V1LAB(i,o)* [p1lab(i,o) + x1lab(i,o)]};
```

Excerpt 5.15 Top nest of industry input demands

```
Variable
 (all,i,IND)  x1tot(i) # Activity level or value-added #;
 (all,i,IND)  a1prim(i) # All factor augmenting technical change #;
 (all,i,IND)  a1tot(i) # All input augmenting technical change #;
 (all,i,IND)  p1tot(i) # Average input/output price #;
 (all,i,IND)  a1oct(i) # "Other cost" ticket augmenting techncal change #;
Equation E_x1_s  # Demands for commodity composites #
(all,c,GNCOM)(all,i,IND)  x1_s(c,i) - [a1_s(c,i) + a1tot(i)] = x1tot(i);
Equation E_x1elcg  # Demands for composite electricity generation #
 (all,i,IND)  x1elcg(i) - [a1elcg(i) + a1tot(i)] = x1tot(i);
Equation E_x1prim  # Demands for primary factor composite #
 (all,i,IND)  x1prim(i) - [a1prim(i) + a1tot(i)] = x1tot(i);
Equation E_x1oct  # Demands for other cost tickets #
 (all,i,IND)  x1oct(i) - [a1oct(i) + a1tot(i)] = x1tot(i);
```

Excerpt 5.16 Industry costs and production taxes

```
Coefficient
 (all,i,IND)  V1CST(i)    # Total cost of industry i #;
 (all,i,IND)  V1TOT(i)    # Total industry cost plus tax #;
 (all,i,IND) PTXRATE(i)   # Rate of production tax #;
 (all,i,IND) V1PTC (i)   #  carbon production tax #;
 (all,i,IND) PTCRATE(i)   # Rate of carbon production tax #;
Formula
 (all,i,IND) V1CST(i)= V1CAP(i)+V1LND(i)+sum{o,OCC, V1LAB(i,o)}+ V1OCT(i) +
V1MAT(i);
 (all,i,IND) V1TOT(i)= V1CST(i) +V1PTX(i)+sum{c,com,TX1CO(c,i)};
 (all,i,IND)  PTXRATE(i)  = V1PTX(i)/V1CST(i);
 (all,i,IND)  V1PTC(i)  = sum{c,com,TX1CO(c,i)};
 (all,i,IND)  PTCRATE(i)  = V1PTC(i)/V1CST(i);
Write PTXRATE to file SUMMARY header "PTXR";
Write PTCRATE to file SUMMARY header "PTCR";
Variable
 (change)(all,i,IND) delV1CST(i) # Change in excluded-tax cost of production #;
 (change)(all,i,IND) delV1TOT(i) # Change in tax-included cost of production #;
 (change)(all,i,IND) delPTXRATE(i) # Change in rate of production tax #;
 (change)(all,i,IND) delPTCRATE(i) # Change in rate of carbon production tax #;

Equation
 E_delV1CST  (all,i,IND) 100*delV1CST(i) = V1CAP(i)  * [p1cap(i) + x1cap(i)]
  +V1LND(i)*[p1lnd(i)+x1lnd(i)]+sum{o,OCC, V1LAB(i,o)*[p1lab(i,o) + x1lab(i,o)]}
  +sum{c,COM,sum{s,SRC,  V1PUR(c,s,i)*[p1(c,s,i) + x1(c,s,i)]}}
                 +  V1OCT(i)    *[p1oct(i)  + x1oct(i)];
 E_delV1TOT  (all,i,IND)
 delV1TOT(i) = delV1CST(i) + delV1PTX(i)+sum{c,com,delTX1CO(c,i)};
```

```
 E_p1tot     (all,i,IND) V1TOT(i)*[p1tot(i) + x1tot(i)] = 100*delV1TOT(i);

Variable (all,i,IND) p1cst(i) # Index of production costs (for AnalyseGE) #;
Equation E_p1cst  (all,i,IND) p1cst(i) =  [1/V1CST(i)]*[
  sum{c,COM,sum{s,SRC,  V1PUR(c,s,i)*p1(c,s,i)}}
                  +  V1OCT(i)    *p1oct(i)
                  +  V1CAP(i)    *p1cap(i)
                  +  V1LND(i)    *p1lnd(i)
         + sum{o,OCC, V1LAB(i,o)  *p1lab(i,o)}];
```

Excerpt 5.17 Output mix of commodities

```
Coefficient
(all,c,COM)(all,i,IND) MAKE(c,i) # Multiproduction matrix #;
Variable
 (all,c,COM)(all,i,IND) q1(c,i) # Output by commodity and industry #;
 (all,c,COM)(all,i,IND) pq1(c,i) # Price of com c produced by ind i#;
 (all,c,COM) p0com(c) #General output price of locally-produced commodity#;
Read MAKE from file BASEDATA header "MAKE";
Update
(all,c,COM)(all,i,IND) MAKE(c,i)= pq1(c,i)*q1(c,i);
Variable
 (all,c,COM) x0com(c) # Output of commodities #;
Coefficient
 (parameter)(all,i,IND) SIGMA1OUT(i) # CET transformation elasticities #;
Read SIGMA1OUT from file BASEDATA header "SCET";
Equation E_q1  # Supplies of commodities by industries #
 (all,c,COM)(all,i,IND)
  q1(c,i) = x1tot(i) + SIGMA1OUT(i)*[p0com(c) - p1tot(i)];
Coefficient
 (all,i,IND) MAKE_C(i) # All production by industry i #;
 (all,c,COM) MAKE_I(c) # Total production of commodities #;
Formula
 (all,i,IND) MAKE_C(i) = sum{c,COM, MAKE(c,i)};
 (all,c,COM) MAKE_I(c) = sum{i,IND, MAKE(c,i)};
Equation E_x1tot # Average price received by industries #
 (all,i,IND) p1tot(i) = sum{c,COM, [MAKE(c,i)/MAKE_C(i)]*pq1(c,i)};
Equation
 E_pq1  # Each industry gets the same price for a given commodity #
 (all,c,COM)(all,i,IND) pq1(c,i) = p0com(c);
 E_x0com # Total output of commodities (as simple addition) #
 (all,c,COM) x0com(c) = sum{i,IND, [MAKE(c,i)/MAKE_I(c)]*q1(c,i)};
```

Excerpt 5.18 Outputs for local and export markets

```
Variable
 (all,c,COM)  x0dom(c)  # Output of commodities for local market #;
Coefficient
 (all, c,COM) EXPSHR(c) # Share going to exports #;
 (all, c,COM) TAU(c) # 1/Elast. of transformation, exportable/locally used #;
Zerodivide default 0.5;
Formula
 (all,c,COM) EXPSHR(c) = V4BAS(c)/MAKE_I(c);
 (all,c,COM) TAU(c) = 0.0;
Zerodivide off;
Equation E_x0dom  # Supply of commodities to export market #
 (all,c,COM) TAU(c)*[x0dom(c) - x4(c)] = p0dom(c) - pe(c);
Equation E_pe # Supply of commodities to domestic market #
 (all,c,COM) x0com(c) = [1.0-EXPSHR(c)]*x0dom(c) + EXPSHR(c)*x4(c);
Equation E_p0com  # Zero pure profits in transformation #
 (all,c,COM) p0com(c) = [1.0-EXPSHR(c)]*p0dom(c) + EXPSHR(c)*pe(c);
```

Excerpt 5.19 Investment demands

```
Variable
 (all,c,COM)(all,i,IND) x2_s(c,i)  # Investment use of imp/dom composite #;
 (all,c,COM)(all,i,IND) p2_s(c,i)  # Price, investment imp/dom composite #;
 (all,c,COM)(all,s,SRC)(all,i,IND)a2(c,s,i) #Investment basic tech change#;
Coefficient
 (parameter) (all,c,COM)  SIGMA2(c) # Armington elasticities: investment #;
Read SIGMA2 from file BASEDATA header "2ARM";
Coefficient
 (all,c,COM)(all,i,IND) V2PUR_S(c,i) # Dom+imp investment purch. value #;
 (all,c,COM)(all,s,SRC)(all,i,IND) S2(c,s,i) # Investment source shares #;
Zerodivide default 0.5;
Formula
  (all,c,COM)(all,i,IND) V2PUR_S(c,i) = sum{s,SRC, V2PUR(c,s,i)};
  (all,c,COM)(all,s,SRC)(all,i,IND) S2(c,s,i) = V2PUR(c,s,i)/V2PUR_S(c,i);
Zerodivide off;
Equation E_x2  # Source-specific commodity demands #
(all,c,COM)(all,s,SRC)(all,i,IND)
x2(c,s,i)-a2(c,s,i)-x2_s(c,i) =-SIGMA2(c)*[p2(c,s,i)+a2(c,s,i)-p2_s(c,i)];
Equation E_p2_s  # Effective price of commodity composite #
(all,c,COM)(all,i,IND)
p2_s(c,i) = sum{s,SRC, S2(c,s,i)*[p2(c,s,i)+a2(c,s,i)]};
! Investment top nest !
Variable
 (all,i,IND)  a2tot(i)       # Neutral technical change - investment #;
 (all,i,IND)  p2tot(i)       # Cost of unit of capital #;
 (all,i,IND)  x2tot(i)       # Investment by using industry #;
```

```
 (all,c,COM)(all,i,IND) a2_s(c,i) # Tech change, investment imp/dom composite #;
Coefficient (all,i,IND) V2TOT(i)  # Total capital created for industry i #;
Formula     (all,i,IND) V2TOT(i)  = sum{c,COM, V2PUR_S(c,i)};
Equation
 E_x2_s
        (all,c,COM)(all,i,IND)  x2_s(c,i) - [a2_s(c,i) + a2tot(i)] = x2tot(i);
 E_p2tot
        (all,i,IND) p2tot(i)= sum{c,COM, (V2PUR_S(c,i)/ID01[V2TOT(i)])*[p2_s(c,i)
+a2_s(c,i) +a2tot(i)]};
```

Excerpt 5.20 Household demands

```
        ! Import/domestic composition of household demands !
Variable
(all,c,COM)(all,s,SRC) a3(c,s)   # Household basic taste change #;
(all,c,COM)            x3_s(c)   # Household use of imp/dom composite #;
(all,c,COM)(all,h,HOU) x3_sh(c,h) # Household use of imp/dom composite#;
(all,c,COM)            p3_s(c)   # Price, household imp/dom composite #;
Coefficient
 (parameter)(all,c,COM) SIGMA3(c) # Armington elasticities: households #;
Read SIGMA3 from file BASEDATA header "3ARM";
Coefficient
 (all,c,COM)     V3PUR_S(c) # Dom+imp households purch. value #;
 (all,c,COM)(all,s,SRC) S3(c,s) # Household source shares #;
Zerodivide default 0.5;
Formula
 (all,c,COM)  V3PUR_S(c) = sum{s,SRC, V3PUR(c,s)};
 (all,c,COM)(all,s,SRC) S3(c,s) = V3PUR(c,s)/V3PUR_S(c);
Zerodivide off;
Equation
E_x3  # Source-specific commodity demands #
(all,c,COM)(all,s,SRC)
x3(c,s)-a3(c,s) = x3_s(c) - SIGMA3(c)*[ p3(c,s)+a3(c,s) - p3_s(c) ];
E_x3h
(all,c,COM)(all,s,SRC)(all, h, HOU)
x3h(c,s,h)-a3h(c,s,h) = x3_sh(c,h)-SIGMA3(c)*[p3(c,s)+a3(c,s) -p3_s(c)];
Equation E_p3_s  # Effective price of commodity composite #
(all,c,COM) p3_s(c) = sum{s,SRC, S3(c,s)*[p3(c,s)+a3(c,s)]};

! Household demands for composite commodities !
Variable
 (all,h,HOU)        p3toth(h) # Consumer price index #;
 (all,h,HOU)        x3toth(h) # Real household consumption #;
 (all,h,HOU)        w3toth(h) # Nominal total household consumption #;
 (all,h,HOU)        w3luxh(h) # Nominal luxury consumption #;
 (all,h,HOU)        qh(h) # Number of households #;
 (all,h,HOU)         utilityh(h) # Utility per household #;
```

```
 (all,c,COM)(all,h,HOU) x3lux(c,h) # Household - supernumerary demands #;
 (all,c,COM)(all,h,HOU) x3sub(c,h) # Household - subsistence demands #;
 (all,c,COM)(all,h,HOU) a3lux(c,h) # Taste change, supernumerary demands #;
 (all,c,COM)(all,h,HOU) a3sub(c,h) # Taste change, subsistence demands #;
 (all,c,COM)(all,h,HOU)a3_s(c,h) # Taste change, hhold imp/dom composite #;
Coefficient
 (all,h,HOU)   V3TOTh(h) # Total purchases by households #;
               V3TOT # Total purchases by households #;
 (all,h,HOU)  FRISCH(h) # Frisch LES 'parameter'= - (total/luxury) #;
 (all,c,COM)(all,h,HOU) EPS(c,h) # Household expenditure elasticities #;
 (all,c,COM)(all,h,HOU)  S3_S(c,h) # Household average budget shares #;
 (all,c,COM)(all,h,HOU) B3LUX(c,h) # Ratio, (supernumerary /total expenditure)#;
 (all,c,COM)(all,h,HOU) S3LUX(c,h) # Marginal household budget shares #;
Read   FRISCH from file BASEDATA header "P21h";
       EPS from file BASEDATA header "XPLh";
Update
        (change)(all,h,HOU) FRISCH(h) = FRISCH(h)*[w3toth(h) - w3luxh(h)]/100.0;
(change)(all,c,COM)(all,h,HOU) EPS(c,h) = EPS(c,h)*[x3lux(c,h)-x3_sh(c,h)+w3toth(h) -
w3luxh(h)]/100.0;
Formula
(all,h,HOU) V3TOTh(h) = sum{c,COM, V3PUR_SH(c,h)};
      V3TOT = sum{h,HOU, V3TOTh(h)};
 (all,c,COM)(all,h,HOU)  S3_S(c,h) = V3PUR_SH(c,h)/V3TOTh(h);
 (all,c,COM)(all,h,HOU) B3LUX(c,h) = EPS(c,h)/ABS[FRISCH(h)];
 (all,c,COM)(all,h,HOU) S3LUX(c,h) = EPS(c,h)*S3_S(c,h);
Write  S3LUX   to file SUMMARY header "LSHR";
      S3_S    to file SUMMARY header "CSHR";
Equation
 E_x3sub # Subsistence demand for composite commodities #
  (all,c,COM)(all,h,HOU) x3sub(c,h) = qh(h) + a3sub(c,h);
 E_x3lux # Luxury demand for composite commodities #
  (all,c,COM)(all,h,HOU) x3lux(c,h) + p3_s(c) = w3luxh(h) + a3lux(c,h);
 E_x3_sh  # Total household demand for composite commodities #
  (all,c,COM)(all,h,HOU)
x3_sh(c,h) = B3LUX(c,h)*x3lux(c,h) + [1-B3LUX(c,h)]*x3sub(c,h);
 E_utilityh # Change in utility disregarding taste change terms #
 (all,h,HOU) utilityh(h) + qh(h) = sum{c,COM, S3LUX(c,h)*x3lux(c,h)};
 E_a3lux # Default setting for luxury taste shifter #
  (all,c,COM)(all,h,HOU)
a3lux(c,h) = a3sub(c,h) - sum{k,COM, S3LUX(k,h)*a3sub(k,h)};
 E_a3sub # Default setting for subsistence taste shifter #
  (all,c,COM)(all,h,HOU) a3sub(c,h) = a3_s(c,h) sum{k,COM,S3_S(k,h)*a3_s(k,h)};
 E_x3toth # Real consumption #
 (all,h,HOU) x3toth(h) = sum{c,COM, S3_S(c,h)*x3_sh(c,h)};
 E_p3toth # Consumer price index #
 (all,h,HOU) p3toth(h) = sum{c,COM, S3_S(c,h)*p3_s(c)};
 E_w3toth # Household budget constraint: determines w3lux #
```

```
  (all,h,HOU) w3toth(h) = x3toth(h) + p3toth(h);

Variable
p3tot # Consumer price index #;
x3tot # Real household consumption #;
w3tot # Nominal total household consumption #;
Equation
 E_x3tot # Real consumption #
x3tot = sum{c, COM,sum{s,SRC,sum{h,HOU,[V3PUH(c,s,h)/V3TOT]*x3h(c,s,h)}}};
 E_p3tot # Consumer price index #
p3tot = sum{c, COM,sum{s,SRC,sum{h,HOU,[V3PUH(c,s,h)/V3TOT]*p3(c,s)}}};
 E_w3tot # Household budget constraint: determines w3lux #
  w3tot = x3tot + p3tot;
 E_x3_s  # Total household demand for composite commodities #
 (all,c,COM) sum{h,HOU, ID01[V3PUR_SH(c,h)]*[x3_sh(c,h)- x3_s(c)]} = 0;

Coefficient
(all,h,HOU) EPSTOTH(h) # Average Engel elasticity: should = 1 #;
Formula     (all,h,HOU) EPSTOTH(h) = sum{c,COM, S3_S(c,h)*EPS(c,h)};
Assertion (initial) # Check ave EPS =1 # (all,h,HOU) ABS[1-EPSTOTH(h)]<0.01;
Assertion # Hou check #
(all,c,COM)(all,h,HOU)
ABS[sum{s,SRC,V3BAH(c,s,h)+V3TAH(c,s,h)+sum{m,MAR,V3MAH(c,s,h,m)}}
          +sum{s,SRC,TX3CC(c,s,h)}-V3PUR_SH(c,h)]<0.1;
```

Excerpt 5.21 Export, Government and Inventory demands

```
          ! Export demands !
Coefficient
 (Parameter)(all,c,COM) IsIndivExp(c) # >0.5 For individual export commodities#;
Read IsIndivExp from file BASEDATA header "ITEX";
Set
TRADEXP # Individual export commodities # = (all,c,COM: IsIndivExp(c)>0.5);
Write (Set) TRADEXP  to file SUMMARY header "TEXP";
Variable
  phi     # Exchange rate, local currency/$world #;
 (all,c,COM)  f4p(c)  # Price (upward) shift in export demand schedule #;
 (all,c,COM)  f4q(c)  # Quantity (right) shift in export demands #;
Coefficient
(parameter)(all,c,COM) EXP_ELAST(c) # Export demand elasticities: typical value -5.0 #;
Read EXP_ELAST from file BASEDATA header "P018";
Equation E_x4A  # Individual export demand functions #
(all,c,TRADEXP) x4(c) - f4q(c) = -ABS[EXP_ELAST(c)]*[p4(c) - phi - f4p(c)];
Set NTRADEXP # Collective Export Commodities # = COM - TRADEXP;
Write (Set) NTRADEXP  to file SUMMARY header "NTXP";
```

```
Variable
 x4_ntrad     # Quantity, collective export aggregate #;
 f4p_ntrad    # Upward demand shift, collective export aggregate #;
 f4q_ntrad    # Right demand shift, collective export aggregate #;
 p4_ntrad     # Price, collective export aggregate #;
Coefficient V4NTRADEXP # Total collective export earnings #;
Formula     V4NTRADEXP = sum{c,NTRADEXP, V4PUR(c)};
Equation
E_X4B  # Collective export demand functions #
 (all,c,NTRADEXP) x4(c) - f4q(c) = x4_ntrad;

Equation
E_p4_ntrad  # Average price of collective exports #
    [TINY+V4NTRADEXP]*p4_ntrad = sum{c,NTRADEXP, V4PUR(c)*p4(c)};
Coefficient
(parameter) EXP_ELAST_NT # Collective export demand elasticity #;
Read EXP_ELAST_NT from file BASEDATA header "EXNT";
Equation
E_x4_ntrad # Demand for collective export aggregate #
x4_ntrad - f4q_ntrad = -ABS[EXP_ELAST_NT]*[p4_ntrad - phi - f4p_ntrad];
          ! Government demand !
Variable
 f5tot  # Overall shift term for government demands #;
 f5tot2 # Ratio between f5tot and x3tot #;
 (all,c,COM)(all,s,SRC) f5(c,s) # Government demand shift #;
 (change) (all,c,COM)(all,s,SRC) fx6(c,s) # Shifter on rule for stocks #;
Equation
 E_x5 # Government demands #
(all,c,COM)(all,s,SRC) x5(c,s) = f5(c,s) + f5tot;
 E_f5tot # Overall government demands shift # f5tot = x3tot + f5tot2;
          ! Inventory demand !
Coefficient (all,c,COM)(all,s,SRC) LEVP0(c,s) # Levels basic prices #;
Formula (initial) (all,c,COM)(all,s,SRC) LEVP0(c,s) = 1;
Update   (all,c,COM)(all,s,SRC) LEVP0(c,s) = p0(c,s);
Equation
 E_delx6 # Stocks follow domestic output #
          (all,c,COM)(all,s,SRC) 100*LEVP0(c,s)*delx6(c,s) = V6BAS(c,s)*x0com(c) + fx6(c,s);
 E_delV6 # Update formula for stocks #
          (all,c,COM)(all,s,SRC) delV6(c,s) = 0.01*V6BAS(c,s)*p0(c,s) +
LEVP0(c,s)*delx6(c,s);
```

Excerpt 5.22 Margin demands

Variable
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND)(**all**,m,MAR)
a1mar(c,s,i,m) *# Intermediate margin tech change #*;
(**all**,c,COM)(**all**,s,SRC)(**all**,i,IND)(**all**,m,MAR)
a2mar(c,s,i,m) *# Investment margin tech change #*;
(**all**,c,COM)(**all**,s,SRC)(**all**, h, HOU)(**all**,m,MAR)
a3mah(c,s,h,m) *# Household margin tech change#*;
(**all**,c,COM)(**all**,m,MAR) a4mar(c,m) *# Export margin tech change #*;
(**all**,c,COM)(**all**,s,SRC)(**all**,m,MAR) a5mar(c,s,m) *# Governmnt margin tech change#*;

Equation
E_x1mar *# Margins to producers #* (**all**,c,COM)(**all**,s,SRC)(**all**,i,IND)(**all**,m,MAR)
x1mar(c,s,i,m) = x1(c,s,i) + a1mar(c,s,i,m);
E_x2mar *# Margins to investment #* (**all**,c,COM)(**all**,s,SRC)(**all**,i,IND)(**all**,m,MAR)
x2mar(c,s,i,m) = x2(c,s,i) + a2mar(c,s,i,m);
E_x3mah *# Margins to households #*
(**all**,c,COM)(**all**,s,SRC)(**all**, h, HOU)(**all**,m,MAR) x3mah(c,s,h,m) = x3h(c,s,h) + a3mah(c,s,h,m);
E_x4mar *# Margins to exports #*
(**all**,c,COM)(**all**,m,MAR) x4mar(c,m) = x4(c) + a4mar(c,m);
E_x5mar *# Margins to government #*
(**all**,c,COM)(**all**,s,SRC)(**all**,m,MAR) x5mar(c,s,m) = x5(c,s) + a5mar(c,s,m);

Excerpt 5.23 Carbon emissions and emissions reduction to ETS-related industries

!carbon emission intensity!
Coefficient
(**all**, c, COM)(**all**,s,SRC)(**all**, i, IND) EMI1(c,s,i)*#industry input emission#*;
(**all**, c, COM) (**all**, i, IND) EMO1(c, i) *#industry output emission#*;
(**all**, c, COM)(**all**,s,SRC)(**all**, h, HOU) EMC3(c,s,h) *#houshold consumption emission#*;
EMIT *# total initial emission by industry #*;
(**parameter**)(**all**, c, COM)(**all**,s,SRC)(**all**, i, IND) ETI1(c,s,i) *# input emission intensity#*;
(**parameter**)(**all**, c, COM)(**all**, i, IND) ETO1(c, i) *# output emission intensity#*;
(**parameter**)(**all**, c, COM)(**all**,s,SRC)(**all**, h, HOU) ETC3(c,s,h) *# houshold emission intensity#*;
Read
EMI1 **from file** BASEDATA **header** *"EMI1"*;
EMO1 **from file** BASEDATA **header** *"EMO1"*;
EMC3 **from file** BASEDATA **header** *"EMC3"*;
ETI1 **from file** BASEDATA **header** *"ETI1"*;
ETO1 **from file** BASEDATA **header** *"ETO1"*;
ETC3 **from file** BASEDATA **header** *"ETC3"*;
Update
(**change**)(**all**, c, COM)(**all**,s,SRC)(**all**, i, IND)
EMI1(c,s,i)=0.01*ETI1(c,s,i)*V1BAS(c,s,i)*x1(c,s,i);

```
(change)(all, c, COM) (all, i, IND)
EMO1(c, i) = 0.01*ETO1(c,i)*MAKE(c,i)*q1(c,i);
(change)(all, c, COM)(all,s,SRC)(all, h, HOU)
EMC3(c,s,h) = 0.01*ETC3(c,s,h)*V3BAH(c,s,h)*x3h(c,s,h);
formula
EMTT = sum{c, COM, sum{i,IND,sum{s,SRC,EMI1(c,s,i)}+EMO1(c,i)}};
Write
ETI1 to file SUMMARY header "ETI1";
ETO1 to file SUMMARY header "ETO1";
ETC3 to file SUMMARY header "ETC3";
EMI1 to file SUMMARY header "EMI1";
EMO1 to file SUMMARY header "EMO1";
EMC3 to file SUMMARY header "EMC3";

        !carbon emissions aggregation!
Variable
(change)(all, c, COM)(all,s,SRC)(all, i, IND) x1ci(c,s,i) # input carbon emissions #;
(change)(all, c, COM) (all, i, IND) x1co(c,i) # output carbon emissions #;
(change)(all, c, COM)(all,s,SRC)(all, h, HOU) x3cc(c,s,h) # consumption carbon emissions #;
(change) delEMIT # total emission cut by industry #;
xco2t # percentage of emissions cut #;
Equation
E_x1ci #input carbon emission by source and by industy#
(all, c, COM)(all,s,SRC) (all, i, IND)
 x1ci(c,s,i)=0.01*ETI1(c,s,i)*V1BAS(c,s,i)*x1(c,s,i);
E_x1co #output carbon emission by source and by industy#
(all, c, COM) (all, i, IND)
 x1co(c,i)=0.01*ETO1(c,i)*MAKE(c,i)*q1(c,i);
E_x3cc #consumption carbon emission by source and by household group#
(all, c, COM)(all,s,SRC)(all, h, HOU)
 x3cc(c,s,h)=0.01*ETC3(c,s,h)*V3BAH(c,s,h)*x3h(c,s,h);
E_delEMIT
          delEMIT = sum{c,COM,sum{I,IND,[x1co(c,i)+sum{s,SRC,x1ci(c,s,i)}]}};
E_xcoit
            EMIT*xcoit=100*delEMIT;
        ! Emission Trading Scheme!
        ! Emissions quota for industry!
Set BLOCI # Industries related to emissions trading scheme #
read elements from file BASEDATA header "BLCI";
Subset BLOCI is subset of IND;
Set BLOCH # Households related to emissions trading scheme #
read elements from file BASEDATA header "BLCH";
Subset BLOCH is subset of HOU;
Set BLOCNI # Industries unrelated to emission trading # = IND - BLOCI;
Set BLOCNH # Industries unrelated to emission trading # = HOU - BLOCH;
Variable
(all,i,IND) xcoiq(i) # emission quota by industries #;
```

```
(all,h,HOU) xcohq(h) # emission quota by households #;
(change)(all,i,IND) delCOIQ(i) # change in emission quota by industry #;
(change) (all,h,HOU) delCOHQ(h) # change in emission quota by households#;
xcoiq_I # total emisison quota by industry#;
xcohq_H # total emission quota by hh#;
xcotq # total emission quota #;
xempp # power of emission purchasers#;
Coefficient
(all,i,IND) COIQ(i) # emission quota by industry#;
(all,h,HOU) COHQ(h) # emission quota by HH #;
COTQ # total emisison quota #;
COIQ_I # total emission quota by industry #;
COHQ_H # total emission quota by hh #;
Update
(all,i,IND) COIQ(i) = xcoiq(i);
(all,h,HOU) COHQ(h) = xcohq(h);
Read
COIQ from file BASEDATA header "COIQ";
COHQ from file BASEDATA header "COHQ";
PCTAX from file BASEDATA header "CTAX";
Formula
COIQ_I = sum{i,BLOCI,COIQ(i)};
COHQ_H = sum{h,BLOCH,COHQ(h)};
COTQ = COIQ_I + COHQ_H;
Equation
E_delCOIQ
(all,i,IND) delCOIQ(i) = 0.01*COIQ(i)*xcoiq(i);
E_delCOHQ
(all,h,HOU) delCOHQ(h) = 0.01*COHQ(h)*xcohq(h);
E_xcoiqA
xcoiq("I20elcblcoal")=xcoiq_B;
E_xcoiqB
xcoiq("I21elcbrcoal")=xcoiq_B;
E_xcoiqC
(all,i,BLOKI) xcoiq(i)=xcoiq_M;
E_xcoiq_I
COIQ_I*xcoiq_I = COIQ("I20elcblcoal")*xcoiq_B+COIQ("I21elcbrcoal")*xcoiq_B+
        sum{i,BLOKI,COIQ(i)*xcoiq(i)};
E_xcoiqD
(all,i,BLOCNI) xcoiq(i) = 0;
E_xcohqA
(all,h,BLOCH) xcohq(h) = xcohq_H;
E_xcohqB
(all,h,BLOCNH) xcohq(h) = 0;
E_xcotq
COTQ*xcotq = COIQ_I*xcoiq_I + COHQ_H*xcohq_H;
```

```
E_xempp
xempp = xcoit - xcotq;

	! Emissions price !
Variable
(change)(all, c, COM)(all,s,SRC)(all, i, IND)
delP1CI(c,s,i) #change in input emissions permits price by industy#;
(change)(all, c, COM)(all, i, IND)
delP1CO(c,i) #change in output emissions permits price by industry#;
(change)(all, c, COM)(all,s,SRC)(all, h, HOU)
delP3CC(c,s,h) #change in emissions permits price by household group#;
(change)(all, c, COM)(all,s,SRC)(all, i, IND)
delTX1CI(c,s,i) #change in input emissions permits revenue#;
(change)(all, c, COM)(all, i, IND)
delTX1CO(c,i) #change in output emissions permits revenue#;
(change)(all, c, COM)(all,s,SRC)(all, h, HOU)
delTX3CC(c,s,h) #change in consumption emissions permits revenue#;
Coefficient
(all, c, COM)(all,s,SRC)(all, i, IND)
P1CI(c,s,i) #price on input carbon emissions by industry#;
(all, c, COM)(all, i, IND)
P1CO(c,i) #price on output carbon emissions by industry#;
(all, c, COM)(all,s,SRC)(all, h, HOU)
P3CC(c,s,h) #price on consumption carbon emissions by household group#;
(all, c, COM)(all, i, IND)
TX1CO(c,i) #output emissions permits revenue by industry#;
(all, c, COM)(all,s,SRC)(all, i, IND)
TX1CI(c,s,i) #input emissions permits revenue by industry#;
(all, c, COM)(all,s,SRC)(all, h, HOU)
TX3CC(c,s,h) #consumption emissions permits revenue by household group#;
Read
P1CI from file BASEDATA header "P1CI";
P1CO from file BASEDATA header "P1CO";
P3CC from file BASEDATA header "P3CC";
TX1CI from file BASEDATA header "TXCI";
TX1CO from file BASEDATA header "TXCO";
TX3CC from file BASEDATA header "TXCC";
Update
(change)(all, c, COM)(all,s,SRC)(all, i, IND) P1CI(c,s,i)=delP1CI(c,s,i) ;
(change)(all, c, COM)(all, i, IND) P1CO(c,i)=delP1CO(c,i) ;
(change)(all, c, COM)(all,s,SRC)(all, h, HOU) P3CC(c,s,h)=delP3CC(c,s,h) ;
(change)(all, c, COM)(all,s,SRC)(all, i, IND)
	TX1CI(c,s,i)=delTX1CI(c,s,i) ;
(change)(all, c, COM)(all, i, IND) TX1CO(c,i)=delTX1CO(c,i) ;
(change)(all, c, COM)(all,s,SRC)(all, h, HOU) TX3CC(c,s,h)=delTX3CC(c,s,h)
Equation
E_delTX1CI #input carbon emissions price by source and by industy#
```

(**all**, c, COM)(**all**,s,SRC)(**all**, i, IND) 1000*delTX1CI(c,s,i)= EMI1(c,s,i)*delP1CI(c,s,i) + P1CI(c,s,i)*x1ci(c,s,i);
E_delTX1CO
(**all**, c, COM)(**all**, i, IND) 1000*delTX1CO(c,i)= EMO1(c,i)*delP1CO(c,i) + P1CO(c,i)*x1co(c,i);
E_delTX3CC
(**all**, c, COM)(**all**,s,SRC)(**all**, h, HOU) 1000*delTX3CC(c,s,h) = EMC3(c,s,h)*delP3CC(c,s,h) + P3CC(c,s,h)*x3cc(c,s,h);
Variable
(**change**)(**all**, i, IND) delP1CI_SC(i) *#change in input carbon price by industry#*;
(**change**)(**all**, i, IND) delP1CO_C(i) *#change in output carbon price by industry#*;
(**change**)(**all**, h, HOU) delP3CC_SC(h) *#change in carbon price by household group#*;
Equation
E_delP1CI
(**all**, c, COM)(**all**,s,SRC)(**all**, i, IND) delP1CI(c,s,i)=delP1CI_SC(i);
E_delP1CO
(**all**, c, COM)(**all**, i, IND) delP1CO(c,i)=delP1CO_C(i);
E_delP3CC
(**all**, c, COM)(**all**,s,SRC)(**all**, h, HOU) delP3CC(c,s,h)=delP3CC_SC(h);
Variable
(**change**) delPCTAX *# change in carbon price, $ per tonne of CO2#*;
Coefficient
PCTAX *# carbon price#*;
Update
(**change**) PCTAX = delPCTAX;
Equation
E_delP1CI_SCA
(**all**,i,BLOCI) delP1CI_SC(i) = delPCTAX;
E_delP1CI_SCB
(**all**,i,BLOCNI) delP1CI_SC(i) = 0;
E_delP1CO_CA
(**all**,i,BLOCI) delP1CO_C(i) = delPCTAX;
E_delP1CO_CB
(**all**,i,BLOCNI) delP1CO_C(i) = 0;
E_delP3CC_SCA
(**all**,h,BLOCH) delP3CC_SC(h) = delPCTAX;
E_delP3CC_SCB
(**all**,h,BLOCNH) delP3CC_SC(h) = 0;

! Emissions revenue !
Variable
(**change**)(**all**,i,BLOCI) delCOIQemi(i) *# difference in emission quota & actual emission#*;
(**change**)(**all**,h,BLOCH) delCOHQemh(h) *# difference in emission quota minus actual emisison#*;
(**change**)(**all**,i,BLOCI) delCOIQrvn(i) *# emissiont trading revenue#*;
(**change**)(**all**,h,BLOCH) delCOHQrvn(h) *# emission trading revenue#*;
Equation

```
E_delCOIQemi
(all,i,BLOCI) delCOIQemi(i) = delCOIQ(i) - x1ci_sc(i) - x1co_c(i);
E_delCOHQemh
(all,h,BLOCH) delCOHQemh(h) = delCOHQ(h) - x3cc_sc(h);
E_delCOIQrvn
(all,i,BLOCI) delCOIQrvn(i) = PCTAX*delCOIQemi(i);
E_delCOHQrvn
(all,h,BLOCH)  delCOHQrvn(h) = PCTAX*delCOHQemh(h);

        ! Government Revenue!
Variable
(change) delCOIQ_I # change in emissions quota by industry#;
(change) delGREV # revenue from the auctioned permits#;
Equation
E_delCOIQ_I
delCOIQ_I = 0.01*COIQ_I*xcoiq_I;
E_delGREV
  1000* delGREV = COIQ_I*delPCTAX +PCTAX*delCOIQ_I;
```

Exerpt 5.24 Coefficients and variables for purchaser's price

```
Coefficient
 (all,c,COM)(all,s,SRC)(all,i,IND) V1PUR(c,s,i)#Intermediate purch. value#;
 (all,c,COM)(all,s,SRC)(all,i,IND) V2PUR(c,s,i)#Investment purch. value#;
 (all,c,COM)(all,s,SRC)           V3PUR(c,s)# Households purch. value #;
 (all,c,COM)(all,s,SRC)(all,h,HOU) V3PUH(c,s,h)# Households purch. value #;
 (all,c,COM)(all,h,HOU)        V3PUR_SH(c,h)  # Households purch. value #;
 (all,c,COM)                   V4PUR(c)      # Export purch. value #;
 (all,c,COM)(all,s,SRC)          V5PUR(c,s)    # Government purch. value #;
Formula
 (all,c,COM)(all,s,SRC)(all,i,IND) V1PUR(c,s,i) = V1BAS(c,s,i) + V1TAX(c,s,i) +
sum{m,MAR, V1MAR(c,s,i,m)} + TX1CI(c,s,i);
 (all,c,COM)(all,s,SRC)(all,i,IND) V2PUR(c,s,i) = V2BAS(c,s,i) + V2TAX(c,s,i) +
sum{m,MAR, V2MAR(c,s,i,m)};
 (all,c,COM)(all,s,SRC)(all,h,HOU) V3PUH(c,s,h) = V3BAH(c,s,h) + V3TAH(c,s,h) +
sum{m,MAR, V3MAH(c,s,h,m)} + TX3CC(c,s,h);
 (all,c,COM)(all,s,SRC) V3PUR(c,s) = sum(h,HOU,V3PUH(c,s,h));
 (all,c,COM)(all,h,HOU) V3PUR_SH(c,h) = sum (s,SRC,V3PUH(c,s,h));
 (all,c,COM)V4PUR(c) = V4BAS(c) + V4TAX(c) + sum{m,MAR, V4MAR(c,m)};
 (all,c,COM)(all,s,SRC) V5PUR(c,s) = V5BAS(c,s) + V5TAX(c,s) + sum{m,MAR,
V5MAR(c,s,m)};
Variable
(all,c,COM)(all,s,SRC)(all,i,IND) p1(c,s,i)# Purchaser's price, intermediate #;
(all,c,COM)(all,s,SRC)(all,i,IND) p2(c,s,i)#Purchaser's price, investment#;
 (all,c,COM)(all,s,SRC) p3(c,s)  # Purchaser's price, household #;
 (all,c,COM)           p4(c)    # Purchaser's price, exports,loc$ #;
```

```
 (all,c,COM)(all,s,SRC) p5(c,s)  # Purchaser's price, government #;
Variable
 (all,c,COM)(all,s,SRC)(all,i,IND) t1(c,s,i) # Power of tax on intermediate #;
 (all,c,COM)(all,s,SRC)(all,i,IND) t2(c,s,i) # Power of tax on investment #;
 (all,c,COM)(all,s,SRC)           t3(c,s)   # Power of tax on household #;
 (all,c,COM)                      t4(c)     # Power of tax on export #;
 (all,c,COM)(all,s,SRC)         t5(c,s)   # Power of tax on government #;
Variable
(all, c, COM)(all,s,SRC)(all, i, IND)
et1(c,s,i) # Power of equivalent tax on intermediate#;
(all, c, COM)(all,s,SRC)(all, h, HOU)
 et3(c,s,h) # Power of equivalent tax on consumption#;
(all, c, COM)
et3_sh(c) #Power of equivalent tax on consumption by commodity#;

Equation E_p1 # Purchasers prices - producers #
 (all,c,COM)(all,s,SRC)(all,i,IND) [V1PUR(c,s,i)+TINY]*p1(c,s,i) =
[V1BAS(c,s,i)+V1TAX(c,s,i)]*[p0(c,s)+ t1(c,s,i)] + sum{m,MAR,
V1MAR(c,s,i,m)*[p0dom(m)+a1mar(c,s,i,m)]} + 100*delTX1CI(c,s,i)-TX1CI(c,s,i)*x1(c,s,i);
Equation E_p2 # Purchasers prices - capital creators #
 (all,c,COM)(all,s,SRC)(all,i,IND) [V2PUR(c,s,i)+TINY]*p2(c,s,i) =
[V2BAS(c,s,i)+V2TAX(c,s,i)]*[p0(c,s)+ t2(c,s,i)]+ sum{m,MAR,
V2MAR(c,s,i,m)*[p0dom(m)+a2mar(c,s,i,m)]};
Equation E_p3 # Purchasers prices - households #
 (all,c,COM)(all,s,SRC) [V3PUR(c,s)+TINY]*p3(c,s) = [V3BAS(c,s)+V3TAX(c,s)]*[p0(c,s)+
t3(c,s)]+ sum{m,MAR, sum{h,HOU,V3MAh(c,s,h,m)*[p0dom(m)+a3mah(c,s,h,m)]}}+
sum{h,HOU,100*delTX3CC(c,s,h)-TX3CC(c,s,h)*x3h(c,s,h)};
Equation E_p4 # Zero pure profits in exporting #
 (all,c,COM)[V4PUR(c)+TINY]*p4(c) = [V4BAS(c)+V4TAX(c)]*[pe(c)+ t4(c)]+
sum{m,MAR, V4MAR(c,m)*[p0dom(m)+a4mar(c,m)]};
Equation E_p5 # Zero pure profits in distribution to government #
 (all,c,COM)(all,s,SRC) [V5PUR(c,s)+TINY]*p5(c,s) = [V5BAS(c,s)+V5TAX(c,s)]*[p0(c,s)+
t5(c,s)]+ sum{m,MAR, V5MAR(c,s,m)*[p0dom(m)+a5mar(c,s,m)]};
```

Excerpt 5.25 Market clearing conditions

```
Coefficient
(all,c,COM) MARSALES(c) # Total usage for margins purposes #;
Formula
 (all,n,NONMAR) MARSALES(n) = 0.0;
 (all,m,MAR) MARSALES(m) = sum{c,COM, V4MAR(c,m)+sum{s,SRC, V3MAR(c,s,m)+
V5MAR(c,s,m)+sum{i,IND, V1MAR(c,s,i,m) + V2MAR(c,s,i,m)}}};
Set DEST # Sale Categories #
(Interm, Invest, HouseH, Export, GovGE, Stocks, Margins);
Coefficient
(all,c,COM)(all,s,SRC)(all,d,DEST) SALE(c,s,d) # Sales aggregates #;
Formula
```

```
 (all,c,COM)(all,s,SRC) SALE(c,s,"Interm") = sum{i,IND, V1BAS(c,s,i)};
 (all,c,COM)(all,s,SRC) SALE(c,s,"Invest") = sum{i,IND, V2BAS(c,s,i)};
 (all,c,COM)(all,s,SRC) SALE(c,s,"HouseH") = V3BAS(c,s);
 (all,c,COM)            SALE(c,"dom","Export") = V4BAS(c);
 (all,c,COM)            SALE(c,"imp","Export") = 0;
 (all,c,COM)(all,s,SRC) SALE(c,s,"GovGE") = V5BAS(c,s);
 (all,c,COM)(all,s,SRC) SALE(c,s,"Stocks") = V6BAS(c,s);
 (all,c,COM)            SALE(c,"dom","Margins") = MARSALES(c);
 (all,c,COM)            SALE(c,"imp","Margins") = 0;
Write SALE to file SUMMARY header "SALE";
Coefficient (all,c,COM) V0IMP(c) # Total basic-value imports of good c #;
Formula     (all,c,COM) V0IMP(c) = sum{d,DEST, SALE(c,"imp",d)};
Coefficient (all,c,COM) SALES(c) # Total sales of domestic commodities #;
Formula     (all,c,COM) SALES(c) = sum{d,DEST, SALE(c,"dom",d)};
Coefficient (all,c,COM) DOMSALES(c) # Total sales to local market #;
Formula     (all,c,COM) DOMSALES(c) = SALES(c) - V4BAS(c);
Variable (change)
 (all,c,COM)(all,s,SRC)(all,d,DEST) delSale(c,s,d) # Sales aggregates #;
Equation
E_delSaleA (all,c,COM)(all,s,SRC)
        delSale(c,s,"Interm") = 0.01*sum{i,IND,V1BAS(c,s,i)*x1(c,s,i)};
E_delSaleB (all,c,COM)(all,s,SRC)
         delSale(c,s,"Invest") = 0.01*sum{i,IND,V2BAS(c,s,i)*x2(c,s,i)};
E_delSaleC (all,c,COM)(all,s,SRC)
        delSale(c,s,"HouseH") = 0.01*V3BAS(c,s)*x3(c,s);
E_delSaleD (all,c,COM) delSale(c,"dom","Export") = 0.01*V4BAS(c)*x4(c);
E_delSaleE (all,c,COM) delSale(c,"imp","Export")=   0;
E_delSaleF (all,c,COM)(all,s,SRC)
        delSale(c,s,"GovGE") = 0.01*V5BAS(c,s)*x5(c,s);
E_delSaleG (all,c,COM)(all,s,SRC)
        delSale(c,s,"Stocks") = LEVP0(c,s)*delx6(c,s);
E_delSaleH (all,m,MAR) delSale(m,"dom","Margins") = 0.01*sum{c,COM,
V4MAR(c,m)*x4mar(c,m)+
sum{s,SRC,sum{h,HOU,V3MAh(c,s,h,m)*x3mah(c,s,h,m)}+V5MAR(c,s,m)*x5mar(c,s,m)
  + sum{i,IND, V1MAR(c,s,i,m)*x1mar(c,s,i,m) + V2MAR(c,s,i,m)*x2mar(c,s,i,m)}}};
E_delSaleI (all,n,NONMAR) delSale(n,"dom","Margins") = 0;
E_delSaleJ (all,c,COM) delSale(c,"imp","Margins") = 0;
Set LOCUSER # Non-export users #(Interm, Invest, HouseH, GovGE, Stocks,Margins);
Subset LOCUSER is subset of DEST;
Equation E_p0A # Supply = Demand for domestic commodities #
(all,c,COM)
         0.01*[TINY+DOMSALES(c)]*x0dom(c) =sum{u,LOCUSER,delSale(c,"dom",u)};
Variable (all,c,COM)  x0imp(c)      # Total supplies of imported goods #;
Equation E_x0imp # Import volumes #
 (all,c,COM)
         0.01*[TINY+V0IMP(c)]*x0imp(c) = sum{u,LOCUSER,delSale(c,"imp",u)};
```

Excerpt 5.26 SAM extension

```
        !labour balance!
Coefficient
(all, h, HOU)(all,o,OCCD)HHL(h,o) # household labour supply #;
(all,o,OCCD)HHL_H(o) # household labour supply #;
LTRW  # labour payment to foreign #;
RWTL # foreign labour in foreign firm #;
Read
HHL from file BASEDATA header "HHL";
LTRW from file BASEDATA header "LTRW";
RWTL from file BASEDATA header "RWTL";
Formula
(all,o,OCCD) HHL_H(o) = sum(h,HOU,HHL(h,o));
variable
(all, h, HOU)(all,o,OCCD) xHHL(h,o) # household labour supply #;
(change)(all, h, HOU)(all,o,OCCD) delHHL(h,o) # household labour income #;
(change)(all, h, HOU) delHHL_O(h) # household labour income #;
(all,o,OCCD)xHHL_H(o) # household labour supply #;
(all, h, HOU)xHHL_O(h) # household labour supply #;
xLTRW  # labour payment to foreign #;
xRWTL # foreign labour in foreign firm #;
(change) delLTRW  # labour payment to foreign #;
(change) delRWTL # foreign labour in foreign firm #;
Update
(change)(all, h, HOU)(all,o,OCCD) HHL(h,o) = delHHL(h,o);
(change)LTRW = delLTRW;
(change)RWTL = delRWTL;
Equation
E_xHHL_H
(all,o,OCCD) HHL_H(o)*xHHL_H(o) = sum(i,IND,V1lab(i,o)*x1lab(i,o));
E_xHHL
(all, h, HOU)(all,o,OCCD) xHHL(h,o) = xHHL_H(o);
E_xHHL_O
(all, h, HOU)
        sum(o, OCCD, HHL(h,o))*xHHL_O(h) = sum(O, OCCD, HHL(h,o)*xHHL(h,o));
E_delHHL
(all, h, HOU)(all,o,OCCD) 100*delHHL(h,o)= HHL(h,o)*(xHHL(h,o)+p1lab_i(o));
E_delHHL_O
(all, h, HOU)delHHL_O(h) = sum(O, OCCD, delHHL(h,o));
E_delLTRW
100*delLTRW = LTRW*(xLTRW+p1lab_io);
E_delRWTL
100*delRWTL = RWTL*(xRWTL+p1lab_io);
E_xLTRW
LTRW*xLTRW = RWTL*xRWTL+sum(i,IND,V1lab(i,"foreign")*x1lab(i,"foreign"));
!capital balance!
```

```
Coefficient
(all, h, HOU) HHK (h) # household capital contribution #;
HHK_H # household capital contribution #;
NFK # non-financial capital contribution #;
FFK # financial capital contribution #;
GGK # government capital contribution #;
Read
HHK from file BASEDATA header "HHK";
NFK from file BASEDATA header "NFK";
FFK from file BASEDATA header "FFK";
GGK from file BASEDATA header "GGK";
formula
HHK_H = sum(h,HOU,HHK(h));
Variable
(all, h, HOU) xHHK (h) # household capital contribution #;
(change)(all, h, HOU) delHHK (h) # household capital income #;
xHHK_H # household capital contribution #;
xNFK # non-financial capital contribution #;
xFFK # financial capital contribution #;
xGGK # government capital contribution #;
(change)delNFK # non-financial capital contribution #;
(change)delFFK # financial capital contribution #;
(change)delGGK # government capital contribution #;
fHHK_H # household capital contribution #;
fNFK # non-financial capital shifter #;
fFFK # financial capital shifter #;
fGGK # government capital shifter #;
Update
(change)(all, h, HOU)HHK(h) = delHHK(h);
(change) NFK = delNFK;
(change) FFK = delFFK;
(change) GGK = delGGK;
Equation
E_xHHK_H
HHK_H*xHHK_H = sum(i,IND,V1cap(i)*x1cap(i));
E_xHHK
(all, h, HOU) xHHK(h) = xHHK_H;
E_delHHK
(all, h, HOU) 100*delHHK(h) = HHK(h)*(xhhk(h)+p1cap_i);
E_delNFK
100*delNFK = NFK*(xnfk+p1cap_i);
E_delFFK
100*delFFK = FFK*(xffk+p1cap_i);
E_delGGK
100*delGGK = NFK*(xggk+p1cap_i);
E_xGGK
sum(h,HOU,HHK(h)*xHHK(h))+NFK*xNFK+FFK*xFFK+GGK*xGGK =
```

```
sum(i,IND,V1cap(i)*x1cap(i))+fHHK_H+fNFK+fFFK+fGGK;

!household account!
Set LHOU # low-income households #
(Group1,Group2,Group3,Group4,Group5,Group6,Group7,Group8,Group9,Group10,Group11,G
roup12);
Subset LHOU is subset of HOU;
Set HHOU # high income groups # = HOU-LHOU;
Coefficient
(all, h, HOU) HHLD (h) # household land income #;
HHLD_H  # household land income #;
(all, n, HOU)(all, h, HOU) HTH (n,h) # household n pay to household h #;
(all, h, HOU) NFTH (h) # non-financial transfer to household #;
(all, h, HOU) FTH (h) # financial transfer to household #;
(all, h, HOU) GTH1 (h) #government transfer to household -social benefit#;
(all, h, HOU) GTH2 (h) #government transfer to household-current transfer#;
(all, h, HOU) GTH3 (h) #government transfer to household-interest transfer#;
(all, h, HOU) GTH (h) # government transfer to household – total #;
(all, h, HOU) RWTH (h) # foreign transfer to household #;
(all, h, HOU) HTNF (h) # household transfer to non-financial #;
(all, h, HOU) HTF (h) # household transfer to financial #;
(all, h, HOU) HTG1 (h) # household transfer to government-income tax #;
(all, h, HOU) HTG2 (h) # household transfer to government-natural assests #;
(all, h, HOU) HTG (h) # household transfer to government – total #;
(all, h, HOU) TXRI (h) # household income tax rate #;
(all, h, HOU) HTRW (h) # household transfer to foreign #;
(all, h, HOU) HINC (h) # household income #;
(all, h, HOU) DINC (h) # household disposable income #;
(all, h, HOU) HEXP (h) # household expenditure #;
(all,h,HOU) S_HHSV(h) # share of HH saving #;
(parameter)(all,h,HOU) RGOV(h) # Received from government pensions and allowances#;
TGOV # total receive from government pensions and allowances #;
(all,h,HOU) S_RGOV(h) # share of government pensions and allowances#;
SUMHTG  # total income tax #;
(all, h, HOU) S_HTG (h) # household social benift share #;
(parameter)RCYC  # share of recycled emissions permits revenue #;
Read
HHLD from file BASEDATA header "HHLD";
HTH from file BASEDATA header "HTH";
NFTH from file BASEDATA header "NFTH";
FTH from file BASEDATA header "FTH";
GTH1 from file BASEDATA header "GTH1";
GTH2 from file BASEDATA header "GTH2";
GTH3 from file BASEDATA header "GTH3";
RWTH from file BASEDATA header "RWTH";
HTNF from file BASEDATA header "HTNF";
HTF from file BASEDATA header "HTF";
```

HTG2 **from file** BASEDATA **header** *"HTG2"*;
TXRI **from file** BASEDATA **header** *"TXRI"*;
HTRW **from file** BASEDATA **header** *"HTRW"*;
RCYC **from file** BASEDATA **header** *"RCYC"*;
NKID **from file** BASEDATA **header** *"NKID"*;
RGOV **from file** BASEDATA **header** *"RGOV"*;
NPER **from file** BASEDATA **header** *"NPER"*;
Formula
TGOV =**sum{**h,HOU,RGOV(h)**}**;
(**all**,h,HOU) S_RGOV(h) = RGOV(h)/TGOV;
(**all**, h, HOU) GTH (h) = GTH1(h)+GTH2(h)+GTH3(h);
(**all**, h, HOU) HINC (h) = **sum**(o,OCCD,HHL(h,o))+HHK(h)+HHLD(h)+
sum(n,HOU,HTH(h,n))+NFTH(h)+FTH(h)+GTH(h)+RWTH(h);
(**all**, h, HOU) HTG1 (h) = HINC(h)*TXRI(h);
(**all**, h, HOU) HTG (h) = HTG1(h)+HTG2(h);
(**all**, h, HOU)
HEXP (h) = V3TOTH(h)+**sum**(n,HOU,HTH(n,h))+HTG(h)+HTNF(h)+HTF(h)+HTRW(h);
HHLD_H = **sum**(h,HOU,HHLD(h));
(**all**, h, HOU)
DINC (h) = HINC(h)-(**sum**(n,HOU,HTH(n,h))+HTG(h)+HTNF(h)+HTF(h)+HTRW(h));
SUMHTG = **sum{**h,HOU,HTG1(h)**}**;
(**all**, h, HOU) S_HTG(h) = HTG1(h)/SUMHTG;
(**all**,h,HOU) S_HHSV(h) = **[**HINC(h)-HEXP(h)**]**/HINC(h);
Write
HEXP **to file** SUMMARY **header** *"HEXP"*;
HINC **to file** SUMMARY **header** *"HINC"*;
DINC **to file** SUMMARY **header** *"DINC"*;
S_HHSV **to file** SUMMARY **header** *"SHSV"*;
Variable
(**all**, h, HOU) xHHLD (h) *# household land supply #*;
(**change**)(**all**, h, HOU) delHHLD (h) *# household land income #*;
xHHLD_H *# household land supply #*;
(**all**, n, HOU)(**all**, h, HOU) xHTH (n,h) *# household n pay to household h #*;
(**all**, h, HOU) xNFTH (h) *# non-financial transfer to household #*;
(**all**, h, HOU) xFTH (h) *# financial transfer to household #*;
(**all**, h, HOU) xGTH1 (h) *# government transfer to household #*;
(**all**, h, HOU) xGTH2 (h) *# government transfer to household #*;
(**all**, h, HOU) xGTH3 (h) *# government transfer to household #*;
(**all**, h, HOU) xGTH (h) *# government transfer to household #*;
(**all**, h, HOU) xRWTH (h) *# foreign transfer to household #*;
(**all**, h, HOU) xHTNF (h) *# household transfer to non-financial #*;
(**all**, h, HOU) xHTF (h) *# household transfer to financial #*;
(**all**, h, HOU) xHTG1 (h) *# household transfer to government #*;
(**all**, h, HOU) xHTG2 (h) *# household transfer to government #*;
(**all**, h, HOU) xHTG (h) *# household transfer to government #*;
(**all**, h, HOU) xTXRI (h) *# household transfer to government #*;
(**all**, h, HOU) xHTRW (h) *# household transfer to foreign #*;

```
(all, h, HOU) xHINC (h) # household income #;
(all, h, HOU) xDINC (h) # household disposable income #;
(all, h, HOU) xHEXP (h) # household expenditure #;
(change)(all, h, HOU) delHINC (h) # household income #;
(change)(all, h, HOU) delDINC (h) # household disposable income #;
(change)(all, h, HOU) delHEXP (h) # household expenditure #;
(change)(all, h, HOU) delHHSV (h) #household savings#;
(all, h, HOU) f3lux(h)  # household consumption propensity shift #;
(change)(all, h, HOU) delGTH(h) # nominal change of government transfer #;
(change)(all, h, HOU) delGTH1(h) # nominal change of social benefit transfer #;
(change)(all, h, HOU) delHTG(h) # nominal change in HH transfer to Government #;
(change)(all, h, HOU) delHTG1(h) # nominal change in income tax #;
Update
(change)(all, h, HOU) HHLD(h) = delHHLD(h);
(all, n, HOU)(all, h, HOU) HTH (n,h) = xHTH(n,h);
(all, h, HOU) NFTH(h) = xNFTH(h);
(all, h, HOU) FTH(h) = xFTH(h);
(all, h, HOU) GTH1(h) = xGTH1(h);
(all, h, HOU) GTH2(h) = xGTH2(h);
(all, h, HOU) GTH3(h) = xGTH3(h);
(all, h, HOU) RWTH(h) = xRWTH(h);
(all, h, HOU) HTNF(h) = xHTNF(h);
(all, h, HOU) HTF(h) = xHTF(h);
(all, h, HOU) HTG2(h) = xHTG2(h);
(all, h, HOU) TXRI(h) = xTXRI(h);
(all, h, HOU) HTRW(h) = xHTRW(h);
Equation
E_w3luxh
 (all,h,HOU) w3luxh(h) = xDINC(h)+ f3lux(h);
E_delHHLD
(all,h,HOU) delHHLD(h) = 0.01*HHLD(h)*(p1lnd_i+xHHLD(h));
E_delHINC
(all,h,HOU) delHINC(h) = 0.01*HINC(h)*xHINC(h);
E_delDINC
(all,h,HOU) delDINC(h) = 0.01*DINC(h)*xDINC(h);
E_delHEXP
(all,h,HOU) delHEXP(h) = 0.01*HEXP(h)*xHEXP(h);
E_xHHLD_H HHLD_H*xHHLD_H = sum(i,IND,V1lnd(i)*x1lnd(i));
E_xHHLD (all,h,HOU) xHHLD(h) = xHHLD_H;
E_xGTH (all,h,HOU)
 GTH(h)*xGTH(h) = GTH1(h)*xGTH1(h)+GTH2(h)*xGTH2(h)+GTH3(h)*xGTH3(h);
E_xHTG (all,h,HOU)
 HTG(h)*xHTG(h) = [TINY+HTG1(h)]*xHTG1(h)+HTG2(h)*xHTG2(h);
E_xHINC (all, h, HOU)
HINC(h)*xHINC(h) = sum(o,OCCD,100*delHHL(h,o)) + 100*delHHK(h) + 100*delHHLD(h)
+ sum(n,HOU,HTH(h,n)*xHTH(h,n))+NFTH(h)*xNFTH(h) +
FTH(h)*xFTH(h)+GTH(h)*xGTH(h)+RWTH(h)*xRWTH(h);
```

```
E_xDINC (all, h, HOU)
DINC(h)*xDINC(h)=HINC(h)*xHINC(h)-(sum(n,HOU,HTH(n,h)*xHTH(n,h))          +
HTNF(h)*xHTNF(h)+HTF(h)*xHTF(h)+HTG(h)*xHTG(H)+HTRW(h)*xHTRW(H));
E_xHEXP (all, h, HOU)
HEXP(h)*xHEXP(h)=V3TOTH(h)*x3toth(h)+sum(n,HOU,HTH(n,h)*xHTH(n,h))          +
HTNF(h)*xHTNF(h)+HTF(h)*xHTF(h)+HTG(h)*xHTG(H)+HTRW(h)*xHTRW(H);
E_delHHSV
(all,h,HOU) delHHSV(h) = ABS(S_HHSV(h))*delHINC(h);
E_delGTH
(all, h, HOU) delGTH(h) = 0.01*GTH(h)*xGTH(h);
E_xGTH1
(all, h, HOU) delGTH1(h) = 0.01*GTH1(h)*xGTH1(h);
E_delHTG
(all, h, HOU) delHTG(h) = 0.01*HTG(h)*xHTG(h);
E_xHTG1
(all, h, HOU) delHTG1(h) = 0.01*[TINY+HTG1(h)]*xHTG1(h);
E_xtxri
(all, h, HOU)
        [TINY+HTG1(h)]*xHTG1(h) = HINC(h)*[TINY+TXRI(h)]*(xTXRI(h)+xHINC(h));

!non-financial coporation account!
Coefficient
NFTN  # non-financial transfer to non-financial #;
FTNF  # financial transfer to non-financial #;
GTNF  # government transfer to non-financial #;
RWTN  # foreign transfer to non-financial #;
NFTF  # non-financial transfer to financial #;
NFTG1 # non-financial transfer to government- income tax #;
NFTG2 # non-financial transfer to government - dividend #;
NFTG3 # non-financial transfer to government rent on natutal assets #;
NFTG4 # non-financial transfer to government - current transfer #;
NFTG  # non-financial transfer to government #;
NTRW  # non-financial transfer to foreign #;
NINC  # non-financial coporrate income #;
NEXP  # non-financial coporrate expenditure #;
NFSV  # non-financial coporrate saving #;
TXNF # non-finance income tax rate #;
Read
NFTN from file BASEDATA header "NFTN";
FTNF from file BASEDATA header "FTNF";
GTNF from file BASEDATA header "GTNF";
RWTN from file BASEDATA header "RWTN";
NFTF from file BASEDATA header "NFTF";
NFTG2 from file BASEDATA header "NTG2";
NFTG3 from file BASEDATA header "NTG3";
NFTG4 from file BASEDATA header "NTG4";
NTRW from file BASEDATA header "NTRW";
```

```
TXNF from file BASEDATA header "TXNF";
Formula
NINC = NFK+sum(h,HOU,HTNF(h))+NFTN+FTNF+GTNF+RWTN;
NFTG1 = NINC*TXNF;
NFTG = NFTG1+ NFTG2+NFTG3+NFTG4;
NEXP = sum(h,HOU,NFTH(h))+NFTN+NFTF+NFTG+NTRW;
NFSV = NINC-NEXP;
Variable
xNFTN  # non-financial transfer to non-financial #;
xFTNF  # financial transfer to non-financial #;
xGTNF  # government transfer to non-financial #;
xRWTN  # foreign transfer to non-financial #;
xNFTF  # non-financial transfer to financial #;
xNFTG  # non-financial transfer to government #;
xNFTG1 # non-financial transfer to government- income tax #;
xNFTG2 # non-financial transfer to government - dividend #;
xNFTG3 # non-financial transfer to government rent on natutal assets #;
xNFTG4 # non-financial transfer to government - current transfer #;
xNTRW  # non-financial transfer to foreign #;
xNINC  # non-financial coporrate income#;
xNEXP  # non-financial coporrate expenditure #;
(change)delNINC;
(change) delNFTG1 # change in non-financial transfer - income tax #;
(change)delNEXP;
xNFSV  # non-financial coporrate saving #;
xTXNF # non-finance income tax rate #;
Update
NFTN = p3tot*xNFTN;
FTNF = p3tot*xFTNF;
GTNF = p3tot*xGTNF;
RWTN = p3tot*xRWTN;
NFTF = p3tot*xNFTF;
NFTG2 = p3tot*xNFTG2;
NFTG3 = p3tot*xNFTG3;
NFTG4 = p3tot*xNFTG4;
TXNF = xTXNF;
NTRW = p3tot*xNTRW;
Equation
E_delNINC
delNINC = 0.01*NINC*xNINC;
E_delNEXP
delNEXP = 0.01*NEXP*xNEXP;
E_xNINC
NINC*xNINC = 100*delNFK+sum(h,HOU,HTNF(h)*xHTNF(h))+
NFTN*xNFTN+FTNF*xFTNF+GTNF*xGTNF+RWTN*xRWTN;
E_xNFTG
NFTG*xNFTG = NFTG1*xNFTG1+NFTG2*xNFTG2+NFTG3*xNFTG3+NFTG4*xNFTG4;
```

E_xNEXP
NEXP*xNEXP = **sum**(h,HOU,NFTH(h)*xNFTH(h))+
NFTN*xNFTN+NFTF*xNFTF+NFTG*xNFTG+NTRW*xNTRW;
E_xNFSV
NFSV*xNFSV = NINC*xNINC-NEXP*xNEXP;
E_xTXNF
NFTG1*xNFTG1 = NINC*TXNF*(xTXNF+xNINC);
E_xNFTG1
delNFTG1 = 0.01*NFTG1*xNFTG1;

!financial coporation account!
Coefficient
FTF *# financial transfer to financial #*;
GTF *# financial transfer to financial #*;
RWTF *# foreign transfer to financial #*;
FTG *# financial transfer to government #*;
FTG1 *# financial transfer to government - income tax #*;
FTG2 *# Financial transfer to government - dividend #*;
FTG3 *# Financial transfer to government - Current transfer #*;
FTRW *# financial transfer to foreign #*;
FINC *# financial coporrate income #*;
FEXP *# financial coporrate expenditure #*;
FFSV *# financial coporrate saving #*;
TXF *# financial corp income tax #*;
Read
FTF **from file** BASEDATA **header** *"FTF"*;
GTF **from file** BASEDATA **header** *"GTF"*;
RWTF **from file** BASEDATA **header** *"RWTF"*;
FTG2 **from file** BASEDATA **header** *"FTG2"*;
FTG3 **from file** BASEDATA **header** *"FTG3"*;
FTRW **from file** BASEDATA **header** *"FTRW"*;
TXF **from file** BASEDATA **header** *"TXF"*;
Formula
FINC = FFK+**sum**(h,HOU,HTF(h))+NFTF+FTF+GTF+RWTF;
FTG1 = FINC*TXF;
FTG = FTG1 + FTG2 + FTG3;
FEXP = **sum**(h,HOU,FTH(h))+FTNF+FTF+FTG+FTRW;
FFSV = FINC-FEXP;
Variable
xFTF *# financial transfer to financial #*;
xGTF *# financial transfer to financial #*;
xRWTF *# foreign transfer to financial #*;
xFTG *# financial transfer to government #*;
xFTG1 *# financial transfer to government - income tax #*;
xFTG2 *# Financial transfer to government - dividend #*;
xFTG3 *# Financial transfer to government - interest rate#*;
xFTRW *# financial transfer to foreign #*;

```
xFINC  # financial coporrate income #;
xFEXP  # financial coporrate expenditure #;
xTXF # Corporation income tax #;
xFFSV  # financial coporrate saving #;
Update
FTF = p3tot*xFTF;
GTF = p3tot*xGTF;
RWTF = p3tot*xRWTF;
FTG2 = p3tot*xFTG2;
FTG3 = p3tot*xFTG3;
FTRW = p3tot*xFTRW;
TXF = xTXF;
Equation
E_xFTG
FTG*xFTG = FTG1*xFTG1+FTG2*xFTG2+FTG3*xFTG3;
E_delFINC
delFINC=0.01*FINC*xFINC;
E_delFEXP
delFEXP=0.01*FEXP*xFEXP;
E_xFINC
FINC*xFINC=100*delFFK+sum(h,HOU,HTF(h)*xHTF(h))+
        NFTF*xNFTF+FTF*xFTF+GTF*xGTF+RWTF*xRWTF;
E_xFEXP
FEXP*xFEXP
=sum(h,HOU,FTH(h)*xFTH(h))+FTNF*xFTNF+FTF*xFTF+FTG*xFTG+FTRW*xFTRW;
E_xFFSV
FFSV*xFFSV =FINC*xFINC-FEXP*xFEXP;
E_xTXF
FTG1*xFTG1 = FINC*TXF*(xFINC + xTXF);
E_xFTG1
delFTG1 = 0.01*FTG1*xFTG1;

!government account!
Coefficient
GTG  # governmetn transfer to government #;
RWTG  # foreign transfer to government #;
GTRW  # government transfer to foreign #;
GINC  # government  income #;
GEXP  # government  expenditure #;
GGSV  # government  saving #;
SUBG # governement production subsidy #;
Read
GTG from file BASEDATA header "GTG";
RWTG from file BASEDATA header "RWTG";
GTRW from file BASEDATA header "GTRW";
SUBG from file BASEDATA header "SUBG";
Formula
```

```
GINC =sum(i,IND,sum(c,COM,sum(s,SRC,V1TAX(c,s,i)+V2TAX(c,s,i)+TX1CI(c,s,i))+
TX1CO(c,i))+V1PTX(i))+sum(c,COM,sum(h,HOU,sum(s,SRC,V3TAH(c,s,h)+
TX3CC(c,s,h)))+V4TAX(c)+sum(s,SRC,V5TAX(c,s)))+V0TAR_C+GGK+sum(h,HOU,HTG(
h))+NFTG+FTG+ GTG+RWTG;
GEXP = V5TOT+sum(h,HOU,GTH(h))+GTNF+GTF+GTG+GTRW+SUBG;
GGSV = GINC-GEXP;
Variable
xGTG  # governmetn transfer to government #;
xRWTG  # foreign transfer to government #;
xGTRW  # government transfer to foreign #;
xGINC  # government  income #;
xGEXP  # government  expenditure #;
(change)delGINC  # government  income #;
(change)delGEXP  # government  expenditure #;
xGGSV  # government  saving #;
xSUBG # government subsidy #;
Update
GTG = p3tot*xGTG;
RWTG = p3tot*xRWTG;
GTRW = p3tot*xGTRW;
SUBG = p3tot*xSUBG;
Equation
E_xGINC
delGINC = 0.01*GINC*xGINC;
E_delGEXP
delGEXP = 0.01*GEXP*xGEXP;
E_delGINC
delGINC = sum{i,IND,sum{c,COM,sum{s,SRC,delV1TAX(c,s,i)+delV2TAX(c,s,i)+
delTX1CI(c,s,i)}+delTX1CO(c,i)}+delV1PTX(i)}+delV0TAR_C+
sum(c,COM,sum(h,HOU,sum(s,SRC,delV3TAH(c,s,h)+delTX3CC(c,s,h))))+delGGK+
 0.01*{sum(h,HOU,HTG(h)*xHTG(h))+
NFTG*xNFTG+FTG*xFTG+GTG*xGTG+RWTG*xRWTG};
E_xGEXP
GEXP*xGEXP =V5TOT*x5TOT+sum(h,HOU,GTH(h)*xGTH(h))+ GTNF*xGTNF+
GTF*xGTF+ GTG*xGTG+GTRW*xGTRW+SUBG*xSUBG;
E_xGGSV
GGSV*xGGSV = GINC*xGINC-GEXP*xGEXP;

!Foreigners account!
Coefficient
RWRW  # foreign transfer to goreign #;
RINC  # ROW  income #;
REXP  # ROW  expenditure #;
RWSV  # ROW  saving#;
Read
RWRW from file BASEDATA header "RWRW";
Formula
```

```
RINC = sum(c,COM,sum(i,IND,V1BAS(c,"imp",i)+V2BAS(c,"imp",i))+
sum(h,HOU,V3BAH(c,"imp",h))+ V5BAS(c,"imp")+V6BAS(c,"imp"))+ LTRW+
sum(h,HOU,HTRW(h))+NTRW+FTRW+GTRW+RWRW;
REXP = V4TOT+RWTL+sum(h,HOU,RWTH(h))+RWTN+RWTF+RWTG+RWRW;
RWSV = RINC-REXP;
Variable
xRWRW  # foreign transfer to foreign #;
xRINC  # ROW  income #;
xREXP  # ROW  expenditure #;
(change) delRINC  # ROW  income #;
(change) delREXP  # ROW  expenditure #;
xRWSV  # ROW  saving #;
Update
RWRW = p3tot*xRWRW;
Equation
E_delRINC
delRINC = 0.01*RINC*xRINC;
E_delREXP
delREXP = 0.01*REXP*xREXP;
E_xRINC
RINC*xRINC = sum(c,COM,sum(i,IND,V1BAS(c,"imp",i)*x1(c,"imp",i)+
V2BAS(c,"imp",i)*x2(c,"imp",i))+sum(h,HOU,V3BAH(c,"imp",h)*x3h(c,"imp",h))+
V5BAS(c,"imp")*x5(c,"imp")+delx6(c,"imp"))+100*delLTRW+
sum(h,HOU,HTRW(h)*xHTRW(h))+NTRW*xNTRW+FTRW*xFTRW+GTRW*xGTRW+R
WRW*xRWRW;
E_xREXP
REXP*xREXP =V4TOT*x4TOT+100*delRWTL+sum(h,HOU,RWTH(h)*xRWTH(h))+
RWTN*xRWTN+RWTF*xRWTF+ RWTG*xRWTG+RWRW*xRWRW;
E_xRWSV
RWSV*xRWSV = RINC*xRINC-REXP*xREXP;
```