The Impact of Implementing Carbon Tax and Feed-in Tariff:
A CGE Analysis of the Indonesian Case

Herbert Wibert Victor Hasudungan

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DECLARATION

I here declare that I am the author of this thesis and that I have consulted all the references cited. All the work of which this thesis is a record has been done by myself and has not been previously used for a higher degree.

Signed:

Herbert Wiber Victor Hasudungan, PhD Candidate

Date:…………………………....

CERTIFICATION

This to certify that Mr. Herbert Wibert Victor Hasudungan conducted his research under my supervision in the Department of Economic Studies, Dundee Universty. Mr. Hasudungan has fulfilled all the conditions of the relevant Ordinances and Regulations of the University of Dundee for obtaining the Degree of Doctor of Philosophy.

Signed:………………………

Hassan Molana, Supervisor
(Professor of Economics)

Date:…………………………....

Abstract

This thesis focuses on the two main works that related in assessing the implications of (i) fiscal expansion (or contraction) and (ii) implementing a carbon tax on carbon-based fuels as well as the feed-in tariffs (subsidies to clean energy production) on Indonesia’s economy, within the context of static computable general equilibrium (CGE) analysis.

In the first study, we investigate the impacts of increasing the public consumptions on Indonesia’s main macroeconomic indicators and to their consequences by examining how different institutions and sectors in the economy are affected. Three scenarios are carried out under different financing options to budgeting neutral the additional public spending. The results suggest that the increase of government expenditure on goods under the adjusted government saving generates the highest improvement on Indonesia’s GDP but results in a rise of budget deficit. In contrast, under the budget-neutral scheme of either reducing the subsidy rates across activities or increasing the output tax rates would result in less improvement to the Indonesia’s GDP. This is because a subsidy cut (or higher output tax) immediately escalates the production costs and, thus, increases the prices of final goods purchased by the households. These changes result in a fall of their real consumption that eventually leads to a drop in aggregate demand. However, compared to the scenario of subsidy cut, a higher output tax has the most adverse effects on national income. The industry’s production costs are more pressurized by a higher output tax. which in turn, creates deindustrialization, lower employment, and thus reduces the national income and output.

In the second study, we investigate the two key frameworks to reduce Indonesia’s greenhouse gas (GHG) emissions: (i) implementing a carbon tax on fossil fuels; and (ii) promoting clean (renewable) energy production through the feed-in tariff (subsidy) scheme. In the carbon tax implementation, we assume that the government levies a tax of Rp. 100,000/ton CO_2e with three possible revenue-recycling scenarios. In a first scenario, we allow the carbon tax to be recycled through adjustment of the labour (income) tax rate. In a second scenario, we allow the government to increase their spending on goods proportionally to compensate the revenue raised from a carbon tax. And finally, in the third scenario, we assume that the additional revenue from carbon tax is kept to run a budget surplus (government saving adjusts). Whilst, in the feed-in tariff (FIT) scenario, we assume that the government sets a 13.14% subsidy rate to renewable generations (hydro and geothermal generation) where the support payments are distributed equally among electricity consumers through a higher electricity tax rate. Overall, the results suggested that the carbon tax, in the short run, reduces the national emissions but raises costs to the economy, resulting a fall in GDP. In terms of income distribution, the carbon tax tends to be progressive in both (first and second) scenarios of

revenue-recycling. However, when there is no compensating (recycling) mechanism (third scenario), the carbon tax tends to be regressive - the poorer households carry a higher share of the carbon tax burden. On the other hand, in case of the FIT scheme (15% subsidy to renewable generation), the impacts are negligible on national income and emissions. This is because the initial renewable shares in the electricity mix are small (a 11% share from hydro generation and a 5% share from geothermal generation); and these technology outputs are only utilized in the electricity industry. Therefore, we argue that the current Indonesia’s FIT regulation – about 13.14% subsidy rate for renewable generation technologies – is ineffective to reduce the national emissions.

Introduction

This thesis aims to investigate the impacts of (i) fiscal expansion (or contraction), and (ii) implementing the carbon tax and incentive (subsidy) on renewable energy production (often called feed-in tariffs) on Indonesia's economy. In the first research, three simulations are conducted in order to analyze the expansion of exogenous public spending using a standard CGE model that is calibrated to the official Social Accounting Matrix (SAM) for Indonesia in year 2008. These simulations are related to the sources of financing to cover the additional public expenditure on goods and services, i.e. borrowing, subsidy cuts, or higher tax rates. In the second research, we carry out a number of scenarios which are principally related to the ways of fiscal schemes in recycling the carbon tax revenues or financing the renewables' subsidy injections. Here, we employ a hybrid CGE model – by incorporating the energy-factors combinations and electricity technological explicitness to the standard CGE – that is calibrated to a hypothetical Energy-SAM for Indonesia in year 2008.

Motivation

Increasing the revenue on taxes or reducing expenditures on subsidies has become the main agenda of the Indonesian government to compensate the increase in public expenditure (The World Bank, 2007). Over recent years, the government expenditures have been sharply increased due to an increase of transfer payments for district development as well as a sharp rise in energy subsidies following a spike in international oil prices. On the other hand, the government deficit also tended to increase over the last decade which influenced by a contraction (and expansion) in government revenue (spending) caused by global recession. To maintain the fiscal sustainability, the Indonesian government has decided to reduce their budget allocation for fuel subsidies by half and to reallocate the budget for improving the public infrastructure in rural areas. Aside from subsidy cuts, Indonesia's government has also been targeting to improve the tax revenues which could be possibly obtained through either improvement in taxation administration or higher tax rates.

Motivated by these challenges, we opt to investigate the implications of increasing the public expenditures on goods and services under three different financing schemes either by (i) borrowing; (ii) reducing the subsidy rates across industries; or (iii) increasing the output tax rates. The findings of this research can provide empirical justifications for policy makers in choosing the sources of financing to cover the additional public expenditures on goods and services as these choices would influence the equilibrium output and national income.

Furthermore, in the second research, we also put our interest to examine the implications of introducing a carbon tax on fossil fuels, and (ii) a subsidy to clean (renewable) energy resources on Indonesia's economy. This study is important since the government of Indonesia has ratified the United Framework Convention on Climate Change (UNFCC) and adopted the Kyoto Protocol in order to seriously mitigate the climate change (Ministry of Finance, 2008). Under the Copenhagen Accord, the Indonesia's government has voluntarily made a commitment to reduce their national greenhouse gas (GHG) emissions by 26% in 2020 where the greenhouse gas emission shares from fossil fuels utilization are targeted to be reduced by about 1% (NCCC, 2009). In the year 2000, Indonesia was among the largest GHG emitters countries. It has been widely recognized that the GHG emissions from fossil fuels combustion in Indonesia tend to increase in line to their GDP growth which would bring severe problems on population such as a rising sea level, extreme weather, prolonged droughts, and heavy flooding (Resosudarmo and Abdurohman, 2011; Lackner *et al.*, 2012; and Baumert *et al.*, 2005).

Motivated by these climate change issues, we also carry out several simulations which are principally related to the revenue-recycling mechanisms of carbon taxation and financing schemes to cover the extra expenditures on renewable subsidies such that the fiscal balance can be maintained. In the study case of carbon tax introduction, we allow two possible revenue-recycling schemes, i.e. a reduction in income (labour) tax rates and an increase in public expenditure on commodities. In addition, we also assess the impact of carbon tax on Indonesia's economy if no compensating mechanism is allowed. In other words, the carbon tax revenues are kept as government saving to run a budget surplus. In the case of implementing the renewable subsidies (feed-in tariffs), we also allow two possible financing schemes, i.e. the subsidies are either paid by electricity customers through a higher electricity tax rate or carbon tax. The findings of this research can also provide empirical justifications for policy makers in choosing the possibilities of (i) compensating the carbon tax; and (ii) financing the feed-in tariffs as these choices would influence the equilibrium output, national income, and households' welfare and income distribution.

Methodology

The first assessment is based on the standard general equilibrium framework –which only features a conventional top-down system of equations to model the economy's transaction flows such as the behavior of economic agents that relate to their income and consumption budget, the industry's production structure, transfers among institutions', investment and saving, and trade aggregations (transformations). In developing countries, CGE models have been commonly employed to examine the short and long-term effects of certain policies on national income, equilibrium outputs, and household income distribution. CGE models are used as tools to address the lack of time series database in econometric models, which is identified as a major issue for a standard economic analysis in the countries. This model is calibrated to the official SAM dataset for Indonesia in year 2008 and other supporting data matrices.

The second assessment is based on a hybrid general equilibrium framework –which incorporates the technological explicitness of bottom-up energy system models for the electricity sector (in addition to the conventional top-down models). The hybrid CGE model is an extended version of the standard CGE model used in the first assessment. The construction of a hybrid CGE model is essential since the targeting sectors in this assessment are those of energy specific. More specifically, a hybrid CGE model can enable us to identify the magnitudes of the carbon taxes (renewable subsidies) on energy supply-demand and to reconcile divergent results between the bottom-up engineering and macroeconomic top-down perspectives. The core modifications in the hybrid model from standard CGE model are as follows:

1) We separate the nested production structure between energy and non-energy producing industries by which we allow the substitution possibilities between energy and production factors as well as inter-fuels.
2) In the refinery sector, we permit a single-to-multiple relationship between refinery industry output (and price) and its relevant commodity supply (and price).
3) In the electricity sector, we explicitly include the generation technologies – i.e. fossil fuels generation, hydro generation, and geothermal generation – to allow switching possibilities among these technologies.
4) We incorporate carbon emissions accounting and its taxation features.
5) We add the households' welfare and inequality measure.

The hybrid CGE model is calibrated to the hypothetical Energy-SAM dataset for Indonesia in year 2008 including emission factors and population data. This hypothetical SAM is an extended version of the official SAM for Indonesia in the year 2008. The extensions are as follows:

1) We disaggregate the specific energy accounts (both industries and commodities) from their aggregated account.
2) We characterize the activity-commodity relationship for each energy type, i.e. a refinery sector is permitted to produce multiple types of petroleum products, and multiple types of generation technologies produce a homogenous electricity commodity.
3) We disaggregate the natural resources factor from the capital account to represent the 'fixed factor' resources input such as water debits to generate hydro turbines, and hot dry rock to generate geothermal-based electricity.

Organization of the Study

The first chapter ‘Overview of Indonesian Economy’ presents Indonesia’s macroeconomic outlook related to economy’s growth, inflation, poverty, and employments; targets and challenges of fiscal policy in general terms; fiscal policies towards sustainable environment; and Indonesia’s energy outlook. This chapter is the fundamental background of initiating our research studies.

The second chapter ‘Social Accounting Matrix (SAM)’ presents the principles and schematic frameworks of the SAM. The chapter also discusses the preliminary modification of the official SAM for Indonesia in year 2008 such that it is fitted to calibrate the standard CGE model. This modification is aimed to simplify the Indonesian SAM structure since some of accounts are too specific and are not utilized in the standard CGE model.

The third chapter ‘The Standard Computable General Equilibrium (CGE) Model’ discusses definitions as well as the construction of the standard CGE model. This chapter also includes the closure choices to equalize the total number of equations and endogenous variables such that the equilibrium condition is obtainable.

The fourth chapter ‘Simulation and Discussion Results of Standard CGE Model for Indonesia’ presents the background and motivation of our first study in examining the impact of exogenous fiscal policies on the Indonesian main macroeconomic indicators and the implications on different institutions and sectors in the economy. This chapter also discusses the fiscal policy scenarios using the standard CGE model developed in Chapter 3 that is calibrated to the SAM database outlined in Chapter 2. Each scenario quantifies the implications of expanding the public spending on goods and services on Indonesia’s economy at macro level, industry level, and households’ level. A sensitivity analysis of the results is performed.

The fifth chapter ‘Constructing Indonesia’s Energy-SAM’ presents the background and the construction of the hypothetical Energy-SAM dataset. This chapter details the steps of developing the Energy-SAM from the official SAM for Indonesia outlined in Chapter 2. The issues and limitations to build this dataset are also discussed in this chapter.

The sixth chapter ‘The Extended CGE Model for Specific Energy Analysis’ discusses the background and the development of the hybrid CGE model for specific energy analysis with emphasis on reducing (and promoting) the fossil fuels (and clean energy) production. The hybrid CGE model is the extended version of the standard CGE model developed in Chapter 3. This chapter presents in details the steps of constructing the energy flows across industries and the carbon emissions and its taxation features; including the required modifications to the other block of equations. This chapter also presents the closure choices to equalize the total number of equations and endogenous variables.

The seventh chapter ‘Policy Experiments using the Hybrid CGE Model for Energy Analysis in Indonesia’ presents the background and motivation of our second study in investigating the impact of implementing the carbon tax and feed-in tariff on the main macroeconomic indicators and the implications on different institutions and sectors in the Indonesian economy. This chapter also discusses the carbon tax and feed-in tariff policy scenarios using the hybrid CGE model developed in Chapter 6 that is calibrated to the database outlined in Chapter 5. Each scenario quantifies the implications of implementing the carbon tax (or feed-in tariff) on national emissions, Indonesia's macroeconomic, sectoral output and commodities, and households' welfare and inequality. A sensitivity analysis of the results is also performed.

Finally, the eighth chapter 'Conclusions' summarizes the main results, underlines this research limitation and suggests future improvements of research.

Chapter 1

An Overview of the Indonesian Economy

1.1. Introduction

This chapter aims to briefly discuss the four main areas of Indonesia's economy that fundamentally become the background of our research studies. These areas are organized as follows. In Section 1.2, we present an outlook of the Indonesia's macroeconomic – in terms of national income-expenditure, institutions' consumption, and households' welfare – over recent years. In Section 1.3, we highlight the fiscal postures in general including challenges and targets of fiscal policy. In Section 1.4, we discuss the specific fiscal policy related to environmental function budget towards sustainable development in order to support the Indonesia's commitment – under the United Framework Convention on Climate Change (UNFCCC) – to lower the emissions generated from energy consumption by 26%. Section 1.5 presents the outlook of Indonesia's energy sector in order to provide references about the national energy pattern in terms of both current conditions and future projection. Finally, Section 1.6 presents the conclusions.

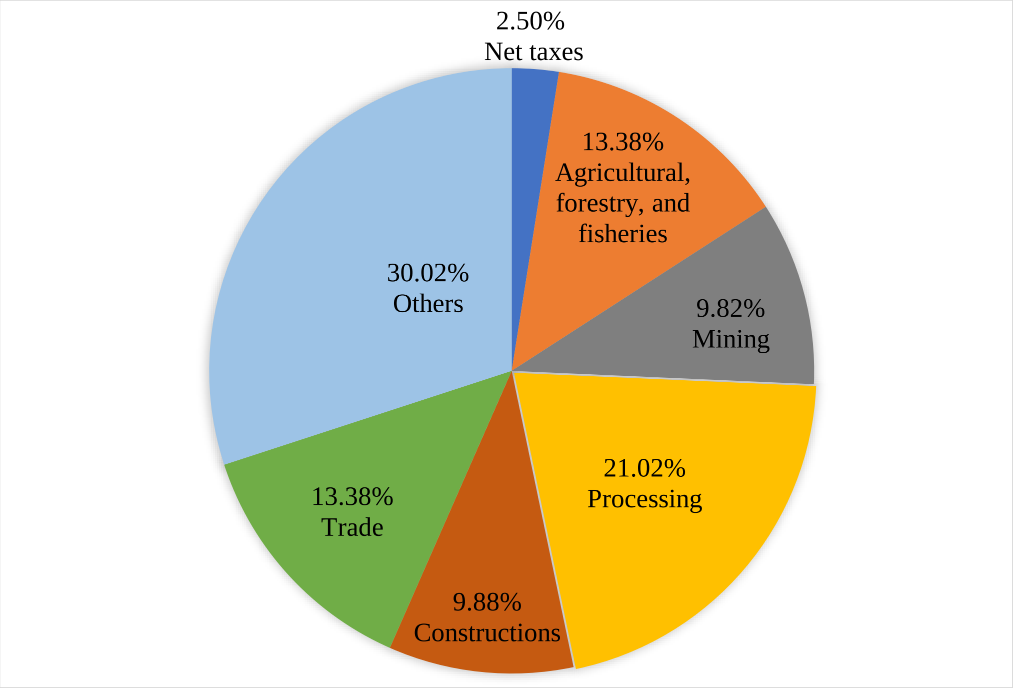
1.2. Indonesia's Macroeconomic Outlook

Indonesia – the world's largest archipelago and the fourth most populous nation – has charted a strong economic growth since the Asian financial crisis in mid-1997. Even after the global financial crisis in year 2008 – 2009, the Indonesian economy was still capable to grow about 4.5%, which ranked as the third-fastest growing country in the G-20 (Francis, 2012; and Financial Note, 2011). However, according to BPS (2015a), since the last 5 years, the Indonesia's economy tends to grow slower. In 2011, the GDP growth was around 6.17%; but it was growing flatter during the period of 2012 - 2015 which only about less than 6%. The downward trend of GDP growth is influenced mostly by the slow global economy's recovery – which results in a decline in investment and exports as well as a higher inflation rate due to the increased price of subsidized gasoline in year 2013 and domestic currency depreciation. The economy's growth in year 2015 (around 5.4 – 5.8%) are induced by government consumption and investment especially on public infrastructure development.

On the sectoral side, in general, all sectors are expected to grow in year 2016 due to improvement in global economy which induces a higher demand for domestic products (Financial Note, 2016). The GDP at producer prices, in 2016, will be mostly dominated by processing, agricultural, trade, and construction industries which contribute about 57% to total GDP (Financial Note, 2016). These sectors are expected to grow sharply because of the following reasons. The processing industry – i.e. food and drink sectors, which contributes about 21% to total GDP, is expected to grow about 5.7% due to their typical labour-intensive sector that could favor the job creation absorption (Financial Note, 2016).

The agricultural industry, which contributes about 13.7% to total GDP, is expected to grow about 4.2% due to the government's main objective to achieve national food sovereignty (Financial Note, 2016). The agricultural sector also plays an important role as a labour-intensive sector. According to World Bank (2009), this sector could absorb employment to more than 40% of total Indonesian labour force and does provide income to two-thirds of total poor households. Furthermore, the trade sector, which contributes about 13%, is expected to grow by 4.8% due to world's economy recovery since 2008's crisis that would improve international trade (Financial Note, 2016). Whilst, the construction sector is expected to grow about 7.0% due to the ongoing government's project of constructing 35 Gigawatts electricity generation infrastructure and a million housing construction for low-income households (Financial Note, 2016). In contrast, mining industry had the smallest contribution to GDP at producer prices where the growth sharply declined from 4.29% in year 2011 to only about 0.55% in year 2014. This large contraction is caused by the mining export restriction as well as their low (high) international demand (price) (BPS, 2015a). Table 1.1 presents the sectoral contribution on GDP at producer prices in the year 2014.

Figure 1.1:The Sectoral Shares on GDP at Producer Prices, 2014



Source: BPS, 2015a

In terms of GDP at market side components, the household consumption (including non-profit households) still indicates the largest growth in year 2014 by about 17.57%; followed by investment (4.12%), import (2.19%), government's consumption (1.98%), and export (1.02%). The increasing trend of household consumption is mainly due to the existence of presidential election as well as expansion of demand for vehicles and electricity. Meanwhile, the government's consumption has reached the lowest growth in year 2014 because of the current regulation of public spending efficiency; this contraction was suggested to be one of the main factors of GDP growth weakening (BPS, 2015a). The growth of exports has declined over the last 5 years from 14.77% in year 2011 to only about 1.02% in year 2014 which was mainly caused by the restricted mining export regulation. While, import growth has tended to expand due to (i) higher demand on imported gasoline, foreign capital, and raw materials; (ii) higher purchasing power of households; and (iii) domestic currency depreciation (BPS, 2015a).

In Indonesia, inflation has always been occurred annually, although the patterns fluctuated due to a number of factors. Between the year of 2011 – 2012, the inflation rate was low (about 3.7%). This was influenced by the decline in global food prices and a regulation delay of elevating the electricity and subsidized gasoline prices (BPS, 2015a). However, between 2013 and 2015, the inflation rate was sharply higher within the range of 5.0% – 8.4% that was subject to the increasing trend of food and energy commodities demand in both international and domestic markets (Financial Note, 2016). The world's economic recovery is suspected to play an important role in boosting the demand in international markets (Financial Note, 2016). Whilst, from the supply side, the geopolitical tensions that occurred in Middle East, North Africa and South Africa would strongly affect the supply, especially fossil fuels, in the international market (Financial Note, 2016). Internally, climate change (and natural disaster) is the most potential factor to induce the future inflation rate for which climate change could distort the production (and the distribution) of foods (Financial Note, 2016). In attempts to ease the fiscal pressures on the budget deficit and the national economy, the government is committed to maintain the stabilization of the prices of food and energy products through improving the food supplies (facilities and distributions) from agricultural sectors (Financial Note, 2016).

Furthermore, in year 2014, the poverty rate reached about 11.25% which was slightly lower than that of year 2013 (11.36%) (BPS, 2015a). However, the number of poor households actually increased from 28.07 million people in year 2013 to about 28.28 million people in year 2014 and 28.59 million people in year 2015 (BPS, 2015a; BPS, 2015b). Indonesia's poverty line – defined as the minimum budget to meet the subsistence level of consumption – has increased from Rp. 271, 626 to Rp. 330,776 during the period 2013 – 2015. The rate of poverty in rural areas reached almost two folds higher than in urban areas. In addition, in year 2015, the inequality among poor households, measured from the Poverty Severity Index[1], increased significantly; inequality among poor households is greater in rural than in urban areas (BPS, 2015b). It is argued that this increasing trend of poverty was influenced by the output contraction in agricultural sector

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[1] Poverty Severity Index is one of the approaches to estimate the expenditure inequality among poor households (Bappenas, 2015).

which results in a reduction of employment demand (BPS, 2015a). The government has set a national target of poverty rate in year 2016 between 9.0% and 10% (Financial Note, 2016). To reach this target, several key strategies will be implemented including (i) improvements in government transfer to the poor households regarding to social aid programs such as health insurance, food subsidy, aid distribution to the victims of natural disasters, and social protection; and (ii) agricultural reform.

Employment can also be used as an indicator of people's welfare (Financial Note, 2016). Based on BPS (2015b), the Indonesian labour force during the period 2011 – 2014 tend to increase from 116.09 million people to 121.87 million people; in other words, the annual growth of labour force was about 1.63%. This increase is influenced by the increasing growth of population by around 1.3% annually. During the period 2012-2013, the number of unemployed increased from 7.34 million people to 7.41 million people. In year 2014, the opened unemployment rate in urban areas (7.12%) is higher than that in rural areas (4.81%). This implied that job creation in urban areas is insufficient to absorb the large number of labour forces; also, there is a tendency of strong urbanization resulting in excessive labour supply in cities (BPS, 2015b). To address these issues, the government has taken some bold strategies including: (i) improving the quality of the labour force, especially the poor workers, through technical training provided by industry partnership programs; and (ii) intensifying the development of basic infrastructure, focused on labour-intensive projects, in rural and urban areas to absorb the local workforce (Financial Note, 2016).

1.3. Targets and Challenges of Fiscal Policy

Fiscal policy plays an important role in stabilizing the aggregate demand and fostering the national income (Romer, 2001; Vladimirov and Neicheva, 2008; Maipita *et al*., 2010). It can directly intervene in correcting market failure and income distribution (Griffiths and Wall, 1997; Damuri and Perdana, 2003). The effectiveness of government intervention to improve the economy's performance is highly dependent on their fiscal sustainability. For instances, if the government increases its expenditure, then the financing schemes could be done through several channels, i.e. increasing the tax revenues, increasing the debt, reducing subsidies, or reducing transfer of payments to certain institutions.

The Indonesian government recently faced uncertainty in their fiscal sustainability (Ikhsan *et al*., 2005). According to World Bank (2009) and BPS (2015a), during the period of 2006 – 2014, total government expenditures increased by about 12% annually in real terms, which related to (i) a sharp rise of government transfers to regions that accounted for one third of central government spending; and (ii) a sharp rise in fuel subsidies following a large increase in its international oil prices. The spending was financed mainly by large increases in non-oil and gas tax revenues which increased from 9.6% of GDP in year 2001 to 11.7% in 2008; meanwhile, the revenues from oil and gas taxes sharply fell from around 6% of GDP in year 2001 to only about 2% of GDP in year 2009 due to a contraction in the international oil prices (World Bank, 2009).

Word Bank (2009) stated that there are at least 5 sectors that should become a priority target in the government spending over recent years, including education, health, infrastructure, agriculture, and government administration. Government spending on education covered about 20% of public expenditures. Apart from its successful achievement in improving the levels of schooling, however, more progress is required to improve human resources, quality of teaching, maintaining school infrastructures, and transition rates to the secondary level (World Bank, 2009). Between 2001 and 2008, public spending on health more than doubled, from about Rp. 16 trillion to more than Rp. 36 trillion in real terms (or about 0.9% of GDP in year 2008). However, the coverage of health insurance is still low; only about 26% of the population who benefited the health insurance. The rates of maternal mortality as well as child malnutrition remained high (World Bank, 2009). Furthermore, total investment (public and private) on infrastructure – especially in the energy sector – remained very low which only about 4.1% of GDP in year 2007. For comparison, in some of Indonesia's regional peers, such as China and Vietnam, total investment on infrastructure reached about 10% of GDP. The poor condition of Indonesia's infrastructure can result in higher business costs, blackouts across the country due to inadequate electricity supply and major health risks due to a limited access to clean water and improved sanitation (World Bank, 2009). To address these issues, the government has included infrastructure, i.e. electricity sector, as a top priority since 2006. Together with private investment, the government has committed to develop 10,000 MW of coal-fired power plants (World Bank, 2009). Government spending on the agricultural sector has increased on average by 16% annually between the period of 2001 – 2008 where half of the budget was directed to agricultural subsidies, especially for fertilizer. However, agricultural productivity has not grown at the same pace as the allocated budget; while value-added per worker remained flat. Finally, in order to address both corruption and administration inefficiency, the government has also been rapidly improved its public services in recent years. Since 2006, spending on government administration has stably increased about 14% of total expenditure of which 83% of the shares were allocated to the sub-national governments (World Bank, 2009).

On the other hand, the government debt has increased by around 1.3% on annual average, from US$ 132 billion to US$ 151 billion since the last ten years. However, the debt burden (as percentage to GDP) has dropped significantly due to the increase in national output and government revenue. For example, the debt to GDP ratio dropped from 90.9% in 2000 to only 33.1% at the end 2008 while the government revenues increased by 14% annually (World Bank, 2009).

The revenues generated from oil and gas are strongly correlated to the government expenditure on energy subsidies (World Bank, 2009). For example, in 2005 and 2008, government spending for energy subsidies made up more than two thirds of their revenues on oil and gas (World Bank, 2009). Most of subsidies, fuel, electricity, and agriculture goods, are found to be regressive. They mostly benefit rich households. Therefore, to address the fiscal burden of subsidies, in 2015, the Indonesian government has targeted to lower their spending on fuel subsidies by about half, from Rp. 415 trillion to only around Rp. 233 trillion (BPS, 2015a). The government would then switch their fiscal priority from fuel subsidies to investment in public infrastructure in rural areas, by increasing the budget more than two fold from Rp. 9 trillion to Rp. 21 trillion; other priorities include maritime, foods, and energy sectors – i.e. constructing a number of ports and achieving the electricity production target about 25,000 MW (BPS, 2015a).

In 2015, the budget deficit reached the level of 2.5% of GDP (or about Rp. 292.1 billion), which exceeded the target of 1.9% of GDP. This increase was influenced by a contraction in government revenue and in expansion in spending caused by the global recession (Bank of Indonesia, 2015). The increased deficit was financed through raising the bonds selling and loans which resulted in a higher level of borrowing ratio to GDP of about 26% (Bank of Indonesia, 2015).

Aside from subsidy cuts, to address such burdens, Indonesia's government has no other choice but to increase the tax revenues (Ikhsan *et al*., 2005). This increase can be achieved either through improvement in taxation administration – i.e. reducing tax avoidance or optimizing the collection from registered tax payers – or by increasing the tax values through higher rates (Ikhsan *et al*., 2005). Since the postcolonial-tax reform in 1985, the Indonesian tax system was based on income tax and a value added tax (Ikhsan *et al*., 2005). The government receipts from taxes collection increased from 5% of GDP to 9.9% of GDP between the year of 1995 – 1996 and remained considerably stable by about 13.3% until 2008 (Amir *et al*., 2013). The revenues from income taxes (including personal and corporate) and value added taxes (including luxury sales taxes) strongly increased from Rp. 0.9 billion and 0.4 billion between the year of 1980 – 1981 to Rp. 327 trillion and 209.6 trillion in 2008, respectively; or equivalently about 23.3% and 32%, respectively, of total revenues (Amir *et al*., 2013). Both taxes contributed more than 81% of total tax revenues or 55% of total government's receipts in year 2008. At the same time, however, the revenues from oil and gas has fallen from 72.9% to 32.1% (Amir *et al*., 2013). Although the Indonesian tax revenues have a tendency to improve, however, the tax revenue ratio rates (as a percentage of GDP) is still low compared to other countries (Ikhsan *et al*., 2005); which indicates an opportunity to increase the government receipts through tax administration improvement without having need to increase their rates. According to World Bank Statistics (2015), the Indonesian tax ratio to GDP was lower (11.4%) than that average of low and middle income countries (12.85%) in year 2012.

1.4. Fiscal Policies towards Sustainable Environment

As an archipelagic nation, Indonesia is vulnerable to threats of climate change– such as prolonged droughts, extreme weather events, and heavy flooding – which could harm the population (Resosudarmo and Abdurohman, 2011). Table 1.1 shows the unscaled amount of GHG emitting in some countries to present a large majority of global GHG emissions (70% of the global population) generated in absolute terms at a particular year. In general, it shows that countries with large economies and (or) population tend to produce the largest GHG emissions even though their emissions per capita may be small (Baumert *et al.*, 2005).

Indonesia was ranked 15th among the top 25 countries with the largest GHG emitters in year 2000 (Baumert *et al.*, 2005)[2]. In fact, if CO_2 emissions generated from land use and non-CO_2 gases are included, Indonesia ranks 4th in total emissions; Indonesia ranks 21th when only CO_2 emissions from fossil fuels are taken into account (Baumert *et al.*, 2005). The main sources of CO_2 emissions are generated from deforestation (48%), energy sector (21%), and peatland (12%); total Indonesia's GHG emission in year 2000 was 1.72 Gigaton (Gt) CO_2e and it is projected to reach 2.95 Gt CO_2e under the business as usual scenarios (NCCC, 2009). Although the largest shares of emissions derived from deforestation and land use change, however, the emissions from the fossil fuel combustion will keep growing as GDP grows, which will cause severe problems in long-run (MEMR, 2011; and Ministry of Finance, 2012).

At the 15th conference of the parties (COP15) in Copenhagen, the Indonesian government has committed to reduce the greenhouse gas (GHG) emissions by 26% (about 767 million tCO_2e) from the 'business as usual (BAU)' level in year 2020. The guidance to this mitigation policy is provided in the National Action Plan on Greenhouse Gases Emission Reduction (RAN-GRK), as defined in the Presidential Regulation Number 61/2011. More specifically, the RAN-GRK is used as a reference for (i) implementing the emissions reduction by priority areas or sectors at the national and regional levels; (ii) investment to mitigate the emissions; and (iii) strategies and action plans to reduce the GHG emissions by regions (Ministry of Finance, 2012).

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[2] In terms of emissions per capita, Australia, United States, and Canada generated the highest per capita emissions globally that ranked 4th, 6th, and 7th (Baumert *et al.*, 2005). Their emissions per capita are more than doubled to the EU (37th globally), six times to China (99th globally), and thirteen times to India (140th globally). On the other hand, Indonesia was ranked 122th globally. To investigate in details the GHG emitting countries – such as emissions per capita, emissions per GDP, emissions per income, etc – see Baumert *et al.*, 2005.

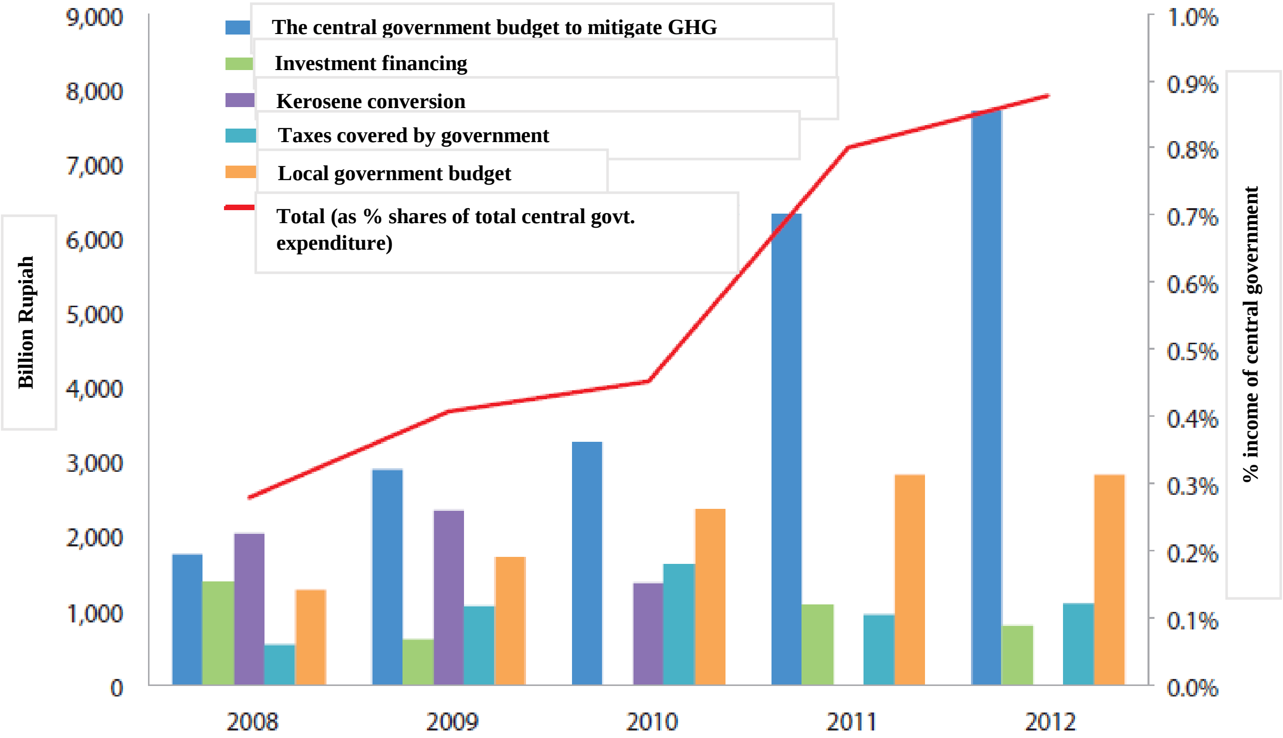
Table 1.1: Top GHG Emitting Countries in year 2000

No.	Country	Million ton CO_2 equivalent	% of World GHGs
1	United States	6,928	20.6
2	China	4,938	14.7
3	EU-25	4,725	14
4	Russia	1,915	5.7
5	India	1,884	5.6
6	Japan	1,317	3.9
7	Germany	1,009	3
8	Brazil	851	2.5
9	Canada	680	2
10	United Kingdom	654	1.9
11	Italy	531	1.6
12	South Korea	521	1.5
13	France	513	1.5
14	Mexico	512	1.5
15	Indonesia	503	1.5
16	Australia	491	1.5
17	Ukraine	482	1.4
18	Iran	480	1.4
19	South Africa	417	1.2
20	Spain	381	1.1
21	Poland	381	1.1
22	Turkey	355	1.1
23	Saudi Arabia	341	1
24	Argentina	289	0.9
25	Pakistan	285	0.8
Top 25		**27,915**	**83**
Rest of World		**5,751**	**17**
Developed		**17,355**	**52**
Developing		**16,310**	**48**

Note: Emissions from international bunker fuels and land use change and forestry are excluded.
Source: Baumert et al., 2005

According to the RAN-GRK, the 26% reduction target of GHG emissions is broken down into sectoral reduction targets, in which the emissions from (i) forestry and peatland are expected to decline the most by 672 million tCO_2e; (ii) energy and transport by 38 million tCO_2e; and (iii) agriculture, industry, and water sectors cover the remaining target. These action plans will be associated with the government budget allocations. In year 2012, the central government budget for mitigation actions was about Rp. 7.7 trillion (less than 1% of total expenditure) or about four times than the budget allocation in year 2009. The budget is mainly aimed to achieve sustainable forest and peatland. The local government budget for mitigation financing was about Rp. 3 trillion. In addition, between the year 2008 – 2012, the government spent about Rp. 5.5 trillion for conversion program from kerosene to LPG; and a further allocation of about Rp. 5.3 trillion tax subsidy in order to support the mitigation activities, especially for geothermal and biofuels production. In total, the budget for the RAN-GRK actions was about Rp. 15.9 trillion in year 2012. Figure 1.2 presents the trends of funding sources for climate change mitigation during the period 2008 – 2012 (Ministry of Finance, 2012). However, it has been argued that if the budget allocation for climate change mitigation from 2012 is kept constant until 2020, thus, the budget would only be able to reduce the GHG emissions by about 15% (116 million tCO_2). In other words, to achieve the emission reduction target of 26%, the government requires more budget allocation to fill the gap of 11% (Ministry of Finance, 2012).

Figure 1.2: The Trend of Budget Allocations for Climate Change Mitigation



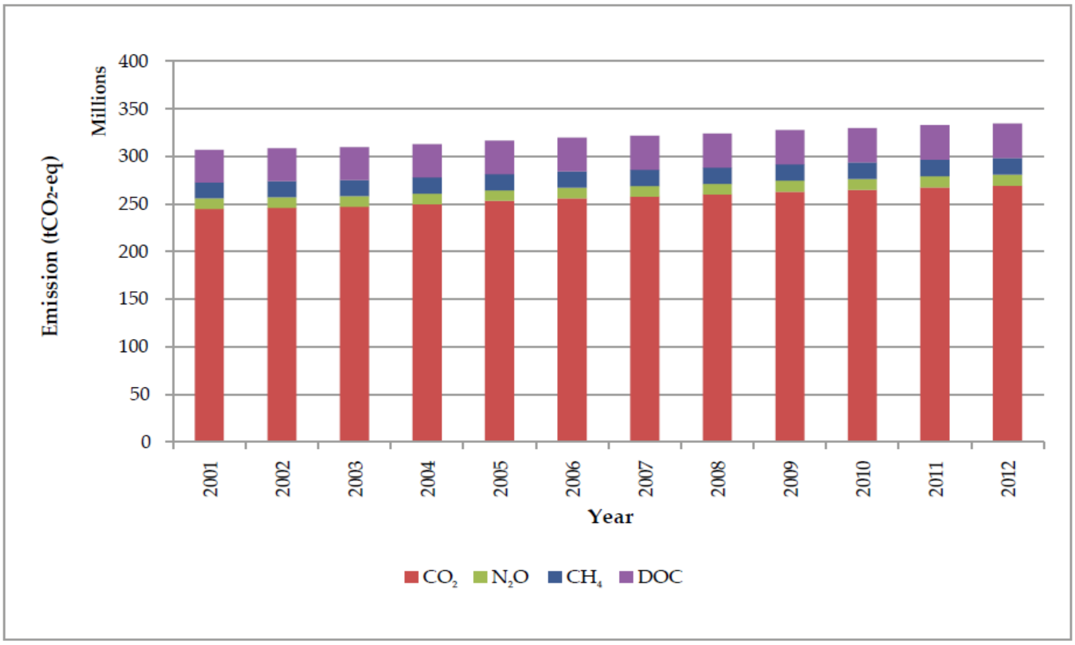
Source: Ministry of Finance, 2012

1.4.1. Emissions from Deforestation and Peatland

Deforestation contributes the largest share of national GHG emissions. Emissions from deforestation are mainly due to land clearing activities including conventional logging (62%) and intense fires (38%) (Ministry of Environment and Forestry, 2015). In 2012, forest degradation (about 1.1 million ha/year) contributes about 450 million tCO_2e of GHG emissions or about 59% of the total net emissions from Land Use, Land Use Change and Forestry (LULUCF) including peatland (Ministry of Finance, 2012). Deforestation usually occurred in production forests (44%), forested land (43%), as well as conservation and protection forests types (13%) (Ministry of Environment and Forestry, 2015).

Meanwhile, the emissions from peatland are mainly caused from the biological oxidation that generates not only CO_2 but also direct N_2O, dissolved organic carbon (DOC) and methane (CH_4) emissions. Figure 1.3 shows the GHG emissions from peatland in Indonesia during the period 2001 – 2012. In total, these emissions increased from about 307 million tCO_2e in year 2001 to about 335 million tCO_2e in year 2012. Regionally, the provinces of Riau, Central Kalimantan and Papua contributed to more than 60% of total GHG emissions from peatland in Indonesia. In addition, peat fires may also contribute to total emissions from peatland in Indonesia, although they substantially fluctuated between the year 2001 – 2012. The largest incidence of peat fires occurred in 2002 and 2006 which contributed to about 180 – 183 million tCO_2e (Ministry of Environment and Forestry, 2015).

Figure 1.3: Indonesia's GHG Emissions from Peatland



Source: Ministry of Environment and Forestry, 2015

According to Ministry of Finance (2012), in order to curb the GHG emissions from forestry, the local government of Indonesia has taken actions to limit deforestation, including restrictions on road construction in new forest areas, from 1.1 million ha/year (generating about 440 million tCO_2e/year) to 450,000 ha/year. These actions will reduce about 260 million tCO_2e lower than the BAU scenario in 2020 or equal to 34% GHG emissions reduction target. However, these restrictions will reduce profits (private sector) due to less timber exploitation and deforested land; and (relatively small) costs to the government due to license and royalty losses. On the other hand, to reduce emissions from the peatland, the government has supported peatland restoration by rewetting the peatland through canal blocking, which could potentially reduce the GHG emissions from 18 to 9 tCO_2/ha/year. This restoration effort, however, was found to be ineffective because of its high uncertainty (Ministry of Finance, 2012). The simple canal blocking appeared to be less beneficial unless it is combined with other techniques that can ensure the sustainability results. Therefore, the peatland restoration approach is currently being reviewed to develop better models.

1.4.2. Emissions from the Energy and Transportation Sectors

Total GHG emissions from the energy sector are suspected to grow rapidly, from 598 million tCO_2e (28% of total national emissions) in 2014 to about 2,900 million tCO_2e in 2050 in the base scenario, or about 3,829 million tCO_2e in the high scenario[3] (BPPT, 2016). The largest emissions contributor is the high rate of fossil fuels combustion in industrial activities that reached around 5.1% on growth rate average per year, with coal accounting for 56% of total fuel consumption. Ministry of Finance (2012) argued that by promoting clean energy production and reducing fossil fuels dependence at current roadmap, the emissions from electricity industry are most likely to be reduced by 26%. If this is achieved, the total national emissions can be cut by around 14% or about 104 million tCO_2e in year 2020. This target, however, requires additional funding at least one third of the total budget either through some joint financing schemes or fiscal compensations.

In a Ministry of Finance (2009) green paper, the government proposed a longer-term strategic framework in order to mitigate the GHG emissions from the energy sector. Some key strategies that related to this sector are given as follows:

1. Imposing a carbon tax on fossil fuel consumption and, at the same time, removing energy subsidies. The levies on fossil fuel combustion has not yet to be implemented. However, the contribution of carbon tax is important since the GHG emissions from energy activities are expected to be increased in line with the economy’s growth in future.
2. Providing incentives for energy efficiency and zero (low) emissions technologies – such as promoting the renewable production. The subsidies on clean energy production has been introduced through the Feed-in Tariff schemes.

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[3] Based on BPPT (2016), the energy projections until 2050 are estimated on two different scenarios: base scenario and high scenario. In base (high) scenario, the Indonesian GDP between 2014 – 2050 is assumed to be increased at average growth rate 6% (7%) per year. GDP growth in year 2014 (5.02%) is projected to be increased by 7% (8%) in year 2025 and then slowly reduces until 5% (6%) in year 2050. These projection trends are in line to the projections given in the national development plan (RPJMN) 2015-2019.

3. Supporting the carbon market mechanisms, such as sectoral carbon targets and crediting, through domestic and international funding. This strategy has been under discussion due to constraints over measurement, reporting, and verification.
4. Strengthening the budget capacity for climate policy coordination. This strategy is important to improve the budget capacity for climate change mitigation and adaption through environmental conservation and renewable energy promotion.

Furthermore, according to Ministry of Finance (2012), land transportation accounted for almost 50% of total fuel demand; and 90% of this consumption are given from the road transportation. Vehicle ownership such as car, bus and lorry, and motorcycle are growing annually by about 12%, 11%, and 17%, respectively; while the growth of urban roadways is less than 1% per year. These patterns generated air pollution which contributed between 60% - 80% of national air pollution. The increased congestion in capital city has also led to an increase in fuel consumption by about 930 million litter per year.

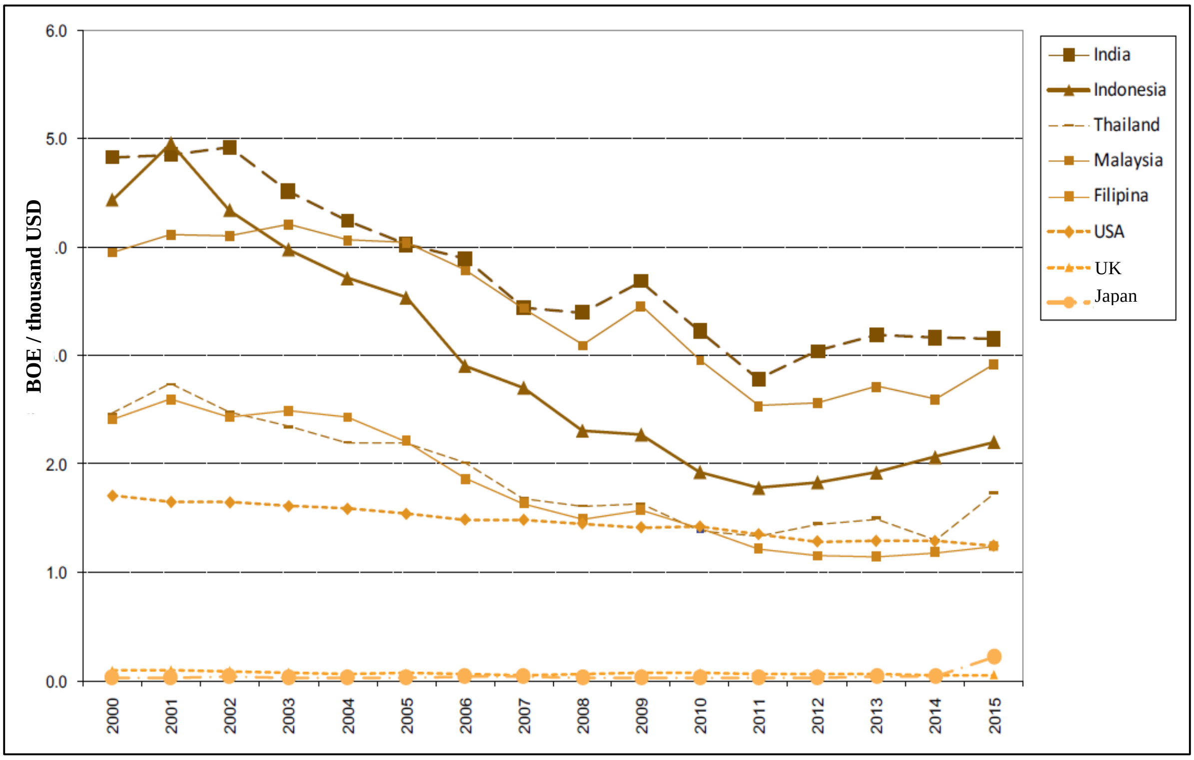
The government of Indonesia has been developing the long term plan to achieve a reliable, sustainable, competitive, affordable, and safe transportation in all sites of the country. This plan includes investment support to public transportation infrastructure, especially in urban areas, which is environmentally friendly and efficient. The government is also considering to support energy diversification in transportation sector from fuels to biofuels and gas.

1.4.3. Energy Outlook

Until date, Indonesia still faces great challenges to reach the target of an evenly distributed energy development. Indonesia’s energy supply has been strongly dominated by fossil fuels (96%), while only 4% energy supply from zero emission (renewable) sources – mostly from hydro and geothermal (National Energy Council, 2014; Ministry of Finance, 2012). On the other hand, fossil energy reserves declined over time which was not offset by new reserve discoveries. Poor development in energy infrastructure also limits the public accesses to energy. These conditions have made Indonesia very vulnerable to disturbances in global energy markets especially at her current position as net-oil importer (National Energy Council, 2014).

Both energy intensity (energy consumption per GDP) and energy elasticity (the percentage of energy consumption growth per GDP growth) are often used to indicate the effectiveness of an economy’s activities in a country (MEMR, 2010; Burakov, 2016). Figure 1.4 compares Indonesia’s energy intensity to some developed and developing countries. It shows that the Indonesia’s energy intensity was more than 2 BOE/thousand USD in year 2015. This implies that Indonesia’s GDP (at producer prices) is influenced mostly by energy-intensive industries (MEMR, 2010). In contrast, the energy intensity in developed countries, i.e. Japan, United Kingdom, United States, reached only between 0 – 1 BOE/ thousand USD in year 2015. Figure 1.5 presents Indonesia’s energy elasticity compared to other countries. The energy elasticity of Indonesia in year 2009 was the highest reaching almost 1.4[4]. While other countries were only less than 0.7. This implies that, in Indonesia, to increase economic growth by 1%, the percentage of the required energy consumption was higher than 1%. According to the National Energy Plan (2014), Indonesian energy elasticity target of less than 1% should be achieved in year 2025.

Figure 1.4: Primary Energy Intensity in some Countries



Source: BP Statistical Review of World Energy, World Economic Outlook, and IMF in MEMR (2016)

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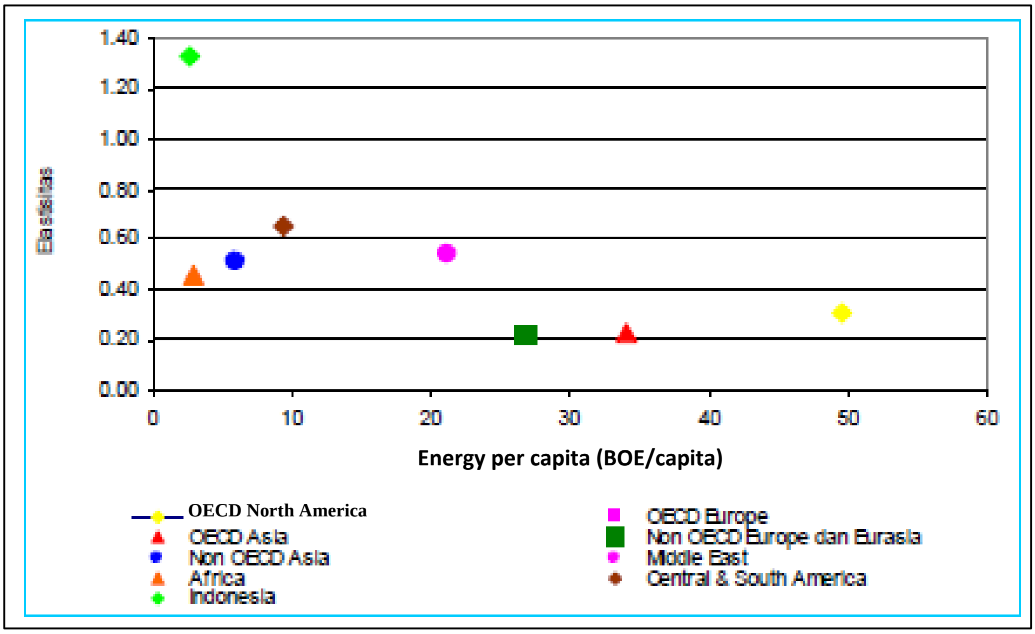
[4] To our findings, the latest statistic of Indonesian energy elasticity compared to other countries was in year 2009. In addition, the Indonesian energy elasticity between 1985 and 2000 was above 1 (1.04 – 1.35), which was higher than those of developed countries (0.55 – 0.65) at the same period (Koalisi Energi cited in Ardiansyah *et al* (2012).

Figure 1.5: The Energy Elasticity (2009)



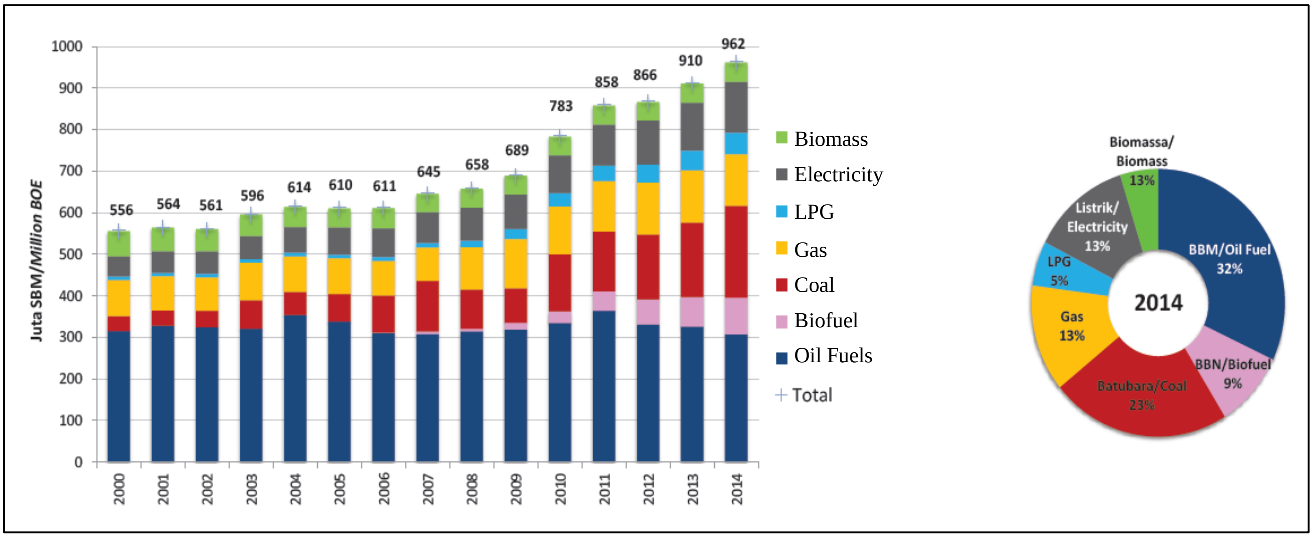
Source: World Energy Outlook, in MEMR, 2010

1.4.3.1. Current Energy Consumption

The Indonesian final energy consumption by sector increased during the period of 2000 – 2014, excluding 2005/06, from about 556 million BOE in year 2000 to 961 million BOE in year 2014 or an average of 4% per year (MEMR, 2015). The largest final energy consumption occurred in industrial sector, followed by households and transportation. However, in terms of annual growth, energy consumption in the transportation sector increased the most by average 6.46% per year due to a sharp increase in vehicle ownership, from 19 million units in 2000 to 114 million units in 2014. Whilst, the average growth of households' energy consumption is only about 1.59% annually due to the implementation of a government program to (i) substitute kerosene for Liquid Petroleum Gas (LPG) for cooking; and (ii) energy efficiency for equipment and technology such as energy-saving lamps and solar cells. Substituting kerosene to LPG leads to a lower energy consumption because the LPG has higher calories (53% efficiency) than the kerosene (40% efficiency) (BPPT, 2016).

By types, between the year 2000 – 2014, the final energy consumption was largely dominated by fuels (gasoline, diesel oil, kerosene, fuel oil, avtur, and avgas) by about 308 million BOE – 315 million BOE. In year 2000, the shares of diesel oil to total energy consumption was the largest (38.7%) followed by gasoline (23.0%), fuel oil (9.6%), diesel oil (3%), and avtur (2.2%) (BPPT, 2016). In year 2014, the shares of gasoline and diesel oil increased sharply by 45.5% and 45.2%, respectively, while diesel oil and avtur slightly dropped about 1.5% each (BPPT, 2016). These trends are due to the high consumption by private cars and airplanes; in the transportation sector, fuel consumption held the largest shares by 79.7% of total Indonesia's fuels consumption (BPPT, 2016). In industrial sector, the consumption of coal increased sharply from 361 million BOE in year 2000 to 220.6 million BOE in year 2014, an increase by an average 13.8% annually (BPPT, 2016). Electricity consumption between 2000 – 2014 had an average growth by 6.8% annually due to higher demand for electrical devices (BPPT, 2016). Figure 1.6 shows the Indonesian final energy consumption by type in year 2014.

Figure 1.6: Indonesia's Final Energy Consumption (and Shares) by Type (2014)



Source: BPPT, 2016

1.4.3.2. Current Energy Potential

In 2014, the national reserves of crude oil, natural gas, and coal were about 3.6 billion barrels, 100.3 TCF, and 32.27 billion tons, respectively. Without new reserve discoveries, these resources are expected to deplete in the next 12 years, 37 years, and 70 years, respectively. On the other hand, the potential of clean (renewable) energy resources has not yet been utilized optimally. As shown in Table 1.2, Indonesia has remarkable geothermal sources by around 28,543 MW or about 40% of the world's geothermal potential. However, their utilization is only about 7.54% of total potential. Total hydro resources reached about 75, 670 MW but only 4.17% of their potential have been utilized. The utilization of biomass is only about 3.25% of its total potential. Whilst, solar and wind resources have not yet been developed significantly MEMR, 2011).

Table 1.2:The Potential of Renewable Resources in year 2011

Types	Potential	Current Electricity Production	Utilization Percentage (%)
Geothermal	28,543 MW	1,189 MW	7.54
Hydro	75,670 MW	5,705.29 MW	4.17
Mini/Micro Hydro	769.69 MW	5,705.29 MW	28.31
Biomass	49,810 MW	5,705.29 MW	3.25
Solar	4.80 kWh/m^2/day	5,705.29 MWp	-
Wind	3 – 6 m/s	1.87 MW	-

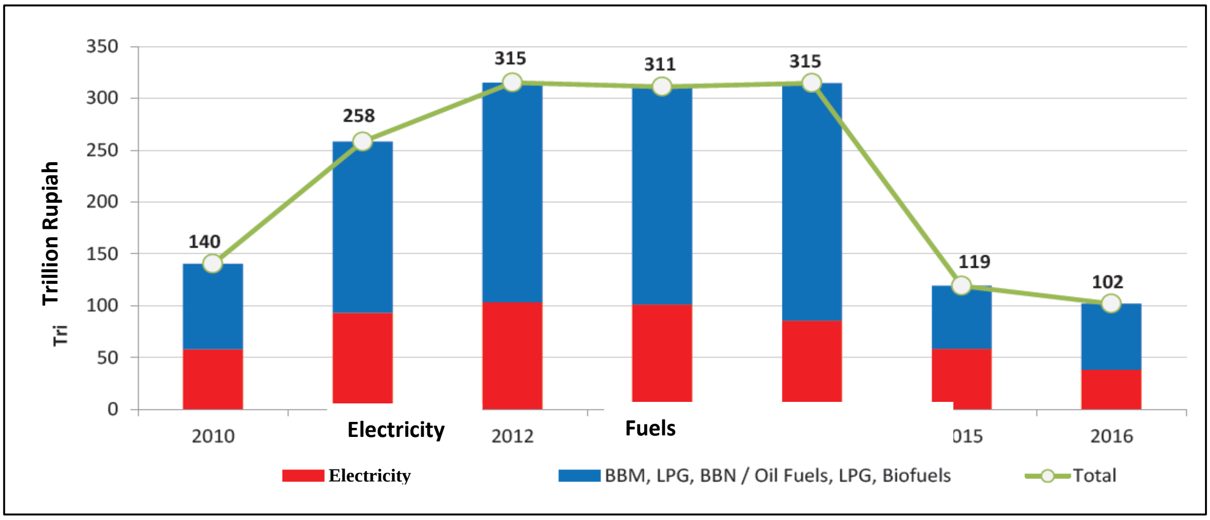
Source: MEMR, 2011

1.4.3.3. Recent Energy Policies

This section discusses a number of recent energy-related policies. In late 2014, the Indonesian government, through Presidential Regulation No. 191/2014, decided to reform the energy subsidies. The subsidy on gasoline was deleted, fuel oil subsidy was kept fixed at Rp. 1,000 per liter, and the electricity subsidy was reduced by eliminating the subsidies to the electricity customers by criteria: (i) households (≥ 1,300 VA); (ii) business ((≥ 6,600 VA); (iii) industry ((≥ 200 kVA); government ((≥ 6,600 VA), low voltage street lightning, and special services. This reform is due to the fact that energy subsidies had been a heavy burden on Indonesia's fiscal sustainability. These policies have reduced the government expenditure from Rp. 315 trillion in year 2014 to Rp. 119 trillion in year 2015, which is used to improve public infrastructure and services (BPPT, 2016).

To speed up the diversification away from kerosene, in 2015, the government developed a gas distribution network for households, which is stipulated in the MEMR Regulation No. 20/2015. This is implemented in residence areas that are available for natural gas distribution. The program also aims to substitute the LPG which is mostly imported. As a result, it increases the foreign exchange saving and energy security as well as reduces the national GHG emissions. In 2015, the gas network reached 213,132 households in Aceh, Riau, Jambi, South Sumatra, Jakarta and its surroundings, West Java, Central Java, East Java, East Borneo, North Borneo, South Sulawesi, and West Papua (BPPT, 2016).

Figure 1.7: Trend of Indonesia's Energy Subsidy



Source: BPPT, 2016

To improve the welfare of small-scale fishermen, the government set a particular regulation of LPG supply, distribution, and price for fishing boats of low-income fishermen. For one fishing boat size of less than 5 Gigatons, it is expected that this program could save about Rp. 37 million per year, assuming that the boat operates 10 hours per day (one-day fishing). From the year 2016 – 2021, the government plans to compensate the low-income fishermen by distributing freely 5,000 packages of LPG as well as fishing equipment (BPPT, 2016).

Biofuel mandatory is also one of the energy policies to support its large production, especially biodiesel, such that the fossil fuels dependence can be reduced. Since 2008, the government has obliged the biofuels mixture in gasoline and diesel oil. In 2015, the government required raised where the portion of biodiesel in the gasoline mixture from 10% to 15%, and again to 20% in 2016 and 30% in 2020. This biofuel mandatory changes are immediately followed by the enactment of oil palm funding for collection and utilization in order to encourage the palm oil plantation improvement as they are primarily used as raw materials of biofuel production. To support their domestic production, the export of palm oil, including its derivative products, will be taxed (BPPT, 2016).

Furthermore, a policy of waste utilization for electricity generation has also been set in the MEMR Regulation No. 19/2013; however, the policy still has weakness in pricing and operational schemes. As a replacement, the government sets the MEMR Regulation No. 44/2015 on power purchasing by the state-owned electricity company from the waste generation producer at the fixed feed-in tariff schemes. This policy is aimed to support the target of clean energy production as defined in the National Medium Term Development Plant for Year 2015 – 2019 (BPPT, 2016). At the end of 2015, the government stipulated the Presidential Regulation No. 15/2015 on Supply, Distribution, and Pricing of Gas for Road Transportation. In this regulation, the government allocates a budget to develop public fuel gas stations aiming to accelerate the substitution of gasoline with gas. Since the last 22 years, oil refinery has never been constructed, while fuel consumption continues to increase – i.e. the national fuel consumption has increased from 40 million kilo liters in 1994 to approximately 59 million kilo liters in 2014. Poor refinery infrastructure results in a higher import demand for fuels, especially gasoline and diesel oil, to meet domestic demand (BPPT, 2016). In Presidential Regulation No. 146/2015, the government has encouraged the establishment of new oil refineries as well as improvement of facilities in the existing refineries, which can be funded from fiscal and non-fiscal incentives, i.e. the reduction of various costs (taxes) during the construction and operation. To this end, the government agreed that new refineries will be built in Tuban (East Java), and Bontang (East Borneo), while the program of facilities improvement will be given to existing refineries (BPPT, 2016).

1.4.3.4. Conclusions

This chapter examined the trends of Indonesia's economy over recent years. By exploring the available information, it is revealed that Indonesia has a strong economic growth during the last two decades where the average GDP growth is between 5% – 6% per year. Even at the global financial crisis in period 2008 – 2009, the GDP growth can be maintained at level 4.5%, which ranked as the third-fastest growing country in the G-20.

However, Indonesia's government has been facing some uncertainty challenges that could harm their fiscal sustainability. Over recent years, the government budget for real public expenditure has been increased sharply due to an increase of transfer payments for regional development as well as a sharp rise in energy subsidies following a spike in international oil prices. The budget is mainly covered from non-oil and gas tax receipts since the revenues from oil and gas levies tend to decline annually. The government debt also tends to increase over the last decade which was influenced by a contraction (and expansion) in government revenue (spending) caused by global recession.

To maintain fiscal sustainability, the government plans to reduce the budget for fuel subsidies by a half, and to reallocate it for improving the public infrastructure in rural areas. Aside from subsidy cuts, Indonesia's government has also been targeting to increase the tax revenues which could be possibly obtained through either improvement in taxation administration or higher tax rates.

Furthermore, at the world's climate change mitigation event (COP15), Indonesia committed to participate in reducing their national GHG emissions by 26% from the BAU level (or about 767 million tCO_2e) in year 2020. To follow-up this commitment, the Indonesian government stipulated the guidance of mitigation policy in the National Action Plan on Greenhouse Gases Emission Reduction (RAN-GRK), as defined in the Presidential Regulation Number 61/2011. The RAN-GRK is used as a reference for (i) implementing the emissions reduction by priority areas or sectors at the national and regional levels; (ii) investment to mitigate the GHG emissions; and (iii) strategies and action plans to reduce the GHG emissions by regions. To meet the emissions reduction target, the emissions generated from forestry and peatland as well as energy and transportation sectors will be expected to decline by 672 million tCO_2e and 38 million tCO_2e, respectively. More specifically, the government introduced a carbon tax on fossil fuels consumption as well as incentives to promote clean energy production through feed-in tariff schemes as one their key strategy framework to curb emissions from energy sectors.

Chapter 2
Social Accounting Matrix (SAM)

2.1. Introduction

A Social Accounting Matrix (SAM) is an essential data set to numerically calibrate the macro models in a convenient format. It is an extended version of the input-output table, for which it integrates detailed information on income distribution for institutions, production factors, and capital accumulation (BPS, 2008). Because a SAM represents the circular flow of economic transactions, it can then be used to investigate the effects of exogenous shocks or injections on endogenous account using a general equilibrium approach. For instance, an increase of demand in a specific sector in a SAM will affect the whole system through a multiplier process (Thorbecke, 2000). In CGE models, a SAM is used to calibrate the initial equilibrium condition and compare its shifting state induced by changing the exogenous variables (Yusuf, 2006).

This chapter aims to present the principle of a SAM in general and its framework for Indonesia. It also discusses the preliminary modification of an existing SAM for Indonesia in the year 2008 such that it is fitted to calibrate the proposed CGE model given in the next chapter.

The chapter is organized as follows: Sections 2.2 and 2.3 describe the standard SAM and the official Indonesian SAM for 2008 that cover its schematic structure and accounts classification. Section 2.4 discusses Indonesia’s macro-economy based on its existing SAM in year 2008. Section 2.5 discusses the preliminary modification of the official SAM by aggregating and eliminating some of its accounts. Section 2.6 provides conclusion and remarks.

2.2. The SAM

A SAM is a square matrix representation of economic accounts that records all transactions between agents in the socio-economic system. The transactions for each account are explicitly shown in the cells corresponding to the relevant rows and columns of the matrix. A SAM is usually understood to picture an economy’s equilibrium in which every agent’s total receipts should be balanced with its total expenditure account (established by the equality between the sums over each row and column). Table 1 shows the schematic structure of a standard SAM.

Table 2.1: Schematic Structure of SAM Framework

				Expenditure					
				Endogenous Account				Exogenous Account	Total
				Activity	Commodity	Production Factor	Institutions’		
				1	2	3	4	5	6
receipt	Endogenous Account	Activity	1		Total cost of production				Gross output
		Commodity	2	Intermediate inputs			Institution consumption	Export, and Investment	Total demand for composite good
		Production Factor	3	Value Added distribution					Factor income
		Institution	4			Factor income to institutions’		Transfer from foreign, indirect tax and import tariff	Institutions’ income
	Exogenous Account		5		Imports, sales tax, and imports tariff	Fixed capital consumption	Institutions’ saving		Exogenous income
	Total		6	Production cost expenditure	Total supply expenditure	Factor expenditure	Institutions’ expenditure	Exogenous expenditure	

Source: Hartono and Resosudarmo (2007), a modification

From Table 2.1, it can be seen that each row represents receipts and column represents expenditure, where the row sum for a given account must be equal to its corresponding column sum. The accounts are usually divided into two groups: endogenous and exogenous accounts. The endogenous accounts are commonly given in the leading rows and columns which usually consist of: production activities, commodities, factors, and institutions. The saving-investment, taxes, subsidies, and rest of world (import and export) are, on the other hand, usually allocated as exogenous accounts (Pyatt and Round, 1979). In addition, the table separates production activities and commodities accounts where their respective row sum (receipt) reflects the producer price and market price[5]. The price separation is important because it allows for: (i) multiple commodities production from each activity, and (ii) a given commodity production from multiple activities.

The production factors’ accounts, which primarily comprise of labour and capital, are utilized as the inputs for processing the production activity. The income generated from these factors is then transferred to institutions’ accounts who supply them. In general, the labour account can be further disaggregated based on several categories, i.e. location, skill,

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[5] The producer price is the market price less import and taxes.

level of education, gender, and so on. However, the capital account usually remains as a single account.

The institutions' accounts record the transactions of households, firms, and the government. The labour factor is fully supplied by households whereas the capital factor can, in principle, be supplied by every institution. The government's account records the indirect taxation and subsidies as well as direct taxes and transfers. However, taxes and subsidies appear in separate (exogenous) accounts and are presented outside the core government institution account to avoid ambiguous interpretation of payments.

Finally, the standard SAM provides the exogenous accounts which record the details of inflows and outflows to and from the country – i.e. the account for the rest of the world showing the value of imports and exports and transfer to and from abroad for every institution as well as the net surplus or deficit of the balance of payments account – and the investment-saving balance – i.e. the surplus or deficit for each institution and their contribution to capital formation, etc.

2.3. The Indonesian SAM

The official Indonesian SAM is published by the Centre of Statistic Agency[6] every five years. Its most recent SAM publication is for the year 2008. This SAM is represented in three different sizes of matrices: 13x13, 37x37, and 105x105. The 13x13 matrices are the aggregated version from the 37x37 matrices, and the 37x37 matrices are the aggregated version from the 105x105 matrices (BPS, 2008).

The framework structure of the Indonesian SAM in year 2008 is similar to that of the standard SAM described above. However, the differences are mainly in the way it also separately records the specific imported commodities, and in providing two margin accounts – trade and transportation margins. Commission of the European Communities (1993) defines the trade margin as: *"The difference between the actual or imputed price realized on a good purchased for resale and the price that would have to be paid by the distributor to replace the good at the time it is sold or otherwise disposed of*". Decaluwé *et al.* (2012) stated that the exclusion of these margins from industry's production costs is intended to differentiate the actual price between final consumer and intermediate (retailers) buyers. The margins can be interpreted as the additional costs to final consumers in purchasing goods from the wholesalers or retailers. Table 2.2 illustrates how these margins are incorporated in the official SAM.

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[6] In Indonesia language: *Badan Pusat Statistik*

Table 2.2: The Schematic Structure of Indonesian SAM 2008

			Expenditures													
			Activities	Commodities	Margin of Trade and Transportation	Factors		Households	Firm	Government	S-I	Indirect Tax	Import Tariff	Subsidy	ROW	Total
						Labour	Capital									
Receipt	Activities		-	Total cost of production	-	-	-	-	-	-	-	-	-	Subsidy to activities	-	Gross output
	Commodities		Intermediate inputs	-	Commodity input used for margins	-	-	Households consumption	-	Government Consumption	Investment	-	-	Subsidy to commodities	Export	Total demand
	Aggregated Margins of Trade (TRDM) and Transportation (TRNSM)		-	Trade and Transportation costs	-	-	-	-	-	-	-	-	-	-	-	Margin income
	Factors	Labour	Employment distribution	-	-	-	-	-	-	-	-	-	-	-	Domestic labour to abroad	Total Labour income
		Capital	Capital input distribution	-	-	-	-	-	-	-	-	-	-	-	Domestic capital to abroad	Total Capital income
	Households		-	-	-	Labour income	Capital income	Transfers	Transfers	Transfers	-	-	-	-	Transfers	Total household income
	Firm		-	-	-	-	Capital income	Transfers	Transfers	Transfers	-	-	-	-	Transfers	Total Firm income
	Government		-	-	-	-	-	Direct income receipt	Transfers	Transfers	-	Indirect Taxes receipt	Tariffs receipt	-	Transfers	Total Government income
	S-I		-	-	-	-	-	Saving	Saving	Saving	-	-	-	-	-	Total saving
	Indirect Tax		-	Sales taxes	-	-	-	-	-	-	-	-	-	-	-	Total indirect taxes
	Import Tariff		-	Tariffs	-	-	-	-	-	-	-	-	-	-	-	Total tariffs
	Subsidy		-	-	-	-	-	-	-	Government expenditure for subsidy	-	-	-	-	-	Total subsidies
	ROW		-	Import	-	Abroad labour to domestic	Abroad capital to domestic	Transfers	Transfers	Transfers	Trade balance	-	-	-	-	Total ROW income
	Total		Production cost expenditure	Total supply expenditure	Total margin costs	Total labour costs	Total capital costs	Households expenditure	Firm expenditure	Government expenditure	Total investment	Total indirect taxes cost	Total tariff cost	Total subsidy cost	Total ROW expenditure	TOTAL

The Indonesian SAM in year 2008 distinguishes 24 accounts for each activity, commodity, and imported commodity classification that is presented in Table 2.3. These sectors are aggregated from the 66 production sectors in the Indonesian Input-Output table in the year 2008.

Table 2.3:The Classification for Each Activity, Commodity, and Import Commodity in Indonesian SAM 2008

No	Description
1	Agriculture Food Crops
2	Agriculture for Other Crops
3	Cattle and the Outcomes
4	Forestry and Hunting
5	Fishery
6	Coal, Metal Seeds, and Oil Mining
7	Other Mining and Excavations
8	Food, Drink, and Tobacco
9	Spinning, Textile, Garment, and Leather Industries
10	Wood and Goods from Wood
11	Paper, Printing, Transport Equipment, and Goods from Metal and Industry
12	Chemical, Fertilizer, Goods from Clay and Cement
13	Electricity, Gas, and Drinkable Water
14	Construction
15	Trade
16	Restaurant
17	Hotel
18	Land Transportation
19	Air, Sea, and Communication Transportation
20	Supporting Services for Transportation and Warehouse
21	Bank and Assurance
22	Real Estate, and Private Services
23	Government and Defence, Education, Health, Film, and Other Social Services
24	Individual Services, Households, and Other Services

Source: BPS, 2008

Furthermore, there are two main groups for the production factors namely: labour and non-labour (capital) account. The labour account is further classified into 16 groups based on worker skills, work status (casual/formal), and location (rural/urban), while the capital account remains in a single account. The classifications of these factors are given in Table 2.4.

Table 2.4: The Classifications of Production Factors in Official SAM 2008

Production Factors	Labour	Agriculture	Formal	Rural
				Urban
			Informal	Rural
				Urban
		Production, Transport Equipment Operators, Manual and Labour	Formal	Rural
				Urban
			Informal	Rural
				Urban
		Administration, Sales, and Services	Formal	Rural
				Urban
			Informal	Rural
				Urban
		Leader, Manager, Military, Professional, and Technician	Formal	Rural
				Urban
			Informal	Rural
				Urban
	Non labour			

Source: BPS, 2008

In the institution accounts, the official SAM distinguishes four main representatives: household, firm, government, and the rest of the world (ROW). Each group is further classified as follows: The household account is first disaggregated in two groups: (1) households who are working in an agricultural sector; and (2) households who are not working in agricultural area (non-agricultural sector). For (1) is further disaggregated in two groups: (1a) agricultural employee; and (1b) agricultural employer. Group (2) is disaggregated in two groups: (2a) non-agricultural households who are located in rural area; and (2b) non-agricultural households who are located in urban area. Finally, each of (2a) and (2b) is subsequently disaggregated in three identical categories of occupational types: low income employee/employer, high income employee/employer, and non-labour forces/ unidentified occupation. Firm and government remain in a single account. The disaggregation of these accounts is shown in Table 2.5.

Total income of households is obtained from a labour and capital endowment, and income transfers from institutions; while its expenditure is given to institution payment transfers and consumption on goods and services. The remainder is then considered as saving.

Lastly, the Indonesian SAM also distinguishes four other accounts namely: (1) saving-investment, (2) indirect tax, (3) subsidy, and (4) ROW account.

Table 2.5: The Classification of Institution Accounts in the Official SAM 2008

Institution	Household	Agriculture	Employee	
			Employer	
		Non Agriculture	Rural	Low level type of income for: independent employer, administration employee, salesman, independent employee in transportation sector, individual services, office employee
				Non-labour forces and unidentified types of occupation
				High level type of income for: independent employer, non-agricultural employer, manager, military, professionals, technician, teacher, administration officer, and salesman
			Urban	Low level type of income for: independent employer, administration employee, salesman, independent employee in transportation sector, individual services, office employee
				Non-labour forces and unidentified types of occupation
				High level type of income for: independent employer, non-agricultural employer, manager, military, professionals, technician, teacher, administration officer, and salesman
	Firm			
	Government			

Source: BPS, 2008

Table 2.6 summarizes the structure of Indonesia's economy based on the 13x13 matrices size of macro-SAM in the year 2008[7]. The macro-SAM accounts consist of the aggregate of 24 types of industry (and commodity), the aggregate of 16 types of labour, and the aggregate of 8 types of representative households[8]. Each entry cell in the macro-SAM is valued at nominal 2008 trillion Rupiah (Rp). It is commonly identified as a SAM ("row, column") combination, i.e. the entry cell of SAM ("labour, activity") refers to the wage earned by the labour factor.

Activity and Commodity

An activity produces output (goods and services) by utilizing the production factors and intermediate commodities input. The output is then supplied to the final consumers (Breisinger *et al.*, 2010). Table 2.6 shows that there are 9 non-zero entries for these accounts. These entries are described as follows: (1) the total domestic supply: SAM ("activity, commodity") is Rp. 10,175.38 trillion; (2) the total subsidy allocation for activity: SAM ("activity, subsidy") is Rp. 199.70 trillion; (3) the total intermediate commodity input cost for activity: SAM ("commodity, activity") is Rp. 5,218.15 trillion; (4) the total demand of commodity for trade and transportation margin: SAM ("commodity, trade and transportation margin") is Rp. 1,170.98 trillion; (5) the total household consumption for commodity: SAM ("commodity",

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[7] Due to the large dimension of 105x105 matrix of Indonesian SAM in the year 2008, here we use the macro-SAM to characterize the Indonesia's economy. However, we use the modified of the prior SAM to calibrate the CGE model exercises. This modification is explained in details in section 2.5.

[8] For the sake of simplicity, we eliminate the intermediate import commodity accounts and allocate them into the corresponding commodity accounts. For the step details of these eliminations, see section 2.

"household") is Rp. 3,318.10 trillion; (6) the total government consumption for commodity: SAM ("commodity", "government") is Rp. 294.57 trillion; (7) the total export of commodity: SAM ("commodity", "ROW") is Rp. 1,487.24 trillion; (8) the total gross capital formation (investment) of commodity: SAM ("commodity", "S-I") is Rp. 1,508.83 trillion; and (9) the total commodity required for the purpose of subsidy: SAM ("commodities, subsidy") is Rp. 41.19 trillion.

Trade and Transportation Margin

The Indonesian Macro-SAM in year 2008 records the trade and transportation margin account to differentiate the purchaser's price between retailers (resale) and final consumers. This record is given in the entry cell of SAM ("trade and transportation margin, commodity") which is Rp. 1,170.98 trillion.

Production Factors

The production factors include the labour and capital account. The total costs of labour and capital from activity are given in the respective entries cell of SAM ("labour, activity") and ("capital", "activity") which are Rp. 2,692.62 trillion and Rp. 2,464.32 trillion. These records imply that the aggregate activity (as a whole) in year 2008 was labour intensive (52.21%). The value added, estimated by the sums of production factors, is Rp. 5,156.94 trillion which is the GDP at factor cost (producer price). Further, the total labour wage and capital return which are endowed from ROW (used abroad) are recorded in the respective entries cell of SAM ("labour", "ROW") and SAM ("capital", "ROW"), which are Rp. 1.71 trillion and Rp. 6.66 trillion.

Institutions

Institutions' account represents the transaction flows of household, firm, government, and ROW account. The households earn wages and capital return due to their factor endowments. These records are given in the respective entries cell of SAM ("households", "labour") and SAM ("households", "capital"), which are Rp. 2,688.91 trillion and Rp. 788.55 trillion. In the other hand, the firm only earns income from capital return (Rp. 1,591.20 trillion), which is given in the entry cell of SAM ("firm", "capital"). Government does not earn any factor returns but they earn receipts from collecting direct taxes (income tax), indirect taxes (output sales tax), and import tariffs. These records are given in the respective entries cell of SAM ("government, households"), SAM ("government, indirect tax"), and SAM ("government, import tariff"), which are Rp. 85.07 trillion, Rp. 237.10 trillion, and Rp. 107.84 trillion.

Furthermore, transactions between institutions are given by the entries cell of "institution, institution". These transactions will become the additional income for institutions apart from factor endowments and taxes. The transactions from household to institutions are given respectively in the entries cell of SAM ("households", "households"), SAM ("households", "firm"), SAM ("households", "government"), and SAM ("households", "ROW"), which are

Rp. 43.36 trillion, Rp. 43.09 trillion, Rp. 199.03 trillion, and Rp. 63.51. The transactions from firm to institutions are identified in the respective entries cell of SAM (“firm”, “households”), SAM (“firm”, “firms”), SAM (“firm”, “government”), and SAM (“firm”, “ROW”), which are Rp. 35.16 trillion, Rp. 176.47 trillion, Rp. 89.69 trillion, and Rp. 24.18 trillion. The transfers from government to institutions are identified in the respective entries cell of SAM (“government”, “firms”), SAM (“government”, “government”), and SAM (“government”, “ROW”) Rp. 650.05 trillion, Rp. 181.68 trillion, and Rp. 2.29 trillion[9]. The transactions from ROW to institutions are recorded in the respective entries cell of SAM (“ROW”, households”), SAM (“ROW”, “firms”), and SAM (“ROW”, “government”), which are Rp. 19.29 trillion, Rp. 56.50 trillion, and Rp. 28.70 trillion.

Finally, total import supply: SAM (“ROW, commodity”) is Rp. 1,347.76 trillion and the abroad labour and capital used in domestic are given in the respective entries cell of SAM (“ROW”, “labour”), and SAM (“ROW”, “capital”), which are Rp. 5.42 trillion and Rp. 91.23 trillion.

Saving-Investment (S-I)

The institution saving accounts, excluding the ROW, are recorded in the respective entry cells of SAM (“S-I”, “households”), SAM (“S-I”, “firm”), and SAM (“S-I, government”), which are Rp. 325.44 trillion, Rp. 990.60 trillion, and Rp. 229.47 trillion. Whilst, investment on commodities are recorded in entry cell of SAM (“commodity, S-I”). Total saving is equal to total of investment.

Taxes and Subsidy

The costs of sales tax and import tariff across commodities are given in the respective entry cells of SAM (“indirect tax”, “commodity”), and SAM (“import tariff”, “commodity”), which are Rp. 237.10 trillion and Rp. 107.84 trillion. Meanwhile, the government subsidy is recorded in the entry cell of (“subsidy”, “government”), which is Rp. 240.89 trillion. Total costs of taxes must be equal to the corresponding receipt to government; and total government expenditure on subsidy must be equal to the corresponding receipts to activity and commodity which are identified as SAM (“activity”, “subsidy”) and SAM (“commodity” and “subsidy”), respectively.

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[9] The official Indonesia SAM 2008 allows the inter-transactions between government and government transfer. It means that the transactions are transferred between inter-ministries or inter-divisions within the government

Table 2.6: The Indonesian Macro-SAM 2008: 13x13 Matrices

			Expenditures													
			Activities	Commodities	Margin of Trade and Transportation	Factors		Households	Firm	Government	S-I	Indirect Tax	Import Tariff	Subsidy	ROW	Total
						Labour	Capital									
Receipt	**Activities**		-	10,175.38	-	-	-	-	-	-	-	-	-	199.70	-	10,375.08
	Commodities		5,218.15	-	1,170.98	-	-	3,318.10	-	294.57	1,508.83	-	-	41.19	1,487.24	13,039.06
	Aggregated Margins of Trade (TRDM) and Transportation (TRNSM)		-	1,170.98	-	-	-	-	-	-	-	-	-	-	-	1,170.98
	Factors	**Labour**	2,692.62	-	-	-	-	-	-	-	-	-	-	-	1.71	2,694.32
		Capital	2,464.32	-	-	-	-	-	-	-	-	-	-	-	6.66	2,470.97
	Households		-	-	-	2,688.91	788.55	43.36	43.09	199.03	-	-	-	-	63.51	3,826.44
	Firm		-	-	-	-	1,591.20	35.16	176.47	89.69	-	-	-	-	24.18	1,916.70
	Government		-	-	-	-	-	85.07	650.05	181.68	-	237.10	107.84	-	2.29	1,264.03
	S-I		-	-	-	-	-	325.44	990.60	229.47	-	-	-	-	-	1,545.51
	Indirect Tax		-	237.10	-	-	-	-	-	-	-	-	-	-	-	237.10
	Import Tariff		-	107.84	-	-	-	-	-	-	-	-	-	-	-	107.84
	Subsidy		-	-	-	-	-	-	-	240.89	-	-	-	-	-	240.89
	ROW		-	1,347.76	-	5.42	91.23	19.29	56.50	28.70	36.68	-	-	-	-	1,585.58
	Total		10,375.08	13,039.06	1,170.98	2,694.32	2,470.97	3,826.44	1,916.70	1,264.03	1,545.51	237.10	107.84	240.89	1,585.58	40,474.52

Source: BPS, 2008: A modification

2.4. An Overview of Indonesia's Macro-Economy Indicators

By referring to the Macro-SAM in the year 2008 in Table 2.6 above, numerous Indonesia's macro-economy indicators such as GDP at market price, GDP at factor cost, GNP, domestic and foreign saving, and other external transactions can be estimated. There are two approaches for estimating these indicators which are either the expenditure (column) or income (row) side (Ethiopian Development Research Institute, 2009).

On the expenditure side, GDP at market prices is measured from the total final demand of institutions. Whilst from income side, it is measured as the sum of value added, output tax (indirect tax), and import tariffs (Breisinger *et al*., 2009). The value added is GDP at factor cost (producer prices). Thus, in other words, GDP at factor cost is GDP at market price excluding indirect taxes and import tariffs.

The GNP is the total GDP at market prices less net factor payments (income approach). Whilst from the expenditure side, it is measured from the sum of domestic consumption (household and government), investment and the net investment abroad (expenditure approach) (Li, 2002).

Furthermore, total saving is the sum of both domestic and external saving. Following Walrasian's law, these total saving should be equal to its expenditure side which is total investment. Finally, the external transactions, which cover total export (income) and import (expenditure) accounts, can also be estimated through its equality law.

In terms of equations identity, the above indicators are measured as follows[10]:

$$AD = GDPMP = C + I + G + X - M = VA + IDT + TAR - SUB \qquad 1)$$

or

$$GDPMP = GDPFC + IDT + TAR - SUB \qquad 2)$$

$$GNP = GDPMP - Fp = C + I + G + In \qquad 3)$$

$$TS = TSD - TSF = (Sh + Sf + Sg) - TSF = I \qquad 4)$$

$$X + Df = M \qquad 5)$$

Where:

AD = Aggregate demand
$GDPMP$ = GDP at market price
C = Household consumption
I = Investment
G = Government consumption
X = Exports
M = Imports
VA = Value added
IDT = Output tax
TAR = Import tariff
SUB = Subsidy;

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[10] Note that there are numerous equations to estimate macro-economy indicators. This is because the SAM is insured to be consistent and balanced (Thorbecke, 2000).

$GDPFC$ = GDP at factor cost
GNP = Gross National Product
Fp = Net factor of payments
In = Investment to abroad
TS = Total saving
TSD = Total saving in domestic
TSF = Total saving in foreign
Sh = Household saving
Sf = Firm saving
Sg = Government saving
Df = current account deficit

The implementation of these equations into the macro-SAM are given as follows:

$$\mathrm{GDPMP} = \mathrm{SAM(C,HH)} + \mathrm{SAM(C,GOV)} + \mathrm{SAM(C,GOV)} + \mathrm{SAM(C,S-I)} + \mathrm{SAM(C,ROW)} - \mathrm{SAM(ROW,C)} \qquad 6)$$

or

$$\mathrm{GDPM} = \mathrm{SAM(L,A)} + \mathrm{SAM(K,A)} + \mathrm{SAM(IDT,C)} + \mathrm{SAM(TAR,C)} - \mathrm{SAM(SUB,GOV)} \qquad 7)$$

$$\mathrm{GDPFP} = \mathrm{SAM(L,A)} + \mathrm{SAM(K,A)} \qquad 8)$$

$$\mathrm{GNP} = \mathrm{SAM(C,HH)} + \mathrm{SAM(C,GOV)} + \mathrm{SAM(C,S-I)} + \mathrm{SAM(ROW,S-I)} \qquad 9)$$

or

$$\mathrm{GNP} = \mathrm{GDPMP} - (\mathrm{SAM(ROW,FIRM)} + \mathrm{SAM(ROW,HH)} + \mathrm{SAM(ROW,GOV)} + \mathrm{SAM(ROW,L)} + \mathrm{SAM(ROW,K)} - \mathrm{SAM(GOV,ROW)} - \mathrm{SAM(HH,ROW)} - \mathrm{SAM(FIRM,ROW)} - \mathrm{SAM(L,ROW)} - \mathrm{SAM(K,ROW)}) \qquad 10)$$

$$\mathrm{TS} = \mathrm{SAM(K,HH)} + \mathrm{SAM(K,FIRM)} + \mathrm{SAM(K,GOV)} - \mathrm{SAM(ROW,K)} \qquad 11)$$

or

$$\mathrm{TS} = \mathrm{SAM(C,S-I)} \qquad 12)$$

$$\mathrm{SAM(C,ROW)} - \mathrm{SAM(ROW,HH)} - \mathrm{SAM(ROW,FIRM)} - \mathrm{SAM(ROW,GOV)} - \mathrm{SAM(ROW,L)} - \mathrm{SAM(ROW,K)} - \mathrm{SAM(ROW,S-I)} + \mathrm{SAM(HH,ROW)} + \mathrm{SAM(FIRM,ROW)} + \mathrm{SAM(GOV,ROW)} + \mathrm{SAM(L,ROW)} + \mathrm{SAM(K,ROW)} = \mathrm{SAM(ROW,C)} \qquad 13)$$

Where:
C = Commodities
A = Activities
K = Capital
L = Labour
HH = Households
Gov = Government
$S-I$ = Saving-Investment
TAR = Import tariff
IDT = Indirect tax
ROW = Rest of world
I = Investment

The estimation of national income accounts for Indonesia's economy based on the macro-SAM in the year 2008 is presented in Table 2.7. The Indonesia's GDP at market prices, GNP, total saving and investment, and ROW transactions are: 5,260.99 trillion Rupiah, 5,158.19 trillion Rupiah, 1,508.83 trillion Rupiah, and 1,347.77 trillion Rupiah, respectively. These estimations are obtained from either income (row) or expenditure (column) side approach.

Table 2.7: Indonesia’s Macro-Economy Indicators Based on The Macro-SAM 2008 (Trillion Rupiah, 2008 nominal price)

Macro-economy Indicator	**Approach**			
	Income side		**Expenditure side**	
GDPMP	GDPFC or total value added	5,156.94	Household consumption	3,318.10
	Output tax	237.1	Investment	294.57
	Import Tariff	107.84	Government consumption	1,508.83
	Subsidy	-240.89	Export	1,487.24
			Import	5,260.98
	Total	5,260.99	**Total**	5,260.99
GNP	GDPMP	5,260.99	Household consumption	3,318.10
	Households transfer to ROW	63.51	Investment	294.57
	Firm transfer to ROW	24.18	Government consumption	1,508.83
	Government transfer to ROW	2.29	Investment to abroad	36.68
	Labour used in ROW	1.71		
	Capital used in ROW	6.66		
	ROW transfer to household	-19.29		
	ROW transfer to firm	-56.50		
	ROW transfer to government	-28.70		
	ROW labour	-5.42		
	ROW capital	-91.23		
	Total	5,158.19	**Total**	5,158.19
Saving-Investment	Households saving	325.44	Investment	1508.83
	Firm saving	990.6		
	Government saving	229.47		
	ROW saving	36.68		
	Total	1,508.83	**total**	1,508.83
ROW transaction	Export		Import	1,347.77
	Households transfer to ROW	63.51		
	Firm transfer to ROW	24.18		
	Government transfer to ROW	2.29		
	Labour used in ROW	1.71		
	Capital used in ROW	6.66		
	ROW transfer to household	-19.29		
	ROW transfer to firm	-56.50		
	ROW transfer to government	-28.70		
	ROW labour	-5.42		
	ROW capital	-91.23		
	Investment to ROW	36.68		
	Total	1,347.77	**Total**	1,347.77

2.4.1. Shares of GDP Generated by Activity

The GDP (at producer prices) shares are obtained from the calculation of value added shares of each activity. By estimating these shares, we can determine which activity contributed the most to factors' income. Table 2.8 presents the shares of GDP generated by activity.

The chemical industries (consisting of fuel refineries, fertilizer, clays materials, and cement) contribute the largest share of GDP at producer prices, which is 10.50%. The second and third largest sectors are: trade sector (9.69%) and mining sector (9.42%). These shares show that Indonesia's economy is heavily dependent on these sectors. Electricity, gas, and clean water sectors aggregate contributed only around 2.47%; while the hotel sector has the smallest contribution by 0.50% (BPS, 2008). It implies that hotel sector is less significant to generate GDP compared to mining and chemical industries.

2.4.2. Shares of Factors' Income (Value Added)

In the SAM, employment bills are measured as worker equivalents (WE), where 1 WE is equal to 1 worker who works 40 hours per week. Thus, a worker who works less than 40 hours per week, is accounted as less than 1 WE. The average wage per WE in the year 2008 was 24,825.88 thousand Rupiah.

As shown in Table 2.9, the most capital-intensive sectors are energy sectors indicated by their higher cost shares on capital than labour. For example, the cost shares of capital to total value added in the mining, utilities (electricity, clean water, and city gas), and petrochemical sector are approximately 87.64%, 87.17%, 69.23%, respectively. In contrast, the most labour-intensive sectors are agricultural and trade sector where the cost shares of labour employments to total value added are about 94.42% and 88.31%, respectively.

Table 2.8: The Shares of GDP at Producer Prices

Sector	% share in GDP at market prices	Sector	% share in GDP at market prices
Agriculture Food Crops	7.32	Electricity, gas, and drinkable water	2.47
Agriculture for Other Crops	2.50	Construction	8.29
Cattle Products	2.52	Trade	9.69
Forestry and Hunting Products	0.78	Restaurant	2.25
Fishery	2.60	Hotel	0.45
Coal, Oil, and Iron Ore Mining	9.42	Land Transportation	2.05
Other Mining	1.22	Air, Sea, and Communication Transportation	3.59
Food, Drink, and Tobacco	5.56	Services for Transportation	0.51
Textile	2.11	Bank and Assurance	3.39
Timber Products	1.40	Real Estate	3.84
Papers and Printing	8.36	Government services and Defense	6.41
Chemical and Petroleum	10.50	Individual and Other Services	2.75

Table 2.9: The Shares of Value Added

Sector	Labour	Capital
Agriculture Food Crops	94.42	5.58
Agriculture for Other Crops	82.55	17.45
Cattle Products	70.51	29.49
Forestry and Hunting Products	38.12	61.88
Fishery	36.89	63.11
Coal, Oil, and Iron Ore Mining	12.36	87.64
Other Mining	74.04	25.96
Food, Drink, and Tobacco	41.94	58.06
Textile	42.16	57.84
Timber Products	49.73	50.27
Papers and Printing	41.58	58.42
Chemical and Petroleum	30.77	69.23
Electricity, gas, and drinkable water	12.83	87.17
Construction	46.98	53.02
Trade	88.31	11.69
Restaurant	89.75	10.25
Hotel	39.57	60.43
Land Transportation	82.38	17.62
Air, Sea, and Communication Transportation	36.83	63.17
Services for Transportation	77.16	22.84
Bank and Assurance	30.38	69.62
Real Estate	22.99	77.01
Government services and Defense	86.56	13.44
Individual and Other Services	60.65	39.35
Total	94.42	5.58

2.4.3. Shares of Intermediate Input for Each Activity

By estimating the shares of intermediate commodity input used in activity, we can determine which commodity contributes the most to produce the output. Table 2.10 shows the shares of intermediate input for each activity.

Based on our findings, mining commodities are the most important intermediate input. In the petrochemical sector, for example, the shares of mining inputs to total output are 24.61%. This means that to produce 100 rupiahs-worth of petrochemical output requires 24.61 rupiahs-worth of mining inputs. Mining inputs are also largely used for their own activity (13.68%) and electricity generation (10.63%). Moreover, electricity sector also depends on petrochemical input (17.46%). These results imply that in year of 2008, the electricity sector in Indonesia was heavily depended on fossil fuel inputs.

2.4.4. Shares of Trade (Import and Export)

The shares of each commodity trade are presented in table 2.11. In terms of types of energy commodities', our finding shows that in year 2008, Indonesia was not depended on the import of energy mining and electricity. This is reflected from their shares of total import, which are 0.52% and 0% respectively. Nevertheless, the import share of secondary energy types of commodities (refineries products) was relatively as high as its export shares: 24.36% and 23.74% respectively. In other hand, the electricity production was not exported (zero shares). But the mining commodities were hugely exported whereas about 16.67% of total national export.

2.4.5. Shares of Commodity as Final Demand

Table 2.12 presents the shares of commodities that are used as intermediate input in total activities and final demand for institutions'. These shares are estimated from the given formula: $\left(\frac{x_{ij}}{\sum_i x_{ij}}\right)$, where subscripts i and j represent commodity type-i and consumer type-j respectively. For the sake of simplicity, we aggregate the following accounts: (1) the margins (trade and transport) account to the corresponding activity account; (2) subsidies transaction to the government account; and (3) eight types of households in a single account.

Based on our estimation, mining commodity is used mostly as intermediate input (7.11%), investment (4.79%), and export (16.67%). The household, however, does not consume this commodity (zero demand). On the other hand, petrochemical commodity is mostly distributed to activity and institutions' – excluding investment, which is indicated through its respective shares in activity (16.15%), households (9.35%), government (16.50%), and export (23.40%). While, electricity contributes only in small shares, which is: activity (1.29%), households (1.18%), and government (0.85%).

Moreover, the households budget is mainly spent on food (including drink and tobacco) (22.83%). While the government spends more than a half of their budget (52.97%) on their own services – government services and defenses. The largest investment shares are given to construction (75.83%).

These results imply that in year 2008, the mining commodities were used mostly as intermediate inputs and exports. The small shares of households' expenditure on electricity might be related from subsidy on electricity, where the price was cheaper than market price.

Table 2.10: The Shares of Intermediate Commodity to Activity

	AGRI_A	OAGRI_A	CATLE_A	FORH_A	FISH_A	COMOIL_A	OMINE_A	FODT_A	STGL_A	WOOG_A	PPTM_A	CHFCC_A	ELEGD_A	CONS_A	TRDE_A	RSTR_A	HTEL_A	LANT_A	AISCOM_A	SUPPS_A	BANKAS_A	ESTPRV_A	GOVTD_A	INDSHO_A
AGRI_C	4.17	0.17	2.79	-	0.37	-	-	27.61	-	-	0.03	0.07	-	-	0.05	8.28	4.57	-	0.02	-	-	-	6.15	-
OAGRI_C	2.53	6.43	0.81	3.97	0.36	-	-	10.84	4.53	0.82	0.11	3.88	-	-	0.00	0.46	0.04	0.00	0.00	-	0.00	-	0.10	0.28
CATLE_C	3.48	2.08	19.94	-	0.08	-	-	1.20	3.61	0.00	0.03	0.03	-	-	-	23.07	14.82	0.03	0.05	-	-	0.00	2.42	-
FORH_C	0.00	0.04	0.02	2.16	0.08	0.00	0.16	0.05	0.04	13.94	0.20	0.07	0.00	2.01	0.00	0.02	0.03	0.00	-	-	-	0.01	0.00	0.11
FISH_C	-	0.01	-	-	12.72	-	-	5.60	0.00	-	0.07	0.00	-	-	-	3.97	1.94	-	0.02	-	-	0.11	0.66	-
COMOIL_C	-	-	-	-	-	13.68	-	0.07	0.20	0.06	4.90	24.61	10.63	0.00	-	-	0.04	0.03	-	-	-	-	-	-
OMINE_C	-	0.00	0.00	-	-	-	0.74	0.05	0.00	-	0.03	1.11	-	7.41	0.00	0.00	-	-	-	-	-	-	0.24	-
FODT_C	-	0.24	25.29	-	4.60	-	-	18.58	0.58	0.53	0.08	0.40	-	-	0.13	20.94	14.75	0.04	1.04	0.28	0.11	0.32	4.89	0.19
STGL_C	0.05	0.11	0.00	0.23	0.01	0.03	0.04	0.03	29.46	0.42	0.25	0.29	0.01	0.09	0.98	0.74	0.33	0.19	0.13	0.36	0.02	0.26	0.27	0.99
WOOG_C	0.02	0.04	0.01	-	0.09	-	0.12	0.03	0.06	22.26	0.56	0.03	-	5.60	0.49	0.01	0.01	0.01	0.00	0.08	0.00	0.01	0.06	0.07
PPTM_C	0.11	1.12	0.03	6.26	1.18	2.16	1.90	1.07	2.14	2.56	40.02	1.13	1.50	25.94	3.48	0.08	0.54	2.64	6.26	2.26	2.45	5.86	5.05	28.24
CHFCC_C	7.95	17.71	1.17	3.33	5.66	1.47	8.45	1.68	14.09	8.51	11.38	18.06	17.46	17.64	6.34	0.61	0.53	28.83	13.79	2.48	1.01	1.80	5.38	11.40
ELEGD_C	0.00	0.02	0.17	0.09	0.12	0.05	0.07	0.18	1.91	0.85	1.16	0.58	6.22	0.03	2.51	0.18	0.31	0.43	0.89	2.73	0.54	0.58	0.35	1.16
CONS_C	0.22	2.69	0.05	2.08	0.30	0.61	5.11	0.02	0.24	0.04	0.15	0.09	0.49	0.10	2.92	0.02	0.08	0.54	1.27	10.19	0.61	5.47	0.70	0.31
TRDE_C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RSTR_C	0.03	0.06	0.00	0.14	0.17	0.00	0.79	0.13	0.46	0.46	0.31	0.22	0.03	0.61	1.99	0.03	0.35	0.32	0.85	0.41	0.35	0.62	0.27	0.42
HTEL_C	0.00	0.01	0.00	0.01	0.00	0.02	0.03	0.03	0.11	0.00	0.06	0.04	0.01	0.10	0.27	0.03	0.04	0.03	0.29	0.06	0.19	0.16	0.04	0.14
LANT_C	0.20	0.51	0.12	0.67	0.03	0.26	0.97	0.29	0.79	1.60	0.93	0.32	0.08	0.30	4.62	0.02	0.07	0.85	0.15	0.48	0.55	0.53	0.25	0.18
AISCOM_C	0.02	0.10	0.07	1.06	0.18	0.57	0.27	0.40	1.15	1.93	1.13	0.67	0.10	0.61	4.75	0.05	0.52	2.04	6.04	7.98	2.06	2.46	0.81	0.95
SUPPS_C	0.01	0.03	0.01	0.16	0.02	0.02	0.07	0.10	0.29	0.79	0.26	0.11	0.00	-	0.25	0.00	0.08	0.94	4.94	6.63	0.06	0.11	0.04	0.01
BANKAS_C	0.23	3.30	0.27	0.95	0.49	0.38	0.65	0.89	1.78	1.62	1.16	0.74	0.50	1.02	6.53	0.28	0.26	2.21	2.66	1.99	20.47	3.44	0.59	0.65
ESTPRV_C	0.18	0.30	0.11	0.67	0.03	0.48	1.39	0.34	0.69	0.71	1.67	0.36	0.96	2.95	10.07	0.33	0.80	1.98	3.07	5.33	3.38	2.65	1.66	2.75

GOVTD_C	-	-	-	-	-	-	-	0.42	0.25	0.37	0.24	0.31	0.01	-	0.08	0.07	0.63	0.00	0.61	0.52	0.73	1.16	2.40	0.64
INDSHO_C	0.16	1.36	0.20	1.48	0.05	0.62	2.29	0.28	0.44	0.85	0.72	0.32	0.08	0.53	2.76	0.05	0.04	19.12	1.32	3.49	2.21	5.31	0.65	0.67
Labour Shares	76.13	52.58	34.51	29.25	27.10	9.85	56.97	12.62	15.67	20.71	14.37	14.33	7.95	16.47	45.72	36.57	23.43	32.76	20.84	42.23	19.82	15.90	58.02	30.83
Capital Shares	4.50	11.11	14.43	47.49	46.36	69.81	19.97	17.48	21.51	20.93	20.19	32.23	53.98	18.59	6.05	4.18	35.79	7.01	35.75	12.50	45.42	53.24	9.01	20.01
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: own calculation

Note: AGRI_C: Agriculture Food Crops commodity; OAGRI_C: Agriculture for Other Crops commodity; CATLE_C: Cattle and the Outcomes commodity; FORH_C: Forestry and Hunting commodity; FISH_C: Fishery commodity; COMOIL_C: Coal, Metal Seeds, and Oil Mining commodity; OMINE_C: Other Mining and Excavations commodity; FODT_C: Food, Drink, and Tobacco commodity; STGL_C: Spinning, Textile, Garment, and Leather Industries commodity; WOOG_C: Wood and Goods from Wood commodity; PPTM_C: Paper, Printing, Transport Equipment, and Goods from Metal and Industry commodity; CHFCC_C: Chemical, Fertilizer, Goods from Clay and Cement commodity; ELECGD_C: Electricity, Gas, and Drinkable Water commodity; CONS_C: Construction commodity; TRDE_C: Trade commodity; RSTR_C: Restaurant commodity; HTEL_C: Hotel commodity; LANT_C: Land Transportation commodity; AISCOM_C: Air, Sea, and Communication Transportation commodity; SUPPS_C: Supporting Services for Transportation and Warehouse commodity; BANKAS_C: Bank and Assurance commodity; ESTPRV_C: Real Estate, and Private Services commodity; GOVTD_C: Government and Defense, Education, Health, Film, and Other Social Services commodity; INDSHO_C: Individual Services, Households, and Other Services commodity

Table 2.11: The Shares of International Trade

Commodity	Import	Export
Agriculture Food Crops	3.35	0.06
Agriculture for Other Crops	2.23	1.55
Cattle Products	0.37	0.04
Forestry and Hunting Products	0.04	0.03
Fishery	0.01	0.26
Coal, Oil, and Iron Ore Mining	0.52	16.67
Other Mining	0.78	0.08
Food, Drink, and Tobacco	7.72	13.82
Textile	5.04	8.07
Timber Products	0.25	3.14
Papers and Printing	55.34	23.16
Chemical and Petroleum	24.36	23.74
Electricity, gas, and drinkable water	-	-
Construction	-	-
Trade	-	-
Restaurant	-	0.88
Hotel	-	1.76
Land Transportation	-	0.08
Air, Sea, and Communication Transportation	-	3.59
Services for Transportation	-	0.36
Bank and Assurance	-	0.25
Real Estate	-	0.94
Government services and Defense	-	1.45
Individual and Other Services	0	0.07
Total	100	100

Table 2.12: The Shares of Commodities

	Activities	Households	Government	S-I	ROW	Total
Agriculture Food Crops	5.45	8.48		-0.49	0.06	4.78
Agriculture for Other Crops	3.08	0.47	0.01	0.05	1.55	1.81
Cattle Products	2.82	5.62		-0.53	0.04	2.75
Forestry and Hunting Products	0.85	0.20		0.20	0.03	0.50
Fishery	1.46	4.66		-0.34	0.26	1.89
Coal, Oil, and Iron Ore Mining	7.11			4.79	16.67	5.94
Other Mining	1.66	0.04		0.00	0.08	0.83
Food, Drink, and Tobacco	5.60	22.83		-1.81	13.82	9.92
Textile	1.77	3.43	0.45	0.90	8.07	2.78
Timber Products	1.88	1.17	0.03	0.78	3.14	1.67
Papers and Printing	16.67	11.50	5.41	22.48	23.16	16.48
Chemical and Petroleum	16.15	9.35	16.50	-3.20	23.74	13.05
Electricity, gas, and drinkable water	1.29	1.18	0.85	0.00	0.00	0.95
Construction	1.29	0.00	5.10	75.83	0.00	9.54
Trade	15.64				0.00	7.66
Restaurant	0.74	6.91	4.08		0.88	2.32
Hotel	0.13	0.63	0.96		1.76	0.45
Land Transportation	3.04	2.24	1.62		0.08	2.11
Air, Sea, and Communication Transportation	2.88	4.55	3.71		3.59	3.07
Services for Transportation	0.80	0.15	0.46		0.36	0.48
Bank and Assurance	3.36	1.67	1.96		0.25	2.15
Real Estate	3.52	3.06	1.23	0.16	0.94	2.66
Government services and Defense	0.54	8.29	52.97	0.13	1.45	3.92
Individual and Other Services	2.27	3.59	4.65	1.04	0.07	2.27
Total	100	100	100	100	100	100

Source: own calculation

2.5. Preliminary Modifications of SAM

The official Indonesian SAM in the year 2008 (the version of 105x105 matrix) has a number of differences compared to the traditional SAM, of which it adds the accounts of intermediate import commodities, and trade and transportation margin. Since our main interest does not necessarily focus on price discrepancies between producers and market sellers, and international trade, we propose to modify this official SAM into its standard form by eliminating the intermediate import commodities and margin accounts (trade and transportation). This SAM can then be employed to calibrate the standard CGE model that is discussed in the next chapter.

2.5.1. First Level of Modification: The Elimination of Imported Commodity Accounts (Rows and Columns)

The official SAM extends its standard form, in which it records not only activity and commodity but also detailed transactions of imported commodities. In other words, it is more comprehensive than the traditional structure since it also adds detailed transactions related to: (1) the intermediate inputs of imported commodities used across activities: SAM ("import commodity", "activity"); (2) the consumption of imported commodities across domestic institutions: SAM ("import commodity", "institution"); (3) specific supply of import from ROW: SAM ("ROW", "import commodity"); and (4) tariff of each imported commodity: SAM ("indirect tax", "imported commodity"). These records imply that producers (and consumers) would utilize the specific import and domestic commodities as intermediate inputs (and final consumption).

The additional transactions given above are obviously more than sufficient to calibrate the CGE model. However, when one starts to upgrade some accounts, i.e. disaggregating the activity or households' account, the specific imported commodity accounts must therefore be disaggregated too. We argue that the supporting information to disaggregate the import commodities, especially in the case of energy specific, is limited. Also since the CGE model we used for analysis is not specifically focused on international trade, we propose to reduce the size of this SAM by eliminating the imported commodity accounts and allocating these values into commodity account. Therefore, the official SAM is then restored to its standard form, in which the SAM dataset distinguishes only specific activity and commodity; while the import transactions are simply recorded as an aggregated account: SAM ("ROW", "Commodity").

The steps to eliminate the imported commodity accounts are as follows: (1) we take each entry cell in: SAM ("Import Commodity", "Activity") and add it to its corresponding SAM ("Commodity", "Activity") account; (2) we take each entries cell in: SAM ("Import Commodity", "Institution") and add it to its corresponding SAM ("Commodity", "Institution"); (3) we take each entries cell in: SAM ("Import Balance", "Saving-Investment") and add it to the corresponding SAM ("Commodity", "Saving-Investment") account; (4) we take each entries cell in: SAM (“Import Commodity”, “Subsidy”) and add it to its corresponding SAM (“Commodity”, “Subsidy”) account; (6) we take each entries cell in: SAM (“ROW”, “Import Commodity”) and add it to its corresponding SAM (“ROW”, “Commodity”) account; (7) we take each entries cell in: SAM (“Trade Margin”, “Import “Commodity”) and add it to its corresponding SAM (“Trade Margin”, “Commodity”) account; and (8) we take each entries cell in: SAM (“Transportation Margin”, “Import Commodity”) and add it to its corresponding SAM (“Transportation Margin”, “Commodity”) account.

Finally, because the imported commodity accounts (rows and columns) have been eliminated, thus the tariff records for each imported commodity, which are given in the SAM (“Indirect tax”, “imported commodity”), should be moved into a new row of the account: (“tariff”, “commodity”).

2.5.2. Second Level of Modification: The Elimination of Trade and Transportation Margins (Row and Columns)

The official SAM also records the trade and transportation margin. According to BPS (2008), these margins are aimed to identify the transaction discrepancies between prices of final consumers and traders (retailers or wholesales). The margins cover: (1) the traders receipt for commodity resale; and (2) the transportation costs for distributing the commodities from producers to final consumers.

From the SAM framework, we notice that the value of trade margin account (TRDM) is obtained from the entries cell of trade commodity account (TRDE_C). This is reflected from commodity-activity transactions where all producers do not purchase input of intermediate trade commodity: SAM (“TRDE_C”, “activity”) is equal to zero. Also, final consumers (institutions) do not purchase trade commodity. TRDE_C is only absorbed for TRDM account. Thus, this transaction implies that total receipt of TRDE_C (row) is equal with the total expenditure (column) of TRDM. We find that the SAM allows a mechanism of purchasing transactions where retailer (or wholesale) traders will purchase the commodities from activity suppliers in the level of price excluding trade margin cost. These traders will then mark-up the price by adding this margin for resale distribution to final consumers.

The transportation margin account (TRNSM) covers the additional costs of distributing the commodities from traders to consumers. TRNSM is obtained from the shares of each type of transportation account, namely land transportation (LANT), air, sea, and communication transportation (AISCOM), and supporting services (i.e. by warehouses) (SUPPS). This margin account aims to separate the price discrepancies between traders and final consumers in the market. The traders will purchase commodities from suppliers and then resale them to the consumers. The additional costs of distributing these commodities from traders to final consumers are then recorded in TRNSM. In other words, the consumers will purchase the final commodities at retailer’s price plus the margin cost.

Because the CGE model we used for analysis is focused only on transactions between suppliers (producer price) and final consumers (consumer price), thus we propose to eliminate these margins (row and column) to avoid ambiguity and complexity of interpretations. The steps of elimination are as follows:

a) In the case of eliminating of trade margin, we take each of entries cell in “TRDM”, “Commodity” and add it to the corresponding cell of “TRDE_C”, “Activity”. Hence the total production costs will be increased at the level of adding this trade margin input. This implies that the relevant output supply should also be increased in order to maintain the receipt-expenditure balance. To do so, we also add this margin to its corresponding domestic supply: SAM (“Activity”, “Commodity”). For examples, the sum of: SAM (“TRDM”, “AGRI_C”) and SAM (“AGRI_A”, “AGRI_C”); SAM (“TRDM”, “OAGRI_C”) and SAM (“OAGRI_A”, “OAGRI_C”); and so on. As a result, the total receipts and expenditures of each activity and commodity account are squared. Thus, the trade margin account (row and column) can then be eliminated.

b) In the case of eliminating the transportation margin, we first estimate how much the shares of each type of transportation account allocated for this margin by the following approach:

   $$S_i = \frac{X_i}{\sum_i X_i},$$

   Where:

   S_i = the shares of the i-th transportation account used for TRNSM; and
   X_i = the supply of the i-th transportation account used for TRNSM

   The supply of each type of transportation account for the margin is obtained from the following entry cell: (“LANT_C”, “TRNSM”), SAM (“AISCOM_C”, “TRNSM”), and SAM (“SUPPS”, “TRNSM”), which are: Rp. 109,626.51 billion, Rp. 44,695.33 billion, and Rp. 17,535.03 billion. Thus, the shares of these accounts allocated for TRNSM are 0.64, 0.29, and 0.10 respectively.

   In the second step, we multiply each of the shares to the entries cell of SAM (“TRNSM”, “Commodity”) to obtain the initial values of each type of transportation account that allocated for TRNSM. Finally, each of this value is added to its corresponding entry cell of SAM (“LANT_C”, “Activity”), SAM (“AISCOM_C”, “Activity”), and SAM (“SUPPS_C”, “Activity”).

   Hence the total production expenditure for each activity will increase due to these additional costs. It implies that activity should balance its receipt by increasing its domestic supply as equal as these additional costs. Therefore, the balance is obtained by adding the initial values to the corresponding domestic supply: SAM (“Activity”, “Commodity”). For examples, the sum of: SAM (“TRNSM”, “AGRI_C”) and SAM

(“AGRI_A”, “AGRI_C”); SAM (“TRNSM”, “OAGRI_C”) and SAM (“OAGRI_A”, “OAGRI_C”); and so on. The transportation margin account (row and column) can then be eliminated.

2.6. Conclusion

The official Indonesia’s SAM in year 2008 provides comprehensive information about the Indonesia’s economy during that period of time. It is a square matrix representation of economic accounts that records all transactions between agents in the socio-economic system.

There are numerous indicators which can be obtained from the Indonesian SAM dataset. For example, in sectoral outputs, it is found that chemical industries contribute the largest shares to GDP at producer prices; while hotel sector contributes the smallest contribution. The most capital-intensive sectors are given to energy sectors indicated through their higher cost shares on capital stock than labour employment; while the most labour-intensive sectors are given to agricultural and trade sector. More specifically, in electricity industry, both mining and petrochemical products tend to be the most important materials to produce electricity output. This implies that Indonesia’s electricity sector, in year 2008, heavily relied on fossil fuels. In terms of energy trade, electricity was not either exported or imported; but mining and petrochemical products were largely exported contributing the highest shares in total national export. Regarding to institutions’ consumption pattern, it can be seen that the household mostly spends their budget on food (including drink and tobacco); while the largest expenditure shares of government consumption are given to their own services which is government services and defense.

Compared to the conventional SAM, the official Indonesian SAM in year 2008 also records specific account of intermediate import commodity as well as trade (and transportation) margins. Since our main interest does not necessarily focus on price discrepancies between producers and market sellers, and international trade, we opt to restore this official SAM into its standard form by which we eliminate the accounts of intermediate import commodity and margins. This standard form of SAM can then be used to calibrate the standard CGE model provided in Chapter 3.

In the next works, we put our interest to investigate the impacts of implementing the carbon tax and feed-in tariff (subsidies on clean energy production) on Indonesia’s economy-wide, within the context of a hybrid CGE model (Chapter 6). However, this model is constrained by limitations of the official Indonesian SAM especially in the case of disaggregated accounts of energy sectors: the existing SAM does not disaggregate the types of energy activity and commodity accounts. For example, the electricity sector is still aggregated with other utility sectors of clean water and city gas; all kinds of fossil mining are aggregated together with metal ores and other mining; and all types of petroleum products – i.e. gasoline, diesel, biodiesel, bioethanol, kerosene, liquid petroleum gas (LPG), and so on – are also aggregated together with chemical, fertilizer, clays, and cement sectors.

Thus, in order to accurately calibrate the hybrid CGE model for specific energy analysis, we continue to extend the Indonesian standard SAM into a hypothetical Energy-SAM by disaggregating the energy sectors. To obtain this Energy-SAM, we use additional information such as the Indonesian Input-Output tables, electricity statistics, and an energy dataset compiled by the National Energy Council. This section will be further discussed in Chapter 5.

Chapter 3
The Standard Computable General Equilibrium (CGE) Model

3.1. Introduction

The CGE model is considered as a transformed application model from the modern theory of general equilibrium that was first founded by Leon Walras. This theory formalizes the observed linkages between real markets, where the changes of supply and demand in one market are generally interdependent from price changes on another market (Bergman 2005).

The existence of general equilibrium theory was then developed by Arrow and Debreu (1954) by using numerous mathematical approaches to obtain the equilibrium snapshot and its stability. The analysis on this study, however, was limited only in the abstract forms without including the numerical analysis (Hosoe *et al*., 2010). The first computable general equilibrium (CGE) model was by Johansen (1960 in Hosoe *et al*., 2010) in order to establish empirical analysis and evaluation purposes of economic policies based on the general equilibrium analysis. Since then, CGE models have become popular and been frequently developed among economists to analyse the wide impact of economic policy shocks (Hosoe *et al*., 2010).

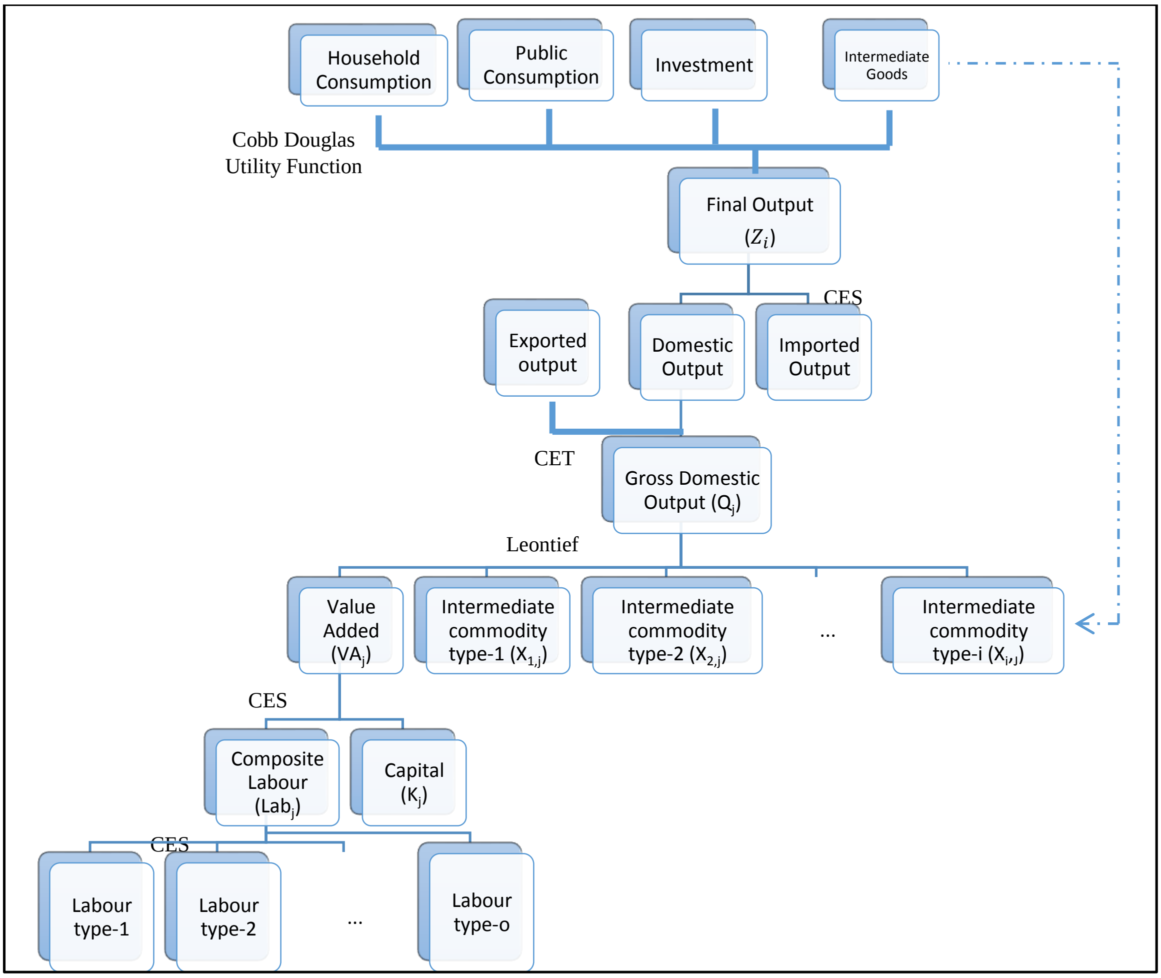
In developing countries, CGE models have been commonly used for examining medium and long-term impacts of a certain policy such as development strategies on economy growth, resource allocation for exhaustible goods, income distribution and tariff reform (De Melo, 1988). CGE models are used as the answers to overcome the lack or insufficient time series data in econometric model, which is identified as a major problem for a standard economic analysis in developing countries. The model is able to describe the economy system within the equations structures along with the comprehensive database that is consistent with the equations model (Resosudarmo *et al*., 2009). CGE models typically assume a static general equilibrium that consists of demand input of industry factor production; commodity supply; household demand; export demands; government demands; basic value relationship between production costs and producer prices; market clearing condition for commodities and primary factors; and several macro economy variables and price index (Horridge, 2000).

The rest of this chapter are organized as follows: Section 3.2 discusses in detail the construction of Indonesia standard CGE model including the choices of closure rules to obtain the solution. Section 3.3 presents the conclusions.

3.2. The Standard CGE Model

In this section, we propose a standard CGE model based on a modified version of Decaluwé *et al.* (2012) and Hosoe *et al.* (2010), which can be appropriately applied to Indonesian SAM data set as the representation of Indonesia's economy in year of 2008. This model, shortly, is a system of equations that features the economy's transactions such as the behavior of the economic representatives that related to their receipt and consumption budget; the structure of industry's output production; transfers of income (and payment) among institutions; investment and saving; and trade aggregations (treatment of imported and exported goods). The framework structure of this model is summarized in Figure 3.1.

Figure 3.1: Structure of Standard CGE Model



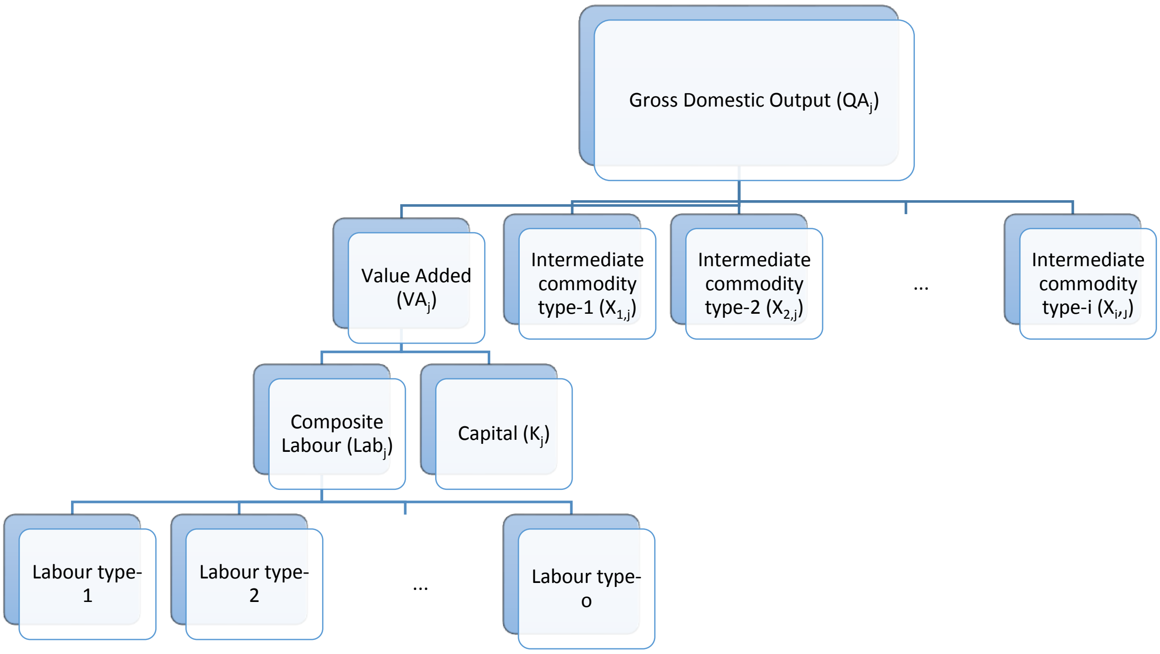
Source: Hosoe et al. (2004), a modification

3.2.1. Production of Gross Domestic Output

Each industry (activity) produces gross domestic output by utilizing the inputs of production factors (types of labour and capital) and intermediate commodities. This industry is assumed to minimize the cost of inputs subject to its production technology, and is operated in a perfectly competitive market (price takers).

In the standard model, we assume that all activities typically follow the nested production structure shown in Figure 3.2. Let the set of activity is represented by indices $j \in A$.

Figure 3.2: The Nested Production Structure



Source: Own Modification

At the top stage, gross domestic output j (QA_j) is produced from the combination between value added (VA_j) and intermediate commodities in a fixed coefficients (Leontief) function. Since the SAM dataset includes subsidy given to the j-th industry, we then assume that the level of subsidy rate $subA_j$ is added to the price of gross domestic output[11].

Let QA_j be the gross domestic output of the j-th industry; i be the element of all intermediate inputs (C) used in the j-th industry; $X_{i,j}$ be the intermediate input of the i-th commodity used by the j-th industry; $ax_{i,j}$ be the coefficient of minimum requirements of the i-th intermediate input for one unit of QA_j; ava_j be the coefficient of minimum requirements of the VA_j for one unit of QA_j; p_j^{VA} be the price of VA_j; and p_i^Z be the price of the i-th final (composite) goods. We assume that the j-th industry minimizes the cost inputs of $X_{i,j}$ and VA_j following a Leontief production function:

<u>Top stage:</u>

$$\min_{VA_j, X_{i,j}} C_j = p_j^{VA} VA_j + \sum_i p_i^Z X_{i,j} \quad , i \in C \quad , j \in A \qquad (1')$$

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[11] For further explanation, see the section of government behaviour

Subject to:

$$QA_j = min\left(\frac{X_{i,j}}{ax_{i,j}}, \frac{VA_j}{ava_j}\right) \quad ,i \in C \quad ,j \in A \tag{2'}$$

Equation (2') implies: $X_{i,j} \ = \ ax_{i,j}QA_j$; and $VA_j = \ ava_jQA_j$. We rearrange equation (1') as follows:

$$C_j = p_j^{VA}ava_jQA_j + \sum_i p_i^Z ax_{i,j}QA_j = \left(p_j^{VA}ava_j + \sum_i p_i^Z ax_{i,j}\right)QA_j \quad ,i \in C \quad ,j \in A$$

If we define the price index p_j^{QA} by including subsidy rate on j-th production ($subA\_rate_j$); such that $C_j = \left(1 + subA\_rate_j\right)p_j^{QA}QA_j$, the relationships are then given as follows:

$$X_{i,j} \ = \ ax_{i,j}QA_j \quad ,i \in C \qquad ,j \in A \tag{1}$$

$$VA_j = \ ava_jQA_j \qquad ,j \in A \tag{2}$$

$$\left(1 + subA\_rate_j\right)p_j^{QA} = p_j^{VA}ava_j + \sum_{i \in C} p_i^Z ax_{i,j} \qquad ,j \in A \tag{3'}$$

In equation (3'), we redefined $subA\_rate_j$ to allow a general average subsidy across activities ($subAArate$) and the subsidy rate of activity specific ($subArate_j$). The relationship is given as follows:

$$subAArate = \frac{1}{card(A)}\sum_{j \in A} sub\_rateA_j$$

$$subA\_rate_j = subAArate\ \left(subArate_j\right) \qquad ,j \in A$$

This rewriting is important since sometimes government makes an exogenous change in their budget, which is paid for by increasing a specific tax or reducing a specific subsidy. In order to allow such experiment, we allow activity's tax (subsidy) rate to adjust. Since there are 24 types of activity, and because these activities cannot be discriminated, the above rewriting of the tax rate allows to having only one endogenous variable to represent the overall tax rate for activity but keeping the structure of the tax rate across activities intact. Clearly, if the government wants to target a specific activity, then we can make endogenous only that activity's subsidy rate, i.e. $subArate_j$ rather than $subAArate$.

Hence, eq. (3') is rewritten as follows:

$$\left(1 + (subAArate)\ \left(subArate_j\right)\right)p_j^{QA} = p_j^{VA}ava_j + \textstyle\sum_{i \in C} p_i^Z ax_{i,j} \qquad ,j \in A \tag{3}$$

Equation (3) determines the unit cost of j-th industry to produce an output (QA_j) which is obtained from the weighted sum of the prices of value added and intermediate inputs.

Moreover, because generally each commodity can be produced by a single or multi activities and each activity can produce a single or multi commodities, the total output of

i-th commodity from all activities should be aggregated to give Q_i. This is modelled as follows:

$$Q_i = \sum_{j \in A} TRANS_{Coef_{j,i}} QA_j \quad ,i \in C \tag{4}$$

$$P_j^{QA} = \sum_{i \in C} TRANS_{Coef_{j,i}} P_i^Q \quad ,j \in A \tag{5}$$

Where:

$TRANS_{Coef_{j,i}} = \frac{QQ_{j,i}}{QA_j}$, is the Input-Output coefficients; and

$QQ_{j,i}$: Output of the j-th activity for the i-th commodity.

The existing SAM we used, however, is based on the principle that each activity produces one type of commodity, so $TRANS_{Coef_{j,i}} = 1, i = j$ and $TRANS_{Coef_{j,i}} = 0, i \neq j$. Hence the model will have a one-to-one relationship between activity output (and price) and commodity supply (and price).

At the second stage, each industry minimizes the input cost combination of composite labour and capital by using a Cobb-Douglas production function to produce composite factor (value added). Let P_j^{LAB} and P_j^K be the respective price of composite labour and capital of j-th industry; LAB_j and K_j be the number of composite labour and capital input of j-th industry; $\delta_{LAB,j}$ be the share parameter of labour composite by j-th industry ($0 \leq \delta_{LAB,j} \leq 1$); $\delta_{K,j}$ be the share parameter of capital by j-th industry ($0 \leq \delta_{K,j} \leq 1$); $\delta_{LAB,j} + \delta_{K,j} = 1$; and sva_j be the efficiency parameter of the j-th VA. The j-th industry problem to minimize cost of value added is therefore calculated as follows:

<u>Second stage:</u>

$$\min_{Lab,K} \left(P_j^{LAB} LAB_j + P_j^K K_j \right) \qquad ,j \in A$$

Subject to:

$$VA_j = sva_j LAB_j^{\delta_{LAB,j}} K_j^{\delta_{K,j}}, \qquad \delta_{LAB,j} + \delta_{K,j} = 1 \quad ,j \in A \tag{6}$$

The solution of the above problem yields the j-th industry demand for capital and composite labour:

$$K_j = \delta_{K,j} \frac{P_j^{VA}}{P_j^K} VA_j \qquad ,j \in A \tag{7'}$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VA}}{P_j^{LAB}} VA_j \qquad ,j \in A \tag{8'}$$

Price index of value added P_j^{VA} is the unit cost of VA production and is obtained from a weighted sum combination of price of composite labour and capital:

$$P_j^{VA} = \frac{P_j^{LAB} LAB_j + P_j^K K_j}{VA_j}, j \in A \tag{9'}$$

Furthermore, we introduce the adjustment terms of factor prices to enable the variation of these prices across activities. Thus, we need to define the additional variables: $P^K,\ P^{LAB}, PDIST_j^K, PDIST_j^{LAB}$ such that:

$$P_j^K = PDIST_j^K P^K$$

Where $PDIST_j^K$ is the adjustment factor for price of capital, and P^K is the aggregate price of capital which together determine the activity level price of capital P_j^K.

Based on the SAM, the total supply of capital stock is obtained from sum of capital demand to activities and rest of world (ROW) (K_ROW) as follows:

$$KS = \sum_j K_j + K\_ROW$$

We assume there is no unused or excess demand for capital: $KU = 0$. Thus, the aggregate price of capital is estimated as: $P^K = \frac{total\ capital\ value\ in\ SAM}{KS}$.

However, since there is no data available on real (physical) capital stock at activity level (K_j) and at rest of world (ROW) (K_ROW) of the given year of SAM, we assume that:

$$P_j^K = {SAM(K,j)}\Big/{K_j} \text{ and } P_{ROW}^K = 1$$

Where $SAM(K,j) = K_j$. Thus, P_j^K is equal to 1. To test that we have correctly initialized these relationships, in the model we calculate the following gap, which should be zero:

$$Cost\_GAP(K,j) = PDIST_j^K P^K K_j - SAM(K,j)$$

The price of labour composite across activities is defined as follows:

$$P_j^{LAB} = PDIST_j^{LAB} P^{LAB}$$

Where $PDIST_j^{LAB}$ is the adjustment factor for price of labour composite, and P^{LAB} is the aggregate price of labour composite, which together determine the activity level price of labour composite P_j^{LAB}. Here we also assume that $P^{LAB} = 1$.

Therefore, based on above definitions, equations (7' – 9') are rewritten as follows:

$$K_j = \delta_{K,j} \frac{P_j^{VA}}{PDIST_j^K P^K} VA_j \qquad ,j \in A \tag{7}$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VA}}{PDIST_j^{LAB} P^{LAB}} VA_j \qquad ,j \in A \tag{8}$$

$$P_j^{VA} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + PDIST_j^K P^K K_j}{VA_j} \qquad ,j \in A \tag{9}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we eliminate one of the above conditions to maintain balance between numbers of equations and free endogenous variables. This choice is considered arbitrary since it is aimed only to keep the income-expenditure accounting identity in a closed system of supply and demand equilibrium (Decaluwe *et al.*, 2012). We choose to exclude eq. 9 from the model specifications[12].

Finally, at the bottom stage, each industry minimizes the input cost of types of labour combination, indexed as $o \in LBR$, by a CES function. Let $L_{o,j}$ be the o-th type of labour used in j-th industry; p_o^L be the wage of o-th labour; $\gamma_{o,j}$ be the share parameter of o-th labour used by j-th industry $(0 \leq \gamma_{o,j} \leq 1)$; sl_j be the efficiency parameter of composite labour used by the j-th industry; and β_j be the substitution parameter of $L_{o,j}$ $(-1 \leq \beta_j \leq \infty, \beta_j \neq 0)$.

Bottom stage:

$$\min_{L_{o,j}} \sum_{o \in LBR} p_{o,j}^L L_{o,j} \qquad ,j \in A$$

subject to:

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}} \qquad ,j \in A \qquad (10')$$

By solving the above minimization problem, the labour demand solution is given as follows (Appendix A1):

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_j}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{P_{o,j}^L}{P_j^{LAB}} \right)^{\frac{-1}{\beta_j+1}} \qquad ,o \in LBR \quad ,j \in A \qquad (11')$$

The price index of industry's composite labour (P_j^{LAB}) is determined from the weighted sum of different types of o-th type of labour wage rates (P_o^L) (Appendix A2):

$$P_j^{LAB} = \frac{\sum_{o \in LBR} p_{o,j}^L L_{o,j}}{LAB_j} \qquad ,j \in A \qquad (12')$$

Denoting the elasticity of substitution by σ_j^L (Appendix A3), we have: $\beta_j = \frac{1}{\sigma_j^L} - 1$. The parameter value of β_j is obtained from Decaluwé *et al* (2012) since in this research we do not econometrically estimate this value. In the CGE model analysis, the modellers commonly choose the parameter values from literature. The way to choose these values is arbitrary. However, the robustness of the results generated from using these values will then be tested through a sensitivity analysis.

In the bottom stage, we also introduce wage adjustment terms per type of labour to enable the variation of labours' wages across activities. Thus, we need to define the additional variables: $p_o^L, PDIST_{o,j}^L$ such that:

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[12] For details, see Decaluwe, *et al* (2012)

$$p^L_{o,j} = PDIST^L_{o,j} p^L_o$$

Where $PDIST^L_{o,j}$ is the adjustment factor for wage of labour type, and p^L_o is the aggregate wage of labour type which together determine the activity level price of capital $p^L_{o,j}$.

Based on the SAM, the total supply per labour type is generated from the sum of labour type demand to activities and abroad (L_ROW_o) as follows:

$$\sum_{j \in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o, \qquad o \in LBR, \quad ROW \in INS$$

We assume there is unemployed labour: LU_o. Thus, the aggregate wage of labour type is estimated as: $p^L_o = \frac{total\ labour\ type\ value\ in\ SAM}{LS_o}$.

We assume $p^L_{o,j} = 1$ and $P^L_{o,ROW} = p^L_o$ [13], thus:

$$p^L_{o,j} = {}^{SAM(o,j)}\!\big/_{L_{o,j}}$$

Where $SAM(o,j) = L_{o,j}$; $SAM(o,ROW) = L\_ROW_o$.

To test the zero gaps, we estimate:

$$Cost\_gap(o,j) = PDIST^L_{o,j} p^L_o L_{o,j} - SAM(o,j)$$

Therefore, based on these definitions, equations (10' – 12') are rewritten as follows:

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad j \in A, \qquad \beta = \frac{1}{\sigma^l} - 1, \qquad \sigma^l > 1 \tag{10}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{PDIST^L_{o,j} P^L_o}{PDIST^{LAB}_j P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR, \qquad j \in A \tag{11}$$

$$PDIST^{LAB}_j P^{LAB} LAB_j = \sum\nolimits_{o \in LBR} PDIST^L_{o,j} P^L_o L_{o,j}\,, \qquad j \in A \tag{12}$$

Due to Walras' Law, one of the above equations is considered redundant. Thus, to obtain the income-expenditure accounting identity, we choose to exclude eq. 10 from the model specifications.

3.2.2. Government Behavior

The government has an important role in the CGE model as its revenue and expenditure influence the aggregate demand and supply in the market. The receipt (eq. (13)) is generally obtained from the collection of various types of taxes (including tariffs) net of subsidies and institutions' transfers, and then is spent to finance public goods and services (Karadag & Westaway, 1999). The remainder between receipt and expenditures will therefore be deposited as saving.

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[13] The introduction of wage for each labour type is applied in next chapter

Government receives income from institutions' transfers $\left(TR_{gov,in}\right)$ and tax collections such as: (1) direct tax of the h-th household income (IH_h) at the tax rate $Htax\_rate_h$; (2) *ad valorem* tax of the i-th gross domestic supply in terms of value $\left(P_i^Q Q_i\right)$ at rate of vat_rate_i; (3) business tax of enterprise income (IB) at the tax rate $Btax\_rate$; and (4) import tariff of the i-th imported goods in terms of value $(P_i^M M_i)$ at rate of $tarif\_rate_i$. In the existing SAM, both direct (1) and business taxes (3) are represented as government transfer income from households' and enterprise. Thus, to avoid a double counting transaction, we represent these taxes as transfer income to government; and let the respective $TR_{gov,h}$ and $TR_{gov,b}$ equal to $Htax\_rate_h IH_h$ and $Btax\_rateIB$, which are defined in the households' and enterprise block of equations.

The government total income from collecting taxes and transfer income is summarized as follows:

$$IG = \sum_{i \in C} vat\_rate_i P_i^Q Q_i + \sum_{i \in CM} tarif\_rate_i P_i^M M_i + \sum_{in \in INS} TR_{gov,in} \qquad (13')$$

Where $in \in INS = \{H_1, \ldots, H_h, Gov,\ firm,\ ROW\}$

Similar to the above principle of rewriting subsidy in activity specific, we redefined vat_rate_i and $tarif\_rate_i$ to obtain a general average *ad valorem* tax and tariffs across commodities ($vatArate$ and $tarifArate$), and a specific *ad valorem* tax and tariffs per commodity specific ($vatrate_i$ and $tarifrate_i$). The relationship is then given as follows:

$$vatArate = \frac{1}{C}\sum_i vat\_rate_i \qquad , i \in C$$

$$tarifArate = \frac{1}{C}\sum_i tarif\_rate_i \qquad , i \in C$$

$$vat\_rate_i = vatArate\ (vatrate_i) \qquad , i \in C$$

$$tarif\_rate_i = tarifArate\ (tarifrate_i) \qquad , i \in C$$

Therefore, eq. 13' is rewritten as follows:

$$IG = \sum_{i \in C} (vatArate)(vatrate_i) P_i^Q Q_i + \sum_{i \in CM} (tarifArate)(tarifrate_i) P_i^M M_i + \sum_{in \in INS} TR_{gov,in} \qquad (13)$$

Government expends their income by (1) purchasing public goods and services (CG_i); subsidizing: (i) some of i-th domestic supply ($P_i^Q Q_i$) at the subsidy rate of $subQ\_rate_i$; and (ii) some of j-th industry gross output ($P_j^{QA} QA_j$) at the subsidy rate of $subA\_rate_j$; and (3) transfer payments to institutions' $\left(TR_{in,gov}\right)$. Thus, equation for government expenditure is written as follows:

$$EG = \sum_{i \in C} P_i^Z CG_i + \sum_{i \in C} (subQArate)(subQrate_i) P_i^Q Q_i + \sum_{j \in A} (subAArate)\big(subArate_j\big) P_j^{QA} QA_j + \sum_{in \in INS} TR_{in,gov} \quad (14)$$

Public spending of each goods and services (CG_i) is adjusted from initial expenditure of i-th final goods $(CGIN_i)$ (equation (15)); and $\big(TR_{in,gov}\big)$ of each institutions' is determined from a fixed proportion of their total transfer payments (TRG_bar) (equation (16a – 16b)). In addition, we assume that government transfer payment to households' is measured in terms of real value, which is linked via CPI-indexed.

$$CG_i = CGIN_i \overline{CGADJ}, \qquad i \in C \quad (15)$$

$$TR_{h,gov} = TRG\_share_{h,gov} TRG\_barCPI, \qquad h \in H, gov \in INS \quad (16a)$$

$$TR_{in,gov} = TRG\_share_{in,gov} TRG\_bar, \qquad in \neq h \in INS \quad (16b)$$

The difference between government income and expenditure is therefore regarded as government saving (SG) as follows:

$$SG = IG - EG \quad (17)$$

3.2.3. Households Behaviour

Following Varian (1992), the households' preferences on output bundles are described from their utility function that is maximized subject to their budget income constraint. Suppose that household income (equation (18)) is earned from its endowed factors (labour and capital) to j-th industry; and institutions' transfers $(TR_{h,in})$. Thus, income sources of the h-th type of households are obtained as follows:

$$IH_h = IHL_h + IHK_h + \sum_{in \in INS} TR_{h,in}\,, \qquad h \in H \quad (18)$$

Where:

IH_h : Total income of the h-th type of households
IHL_h : Labour income of the h-th type of households
IHK_h : Capital income of the h-th type of households
$TR_{h,in}$: Transfer income of the h-th type of households from the in-th institution's

IHL_h and IHK_h are determined from household income shares of each labour type and capital endowment to activity and ROW respectively:

$$IHL_h = \sum_{o \in LBR} IHL\_share_{h,o} P_o^L \left(\sum_{j \in A} PDIST_{o,j}^L \, L_{o,j} + L_{o,ROW} \right), \qquad h \in H \quad (19)$$

$$IHK_h = IHK\_share_h P^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right) \quad , h \in H \quad , ROW \in IN \quad (20)$$

Where:

$IHL\_share_{h,o}$: Share of the o-th type of labour income received by h-th type of households

IHK_share_h : Share of capital income received by h-th type of households

L_ROW_o : The o-th type of labour supply from ROW used in j-th industry

K_ROW : The abroad capital supply used in j-th industry

The government collects income taxes on h-th type of households which is represented as government transfer income from households' ($TR_{gov,h}$). It yields the disposable income of households' (DIH_h) as follows:

$$DIH_h = IH_h - TR_{gov,h}, \qquad h \in H, \qquad gov \in INS \qquad (21)$$

Households' transfer payments to institutions' except the government ($TR_{in,h}$) are adjusted proportionally to their disposable income (equation (22a)); and household income tax which is regarded as households' transfer payment to government is given in equation (22b).

$$TR_{in,h} = TRH\_share_{in,h} DIH_h, \qquad in \neq gov \in INS, \qquad h \in H \qquad (22a)$$

$$TR_{gov,h} = (HAtaxrate\ )(Htaxrate_h)\ IH_h, \qquad h \in H \qquad (22b)$$

Where $TRH\_share_{in,h}$ is the share of the h-th type of households' transfer payment to the in-th institution.

In eq. 22b, we also rewritten household tax rate $Htax\_rate_h$ as $(HAtaxrate\ )(Htaxrate_h)$ to distinguish a representation of overall and specific tax rate for households.

Furthermore, the subtractions of households' transfer payments yield the actual disposable income ($ADIH_h$) of the h-th type of households as follows:

$$ADIH_h = DIH_h - \sum_{in \neq gov \in INS} TR_{in,h}\,, \qquad h \in H \qquad (23)$$

The representative households are motivated to save some portions of their actual disposable income according to the constant average propensities for saving (equation 24), of which these portions are allowed to adjust endogenously (equation (25)).

$$SH_h = sh\_ratio_h ADIH_h, \qquad h \in H \qquad (24)$$

$$sh\_ratio_h = sh\_rin_h(1 + sh\_dum_h sh\_adj), \qquad h \in H \qquad (25)$$

Where:

SH_h : Saving of the h-th type of households

sh_ratio_h : Adjusted average propensity for saving of the h-th type of households
sh_rin_h : Initial value of average propensity for saving of the h-th type of households
sh_dum_h : 0, if $sh\_ratio_h = sh\_rin_h$, i.e. no change in saving ratio
sh_dum_h : 1, if sh_ratio_h is allowed to adjust, in which case sh_adj is the endogenous adjustment of sh_ratio_h

Therefore, the available budget of household consumption on final goods (EH_h) is then obtained from their actual disposable income less saving (equation (26)).

$$EH_h = ADIH_h - SH_h, \qquad h \in H \tag{26}$$

Finally, by assuming a Cobb-Douglas utility function (homogenous of degree one)[14], the optimization problem of the h-th type of households can be written as follows:

Let $(CH_{1,h},\ CH_{2,h}, \ldots, CH_{3,h})$ and $p = (p_1^Z, p_2^Z, \ldots, p_i^Z)$ be quantity and price vectors associated with i-th final goods. For each household type, $h \in H$, the utility function and total expenditure are:

$$\max_{CH_{i,h}} U_h = \prod_i CH_{i,h}{}^{CH\_share_{i,h}}, \qquad i \in C, \qquad h \in H$$

Subject to:

$$\sum_{i \in C} P_i^Z CH_{i,h} = EH_h, \qquad h \in H$$

Where:

U_h : Utility of the h-th type of households
$\alpha_{i,h}$: Share parameter in utility function of the h-th type of households

By solving the above conditions, we obtain the solution to which yield the corresponding demand function (Appendix A4):

$$P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h, \qquad i \in C, \qquad h \in H \tag{27}$$

3.2.4. Consumer Price Index (CPI)

In this model, CPI is adjusted from total price index of i-th households (equation (28)), which is obtained from the homogeneity relationship of i-th final goods price (equation (29)) as follows:

$$PI_h = \prod_{i \in C} (P_i^Z)^{CH\_share_{i,h}}, \qquad h \in H \tag{28}$$

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[14] (X) is a homogenous degree of b if $u(tX) = t^b u(X)$ for all $X > 0$. Homogenous degree one where: $b = 1$. The Cobb-Douglas utility function has a homogenous degree one because $\sum_i \propto_i = 1$. Therefore $u(tX_1, tX_2, \ldots, tX_i) = \prod_i (tX)_i^{\alpha_i} = tu(X_1,\ X_2, \ldots, X_i)$

$$CPI = \sum_{h \in H} w_h PI_h \tag{29}$$

Where w_h is the weight of commodity purchased by h-th of household.

3.2.5. Enterprise Behavior

The enterprise receipt (IB) is obtained from its capital endowment to j-th industry and institutions' transfers (equation (30)). IBK is determined from enterprise shares of capital supply (31).

$$IB = IBK + \sum_{in \in INS} TR_{b,in} \tag{30}$$

$$IBK = IBK\_shareP^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right), \quad ROW \in INS \tag{31}$$

Where:

IBK_share : Share of capital income received by enterprise

$TR_{b,in}$: Enterprise transfer income from in-th institutions'

Government collects income taxes from enterprise income, which is represented as business transfer payment to government. This yields enterprise disposable income as follows:

$$DIB = IB - TR_{gov,b}, \qquad gov, b \in INS \tag{32}$$

Enterprise transfer payments to institutions' excluding government are assumed to adjust proportionally to their disposable income ($TRB\_share_{in,b}$) (equation (33a)) while enterprise transfer payments to government are regarded as enterprise income tax (equation (33b)).

$$TR_{in,b} = TRB\_share_{in,b} DIB, \qquad in \neq gov \in INS \tag{33a}$$

$$TR_{gov,b} = (Btaxrate) IB, \quad b \in INS \tag{33b}$$

These subtractions yield the actual disposable income of enterprise ($ADIB$) as follows:

$$ADIB = DIB - \sum_{in \neq gov \in INS} TR_{in,b} \tag{34}$$

Since enterprise does not purchase any goods, the enterprise saving (SB) is thus simply equal with the actual disposable income (equation (35)).

$$SB = ADIB \tag{35}$$

3.2.6. Rest of World (ROW)

In the existing SAM, total labour income (TLI) generated within the country (payments to labour from activities and ROW) is defined as follows[15]:

$$TLI = \sum_{o}\left(P_o^L\sum_{j}PDIST_{o,j}^L L_{o,j} + P_o^L L_{o,ROW}\right) = \sum_{o}\left(\sum_{j}SAM(o,j) + SAM(o,ROW)\right)$$

$L_{o,ROW}$ is the labour employed within the country by ROW and it is treated as exogenous. TLI is distributed across institutions' (households' and ROW ($ROWLI$)) as:

$$TLI = IHL_h + ROWLI = \sum_{h}\sum_{o}SAM(h,o) + \sum_{o}SAM(ROW,o)$$

Thus, we need a distribution mechanism across ROW. We propose:

$$ROWLI = \sum_{o}RL\_share_o\left(P_o^L\sum_{j}PDIST_{o,j}^L L_{o,j} + P_o^L L_{o,ROW}\right)$$

Therefore, ROW total outflow is generated from total of import, institutions' income transfers to ROW, and ROW endowments of factors supply to domestic (equation (36)).

$$IROW = \sum_{i\in CM}P_i^M M_i + \sum_{in\in INS}TR_{ROW,in} + \sum_{o\in LBR}RL\_share_o P_o^L\left(\sum_{j\in A}PDIST_{o,j}^L L_{o,j} + L_{o,ROW}\right) + RK\_share P^K\left(\sum_{j\in A}PDIST_j^K K_j + K_{ROW}\right), \quad ROW \in INS \tag{36}$$

Where $IROW$ denotes ROW total outflow; M_i denotes import of the i-th goods; $TR_{ROW,in}$ denotes transfer income from in-th institutions to ROW; CM denotes the exported and imported commodities; and respective RL_share_o and RK_share denote the shares of the o-th foreign labour and capital used domestically which are identified in SAM as:

$$RL\_share_o = \frac{SAM(ROW,o)}{\sum_j SAM(o,j) + SAM(o,ROW)}, \quad o \in LBR$$

$$RK\_share = \frac{SAM(ROW,K)}{\sum_j SAM(K,j) + SAM(K,ROW)}$$

ROW total inflow is determined from total exports, ROW payment transfers to institutions', payment to labour and capital employed by ROW (equation (37)).

$$EROW = \sum_{i\in CE}P_i^E E_i + \sum_{in\in INS}TR_{in,ROW} + \sum_{o\in LBR}P_o^L L_{o,ROW} + P^K K_{ROW}, \quad ROW \in INS \tag{37}$$

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[15] The same principal applies to define total capital income.

Where $EROW$ denotes ROW total inflow; E_i denotes export of the i-th goods; $TR_{in,ROW}$ denotes transfer payment from RoW to institutions; and CE denotes the exported and imported commodities.

ROW transfer payments to institutions are determined from a fixed proportion of ROW total transfer payments ($TROW\_bar$) (equation (38a – 38b)). Since there is no transaction record from ROW to ROW, we treat this as exogenous. Finally, ROW saving (balance of payments) is determined equivalently from the current account deficit or residual between ROW outflow and inflow (equation (39)).

$$TR_{in,ROW} = TRW\_share_{in,ROW}(EXR)TROW\_bar, \qquad ROW \notin in \in INS \qquad (38a)$$

$$TR_{ROW,ROW} = 0 \qquad (38b)$$

$$SROW \ = EROW - IROW \qquad (39)$$

Where $SROW$ denotes current acount deficit; $TRW\_share_{in,ROW}$ denotes the shares of ROW transfer payments to in-th institutions' excluding ROW; and EXR denotes Exchange rate (domestic currency/foreign currency).

The price relationships in terms of local and ROW currency between export and import commodities are given in equation (40) and (41) as follows:

$$P_i^E = (EXR)P_i^{EW} \qquad ,i \in CE \qquad (40)$$

$$P_i^M = (EXR)P_i^{MW} \qquad ,i \in CM \qquad (41)$$

Where:

P_i^{MW} : Imported price of the i-th goods in terms of foreign currency (exogenous)

P_i^{EW} : Exported price of the i-th goods in terms of foreign currency (exogenous)

P_i^M : Imported price of the i-th goods in terms of domestic currency

P_i^E : Exported price of the i-th goods in terms of domestic currency

3.2.7. Investment

In the static version of a CGE model, the behaviour of investment does not involve with its dynamic factors. We allow the case if the investment is kept fixed or otherwise is treated as endogenous to allow investment to adjust (equation (42)). The total investment demand will be therefore equal to total saving of all institutions (household, firm, government, and rest of world) of an economy. Walras law states that the values of excess demand for all market systems must equal to the values of excess supplies. This implies that if an excess demand occurs in a market, excess supply must also exist in the other market. In other words, excess demand across all industries must equal to zero. Thus, to check Walras law identity, we apply equation (43), in which $WALRASRES$ should be zero in the equilibrium state.

Thus, the final demand of the i-th investment commodity is given as follows:

$$CINV_i = CINVIN_i(1 + INVADJ), \qquad i \in C \tag{42}$$

Where $CINVIN_i$: Initial investment demand of the i-th commodity, $INVADJ$: The investment adjustment index ($INVADJ$=0 if investment is fixed; otherwise if it is allowed to adjust endogenously).

The Walras identity is then determined from the saving-investment balance as follows:

$$WALRASRES = \sum_{h \in H} SH_h + +SB + SG + SROW - \sum_{i \in C} P_i^Z CINV_i \tag{43}$$

Where:

$WALRASRES$: Walras residual

3.2.8. The Armington Aggregations

In open economy model, we adopt Armington's assumption to differentiate between a country's domestically produced and exported or imported commodities. We assume that the industry combines its inputs (imported and domestic-produced goods) by a CES production function to produce composite goods. The exported goods are produced from the transformation of gross domestic output sold for domestic and export sales by a CET (Constant Elasticity of Transformation) production function, where industry will maximize its profit subject to this function. The isoquants of a CET function are actually the mirror images of CES function (Hosoe, 2004). For the sake of simplification, we assume no simultaneous cross hauling: export and import for the same goods.

Therefore the industry maximization problem to produce the i-th composite good can be written as follows: let π_i^z be the profit of the industry to produce the i-th Armington's composite goods; D_i and M_i be the i-th domestic and imported commodity respectively; p_i^d and p_i^m be the domestic and import price of the i-th commodity (in terms of domestic currency) respectively; Z_i be the i-th Armington's composite goods; δ_{mi} and δ_{di} be the import and domestic share parameter of Armington's for i-th composite commodity respectively; $\delta_{mi} + \delta_{di} = 1$, $(0 \leq \delta_{mi} \leq 1)$ and $(0 \leq \delta_{di} \leq 1)$; sz_i be the shift parameter of the i-th composite goods; and Φ_i be the substitution parameter of Armington's for i-th composite commodity.

$$\max_{\mathrm{Z_i}, M_i, D_i} \pi_i^z = P_i^z Z_i - \left(\left(1 + (tarifArate)(tarifrate_i)\right) p_i^M M_i + p_i^D D_i \right) \qquad , i \in CM \cap CD$$

Subject to:

$$Z_i = sz_i \left({\delta_{mi}}^{1+\Phi_i} {M_i}^{-\Phi_i} + {\delta_{di}}^{1+\Phi_i} {D_i}^{-\Phi_i} \right)^{-\frac{1}{\Phi_i}} \quad , i \in CM \cap CD \quad , \Phi = \frac{1}{\sigma^z} - 1 \quad , \sigma^z > 1 \tag{44}$$

Thus, by solving the above maximization problems, the solution for import (equation (46)) and domestic demand function (equation (47)) of the i-th good can be written as follows (appendix A5):

$$M_i = \left(\frac{\delta_{mi}}{sz_i^{\frac{\Phi_i}{1+\Phi_i}}}\right) Z_i \left\{\frac{\big(1 + (tarifArate)(tarifrate_i)\big)P_i^M}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}} \qquad ,i \in CM \cap CD \qquad (46)$$

$$D_i = \left(\frac{\delta_{di}}{sz_i^{\frac{\Phi_i}{1+\Phi_i}}}\right) Z_i \left\{\frac{P_i^D}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}} \qquad ,i \in CM \cap CD \qquad (47)$$

The price index of the composite (final) commodity (P_i^Z) is determined from the zero profit condition or a weighted sum of values of domestic sales and imported goods:

$$P_i^Z Z_i = \big(1 + (tarifArate)(tarifrate_i)\big)P_i^M M_i + P_i^D D_i \qquad ,i \in CM \cap CD \qquad (48)$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, one of the above equations is considered redundant. Thus, to obtain the income-expenditure accounting identity, we choose to exclude eq. 44 from the model specifications. In addition, the parameter value of Φ_i is obtained from Decaluwé *et al* (2012) since in this research work we do not econometrically estimate this value. The robustness of the results generated from using these values will then be tested through a sensitivity analysis.

For the case where industry does not utilize imported goods, however, the relationship will be simply written as follows:

$$Z_i = D_i \qquad ,i \in CD \ \& \ \notin CM \qquad (45)$$

$$P_i^Z = P_i^D \qquad ,i \in CD \ \& \ \notin CM \qquad (49)$$

Next, the industry profit maximization problem solved for the i-th transformation (export and domestic) commodity can be written as follows: let π_i be the profit of the industry for the i-th transformed commodity; D_i and E_i be the i-th domestic and exported commodity respectively; p_i^d and p_i^e be the domestic and export price (in terms of domestic currency) of the i-th commodity respectively; Q_i be the i-th gross domestic output; ω_{ei} and ω_{di} be the share parameter of i-th transformation commodity ($0 \le \omega_{ei} \le 1;\ 0 \le \omega_{ei} \le 1;\ \omega_{ei} + \omega_{di} = 1$) respectively; and ς_i be the substitution parameter for i-th transformation.

$$\max_{Q_i,E_i,D_i} \pi_i = \big(p_i^d D_i + p_i^E E_i\big)$$
$$- \big(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\big)P_i^q Q_i \qquad ,i \in CE \cap CD$$

Subject to:

$$Q_i = sq_i\big(\omega_{e,i}{}^{1-\mu_i}(E_i)^{\mu_i} + \omega_{d,i}{}^{1-\mu_i}(D_i)^{\mu_i}\big)^{\frac{1}{\mu_i}}$$
$$,i \in CE \cap CD, \quad \mu = \frac{1}{\sigma^q} + 1, \quad \sigma^q > 0 \qquad (50)$$

Let ξ be a Lagrangian and μ be a Lagrange multiplier.

$$\xi = \left(p_i^d D_i + p_i^E E_i\right) - \left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right)P_i^q Q_i$$
$$+\ \mu \left(sq_i(\omega_{ei}{}^{1-\varsigma_i}(E_i)^{\varsigma_i} + \omega_{di}{}^{1-\varsigma_i}(D_i)^{\varsigma_i})^{\frac{1}{\varsigma_i}} - Q_i\right)$$

By deriving the above profit maximization problems, demand solution of export (equation (50)) and domestic goods (equation (51)) can be written as follows:

$$E_i = \frac{\omega_{ei}}{sq_i{}^{\mu_i/\mu_i-1}} Q_i \left\{\frac{P_i^E}{\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right)P_i^Q}\right\}^{\frac{1}{\mu_i-1}}$$
$$, i \in CE \cap CD \qquad (51)$$

$$D_i = \frac{\omega_{di}}{sq_i{}^{\varsigma_i/\varsigma_i-1}} Q_i \left\{\frac{P_i^D}{(1 + vat_i - subQ_i)P_i^Q}\right\}^{\frac{1}{\varsigma_i-1}} \qquad , i \in CE \cap CD \qquad (52)$$

The price index of domestically produced commodity (P_i^q) is determined from the zero profit condition or a weighted sum of values of domestic sales and export:

$$\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right)P_i^Q Q_i = P_i^D D_i + P_i^E E_i$$
$$, i \in CE \cap CD \qquad (53)$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law condition, eq. 50 is excluded from the model specifications.

For the case where the industry produces only domestic commodities (not exported), however, the relationship will be simply written as follows:

$$Q_i = D_i \qquad , i \in CD \ \& \ \notin CE \qquad (54)$$

$$\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right)P_i^Q = P_i^D$$
$$, i \in CD \ \& \ \notin CE \qquad (55)$$

3.2.9. Market-clearing

Finally, at the last stage, we define market-clearing conditions to measure the equilibrium between supply and demand in all markets as follows:

$$P_i^Z Z_i = \sum_h P_i^z CH_{i,h} + P_i^Z CG_i + P_i^Z CINV_i + P_i^z \sum_j X_{i,j}$$

By eliminating P_i^z, we obtain the equilibrium between demand (total consumption of households, government, investment, and intermediate input) and supply of the i-th goods in domestic market.

$$Z_i = \sum_{h \in H} CH_{i,h} + CG_i + CINV_i + \sum_{j \in A} X_{i,j} \qquad , i \in C \qquad (56)$$

Factor market-clearing conditions:

$$\sum_{j \in A} K_j + K_{ROW} + KU = KS \qquad , ROW \in INS \qquad (57)$$

$$\sum_{j \in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o \quad , o \in LBR, \quad ROW \in INS \tag{58}$$

Where:

KS : Total capital supply

KU : Unused or excessive capital stock

LU_o : The o-th unemployed labour

LS_o : Total supply of o-th labour

3.2.10. Closures

In CGE modeling, the equilibrium condition is obtainable by equalizing the total number of equations and endogenous variables. It is commonly that in CGE model, total numbers of equations are less than endogenous variables. Thus to obtain the solution, model closures must be applied. These problems are usually solved by setting a number of closure rules, either by adding a new equation to the standard model or by choosing the exogenous variables among all variables in the model based on justification of assumptions in the values (Pezzey and Lambie, 2001). Yusuf (2008) noted that the specification of closures should consider three crucial aspects: accomodating towards the research focus and objectives of the modellers; minimizing the weakness of the model in its description of the real world economy; and adjusting the timescale period (short run vs long run) of research investigation.

The model consists of 2,333 endogenous variables. There are 1,818 equations describing the behavioural rules and constraints. We therefore need 515 additional equations in order to close the model and obtain a solution. These equations are specified as our closure rules, which are divided into 2 main categories: micro-closures that relates mostly to market clearing processes for production factors; and macro-closures that relates mostly to saving-investment and government balance (Gilbert & Tower, 2013). We also assume Indonesia as a small open economy country where the country cannot influence the world price of imports and exports. Thus, these assumed as exogenous.

3.2.10.1. Micro-closures

For micro-closures, the CGE modellers can choose some alternative ways to equalize the supply and demand of factor markets: by fixing the quantity of each factor suppy (full employment) and allowing their prices (wages and rental) to assure the clearing of supply-demand factors; or choosing reversely, where the factors may endogenously unemployed and their prices are held fixed (Lofgren *et al.*, 2002). These choices, however, can also be done through a combination, i.e. assuming full employment for high skilled labour and allowing the mobility (unemployment) of low skilled labour (Kyalimpa, 2014). In the model, we design three choices of closures for each production factor (capital, types of labour, and composite labour).

For capital and labour closures, they either fully employed or there is excess demand or supply. They can also be either mobile or activity specific. The choices for capital closures are expressed as follows:

i) The capital stock across activities K_j is exogenous or kept constant, and $PDIST_j^K$ adjusts across activities to ensure market clearing. The aggregate rent of capital P^K is also exogenous, and thus KU adjusts to ensure overall market clearing.

ii) K_j adjusts between j-th activities to ensure market clearing in each industry, and $PDIST_j^K$ is kept constant. P^K is also kept constant, and thus KU adjusts to ensure overall market clearing.

iii) K_j adjusts between j-th activities to ensure market clearing of each industry, and $PDIST_j^K$ is kept constant. However, KU is kept constant ($KU = 0$) and P^K adjusts to ensure overall market clearing.

The choices for labour closures are expressed as follows:

i) The number of employed labour types across activities $L_{o,j}$ is exogenous; while LAB_j, $PDIST_j^{LAB}$, P^{LAB}, and $PDIST_{o,j}^L$ are endogenous such that constraint of: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_o \left(PDIST_{o,j}^L P_o^L L_{o,j} \right)$ holds for each activity. P_o^L is fixed, $LU_o = 0$ adjusts to ensure labour market clearing: $\sum_{j \in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o$.

ii) $PDIST_{o,j}^L$ is exogenous while $L_{o,j}$ adjust and determine LAB_j; $PDIST_j^{LAB}$ and P^{LAB} are also endogenous such that the constraint of: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_o \left(PDIST_{o,j}^L P_o^L L_{o,j} \right)$ holds for each activity. Fully employed is assumed where $LU_o = 0$ is kept constant; P_o^L adjusts to obtain labour market clearing.

iii) $PDIST_{o,j}^L$ is exogenous while $L_{o,j}$ adjusts and determine LAB_j; $PDIST_j^{LAB}$ and P^{LAB} are also endogenous such that the constraint of: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_o \left(PDIST_{o,j}^L P_o^L L_{o,j} \right)$ holds for each activity. P_o^L is exogenous and $LU_o = 0$ adjusts to ensure labour market clearing.

In the model experiments, we opted to choose the third option (iii) for both capital and labour closures because it relaxes the typical neoclassical closure of labour market where all types of labour are mobile inter-industries having fixed wages so that the labour market equilibrium is achievable through the endogenous adjustment of the rate of unemployment. This choice is deemed due to the fact that Indonesia is currently a developing country with a high labour surplus (Yusuf *et al.*, 2008). We assume that the Indonesian economy does not operate on the production possibility frontier. For short-run analysis, we assume that there is no excessive capital. The capital stock is mobile across industries but its adjusted rent across activities remain as exogenously fixed so that the equilibrium solution is achievable through the flexible adjustment of its aggregated prices.

3.2.10.2. Macro-closures

For simplicity, we specify macro-closures by categorizing them into three areas that related with: saving-investment balance; balance of payments; and government expenditure.

In the saving-investment block, the model has one equation that represents the saving-investment identity (eq. 42), with two groups of endogenous variables: institution saving and investment. One of these variables should be exogenously fixed to achieve the solution. There are two ways to obtain it: (1) investment-driven closure as part of Neoclassical Closure, where investment is fixed and institution saving is endogenously determined to equalize the equilibrium; or (2) saving-driven closure as part of Johansen Closure, where institution saving is exogenous and investment will adjust to equalize the equilibrium (Robinson, in Janvry and Kanbur (2006)).

Investment-driven closure is usually used for a static CGE model to avoid distorted results from inter-temporal allocation of welfare impact (Warr cited in Yusuf, 2008). Thus, the fixed and independent investment on the change of income will lead to fully change of welfare (Hosoe *et al.*, 2010). In contrast, a saving-driven assumes the changes of welfare generated by the changes of income will be partly cancelled out by the changes of investment goods (Hosoe *et al.*, 2010).

In the model, we propose three variations of saving-investment closures, which are summarized as follows:

1) Investment-driven closure:
    i) The actual investment good ($CINV_i$) is fixed and equal with the initial investment good ($CINVIN_i$). It also implies that there is no adjustment of investment ($INVADJ = 0$). Enterprise saving (SB) is also exogenous. Thus, the saving of h-th type of households (SH_h) and government (SG) are endogenously determined to obtain the saving-investment balance, which imply (WAL_RES) variable is zero. In addition, since SH_h is endogenous, it means that the average propensity to save of the h-th households (sh_ratio_h) is allowed to adjust proportionally to the level of (sh_adj) and assuming dummy variable of $sh\_dum_h = 1$.
    ii) The actual investment goods ($CINV_i$) and household saving are exogenous while enterprise saving (SB) and government saving (SG) are endogenous to ensure the balance.
2) Saving-driven closure:

    All institutions saving are fixed. The actual investment goods is therefore endogenously determined to obtain saving-investment balance, in which (WAL_RES) variable is zero.

This adjusment implies that: $INVADJ \neq 0$ to equalize between the actual and initial investment.

For (ii) and (2), because SH_h is exogenously fixed, sh_ratio_h is then fixed and equal to its initial level of sh_rin_h, where there is no saving rate adjustment ($sh\_adj = 0$) and $sh\_dum_h = 0$. In the CGE exercises, we choose option (i).

Furthermore, within the context of open-economy model, the saving-investment balance has two additional variables namely: foreign saving ($SROW$) and the exchange rate (EXR) but within one additional equation: the current account deficit constraint (Hosoe *et al.*, 2010). Thus, the model has one endogenous variable that requires to be changed as exogenous variable to clear the solution. There are two ways to resolve this problem: (i) exchange rate is pegged and allowing foreign saving to clear the inflow – outflow deficit (or surplus); or (ii) foreign saving is fixed and allowing the exchange rate to clear the inflow – outflow deficit (or surplus). In the model simulations, we choose option (ii) where exchange rate is flexible to ensure that the balance of payments equals to zero. This assumption is in accordance to the flexible exchange rate regime of Indonesia, which has been implemented since post global monetary crisis in year of 1997.

For government balance, Lofgren *et al.* (2002) proposed three alternative ways to close the model: (i) the default closure by which all net tax rates (including subsidy rates)[16] are exogenous, while government saving is endogenously flexible to obtain the balance; (ii) in contrast with (i) where all net tax rates are endogenous and government saving is fixed; and (iii) that is similiar with (ii) where all tax rates are flexible, but some of the tax rates are multiplied by a scaled scalar. Government expenditure on goods and services are held exogenously fixed on all of these proposals. Nonetheless, there is no choice of closure where both government saving and tax rates are exogenous while government expenditure is flexibly endogenous. In the model exercises, we choose option (i) as this is suitable for simulating the shock of government spending (increasing) and subsidy for activities (decreasing).

The model also allows transfer payments (income) between institutions to be endogenously determined. This is because we assume that any changes to income and budget spending of institutions will adjust to their level of transfers. It is implausible justified to assume fixed transfers when income rate decreases (increases).

As a result, the total number of equations (1,818 equations) is equal to total endogenous variables (1,818 variables).

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[16] Athough Lofgren, *et al* (2002) stated the rates of tax, here we change it slighlty as net tax rates to include the subsidy rates. This is because the SAM dataset has specific account for subsidy transactions.

3.3. Conclusion

This chapter aims to explain a detailed construction of the features of the CGE model for Indonesia’s economy. The constructions are based on the modified version of Decaluwé *et al.* (2012) and Hosoe *et al.* (2010), such that the model can be appropriately calibrated to the Indonesia’s SAM dataset in the year 2008. A number of optimization conditions of agent behaviours are explained. Since the total numbers of equations are less than the endogenous variables, we adopt a set of closure rules that are closely related to the real condition of Indonesia’s economy. These closures are divided into two main groups: macro and micro closure rules.

The standard CGE model is applied for simulating the variations of fiscal policies given in the next chapter. Afterwards, this model will be further extended to examine the economy-wide impact of fiscal policies to promote clean electricity utilizations on Indonesia’s economy.

Appendix 3.A: Mathematical Derivations

3.A1. Labour Demand

The j-th industry problem to minimize the cost of o-th labour demand subject to a CES technology:

$$\min_{L_{o,j}} \sum_{o \in LBR} p_{o,j}^{L} L_{o,j} \,, j \in A$$

Subject to:

$$LAB_j = \; sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}} ,j \in A \qquad (1a)$$

Let £ be a Lagrangian and µ be a Lagrange multiplier.

$$£ \; = \; \sum_{o \in LBR} p_{o,j}^{L} L_{o,j} + µ \left(sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}} - VA_j \right)$$

First order conditions:

$$\frac{\partial £}{\partial L_{o,j}} = p_{o,j}^{L} + µ \left(-\frac{1}{\beta_j} \right) \left(sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}-1} \right)$$

$$\left(-\beta_j {\gamma_{o,j}}^{1+\beta_j} L_{o,j}^{-\beta_j - 1} \right) = 0 \qquad (1b)$$

$$\frac{\partial £}{\partial µ} = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}} - LAB_j = 0 \qquad (1c)$$

Ratio of two foc (2b):

$$\frac{p_{o,j}^{L}}{p_{m,j}^{L}} = \frac{{\gamma_{o,j}}^{1+\beta_j} L_{o,j}^{-\beta_j - 1}}{{\gamma_{m,j}}^{1+\beta_j} L_{m,j}^{-\beta_j - 1}} = \left(\frac{\gamma_{m,j} L_{o,j}}{\gamma_{o,j} L_{o+1,j}} \right)^{-\beta_j - 1}$$

$$L_{o,j}^{-\beta_j - 1} = \left(\frac{\gamma_{o,j}}{\gamma_{m,j}} \right)^{-\beta_j - 1} \frac{p_{o,j}^{L}}{p_{m,j}^{L} L_{m,j}^{\beta_j + 1}}$$

$$L_{o,j}^{-\beta_j - 1} = \left(\frac{\gamma_{o,j}}{\gamma_{m,j}} \right)^{-\beta_j - 1} \frac{p_{o,j}^{L}}{p_{m,j}^{L} L_{m,j}^{\beta_j + 1}}$$

$$L_{o,j}^{-\beta_j} = \left\{ \left(\frac{\gamma_{o,j}}{\gamma_{m,j}} \right)^{-\beta_j - 1} \frac{p_{o,j}^{L}}{p_{m,j}^{L} L_{m,j}^{\beta_j + 1}} \right\}^{\frac{\beta_j}{\beta_j + 1}} \qquad (1d)$$

Substitute (1d) to (1c) to obtain:

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}^{1+\beta_j} \left(\left(\frac{\gamma_{o,j}}{\gamma_{p_{m}^{L},j}} \right)^{-\beta_j - 1} \frac{p_{o,j}^{L}}{p_{m,j}^{L} L_{m,j}^{\beta_j + 1}} \right)^{\frac{\beta_j}{\beta_j + 1}} \right\}^{-\frac{1}{\beta_j}}$$

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}^{1+\beta_j} \left(\left(\frac{\gamma_{o,j}}{\gamma_{p_{m}^{L},j}} \right)^{-\beta_j - 1} \frac{p_{o,j}^{L}}{p_{m,j}^{L}} \right)^{\frac{\beta_j}{\beta_j + 1}} L_{m,j}^{\frac{-(\beta_j + 1)\beta_j}{\beta_j + 1}} \right\}^{-\frac{1}{\beta_j}}$$

$$LAB_j = \frac{L_{m,j}}{\gamma_{m,j}} sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j} \left(\frac{p_{o,j}^{L}}{p_{m,j}^{L}} \right)^{\frac{\beta_j}{\beta_j + 1}} \right\}^{-\frac{1}{\beta_j}}$$

$$L_{m,j} = \frac{LAB_j \gamma_{m,j} \left(p_{m,j}^{L} \right)^{\frac{-1}{\beta_j + 1}}}{sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j} \left(p_{o,j}^{L} \right)^{\frac{\beta_j}{\beta_j + 1}} \right\}^{-\frac{1}{\beta_j}}} \qquad (1e)$$

By defining the Lab_j Price index:

$$P_j^{LAB} = \frac{1}{sl_j} \left\{ \sum_{o \in LBR} \gamma_{o,j} \left(p_{o,j}^{L} \right)^{\frac{\beta_j}{\beta_j + 1}} \right\}^{\frac{\beta_j + 1}{\beta_j}}$$

Equation (1e) can then be simplified as follows:

$$L_{m,j} = LAB_j \frac{\gamma_{m,j}}{b_j} \left(\frac{p_{m,j}^{L}}{b_j P_j^{LAB}} \right)^{\frac{-1}{\beta_j + 1}} = LAB_j \left(\frac{\gamma_{m,j}}{b_j^{\frac{\beta_j + 1}{\beta_j}}} \right) \left(\frac{p_{m,j}^{L}}{P_j^{LAB}} \right)^{\frac{-1}{\beta_j + 1}}$$

Or

$$L_{o,j} = LAB_j \left(\frac{\gamma_{o,j}}{b_j^{\frac{\beta_j}{\beta_j + 1}}} \right) \left(\frac{P_{o,j}^{L}}{P_j^{LAB}} \right)^{\frac{-1}{\beta_j + 1}} \qquad , o \in LBR, j \in A$$

3.A2. The Price Index of Labour Composite (LAB)

Here, we show that the price index of P_j^{LAB} is the unit cost of labour composite. Define E_j as the total cost of LAB production in j-th industry:

$$E_j = p_{o,j}^L L_{o,j} + p_{m,j}^L L_{m,j}$$

$$= p_{o,j}^L LAB_j \frac{\gamma_{o,j}}{sl_j^{\frac{\beta_j}{\beta_j+1}}} \left(\frac{p_{o,j}^L}{P_j^{LAB}}\right)^{\frac{-1}{\beta_j+1}} + p_{m,j}^L LAB_j \frac{\gamma_{m,j}}{sl_j^{\frac{\beta_j}{\beta_j+1}}} \left(\frac{p_{m,j}^L}{P_j^{LAB}}\right)^{\frac{-1}{\beta_j+1}}$$

$$= \frac{1}{sl_j^{\frac{\beta_j}{\beta_j+1}}} LAB_j {P_j^{LAB}}^{\frac{1}{\beta_j+1}} \left(\gamma_{o,j} {p_{o,j}^L}^{\frac{\beta_j}{\beta_j+1}} + \gamma_{m,j} {p_{m,j}^L}^{\frac{\beta_j}{\beta_j+1}}\right)$$

$$= \frac{1}{sl_j^{\frac{\beta_j}{\beta_j+1}}} LAB_j {P_j^{LAB}}^{\frac{1}{\beta_j+1}} \left(P_j^{LAB} sl_j\right)^{\frac{\beta_j}{\beta_j+1}}$$

$$E_j = P_j^{LAB} LAB_j$$

3.A3. Elasticity of Substitution

Here we prove that $\beta_j = \frac{1}{\sigma_j^L} - 1$ as follows:

Recall equation (1b) from above:

$$\frac{L_{o,j}}{L_{m,j}} = \frac{\gamma_{o,j}}{\gamma_{m,j}} \left(\frac{p_{o,j}^L}{p_{m,j}^L}\right)^{-1/(\beta_j+1)}$$

$$\text{MRS} = \frac{p_{m,j}^L}{p_{o,j}^L} = \frac{\gamma_{m,j}}{\gamma_{o,j}} \left(\frac{L_{o,j}}{L_{m,j}}\right)^{\beta_j+1}$$

$$ln\, MRS = ln\left(\frac{\gamma_{m,j}}{\gamma_{o,j}}\right) + ln\left(\frac{L_{o,j}}{L_{m,j}}\right)^{\beta_j+1}$$

$$\frac{dln(MRS)}{dln\left(\frac{L_{o,j}}{L_{m,j}}\right)} = \beta_j + 1 = 1/\sigma_j^L$$

$$\sigma_j^L = \frac{1}{\beta_j + 1} \Rightarrow \beta_j = \frac{1}{\sigma_j^L} - 1$$

3.A4. The Households Demand Functions

$$\max_{CH_{i,h}} U_h = \prod_i {CH_{i,h}}^{CH\_share_{i,h}}, i \in C, h \in H$$

Subject to:

$$\sum_{i \in C} P_i^Z CH_{i,h} = EH_h, h \in H$$

The above optimization problem is solved by using the Lagrange multiplier. Let £ be a Lagrangian and μ be a Lagrange multiplier.

$$£ = \prod_{i} {CH_{i,h}}^{CH\_share_{i,h}} + \mu\left(\sum_{i \in C} P_i^Z CH_{i,h} - EH_h\right) \tag{3a}$$

The first order condition:

$$\frac{\partial £}{\partial CH_{i,h}} = \frac{CH\_share_{i,h}}{CH_{i,h}} \prod_{i} {CH_{i,h}}^{CH\_share_{i,h}} + \mu P_i^Z \ = \ 0 \tag{3b}$$

$$\frac{\partial £}{\partial \mu} = \sum_{i} P_i^Z CH_{i,h} - EH_h \ = \ 0 \tag{3c}$$

Ratio of two foc (3b):

$$\frac{P_i^Z}{P_j^Z} = \frac{\frac{CH\_share_{i,h}}{CH_{i,h}}}{\frac{CH\_share_{j,h}}{CH_{j,h}}} = \frac{CH\_share_{i,h} CH_{j,h}}{CH\_share_{j,h} CH_{i,h}}$$

$$P_i^Z CH_{i,h} = \left(\frac{CH\_share_{i,h}}{CH\_share_{j,h}}\right) P_j^Z CH_{j,h} \tag{3d}$$

Substitute (3d) to (3c) to obtain:

$$\sum_{i} \left(\frac{CH\_share_{i,h}}{CH\_share_{j,h}}\right) P_j^Z CH_{j,h} = EH_h$$

$$\left(\frac{1}{CH\_share_{j,h}}\right) P_j^Z CH_{j,h} \sum_{i} CH\_share_{i,h} = EH_h$$

Because $\sum_i \alpha_{i,h} = 1$, we obtain equation (3e):

$$CH_{j,h} = \frac{CH\_share_{j,h}}{P_j^Z} EH_h, i \in C, h \in H \tag{3e}$$

3.A5. Import and Domestic Demand Function

$$\max_{Z_i, M_i, D_i} \pi_i^z = P_i^z Z_i - \left((1 + tarif_i) p_i^M M_i + p_i^D D_i\right) \qquad , i \in CM \cap CD$$

Subject to:

$$Z_i = sz_i \left({\delta_{mi}}^{1+\Phi_i} {M_i}^{-\Phi_i} + {\delta_{di}}^{1+\Phi_i} {D_i}^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}} \qquad , i \in CM \cap CD$$

Let ξ be a Lagrangian and μ be a Lagrange multiplier.

$$\xi = P_i^z Z_i - \left((1 + tarif_i) p_i^M M_i + p_i^D D_i\right)$$

$$+ \mu\left(\left\{sz_i \left({\delta_{mi}}^{1+\Phi_i} {M_i}^{-\Phi_i} + {\delta_{di}}^{1+\Phi_i} {D_i}^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}}\right\} - Z_i\right) \tag{4a}$$

First order condition:

$$\frac{\partial \xi}{\partial \mathrm{Z_i}} = P_i^Z - \mu = 0 \tag{4b}$$

$$\begin{aligned}\frac{\partial \xi}{\partial M_i} =&- (1+tarif_i)p_i^M \\ &+ \mu\left(-\frac{1}{\Phi_i}\right)(-\Phi_i)\left({\delta_{mi}}^{\Phi_i+1}{M_i}^{-\Phi_i-1}\right)\left(sz_i\left({\delta_{mi}}^{1+\Phi_i}{M_i}^{-\Phi_i}\right.\right.\\ &\qquad\left.\left. + {\delta_{di}}^{1+\Phi_i}{D_i}^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}-1}\right) = 0\end{aligned} \tag{4c}$$

$$\begin{aligned}\frac{\partial \xi}{\partial D_i} =&- p_i^D \\ &+ \mu\left(-\frac{1}{\Phi_i}\right)(-\Phi_i)\left({\delta_{di}}^{\Phi_i+1}{D_i}^{-\Phi_i-1}\right)\left(sz_i\left({\delta_{mi}}^{1+\Phi_i}{M_i}^{-\Phi_i}\right.\right.\\ &\left.\left. + {\delta_{di}}^{1+\Phi_i}{D_i}^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}-1}\right) = 0\end{aligned} \tag{4d}$$

$$\frac{\partial \xi}{\partial \mu_i} = \left(sz_i\left(\delta_{mi}\left(\frac{M_i}{\delta_{mi}}\right)^{-\Phi_i} + \delta_{di}\left(\frac{D_i}{\delta_{di}}\right)^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}} - Z_i\right) \tag{4e}$$

Substituting μ with P_i^Z (equation 4b) and rearranging ${\delta_{mi}}^{\Phi_i+1}{M_i}^{-\Phi_i} + {\delta_{di}}^{\Phi_i+1}{D_i}^{-\Phi_i} = \left(\frac{Z_i}{sz_i}\right)^{-\Phi_i}$ (equation (4e)), we modify the respective equation (4c) and (4d) as follows:

$$-(1+tarif_i)p_i^M + P_i^z\left({\delta_{mi}}^{\Phi_i+1}{M_i}^{-\Phi_i-1}\right)sz_i\left(\frac{Z_i}{sz_i}\right)^{1+\Phi_i} = 0 \tag{4c'}$$

$$-p_i^D + P_i^Z\left({\delta_{di}}^{\Phi_i+1}{D_i}^{-\Phi_i-1}\right)sz_i\left(\frac{Z_i}{sz_i}\right)^{1+\Phi_i} = 0 \tag{4d'}$$

Next, equation (4c’) and (4d’) are then reconstructed to obtain the following demand solution for import and domestic of the i-th goods as follows:

$$M_i = \left(\frac{\delta_{mi}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}}\right)Z_i\left\{\frac{(1+tarif_i)P_i^M}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}}, i \in CM \cap CD$$

$$D_i = \left(\frac{\delta_{di}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}}\right)Z_i\left\{\frac{P_i^D}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}}, i \in CM \cap CD$$

Appendix 3.B: List of equations of the CGE model

Eq. No	Equations and their description	No. of Eqs.	End. Var.
Domestic Production Block			
A. Top Stage: Activity Output (Gross Domestic Output) We assume a Leontief type of function:			
1. `	The intermediate input of i-th commodity used by j-th industry: $X_{i,j} = ax_{i,j}QA_j, \quad i \in C, \quad j \in A$	24x24	$X_{i,j}$
2.	The j-th VA used: $VA_j = ava_j QA_j \quad ,j \in A$	24	QA_j
3.	The Price of Gross Domestic Output: $\left(1 + (subAArate)(subArate_j)\right) P_j^{QA} = P_j^{VA} ava_j + \sum_{i \in C} P_i^Z ax_{i,j}, \quad j \in A$	24	P_j^{VA}
4.	The Relationship Between Activity Output and Commodity Supply: $Q_i = \sum_{j \in A} TRANS\_Coef_{j,i} QA_j, \quad i \in C$	24	Q_i
5.	The Relationship Between Activity Price and Commodity Price: $P_j^{QA} = \sum_{i \in C} TRANS\_Coef_{j,i} P_i^Q, \quad j \in A$	24	P_j^{QA}
B. Second stage: Value Added (VA) from Primary Factors We assume a Cobb-Douglas production function:			
6.	$VA_j = sva_j LAB_j^{\delta_{LAB,j}} K_j^{\delta_{K,j}}, \quad \delta_{LAB,j} + \delta_{K,j} = 1, \quad j \in A$	24	VA_j

Eq. No	Equations and their description	No. of Eqs.	End. Var.
7.	The demand solution of j-th industry for capital factor used: $PDIST_j^K P^K K_j = \delta_{K,j} P_j^{VA} VA_j, \quad j \in A$	24	K_j
8.	The demand solution of j-th industry for composite labour factor used: $PDIST_j^{LAB} P^{LAB} LAB_j = \delta_{LAB,j} P_j^{VA} VA_j, \quad j \in A$	24	LAB_j
9.	Zero profit condition: $P_j^{VA} VA_j = PDIST_j^{LAB} P^{LAB} LAB_j + PDIST_j^K P^K K_j, \quad j \in A$	24	redundant
C. Bottom stage: The choice of labour factor We assume a CES production function:			
10.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}} \quad ,j \in A \quad ,\beta = \frac{1}{\sigma^l} - 1, \quad \sigma^l > 1$	24	redundant
11.	The o-th labour used: $L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_j}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{PDIST_{o,j}^L P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}} \quad ,o \in LBR \quad ,j \in A$	16X24	$L_{o,j}$
12.	Zero profit condition: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST_{o,j}^L P_o^L L_{o,j} \quad ,j \in A$	24	$PDIST_j^{LAB}$
Total No. of Equations		1200	
Government Block			

Eq. No	Equations and their description	No. of Eqs.	End. Var.
13.	Total government revenue: $IG = \sum_{i \in C} (vatArate)(vatrate_i) P_i^Q Q_i + \sum_{i \in CM} (tarifArate)(tarifrate_i) P_i^M M_i + \sum_{in \in INS} TR_{gov,in}$	1	IG
14.	Total government expenditure: $EG = \sum_{i \in C} P_i^Z CG_i + \sum_{i \in C} (subQArate)(subQrate_i) P_i^Q Q_i + \sum_{j \in A} (subAArate)\left(subArate_j\right) P_j^{QA} QA_j + \sum_{in \in INS} TR_{in,gov}$	1	EG
15.	Public spending on i-th final goods: $CG_i = CGIN_i \overline{CGADJ}, \qquad i \in C$	24	CG_i
16.	Government spending on public services: $TR_{h,gov} = TRG\_share_{h,gov}(CPI)TRbar, \qquad h \in H,\ \ gov \in INS$ $TR_{in,gov} = TRG\_share_{in,gov} TRG\_bar, \qquad in \neq h \in INS$	11x1	$TR_{in,gov}$
17.	Government saving: $SG = IG - EG$	1	SG
Total No. of Equations		38	
Households Block			
18.	Total income of the h-th household: $IH_h = IHL_h + IHK_h + \sum_{in \in INS} TR_{h,in}\,, \qquad h \in H$	8	IH_h

Eq. No	Equations and their description	No. of Eqs.	End. Var.
19.	Labour income of the h-th household: $IHL_h = \sum_{o \in LBR} IHL\_share_{h,o} P_o^L \left(\sum_{j \in A} PDIST_{o,j}^L \, L_{o,j} + L_{o,ROW} \right) \quad , h \in H$	8	IHL_h
20.	Capital income of the h-th household: $IHK_h = IHK\_share_h P^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right) \quad , h \in H \quad , ROW \in INS$	8	$IHKL_h$
21.	Disposable income of the h-th household: $DIH_h = IH_h - TR_{gov,h} \quad , h \in H \quad , gov \in INS$	8	DIH_h
22.	The the h-th household transfer payments to institution's: $TR_{in,h} = TRH\_share_{in,h} DIH_h \quad , in \neq gov \in INS \quad , h \in H$ $TR_{gov,h} = (HAtaxrate\ )(Htaxrate_h)\ IH_h \quad , h \in H$	11x8	$TR_{in,h}$
23.	Actual disposable income of the h-th household: $ADIH_h = DIH_h - \sum_{in \neq gov \in INS} TR_{in,h} \quad , h \in H$	8	$ADIH_h$
24.	The h-th household saving: $SH_h = sh\_ratio_h ADIH_h \quad , h \in H$	8	SH_h
25.	Adjusted average propensity for saving of the h-th households: $sh\_ratio_h = sh\_rin_h (1 + sh\_dum_h sh\_adj) \quad , h \in H$	8	sh_ratio_h

Eq. No	Equations and their description	No. of Eqs.	End. Var.
26.	Consumption budget of the h-th household: $EH_h = ADIH_h - SH_h \quad , h \in H$	8	EH_h
27.	Final demand of the h-th household: We assume a Cobb-Douglas utility function $P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h \quad , i \in C \quad , h \in H$	24x8	$CH_{i,h}$
Total No. of Equations		344	
Consumer Price Index (CPI)			
28.	Price index of h-th households: $PI_h = \prod_{i \in C} {P_i^Z}^{CH\_share_{i,h}} \quad , h \in H$	8	PI_h
29.	CPI: $CPI = \sum_{h \in H} w_h PI_h$	1	P^{LAB}
Total No. Of equation		9	
Enterprise			
30.	Total enterprise income: $IB = IBK + \sum_{in \in INS} TR_{b,in} \quad , b \in INS$	1	IB
31.	Capital income of enterprise:	1	IBK

Eq. No	Equations and their description	No. of Eqs.	End. Var.
	$IBK = IBK\_shareP^{K}\left(\sum_{j\in A} PDIST_j^{K} K_j + K_{ROW}\right) \quad ,ROW \in INS$		
32.	Disposable income of enterprise: $DIB = IB - TR_{gov,b} \quad ,gov,b \in INS$	1	DIB
33.	Enterprise transfer payment to in-th institutions: $TR_{in,b} = TRB\_share_{in,b}DIB \quad ,in \neq gov \in INS$ $TR_{gov,b} = (Btaxrate)IB \quad ,b \in INS$	11x1	$TR_{in,b}$
34.	Actual disposable income of enterprise: $ADIB = DIB - \sum_{in\neq gov\in INS} TR_{in,b}$	1	$ADIB$
35.	Saving of enterprise: $SB = ADIB$	1	$INVADJ$
Total No. of Equations		16	
Export, Import and The Balance of Payments Constraint Block			
36.	RoW total outflow:	1	$IROW$

Eq. No	Equations and their description	No. of Eqs.	End. Var.
	$IROW = \sum_{i \in CM} P_i^M M_i + \sum_{in \in INS} TR_{ROW,in} + \sum_{o \in LBR} RL_{share_o} P_o^L \left(\sum_{j \in A} PDIST_{o,j}^L L_{o,j} + L_{o,ROW} \right)$ $+ RK\_share P^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right) \quad , ROW \in INS$		
37.	RoW total inflow: $EROW = \sum_{i \in CE} P_i^E E_i + \sum_{in \in INS} TR_{in,ROW} + \sum_{o \in LBR} P_o^L L_{o,ROW} + P^K K_{ROW} \, , ROW \in INS$	1	$EROW$
38.	ROW transfer payment to institutions': $TR_{in,ROW} = TRW\_share_{in,ROW} (EXR) TROW\_bar \quad , ROW \notin in \in INS$ $TR_{ROW,ROW} = 0$ is treated as exogenous	11x1	$TR_{in,ROW}$
39.	Current account deficit: $SROW = EROW - IROW$	1	$SROW$
40.	The price of export for the i-th of commodities: $P_i^E = (EXR) P_i^{EW} \quad , i \in CE$	21	P_i^E
41.	The price of import for the i-th of commodities: $P_i^M = (EXR) P_i^{MW} \quad , i \in CM$	21	P_i^M
Total No. of Equations		56	
Investment Block			

Eq. No	Equations and their description	No. of Eqs.	End. Var.
42.	Final demand of the i-th investment commodities: $CINV_i = CINVIN_i(1 + INVADJ) \quad , i \in C$	24	$CINV_j$
43.	Saving-Investment identity used for Walras law $WAL\_RES = \sum_{h \in H} SH_h + SB + SG + SROW - \sum_{i \in C} P_i^Z CINV_i$	1	WAL_RES
Total No. of Equations		25	
Production of composite good			
44.	Armington' s production function: $Z_i = sz_i \left({\delta_{m,i}}^{1+\Phi_i} {M_i}^{-\Phi_i} + {\delta_{d,i}}^{1+\Phi_i} {D_i}^{-\Phi_i} \right)^{-\frac{1}{\Phi_i}} \quad , i \in CM \cap CD \ , \Phi = \frac{1}{\sigma^z} - 1 \ , \sigma^z > 1$	21	redundant
45.	The final goods production by only utilizes the input of domestic commodities (not imported): $Z_i = D_i, \qquad i \in CD \ \& \ \notin CM$	3	D_i
46.	The i-th import commodity used: $M_i = \left(\frac{\delta_{mi}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}} \right) Z_i \left\{ \frac{\left(1 + (tarifArate)(tarifrate_i)\right) P_i^M}{P_i^Z} \right\}^{-\frac{1}{1+\Phi_i}} \qquad , i \in CM \cap CD$	21	M_i
47.	The i-th domestic commodity used: $D_i = \left(\frac{\delta_{di}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}} \right) Z_i \left\{ \frac{P_i^D}{P_i^Z} \right\}^{-\frac{1}{1+\Phi_i}} \qquad , i \in CM \cap CD$	21	D_i

Eq. No	Equations and their description	No. of Eqs.	End. Var.
48.	Zero profit condition: $P_i^Z Z_i = \left(1 + (tarifArate)(tarifrate_i)\right) P_i^M M_i + P_i^D D_i \quad , i \in CM \cap CD$	21	P_i^Z
49.	Zero profit condition in which the industry only utilizes the input of domestic commodities (not imported): $P_i^Z = P_i^D \qquad , i \in CD \ \& \ \notin CM$	3	P_i^Z
Total No. of Equations		90	
Division of gross production to domestic and exports sales			
50.	Armington's transformation equation: $Q_i = sq_i\left({\omega_{e,i}}^{1-\mu_i}(E_i)^{\mu_i} + {\omega_{d,i}}^{1-\mu_i}(D_i)^{\mu_i}\right)^{\frac{1}{\mu_i}} \quad , i \in CE \cap CD \quad , \mu = \frac{1}{\sigma^q} + 1 \qquad , \sigma^q > 0$	21	redundant
51.	Gross Domestic Output in the case where the industry produces only domestic commodities (not exported): $Q_i = D_i \quad , i \in CD \ \& \ \notin CE$	3	P_i^D
52.	The i-th export commodity: $E_i = \frac{\omega_{ei}}{{sq_i}^{\mu_i/\mu_i - 1}} Q_i \left\{\frac{P_i^E}{\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right) P_i^Q}\right\}^{\frac{1}{\mu_i - 1}} \quad , i \in CE \cap CD$	21	E_i
53.	The i-th domestic commodity supply: $D_i = \frac{\omega_{di}}{{sq_i}^{\varsigma_i/\varsigma_i - 1}} Q_i \left\{\frac{P_i^D}{\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right) P_i^Q}\right\}^{\frac{1}{\mu_i - 1}} \quad , i \in CE \cap CD$	21	P_i^D
54.	Zero profit condition: $\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right) P_i^Q Q_i = P_i^D D_i + P_i^E E_i \quad , i \in CE \cap CD$	21	P_i^Q

Eq. No	Equations and their description	No. of Eqs.	End. Var.
55.	Zero profit condition in the case where the industry produces only for domestic commodities (not exported): $\big(1+(vatArate)(vatrate_i)-(subQArate)(subQrate_i)\big)P_i^Q = P_i^D \quad , i \in CD \ \& \ \notin CE$	3	P_i^Q
Total No. of Equations		90	
Market Clearing Conditions Block			
56.	Total supply equals with the total demand: $Z_i = \sum_{h\in H} CH_{i,h} + CG_i + CINV_i + \sum_{j\in A} X_{i,j}\,, \qquad i \in C$	24	Z_i
57.	Capital factor market-clearing conditions: $\sum_{j\in A} K_j + K_{ROW} + KU = KS \quad , ROW \in INS$	1	P^K
58.	Labour factor market-clearing conditions: $\sum_{j\in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o, \qquad o \in LBR, \quad ROW \in INS$	16	P_o^L
Total No. of Equations		57	
Overall Equations		1,818	

Appendix 3.C: Sets

Set	Element	Description
Commodities Set C $i \in C$	AGRI_C	Agriculture Food Crops
	AISCOM_C	Air, Sea, and Communication
	BANKAS_C	Bank and Assurance
	CATLE_C	Cattle and the Outcomes
	CHFCC_C	Chemical, Fertilizer, Goods from Clay and Cement
	COMOIL_C	Coal, Metal Seeds, and Oil Mining
	CONS_C	Construction
	ESTPRV_C	Real Estate, and Private Services
	ELEGD_C	Electricity, Gas, and Drinkable Water
	FISH_C	Fishery
	FODT_C	Food, Drink, and Tobacco
	FORH_C	Forestry and Hunting
	GOVTD_C	Government and Defence, Education, Health, Film, and Other Social Services
	HTEL_C	Hotel
	INDSHO_C	Individual Services, Households, and Other Services
	LANT_C	Land Transportation
	OAGRI_C	Agriculture for Other Crops
	OMINE_C	Other Mining and Excavations
	PPTM_C	Paper, Printing, Transport Equipment, and Goods from Metal and Industry
	RSTR_C	Restaurant
	STGL_C	Spinning, Textile, Garment, and Leather Industries
	SUPPS_C	Supporting Services for Transportation and Warehouse Transportation
	TRDE_C	Trade
	WOOG_C	Wood and Goods from Wood
$CM \subset C$: Set of commodities for which some of the output is imported	AGRI_C AISCOM_C BANKAS_C CATLE_C CHFCC_C COMOIL_C ESTPRV_C FODT_C FORH_C FISH_C GOVTD_C HTEL_C INDSHO_C LANT_C OAGRI_C OMINE_C PPTM_C RSTR_C STGL_C SUPPS_C WOOG_C	
$CE \subset C$: Set of commodities for which some of the output is exported	AGRI_C AISCOM_C BANKAS_C	

	CATLE_C CHFCC_C COMOIL_C ESTPRV_C FODT_C FORH_C FISH_C GOVTD_C HTEL_C INDSHO_C LANT_C OAGRI_C OMINE_C PPTM_C RSTR_C STGL_C SUPPS_C WOOG_C	
Commodities Set A $j \in A$: where $i = j$ and $A = C$	AGRI_A AISCOM_ A BANKAS_ A CATLE_ A CHFCC_ A COMOIL_ A CONS_ A ESTPRV_ A ELEGD_ A FODT_ A FORH_ A FISH_ A GOVTD_ A HTEL_ A INDSHO_ A LANT_ A OAGRI_ A OMINE_ A PPTM_ A RSTR_ A STGL_ A SUPPS_ A TRDE_ A WOOG_ A	
Labour Set LAB $o \in LAB$	FAGR_LAB_U	Formal agricultural labour in urban
	FAGR_LAB_R	Formal agricultural labour in rural
	IAGR_LAB_U	Informal agricultural labour in urban
	IAGR_LAB_R	Informal agricultural labour in rural
	FMAN_LAB_U	Formal manual labour in urban
	FMAN_LAB_R	Formal manual labour in rural
	IMAN_LAB_U	Informal manual labour in urban
	IMAN_LAB_R	Informal manual labour in rural
	FCLER_LAB_U	Formal clerical labour in urban
	FCLER_LAB_R	Formal clerical labour in rural
	ICLER_LAB_U	Informal clerical labour in urban
	ICLER_LAB_R	Informal clerical labour in rural

	FPROF_LAB_U FPROF_LAB_R IPROF_LAB_U IPROF_LAB_R	Formal professional labour in urban Formal professional labour in rural Informal professional labour in urban Informal professional labour in rural
Primary Factors Set FAC $f \in FAC$	FAGR_LAB_U FAGR_LAB_R IAGR_LAB_U IAGR_LAB_R FMAN_LAB_U FMAN_LAB_R IMAN_LAB_U IMAN_LAB_R FCLER_LAB_U FCLER_LAB_R ICLER_LAB_U ICLER_LAB_R FPROF_LAB_U FPROF_LAB_R IPROF_LAB_U IPROF_LAB_R K	Formal agricultural labour in urban Formal agricultural labour in rural Informal agricultural labour in urban Informal agricultural labour in rural Formal manual labour in urban Formal manual labour in rural Informal manual labour in urban Informal manual labour in rural Formal clerical labour in urban Formal clerical labour in rural Informal clerical labour in urban Informal clerical labour in rural Formal professional labour in urban Formal professional labour in rural Informal professional labour in urban Informal professional labour in rural Capital
Household Set H $h \in H$	HH_AGR_L	Households who work as employee in agriculture
	HH_AGR_NL	Households who work as employer in agriculture
	HH_NAGR_LL	Households who have low level of income in rural: non-agriculture
	HH_NAGR_NA	Households in rural area with unidentified types of occupation: non agriculture
	HH_NAGR_HL	Households who have high level of income in rural: non-agriculture
	HH_NAGU_LL	Households who have low level of income in urban: non-agriculture
	HH_NAGU_NA	Households in urban area with unidentified types of occupation: non agriculture
	HH_NAGU_HL	Households who have high level of income in rural: non-agriculture
Institution Set INS $in \in INS$	HH_AGR_L	Households who work as employee in agriculture
	HH_AGR_NL	Households who work as employer in agriculture
	HH_NAGR_LL	Households who have low level of income in rural: non-agriculture
	HH_NAGR_NA	Households in rural area with unidentified types of occupation: non agriculture

	HH_NAGR_HL	Households who have high level of income in rural: non-agriculture
	HH_NAGU_LL	Households who have low level of income in urban: non-agriculture
	HH_NAGU_NA	Households in urban area with unidentified types of occupation: non agriculture
	HH_NAGU_HL	Households who have high level of income in rural: non-agriculture
	FIRM	Firms
	GOV	Government
	FOR_BAL	Foreign Balance

Appendix 3.D: List of all variables appearing in the CGE model (Alphabetical Orders)

Notation used for the variable	Number of Variables		Definition of the Variable
	Endogenous	Exogenous	
$ADIB$	1		Actual disposable income of enterprise
$ADIH_h$	8		Actual disposable income of the h-th type of households
$Btaxrate$		1	Income tax rate of enterprise
CG_i	24		Government demand of the i-th composite goods
$CH_{i,h}$	24*8		The h-th household final demand of the i-th composite goods
$CINV_i$	24		Investment demand of the i-th composite goods
CPI		1	Consumer Price Index
D_i	24		The i-th domestic commodity
DIB	1		Disposable income of enterprise
DIH_h	8		Disposable income of the h-th type of households
E_i	21		The i-th exported commodity
EG	1		Total government expenditure
EH_h	8		Consumption budget of the h-th household
$EROW$	1		RoW total inflow
EXR		1	Exchange rate: units of domestic currency per unit of foreign currency
$HAtaxrate$		1	Average tax rate of h-th household income
IB	1		Total enterprise income
IBK	1		Capital income of enterprise
IG	1		Total government revenue
IH_h	8		Total income of the h-th type of households
IHK_h	8		Capital income of the h-th type of households
IHL_h	8		Labour income of the h-th type of households
$INVADJ$	1		The investment adjustment index ($INVADJ$=0 if investment is fixed; otherwise if it is allowed to adjust endogenously)
$IROW$	1		RoW total outflow
K_j	24		Capital used in j-th activity
K_{ROW}		1	Capital used in abroad
KS		1	Total of capital supply
KU		1	Unemployed (unused) capital
$L_{o,j}$	16*24		The o-th labour used in j-th activity
LAB_j	24		The composite labour in j-th activity
$L_{o,ROW}$		16	The o-th labour used abroad
LS_o		16	Total supply of labour types
LU_o		16	Total unemployment of labour types
M_i	21		The i-th import commodity
P_i^D	24		Price of the i-th commodity
$PDIST_j^K$		24	The adjusted capital rent across activities
$PDIST_{o,j}^L$		16*24	The adjusted labour type wages across activities
$PDIST_j^{LAB}$	24		The adjusted labour composite wage across activities
P_i^E	21		Price of the i-th exported commodity
P_i^{EW}		21	The price of the i-th of exported commodities in terms of foreign currency
PI_h	8		Price index of h-th households
P^K	1		Price of aggregate capital
P_o^L	16		Wages rate of the o-th labour
P^{LAB}	1		Wages rate of the composite labour in aggregated activities

P_i^M	21		Price of the i-th imported commodity
P_i^{MW}		21	The price of the i-th imported commodities in terms of foreign currency
P_i^Q	24		Price of the i-th domestically produced goods
P_j^{QA}	24		Price of gross domestic output of j-th activity
P_j^{VA}	24		Price of value added in j-th activity
P_i^Z	24		Price of the i-th final (composite) goods
Q_i	24		The i-th domestic goods
QA_j	24		Gross domestic output of j-th activity
SB		1	Enterprise saving
SG	1		Government saving
SH_h	8		Household saving
sh_adj		1	The endogenous adjustment of sh_ratio_h
sh_ratio_h	8		Adjusted average propensity for saving of the h-th type of households
$SROW$	1	1	Current account deficit
$SubAArate$		1	Average subsidy rate of the j-th activity
$SubQArate$		1	Average subsidy rate of the i-th gross domestic output
$tarifArate$		1	Average import tariff rate of i-th imported commodity
$TR_{in,in}$	120	1	Transfers between in-th institution’s
TRG_bar		1	Total government transfer payments
$TROW\_bar$		1	Total ROW transfer payments
VA_j	24		The value added output in j-th activity
$vatArate$		1	The average *ad valorem* tax rate of the i-th gross domestic output
WAL_RES	1		Saving-Investment identity used for Walras law
$X_{i,j}$	24*24		The i-th intermediate commodity input for j-th activity
Z_i	24		Final output of the i-th composite commodity
TOTAL No:	1,818		

Appendix 3.E: List of all parameters used in the CGE model

Parameters	**Description and measurement**
ava_j	Coefficient of minimum requirements of the VA_j for one unit of QA_j
$ax_{i,j}$	Coefficient of minimum requirements of i-th intermediate input for a unit of QA_j
$\delta_{di} + \delta_{mi} = 1$	Import and domestic share parameter of Armington's for i-th composite commodity, $0 \leq \delta_{di} \leq 1$
$\delta_{LAB,j} + \delta_{K,j} = 1$	Share parameter of capital and labour by j-th industry, $0 \leq \delta_{K,j} \leq 1$
$\gamma_{o,j}$	Share parameter of o-th labour used by j-th industry ($0 \leq \gamma_{o,j} \leq 1$)
ω_{ei}	Share parameter of i-th transformation commodity, $0 \leq \omega_{ei} \leq 1$
$\omega_{di} + \omega_{ei} = 1$	Export and domestic share parameter of Armington's for i-th composite commodity, $0 \leq \omega_{di} \leq 1$
$\beta_j = \frac{1}{\sigma_j^l} - 1, \quad \sigma_j^l > 1$	Elasticity (CES-composite labour)
$\mu = \frac{1}{\sigma_i^q} + 1, \quad \sigma_i^q > 0$	Elasticity (CET-Armington's)
$\Phi_\mathrm{i} = \frac{1}{\sigma_i^z} - 1, \quad \sigma_i^z > 1$	Elasticity (CES-Armington's)
sl_j	Efficiency parameter of composite labour used by the j-th industry
sq_i	Shift parameter of CET transformation of i-th commodity supply
sva_j	Efficiency parameter of VA used by the j-th industry
sz_i	Shift parameter of Armington's production of i-th final goods

Appendix 3.F: List of Shares, Rates, and Weights

Parameters	Description and measurement
$\overline{CGADJ}$	Adjustment factor for government consumption
$CGIN_i$	Initial government consumption on the i-th types of composite goods
$CH\_share_{i,h}$	Share parameter of Cobb-Douglas utility function of the h-th type of households to consume the i-th composite goods
$CINVIN_i$	Initial investment demand of the i-th commodity
$Htaxrate_h$	Specific tax rate adjustment of h-th household
IBK_share	Share of capital income received by enterprise
IHK_share_h	Share of capital income received by h-th type of households
$IHL\_share_{h,o}$	Share of the o-th type of labour income received by h-th type of households
RK_share	Share of the foreign capital used domestically
RL_share_o	Share of the o-th type of foreign labour used domestically
sh_dum_h	Dummy parameter to allow sh_ratio_h to adjust
sh_rin_h	Initial value of average propensity for saving of the h-th type of households
$SubArate_j$	Subsidy rate adjustment across j-th activity
$SubQrate_i$	Subsidy rate adjustment across i-th gross domestic output
$tarifrate_i$	Import tariff rate adjustment across i-th imported commodity
$TRANS\_Coef_{j,i}$	Input-Output coefficients
$TRB\_share_{in,b}$	The share of enterprise transfer payment to the in-th institution’s
$TRG\_share_{in,gov}$	The share of government transfer payment to the in-th institution’s
$TRH\_share_{in,h}$	The share of the h-th type of households transfer payment to non-government institution’s
$TRW\_share_{in,ROW}$	The share of the ROW transfer payment to the in-th institution’s
$vatrate_i$	The *ad valorem* tax rate adjustment across i-th gross domestic output
w_h	CPI weight as share of each households’ expenditure in total expenditure

Appendix 3.G: Value of CES and CET Elasticity

CES and CET Parameter	Value	Source
β_j	0.8	Decaluwé *et al* (2012)
ς_i	2	
ρ_j	1.5	
Φ_i	2	

Chapter 4
Simulation and Results Discussion
Of Standard CGE Model for Indonesia

4.1. Introduction

The effectiveness of government interventions to improve the economy's performance is highly dependent on their fiscal sustainability. For instance, if the government increases its expenditure, then the financing schemes could be done through several channels, i.e. increasing the tax revenues, increasing the debt, reducing subsidies, or reducing transfer payments to certain institutions. These decisions should attain a primary objective of which it leads to the improvement of national income. In other word, the chosen fiscal policies should be well-designed to avoid adverse effects on the economy's performance.

According to Indonesia's Public Expenditure Review published by The World Bank (2007), total public spending of Indonesia in real terms increased annually by 11% in average between the year 2001 and 2005. However, since the 1997 Asian financial crisis, the Indonesian government debt for domestic and foreign, rose from 25% of GDP at pre-crisis to about 100% of GDP in the year 2000 (Francis, 2012). At the receipt side, Indonesia's tax ratio is relatively low compared to other Southeast Asian countries (ASEAN). The percentage ratio of government tax revenues to Indonesia's GDP was 11.9% in the year 2003 and 12.6% in the year 2011. Whilst, the tax ratio of developed ASEAN and OECD countries reached more than 15% and 33.8% of their respective GDP in the year 2009 (Francis, 2012; Ikhsan *et al*., 2005). In order to overcome such burden, the Indonesian government has been starting to implement one of the main agendas, i.e. improving its revenue by either raising the *ad valorem* tax rates or reducing subsidies to gradually achieve fiscal sustainability (Amir *et al*., 2013; Oktaviani *et al*., 2004; Ikhsan *et al*., 2005).

It is usually argued that the Indonesian economy has been adversely affected by the subsidies policies. In particular, subsidies applied to energy-related products are considered to be harmful (Dartanto, 2013; Yusuf and Resosudarmo, 2008). In general, the budget allocation for total subsidies is gradually growing about Rp. 72.8 trillion nominally or within the average growth rate of 4.8% annually. In year 2014, the government spent about 30% of its total budget for subsidies, which regarded as the largest shares to total government expenditures (Financial Note and Indonesian Budget, 2014). These burdens are further deteriorating due to factors such as: the upward trend of world oil price; the increasing rate of population; the rise in per capita domestic consumption on fuels and electricity; and the low utilization of renewable energy sources and instead heavily reliance on fossil fuels input to generate electricity.

Fiscal policy plays an important role in stabilizing the aggregate demand and fostering the national income (Romer, 2001; Vladimirov and Neicheva, 2008; Maipita *et* *al*., 2010). The instruments of fiscal policy are generally categorised into three components: net taxes (total taxes less subsidies), government expenditure, and transfer payments – including social security payments and debt interest payments (Case *et al*., 2012). The government levies taxes (net of transfer benefits) and spends them to purchase goods and services. A budget deficit will occur when government expenditure exceeds its receipt in a given period. Thus, in order to finance this deficit, the government must borrow from institutions mainly by selling the bonds (Begg *et al*., 2003).

Higher public spending increases the equilibrium output. With fixed tax revenues, the extra expenditures imply larger budget deficit. Begg *et al*. (2003) argues that a huge budget deficit can lead to a vicious circle of additional borrowing, additional interest payments, and yet more borrowing from public and foreign to finance the deficit. To reduce the deficit, the government should therefore undertake either fiscal contraction such as reducing their spending on subsidy or fiscal expansion such as increasing taxes (Maipta *et al*., 2010; Mabugu *et al*., 2013).

This chapter aims to investigate, within the context of computable general equilibrium analysis, the impact of exogenous fiscal expansions/contractions on Indonesia’s main macroeconomic indicators and to their consequences by examining how different institutions and sectors in the economy are affected as a result. The main questions to be asked in this chapter: What is the macroeconomic impact of government fiscal policy? Could the economy’s income be improved by higher government expenditure? Whether the increased indirect tax rates (or reduced subsidy rates) constitute a progressive economy performance? More specifically, following the approach advocated in the literature by studies such as Damuri and Perdana (2003); Amir *et al*. (2013); Mabugu *et al*. (2013); Maipita *et al*. (2010); and Solaymani *et al*. (2014), we use a policy shock of a 10% increase in government spending. Three different scenarios are considered to finance the extra expenditure: (1) the government is allowed to borrow by government saving adjustment without any changes in all tax and subsidy rates; (2) the subsidy rates across activities adjust without any changes in government saving as well as the rests of tax and subsidy rates; and (3) the output tax rates adjust without any changes in government saving as well as the rests of tax and subsidy rates.

Damuri and Perdana (2003) argue that in the short run an increase in public spending financed by loan only (scenario 1) raises the level of GDP by more than that case of both simultaneous loan and tax rates adjustment to finance the additional government’s expenditure. They argue that the increase in tax rates impedes the market mechanism and restrict consumer choice and thus could lead to a contraction in economy’s performance (Griffiths and Wall 1997). However, Begg *et al*. (2003) obtain a different result: the financing scheme through both loans and taxes leads to higher GDP because of the balanced budget multiplier effect. This multiplier leads to changes in autonomous demand, which in turn results in changes in equilibrium national income and output[17]. This chapter, therefore, aims to investigate these contradictions by adopting two channels of financing the extra government expenditure, i.e., allowing the borrowing adjustment or a simultaneous injection of both borrowing adjustment and increasing the exogenous output tax rates.

Alternatively, to ease the fiscal pressures on higher public expenditures, the government also can reduce its subsidy payments. Subsidy is a form of government expenditure which is aimed to help poor households in reducing the price of a specific domestic good relatively to its market price (Maipita *et al*., 2010; Solaymani *et al*., 2014). However, the effectiveness of subsidy is highly dependent on the fluctuation of these price margins. For example, suppose the government grants a subsidy in order to lower the burden stemming from a high fuel price, the producers of fuel could, at the same time, increase their market price; hence the effects of subsidy are offset by an increase in price level, which renders the subsidy ineffective. In other words, subsidies could create adverse consequences such as inefficient distribution, misallocation of recipients, market failures and could diminish welfare (Solaymani *et al*., 2014; World Trade Reports, 2006; Karami *et al*., 2012; Morgan, 2007; OECD, 2005). Therefore, motivated by these implications, we also assess the impact of a 10% subsidy rates cut of all activities to increase the net government revenue. Lofgren (1995) found that, within a fixed government spending on commodities, a subsidy cut leads to contraction in GDP and income distribution. In the short run, a reduction of specific fuel subsidies increases the domestic price which in turn reduces the household consumption particularly the lower-income households' (Clements *et al*., 2007). However, in long run, it improves the poor households because subsidy removal increases government expenditure, i.e. infrastructure development, human capital investments, and social protection (Dartanto, 2013).

The rest of this chapter is organized as follows: section 4.2 discusses an overview of the specific literatures that assess the distribution impact of fiscal policy using a CGE model framework. The scenarios provided in these literatures are used to motivate the simulations proposed in our model. Section 4.3 discusses the theoretical model and identification of scenarios motivated in Section 4.2 in the context of the specific model. It refers to the benchmark CGE model of the previous chapter and uses the relevant equations to demonstrate our scenarios and closure rules. Section 4.4 discusses simulation results and sensitivity analysis. Finally, section 4.5 presents the conclusions.

4.2. Literature and motivation

A number of studies have been conducted to analyse the distributional impact of fiscal policies in Indonesia (Damuri and Perdana, 2003; Amir *et al*., 2013 and Maipita *et al*., 2010, among others) and other countries (see, for example, Solaymani *et al*., 2013 and

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[17] For details see: Begg *et al* (2003).

Mabugu *et al*., 2013). These studies look at the impact of fiscal policy expansions/contractions in various scenarios by using a SAM based CGE model, which closely relates to the objectives of this research. Moreover, the simulations proposed in our current study are motivated by these literatures. In what follows, we provide a brief overview of these studies.

Damuri and Perdana (2003) analysed the effect of a fiscal expansion on income distribution and poverty in Indonesia. The model was based on a comparative static CGE model that is specifically designed by Warr *et al.* (1998) and Wittwer (1999) for Indonesia's economy[18]. The study examined the impact of a 20% increase in government expenditure with 4 different scenarios to cover the extra spending budget: (i) government deficit and balance of payments are allowed to adjust in response to the increasing level of public spending but government revenues from net tax collection remained exogenous; (ii) income tax rate adjusts while other taxes, budget deficit, and balance of payments are fixed; (iii) *ad valorem* tax adjusts but other taxes, budget deficit and balance of payments are fixed; and (iv) as in (i) but keeping balance of payments fixed to prohibit foreign borrowing. Damuri and Perdana (2003) concluded that the impact of fiscal expansion on the Indonesian economy depends on the source of financing. They found that scenario (i) had the strongest impact on the national income. This was explained by the fact that the excess of public spending was covered by loans in current year which would be paid in future. The fixed balance of payment in scenario (iv), however, led to a lower GDP level compared to scenario (i). In scenario (ii), the income tax rate would adjust to a higher level which reduced households' disposable income, thus reducing demand on final goods. This led to a drop in Indonesia's GDP. Nevertheless, the scenario of tax income rate adjustment resulted in a higher level of GDP compared to scenario (iii) because the increased level of *ad valorem* tax rates directly increases commodities' prices. Furthermore, in terms of poverty incidence, scenarios (i) and (iv) were found to have a positive impact on poverty reduction while scenarios (ii) and (iii) generated the opposite result.

Amir *et al*. (2013) investigated the impact of income tax reform on Indonesia's economy. The study used a SAM based CGE model approach that combined the framework of ORANI-G developed by Horridge (2003) and AGEFIS developed by Yusuf *et al.* (2008). Calibration was based on the Indonesian SAM in year 2005. The policy scenarios were considered under two conditions: (i) fixed budget deficit (interpreted as balanced budget); and (ii) flexible budget deficit condition (interpreted as borrowing financed budget). For each condition, the authors simulated three different scenarios: (a) a reduction in household income tax rate; (b) a reduction in business income tax rate; and (c) simultaneous reduction in both tax rates. The magnitude of each shock was estimated according to tax returns data

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[18] The model is called WAYANG model, which is designed closely to the family of the ORANI model, a single region model for Australia's economy. For details see Warr (1998) and Witwerr (1999).

published by the Indonesian Financial Ministry. For the business income tax rate, the authors determined a shock of -0.57%, while household income tax rate varied for each category of 200 types of households. They concluded that the reduction of income tax rate within a fixed budget deficit immediately reduces government expenditure. The specific supply from public activity (government administration, defence, education, health, and social service sector)[19] is dropped, which in turn reduces government demand for labour. Meanwhile, households' disposable income is increasing, and hence it improves their consumption on goods by 0.418%. The increased demand of goods from households' offsets the reduction of public sector production. Overall, this simulation still indicates a strong income effect that leads to higher demand for final goods, real investment, and net exports; which results in real GDP improvement. In the second scenario, which business income tax rate is reduced under the fixed budget deficit, Amir *et al*. (2013) found that again government spending reduces. Supply production from public activity drops, which in turn also reduces its demand for labour. In comparison with the simulation of income tax rate reduction, this scenario does not directly affect households' disposable income. Therefore, the improvement of private consumption on goods is smaller by only 0.018%. A reduction of the business income tax rate provides lower stimuli to real GDP growth. Furthermore, under the endogenous budget deficit condition, government expenditure does not decline although its revenue is decreasing. The government is allowed to increase their level of borrowing in order to cover the inadequate receipts, which will be paid in the future. The reduction of both income and business tax rates improve the national income. It induces higher demand for final goods, leading to the increased level of output volumes and prices. The author's concluded that under both conditions: exogenous and endogenous budget deficits, the reduction of income and business tax rates have a positive impact on Indonesia's economy. The aggregate supply and demand are increasing.

Mabugu *et al*. (2013) constructed a dynamic CGE model to simulate the expansion of government spending on South Africa's economy. The model is based on the PEP standard CGE model developed by Decaluwé *et al*. (2010). It is calibrated from the South African SAM in the year 2005. The study simulates about 6% increase of government expenditure and assumes that this magnitude of shock will be levelled off to initial level in the future. Three scenarios are proposed to finance the increased level of public expenditure: (i) income tax rate adjusts to compensate the additional expenditure but other tax rates and budget deficit are exogenous; (ii) output tax rate adjusts to compensate the additional expenditure but other tax rates and budget deficit are exogenous; and (iii) All taxes are fixed but the budget deficit adjusts to finance the additional expenditures. The author's concluded that in scenario (i), income tax rate increases by 2.65% in short run.

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[19] The author's defines the aggregated activity account of government administration, defence, education, health, and social services in the Indonesia's SAM in the year 2005 as public sector.

However, this increase would decline accordingly to the inter-temporal magnitude of government expenditures. If the government decides scenario (ii) to compensate the additional spending, the output tax rate would increase by 1% for all commodities. Of all scenarios, the increased expenditure slightly improved the GDP in short run. However, in the long run, because of the effects on investment are higher, it thus induces GDP to increase more sharply. The impact on investment is stronger under the scenario (i) and (iii). This is because the endogenous income tax rate and budget deficit would give greater effect to increase the household and government saving.

Maipita *et al*. (2010) investigated the impact of fiscal policies on Indonesia's economy and its poverty rate. The study is based on a CGE model developed by Lofgren *et al*. (2002) from the International Food Policy Research Institute (IFPRI). By using the cross-entropy method, the author's first updated the Input-Output table for Indonesia in the year 2003 to 2005 to calibrate the model. Three simulations are covered in this study: (i) a contraction of fiscal policy by increasing the *ad valorem* tax rate by 10%; (ii) an expansion of fiscal policy by increasing subsidy rates in all activities by 10%; and (iii) an increase of government transfer payments to rural households by Rp. 100,000. In addition, of all scenarios, the government deficit is endogenous and all net taxes rates are fixed. The study concluded that the increased output tax rate in scenario (i) has a negative impact on GDP. This is due to the decline of its components such as private consumption, government consumption, and net exports. Across sectors, all activities indicate an improvement in output volumes, excluding manufacturing and trade, hotel, and restaurant activities. All prices of activity output increase. Labour demand in manufacturing and trade, hotel, and restaurant activities decline. Furthermore, higher prices of output lead to the reduction of households' real income excluding rural agricultural labour and rural agricultural entrepreneur types[20], due to the decline of their purchasing power. Thus, it leads to an increasing incidence of poverty. In contrast, the increased subsidy rate across activities in scenario (ii) has a positive impact on GDP. It favours producers to lower the output price, which in turn increases private and government consumption. Households' real income increases. Hence, poverty declines particularly among households' in the rural area. Finally, in scenario (iii), for which the government increases its transfer of payments to rural households', real GDP slightly decreases by 0.002%. Across sectors, this scenario has a positive impact mostly on sectors that produce basic needs such as agriculture, public utilities (electricity, gas, and water), transportation, and telecommunication. It improves the labour demand to these sectors. Other sectors contract. Scenario (iii) immediately increases the real income among rural households'. Thus, it only reduces poverty incidence among

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[20] Maipita *et al*. (2010) distinguished the households into 8 groups: rural agricultural labour; rural agricultural entrepreneur; rural low-income non-agricultural labour; rural non-labour force and undefined group; rural high-income non-agricultural labour; urban low-income non-agricultural labour; urban non-labour force and undefined group; and urban high-income non-agricultural labour.

these groups. Since fiscal policy aims to improve the country's economy performance as a whole, the authors' argued that this scenario cannot appropriately be implemented.

In summary, the above literatures show that the changes of fiscal policy can affect equilibrium national income and output. The effectiveness of government intervention to improve economy's performance is highly dependent on their fiscal sustainability. For instance, if the government increases its expenditure, then the financing could be done by initiating the following: increasing the tax revenues; increasing the debt; reducing subsidies, or reducing transfer of payments to certain institutions'. These decisions should attain a primary goal: to boost the national income. In other words, the implementation of fiscal policies should be well-designed to avoid adverse effects on the economy's performance.

4.3. Fiscal Policy Scenarios for Indonesia and Their Impacts

In this section we use the CGE model developed in Chapter 3 to examine the impact of implementing specific fiscal policies in Indonesia. This model is a large-scale model that is based on the circular flow of income distribution. The household and enterprise gain income from the endowment of production factors. The industries produce goods and services by utilizing the production factors and raw materials in a perfectly competitive market: no entry or exit barriers of the market. In other words, the firm cannot influence the market price (price takers), hence, the firms can only generate normal profits. We assume the perfect market competition because there are numerous types of the aggregated industries (24) in the SAM data set which are too difficult to determine their market competition in reality. We assume no externalities – no external cost or benefit transactions caused by the third parties or non-marketable transactions. For example, the effect of carbon tax on CO_2 emissions generated from fossil fuels combustion is not incorporated.

The CGE model used for this analysis, however, has several limitations that could affect the likely results. First, the model is calibrated to the one year of a SAM benchmark which means that the model does not take into account the stochastic anomalies which occur in that one year of data set. Iqbal and Siddiqui (2001) argue that this generalization will detract the validity of the results drawn from the model. Second, some of parameters used in the model are obtained from the literature. In other words, these parameters are not econometrically estimated. This approach will detract the ability of the model to correctly represent the Indonesian economy (McKitrick, 1998). Third, the production structure across industries is derived from the first order functional forms of the constant elasticity of substitutional (CES). McKitrick (1998) argued that the chosen functional structure strongly influences the results from a policy simulation. Fourth, the model is static (a single period model) which means that the model does not incorporate the dynamic behavior. In other words, expectations are assumed to be perfect foresight. Fifth, the model does not explicitly incorporate the monetary effects since there is no money market transaction provided in the SAM data set. Thus, the changes in money supply are assumed not to affect the real side of the economy. The absence of money variables implicitly imply that the financial sector passively adjusts to facilitate the observed changes in real economy (Thurlow and Seventer, 2002). For instance, the adjusments of interest rate due to changes in saving and investment are assumed without the explicit model of loanable funds market. Thurlow and Seventer (2002) argue that although this 'black box' approach limits the model to assess the implication of policy changes, it might not severely distort the conclusions obtained for the real economy. To extend the model by including the financial sector requires additional data in the form of a financial accounting matrix that must be consistent with the SAM data set. To obtain this data involve with sophisticated processes (Thurlow and Seventer, 2002).

We are interested in fiscal policy assessment because it can directly intervene in correcting market failure and income distribution (Griffiths and Wall, 1997; Damuri and Perdana, 2003). Indeed, analysing public expenditures should be conducted in a routine process (The World Bank, 2007). Fiscal policy is also useful in targeting specific agents in the economy, which experience a severe condition in a given period (Damuri and Perdana, 2003). This study seeks to provide empirical justifications for policy makers to implement these policies in Indonesia's economy. It emphasizes the sources of financing to cover the additional public expenditure on goods and services and how these choices influence the equilibrium output, national income, and individuals' income distribution.

Increasing the revenue on taxes or reducing expenditures on subsidies has become the main agenda of Indonesian government to compensate the increase in public expenditure (The World Bank, 2007). Based on the World Bank (2007) information, the total public spending of Indonesia in real terms has increased annually by 11% between the year 2001 and 2005. Thus, by following this justification, we choose to undertake three different scenarios to finance the 10% increase in the exogenous government expenditure. The justification to choose the financing scenarios are explained as follows:

i) Simulation 1: the government is allowed to borrow by government saving adjustment. This simulation adopts the first scenario given in Damuri and Perdana (2003) study, where government deficit and the balance of payments are allowed to adjust in response to the increasing level of public spending but government revenues from net taxes collection remained exogenous. This scenario ensures that the government can only borrow to finance the extra expenditure without having any change in tax revenues. We expect that in the short run, this expansion has the strongest impact on Indonesia's economy since there are no adverse effects through the increased tax rates.
ii) Simulation 2: the subsidy rates across activities adjusts to keep the budget balance. In this simulation, we modify the second scenario proposed in Amir *et al.* (2013) study, in which we allow the subsidy rate to activities increases under the fixed budget deficit condition. By reducing the subsidy expenditures, the net tax revenues can be escalated

without having any increase in tax rates. This scenario contributes as the first study within the context of CGE modelling analysis. Most studies to investigate the distributional impact of reducing subsidy were focused in specific sector. For examples, Dartanto (2013), Yusuf and Resosudarmo (2008), Octaviani *et al.* (2007), Azis (2006), Yusuf (2008), and Clements *et al.* (2003) focused in examining the economic impact of reducing fuel subsidies in Indonesia. Lofgren and El-Said (2001) examined the short-run effects of eliminating food subsidies in Egypt. Liu and Li (2011) investigated the impact of reforming fossil energy subsidies on China's economy. Steenblik and Coroyannakis (1995) assessed the economic impact of eliminating coal subsidies in western European countries. The results generally proved that subsidy reduction without any compensation could increase the poverty incidence. Therefore, in this scenario, we propose to reduce the subsidy rates to all activities uniformly in order to compensate the increased government expenditure. We expect that this strategy could generate a positive impact on Indonesia's economy.

iii) Simulation 3: the output tax rates adjusts to keep the budget balance. In this simulation, we follow Damuri and Perdana (2003) and Maipita *et al.* (2010) in which the additional public expenditures are financed by increasing the output tax rates. We suspect that this scenario would lead to the most adverse effects on the Indonesia's economy. This is because the reduction of output tax rates would lead to a contraction in national income (Begg *et al*., 2003).

We now briefly discuss the theoretical model and identification of scenarios motivated in previous section in the context of the specific model. Based on the standard CGE model given in the previous chapter, the government behaviors are expressed in equations (3.13) – (3.17).

The government levies revenues from the economy's circular flow through taxes less subsidies (net taxes) and income transfers less transfer of payments. The taxes cover income taxes on households (IH_h) at the rate of $Htax\_rate_h$; *ad valorem* taxes on gross production sales $\left(P_i^Q Q_i\right)$ at the rate of vat_rate_i; income tax of enterprise (IB) at the rate of $Btax\_rate$; and tariff on import sales $(P_i^M M_i)$ at the rate of $tarif\_rate_i$. The subsidies are allocated to some domestic commodities $(P_i^Q Q_i)$ at the rate of $subQ\_rate_i$; and some of j-th industry gross output $(P_j^{QA} QA_j)$ at the rate of $subA\_rate_j$. All of these tax (subsidy) rates are redefined in order to distinguish the average and specific rates such that the government is allowed to choose an exogenous change in their tax revenues. For example, the income tax rate for households' $Htax\_rate_h$ is rewritten as $(HAtaxrate\ )(Htaxrate_h)$. Furthermore, the government also receives transfer income from their internal government transactions $\left(TR_{gov,ROW}\right)$ and foreign $\left(TR_{gov,ROW}\right)$ less transfers payments to institutions' $\left(TR_{in,gov}\right)$. The government spends these revenues to purchase goods and services, which are expressed as $\sum_{i\in C} P_i^Z CG_i$. The residuals between the government expenditure and revenue are regarded as government saving: $SG = IG - EG$. A budget deficit (surplus) occurs when government spending is higher (lower) than its receipt.

The solution software is the General Algebraic Modelling System (GAMS) with the Mixed Complementarity Problem (MCP) solver that has advantage in flexibility and speed to solve complex economic models (Flakowski, 2003). To implement the proposed scenarios given in the previous section, we execute the model as follows. The adjusted government expenditure ($CGADJ$), where its initial value is assumed 1, is shocked by a 10% increase with three different financing scenarios:

i) In scenario 1, all tax and subsidy rates are fixed, which are income tax rates ($HAtaxrate$); *ad valorem* tax rates ($vatArate$); business income tax rates ($Btaxrate$); tariff rate ($tarifArate$); subsidy rates to domestic commodities ($subQArate$); and subsidy rates to activities ($subAArate$). Hence, the government saving (SG) adjusts to clear the changes of public spending.

ii) In scenario 2, the subsidy rates to activities ($subAArate$) adjust to clear the budget balance. Whilst the rests of tax and subsidy rates including government saving are fixed, which are: income tax rates ($HAtaxrate$); *ad valorem* tax rates ($vatArate$); business income tax rates ($Btaxrate$); tariff rates ($tarifArate$); subsidy rates to domestic commodities ($subQArate$); and the government saving (SG)

iii) In scenario 3, the output tax rates adjust to clear the budget balance. Whilst the rests of tax and subsidy rates are fixed, which are: income tax rates ($HAtaxrate$); business income tax rates ($Btax\_rate$); tariff's rate ($tarifArate$); subsidy rates to domestic commodities ($subQArate$); subsidy rates to activities ($subAArate$); and the government saving (SG).

Moreover, the closure rules of all experiments are determined as follows:

1. Flexible exchange rate regime, where balance of payment ($SROW$) is fixed and exchange rate adjusts to ensure $SROW = 0$. This closure setting is selected to reflect the real condition of Indonesia's economy regime, where Indonesia has been following a floating exchange rate regime since the year of 1977 (Bank of Indonesia, 2014). In the model, the endogenous exchange rate ensures the model to avoid capital flow and foreign borrowing. Hence, this model restricts the government to only financing its budget deficit by selling their treasury bonds to domestic institutions. Lofgren *et al.* (2002) stated that by fixing the trade balance, within the context of *ceteris paribus*, a depreciation of exchange rate (domestic per foreign currency units) would occur to cover a drop of foreign saving below the exogenous level. Damuri and Perdana, (2003) argued that this closure ensures the private investment unaffected by the endogenous trade

balances. Fiscal expansion would therefore push the interest rate to soar[21]. The increased interest rate would reduce investment, which in turn lowers the positive effect on aggregate demand (Damuri and Perdana, 2003).

2. Investment-driven, where the actual investment ($CINV_i$) and enterprise saving (SB) are exogenous. Whilst household saving (SH_h) and government saving (SG) adjust to obtain the saving-investment balance. More specifically, in scenario 1 and 3, we allow only the richest type of household (non-agricultural-urban households with high wages (HH_NAGU_HL))[22] to adjust their saving ratio ($sh\_dum_h = 1$) but the saving of other household types is assumed fixed. Here, we expect that this scenario would increase the level of real income of household such that only the richest households could afford to increase their saving for the sake of investment on goods. In scenario 2, we allow two groups of households, non-agricultural-urban households with low (HH_NAGU_LL) and high wages (HH_NAGU_HL), adjust their saving ratio; and let other types of household saving exogenous. This assumption is opted to examine the income distribution effects when two endogenous saving of these household groups are set in the model.
3. Capital factor closure, where the distorted price of capital across activities ($PDIST\_K_j$) and unemployed capital are exogenous. The stock of capital (K_j) adjusts to ensure clearing of each j-th activity. Rent of capital (P^K) also adjusts to ensure overall market clearing. In other words, the capital stock is assumed to be mobile across activities. Capital rent of activity specific is fixed and hence the equilibrium can be achieved through the flexible adjustment of aggregated capital rent. Here we assume no excessive capital (fully employed capital).
4. Labour factor closure, where the employed labour types used in ROW ($L_{o,ROW}$); labour types supply (LS_o); adjusted wage of labour types across activities ($PDIST\_L_{o,j}$); and average wage of labour types (P_o^L) are all exogenous. Whilst the employed labour used across activities ($L_{o,j}$); labour composite (LAB_j); adjusted wage of labour composite across activities ($PDIST\_LAB_j$); and average wage of labour composite (P^{LAB}) are endogenous such that the constraint of below is obtained:

$$\left(PDIST\_LAB_j\right)\left(P^{LAB}\right)\left(LAB_j\right) = \sum_o \left(PDIST\_L_{o,j}\right)\left(P_o^L\right)\left(L_{o,j}\right)$$

This closure relaxes the typical neoclassical closure where workers are mobile between industries with fixed wages. Hence, the labour market is cleared through the adjusted

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[21] In their simulations, Damuri and Perdana (2003) set the closure combinations of either fixed balance of payment (BOP) with the adjusted interest rate or flexible BOP while having interest rate fixed.

[22] We define the richest households' based on the highest income ratio to total income of households given in the SAM classifications.

unemployment rates. This setting follows the fact that Indonesia currently faces a massive labour surplus (Yusuf *et al*., 2008).

4.4. Simulation Results

This section presents the simulation results of all scenarios. It aims to assess the implications of various fiscal policies shocks on Indonesia's macroeconomy as well as distributional of income and output.

4.4.1. Scenario 1: A 10 percent increase in government expenditure ($CGADJ$) with Government Saving Adjustment

In scenario 1, we examine the impact of a 10% increase in government expenditure on Indonesia's economy. The government saving are endogenous to clear the government budget balance. All tax and subsidy rates are exogenous. Therefore, this simulation only allows the government to finance its excess expenditures by borrowing.

4.4.1.1. Impact on Macroeconomic Account

Table 4.1 presents the macroeconomic impact of scenario 1. It shows that the shock directly increases the aggregate demand side, forcing the level of GDP positively adjusts. The results are consistent to Keynes postulation, which stated that the government has a pivotal role in rapidly increasing the aggregate demand towards achieving full employment level (Maipita *et al*., 2010). Therefore, the increased level of factor returns influences the improvement of private consumption as well as net exports.

In the model, we distinguish three types of GDP: GDP at factor cost which is obtained from total of wage bill and capital bill; GDP at market price from income side which is obtained from total of private consumption, government consumption, investment and net export; and GDP at market price from expenditure side which is the sum of GDP at factor costs and net taxes. The increased level of GDP at factor cost does not considerably different than that of GDP at market price (income side and expenditure side). Nevertheless, the differences could be explained from the linkage on each of GDP components and also the choices of factors closure.

Scenario 1 immediately increases the level of output production which leads to an increase of factors cost across all activities. This is reflected from the increase of GDP at factor costs by 2.42% due to the increase of its total wage bill component by 4.63% while total capital bill only slightly increases by 0.01%. The slight change of capital bill is due to the choice of capital closures. The model assumes that the rent of capital is fixed, capital is fully employed, and the stock of capital is mobile inter-industries. This assumption would generate a negligible change on total capital bill because the changes of capital stock in some activities would be offset by the changes of stock in others. In the other hand, at labour factor closures, there are two main distinctions: closure on labour types and labour composite. The labour type closure is similar to that of capital closure of which wage of each labour is exogenous, and employment is mobile between industries. However, for composite labour closure, both of its activity specific wage and average wage to all industries are endogenously determined. Thus, scenario 1 only induces the GDP at factor costs component of total wage bill to increase strongly.

GDP at market price improves higher than GDP at factor costs because of the effect on factors return to households' which in turn increases their demand on final goods. Table 4.1 summarizes that GDP at market price from income side increases by 2.67% and GDP at market price from expenditure side increases by 2.56%. The components of GDPMP1 such as household and government consumption, investment, and net export are increased largely excluding investment by 3.02%, 8.54%, 0.26%, and 3.92%. This is because in the model, investment of goods ($CINV_i$) is fixed, thus the slight increase of total real investment (0.26%) is determined from the rise of final goods price index (P_i^Z). Total investment on goods is obtained from the following relationship:

$$INVEST = \sum_i P_i^Z CINV_i\,, \qquad i \in C$$

The increased demand in public goods also leads to a sharp increase of net indirect tax (9.32%). This is because a higher level of final demand causes aggregate supply to increase in order to clear the market, which in turn increases the net tax receipts to government. However, the expansion of government expenditure leads to an increase of its budget deficit by 5.59%. Due to static nature of the CGE model we used, the effects of this budget deficit cannot be captured in the analysis.

Table 4.1: Impact of Scenario 1 on National Income Account

Variables	BASE	SHOCKED	% CHANGE
	(Billions Rupiah)		
GDP at factor costs	5156935.19	5281935.23	2.42
GDP gap	0.04	0.04	2.71
GDP at market prices from income side	5472873.35	5618877.83	2.67
GDP at market prices from expenditure side	5260983.61	5395679.76	2.56
Total private consumption	3318104.75	3418313.57	3.02
Total investment	1508830.58	1512708.37	0.26
Total real government consumption	294566.35	319708.98	8.54
Total export	1487237.85	1497408.46	0.68
Total import	1347755.91	1352459.63	0.35
Net export	139481.93	144948.84	3.92
Net indirect tax	104048.42	113744.52	9.32
Total payment to all workers (WAGEBILL)	2692617.74	2817376.29	4.63
Total payment to capital (CAPBILL)	2464317.45	2464558.94	0.01
Government Saving (SG)	229473.00	216656.00	-5.59

4.4.1.2. Impact on Gross Output and Value Added

Tables 4.2 and 4.3 present the effects of scenario 1 on gross domestic output and value added across industries. As discussed above, the increase in public consumption leads to higher aggregate demand of commodities. This implies that producers will optimize their revenue constrained by input reallocations such as production factors and intermediate inputs. The result found that those industries that increased their gross output are mostly due to lower costs of value added input – although a higher price of intermediate input could also negatively affect the output production across industries.

Table 4.2 shows that an improvement in public expenditures does not necessarily increase the output production in each industry. There are 4 sectors that indicate a contraction in output production, namely fisheries (FISH_A); forestry products (FORH_A); other agricultural (OAGRI_A); restaurant (RSTR_A); and woods products (WOOG_A) by -18.47%, -0.39%, -6.57%, -3.21%, and -1.67%, respectively. Their output prices – excluding woods sector – also substantially increased, which are 58.65%, 0.48%, 32.83%, 11.22%, and 0.10%, respectively. Their decline in output volumes (excluding woods sector) are strongly related to a higher cost per unit of value added presented in table 4.3. The percentage changes of value added cost per unit of these industries are 2.24%, 18.21%, 12.98%, 12.57%, and -3.27%, respectively.

In contrast, the sector of supporting service for transportation (SUPPS_A) and hotel (HTEL_A) indicate the highest improvement on their output volumes by 61.90% and 29.53%. Other sectors such as textiles (STGL_A), agricultural (AGRI_A), petrochemical products (CHFCC_A), fossils mining (COMOIL_A), and electricity-city gas-clean water (ELEGD_A) are also improved by 14.13%, 3.55%, 2.85%, 5.41%, and 6.34% respectively. This improvement is due to a reduction in their value added cost which are -16.35%, -8.44%, -8.81%, -5.08%, and -7.25%.

Table 4.2: Impact of Scenario 1 on Activity Gross Domestic Output

Activity	Volume of Gross Domestic Output (QA_j)			Price of Gross Domestic Output (PQA_j)		
	BASE	SHOCKED	% Change	BASE	SHOCKED	% Change
AGRI_A	577097	597590	3.55	1	0.96	-3.68
AISCOM_A	325709	329841	1.27	1	0.99	-0.92
BANKAS_A	268190	268918	0.27	1	1.05	5.07
CATLE_A	351964	353240	0.36	1	1.03	3.16
CHFCC_A	1274343	1310694	2.85	1	0.96	-3.65
COMOIL_A	616125	649438	5.41	1	0.95	-4.89
CONS_A	1243976	1250607	0.53	0.98	1.00	2.10
ESTPRV_A	286491	305818	6.75	1	0.92	-7.63
ELEGD_A	124491	132382	6.34	0.98	0.92	-6.32
FISH_A	244882	199653	-18.47	1	1.38	37.98
FODT_A	1173301	1181895	0.73	1	0.99	-0.64
FORH_A	62143	61902	-0.39	1	1.02	1.98
GOVTD_A	493287	521596	5.74	1	0.99	-1.06
HTEL_A	39603	51298	29.53	1	0.94	-6.21
INDSHO_A	279477	293948	5.18	1	0.95	-4.56
LANT_A	265679	269945	1.61	1	1.02	2.32
OAGRI_A	220411	205935	-6.57	1	1.21	20.51
OMINE_A	99298	102702	3.43	1	0.83	-17.30
PPTM_A	1579245	1618727	2.50	1	0.96	-3.84
RSTR_A	285032	275883	-3.21	1	1.06	6.39
STGL_A	336199	383689	14.13	1	0.94	-5.85
SUPPS_A	48418	78387	61.90	1	0.65	-35.25
TRDE_A	999123	1010054	1.09	0.97	1.07	10.49
WOOG_A	211879	208343	-1.67	1	1.00	0.10
TOTAL	11406362	11662484	2.25	1.00	0.99	-0.49

Table 4.3: Impact of Scenario 1 on Value Added

ACTIVITY	Value Added Price (PVA_j)			Volume of Value Added (VA_j)		
	BASE	SHOCKED	% Change	BASE	SHOCKED	% Change
AGRI_A	1	0.92	-8.44	377515	390921	3.55
AISCOM_A	1	1.04	3.53	184908	187254	1.27
BANKAS_A	1	1.07	7.14	174958	175434	0.27
CATLE_A	1	1.01	1.45	129760	130230	0.36
CHFCC_A	1	0.91	-8.81	541374	556817	2.85
COMOIL_A	1	0.95	-5.08	485997	512274	5.41
CONS_A	1	1.15	15.07	427655	429935	0.53
ESTPRV_A	1	0.90	-10.24	198081	211443	6.75
ELEGD_A	1	0.93	-7.25	127591	135679	6.34
FISH_A	1	1.59	58.65	134055	109295	-18.47
FODT_A	1	0.80	-20.35	286708	288808	0.73
FORH_A	1	1.01	0.48	40074	39918	-0.39
GOVTD_A	1	0.99	-0.73	330641	349616	5.74
HTEL_A	1	0.88	-11.86	23451	30376	29.53
INDSHO_A	1	0.95	-5.07	141973	149324	5.18
LANT_A	1	1.12	12.39	105917	107618	1.61
OAGRI_A	1	1.33	32.83	128807	120347	-6.57
OMINE_A	1	0.72	-27.78	63134	65299	3.43
PPTM_A	1	0.87	-12.83	430990	441765	2.50
RSTR_A	1	1.11	11.22	116147	112419	-3.21
STGL_A	1	0.84	-16.35	108712	124069	14.13
SUPPS_A	1	0.41	-58.61	26498	42900	61.90
TRDE_A	1	1.22	22.36	499883	505352	1.09
WOOG_A	1	0.97	-3.27	72105	70902	-1.67
Average	1	0.99	-1.31			5.12

4.4.1.3. Impact on Employed Factors

Table 4.4 summarizes the impacts of scenario 1 on employed factors (labour composite and capital). The changes of value added cost across activities are strongly linked to its corresponding level of employed factors. Since the model assumes exogenous wages of labour types and capital rent, hence, the shock induces only the changes in capital stock, the number of labour composite; and wage labour composite.

Scenario 1 improves the overall aggregate labour composite by 7.51% but capital stock negligibly increases by 0.00%. However, in activity specific, the results vary. For examples, the demand for capital stock increases for the respective of air communication (AISCOM_A); public services (GOVTD_A); hotel (HTEL_A); other agricultural (OAGRI_A); trade (TRDE_A); and fisheries (FISH_A) sector by 4.83%, 4.96%, 14.16%, 24.09%, 23.69%, and 29.34%. In contrast, the decline of capital stock demand occurs in the sectors, namely: agricultural (AGRI_A); petrochemical products (CHFCC_A); real estates (ESTPRV_A); electricity-city gas-clean water (ELEGD_A); food and tobaccos (FODT_A); other mining (OMINE_A), paper and metal goods (PPTM_A); textiles (STGL_A); supporting services for transportation (SUPPS_A); and woods (WOOG_A) sector by -5.20%, -6.22%, -4.19%, -1.39%, -19.77%, -25.31%, -10.66%, -4.54%, -32.99%, and -4.89% respectively.

There are 9 sectors which indicate a reduction of labour demand. These are air communication (AISCOM_A); bank and insurances (BANKAS_A); cattle products (CATLE_A); construction (CONS_A); fisheries (FISH_A); forestry (FORH_A); land transportation (LANT_A); other agricultural (OAGRI_A); restaurant (RSTR_A); and trade (TRDE_A) sector by -4.57%, -14.37%, -0.24%, -14.19%, -62.97%, -1.14%, -12.01%, -4.38%, and -1.57% respectively. Fisheries sector has the most severe effect of SIM-1. Other sectors generate the opposite results where they tend to increase the labour composite demand. In overall, table 4.4 indicates that hotel sector (HTEL_A), fossils mining (COMOIL_A), and government services (GOVTD_A) benefited the most from factors movement effects of both capital stock and labour composite.

Table 4.4: Impact of Scenario 1 on Employed Factors (LAB_j and K_j)

Activity	Labour Composite (LAB_j)			Capital (K_j)		
	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE
AGRI_A	356465	371052	4.09	21051	19956	-5.20
AISCOM_A	68100	64991	-4.57	116808	122454	4.83
BANKAS_A	53146	45509	-14.37	121813	130852	7.42
CATLE_A	91495	91280	-0.24	38265	38956	1.80
CHFCC_A	166589	210890	26.59	374785	351485	-6.22
COMOIL_A	60075	91687	52.62	425923	426114	0.05
CONS_A	200904	172401	-14.19	226751	262287	15.67
ESTPRV_A	45543	69830	53.33	152538	146141	-4.19
ELEGD_A	16371	29056	77.49	111220	109680	-1.39
FISH_A	49457	18313	-62.97	84598	109415	29.34
FODT_A	120241	165990	38.05	166467	133550	-19.77
FORH_A	15275	15100	-1.14	24799	24818	0.08
GOVTD_A	286212	302984	5.86	44429	46633	4.96
HTEL_A	9279	14577	57.10	14172	16178	14.16
INDSHO_A	86104	93680	8.80	55869	55775	-0.17
LANT_A	87258	86474	-0.90	18660	21306	14.18
OAGRI_A	106334	93567	-12.01	22473	27887	24.09
OMINE_A	46746	54194	15.93	16388	12240	-25.31
PPTM_A	179195	222801	24.33	251795	224950	-10.66
RSTR_A	104242	99680	-4.38	11905	12814	7.64
STGL_A	45829	66825	45.81	62884	60030	-4.54
SUPPS_A	20445	42978	110.22	6053	4056	-32.99
TRDE_A	441454	434528	-1.57	58429	72268	23.69
WOOG_A	35860	36470	1.70	36245	34472	-4.89
Total	2692618	2894856	7.51	2464317	2464317	0.00

4.4.1.4. Impact on Commodity Prices and Volumes

Table 4.5 presents the effects of scenario 1 on commodity prices and volumes. The changes of commodity volumes are strongly linked to the changes of institutions' final consumption: aggregated household consumption, government consumption, investment on goods, and net export.

In the model, the price indexes of export (P_i^E) and import (P_i^M) commodities are determined from the following relationships:

$$P_i^E = (EXR)P_i^{EW}, \qquad i \in CE$$

$$P_i^M = (EXR)P_i^{MW}, \qquad i \in CM$$

where: EXR is the exchange rate

We assume that Indonesia's economy constitutes a small and open economy country, for which the country cannot influence the world price of trade. Thus, based on the above descriptions, the world price indexes of exported and imported commodities (P_i^{EW} and

P_i^{MW}) are exogenous. It simply implies that the changes of both P_i^E and P_i^M are determined only by the adjusted exchange rate (depreciation/appreciation). The assumption of small-open economy in the CGE model analysis is commonly adopted for the sake of simplification. This is because the transaction flows of industries and commodities recorded in the SAM data set are usually in terms of an aggregate level.

At a certain commodity, this assumption might not reflect its reality of international trade between Indonesian and the rest of world. For instance, Indonesia in 2014 accounted for about 60% of world's palm oil production. In this context, the assumption where Indonesia cannot influence the world price of palm oil may not be realistic. However, to implement the endogenous world price (export and import) of palm oil commodity into the model, one will require a specific transaction of palm oil (industry and commodity) recorded in the SAM data set to calibrate the model. In the Indonesian SAM for 2008, the palm oil commodity is aggregated together with other agricultural (food crops) type of commodities in one transaction account. This limitation is the reason behind the assumption of exogenous world's price of all exported and imported commodities.

Table 4.5 shows that the price indexes of all exported and imported commodities are shifting equally with the appreciated exchange rate (domestic per foreign currency unit), which is -5.15%. Overall, scenario 1 generates the increasing level of the relative price ratios of aggregated domestic-import (P_i^D/P_i^M) by 4.52% which creates a substitution effect from domestically produced commodity to imports. This is due to the fact that fiscal expansion will increase the aggregate demand which in turn increases the prices of domestic goods. Hence, the imported commodity would be relatively cheaper to purchase than its corresponding domestic commodity. It triggers a substitution effect by which the aggregate sectors would preferably increase the shares of imported input relatively to domestic input in order to produce the final output (Z_i). Table 4.5 shows that the aggregate sectors tend to increase the utilization of imported volumes (2.37%) higher than the domestic intermediate inputs (1.91%). Taken together, these changes lead to a rise of aggregated composite commodities by 2.38%.

Across specific commodity, the impact of scenario 1 varies substantially. This is due to the trade assumptions of the model: imperfect substitutability of domestic-imported commodity and domestic-export transformation function. Thus, the solution of optimizing these problems determines the output reallocation inter-industries.

There are only two types of imported commodities that decline strongly in volume: other agricultural (OAGRI_C) and textiles (STGL_C) import by -22.12% and -50.87% respectively. Conversely, other commodity types are experiencing a volume expansion in which the import of fisheries (FISH_C) and other agricultural (OAGRI_C) indicate the most improvement by 74.90% and 62.23% respectively.

In terms of export, there are 10 types of commodities that indicate a contraction in volumes in which fisheries (FISH_C) and other agricultural (OAGRI_C) experience the highest drop by -59.38% and -38.97% respectively. Other types of exports indicate a less decline. These are air-sea communication (AISCOM_C); bank and insurances (BANKAS_C); cattle products (CATLE_C); food and tobaccos (FODT_C); forestry (FORH_C); land transportation (LANT_C); restaurant (RSTR_C); and woods (WOOG_C) by -2.16%, -13.85%, -10.55%, -3.23%, and -9.15%, -7.95%, -18.88%, and -6.92% respectively. In contrast, other commodities have tendencies on export expansions where the most improved sectors are of those export in supporting services for transportation (SUPPS_C); other mining (OMINE_C); and hotel (HTEL_C) by 266.22%, 43.46%, and 39.68% respectively.

In the domestic market, there are two types of domestic (D_i) and composite commodities (Z_i) that indicate a drop in volumes: fisheries (-17.85% and -17.91%) and restaurant (-3.21% and -1.72%). These are due to the price effect, of which their commodities are costlier to purchase in market. Table 4.5 shows that these commodities price indexes increase by (38.45% and 38.40%) and (6.80% and 6.41%) respectively. By contrast, those commodities which are cheap to purchase tend to increase their quantities sold in the domestic market.

Table 4.5: Impact of Scenario 1 on Prices and Quantities of Commodities (% Change)

Commodity	P^Q	P^Z	P^D	P^E	P^M	P^D/P^E	P^D/P^M	Q	Z	D	E	M
AGRI_C	-3.68	-3.78	-3.68	-5.15	-5.15	1.53	1.53	3.55	3.77	3.55	5.86	6.79
AISCOM_C	-0.92	-1.37	-0.45	-5.15	-5.15	4.90	4.90	1.27	4.13	2.23	-2.16	12.60
BANKAS_C	5.07	4.78	5.18	-5.15	-5.15	10.91	10.91	0.27	1.26	0.48	-13.85	23.56
CATLE_C	3.16	3.04	3.17	-5.15	-5.15	8.80	8.80	0.36	0.62	0.38	-10.55	18.76
CHFCC_C	-3.65	-4.18	-3.72	-5.15	-5.15	1.53	1.53	2.85	3.68	2.70	5.08	5.82
COMOIL_C	-4.89	-5.65	-5.82	-5.15	-5.15	-0.69	-0.69	5.41	2.98	3.36	10.53	1.89
CONS_C	2.10	2.10	2.10	-5.15	-5.15	7.64	7.64	0.53	0.53	0.53	0.00	0.29
ESTPRV_C	-7.63	-7.45	-7.85	-5.15	-5.15	-2.79	-2.79	6.75	5.33	6.25	18.67	74.90
ELEGD_C	-6.32	-6.32	-6.32	-5.15	-5.15	-1.21	-1.21	6.34	6.34	6.34	0.00	0.00
FISH_C	37.98	38.40	38.45	-5.15	-5.15	45.91	45.91	-18.47	-17.85	-17.91	-59.38	13.02
FODT_C	-0.64	-0.42	-0.09	-5.15	-5.15	5.32	5.32	0.73	2.53	1.85	-3.23	15.34
FORH_C	1.98	1.95	2.02	-5.15	-5.15	7.54	7.54	-0.39	-0.16	-0.31	-9.15	15.55
GOVTD_C	-1.06	-1.08	-0.95	-5.15	-5.15	4.37	4.37	5.74	6.24	5.97	2.45	2.83
HTEL_C	-6.21	-8.17	-10.97	-5.15	-5.15	-6.17	-6.17	29.53	9.69	16.72	39.68	6.48
INDSHO_C	-4.56	-4.58	-4.56	-5.15	-5.15	0.58	0.58	5.18	5.22	5.17	9.52	18.35
LANT_C	2.32	2.30	2.34	-5.15	-5.15	7.85	7.85	1.61	1.74	1.65	-7.95	62.23
OAGRI_C	20.51	20.49	22.73	-5.15	-5.15	29.36	29.36	-6.57	0.54	-3.10	-38.97	-22.12
OMINE_C	-17.30	-16.78	-17.50	-5.15	-5.15	-13.02	-13.02	3.43	1.18	2.94	43.46	4.88
PPTM_C	-3.84	-4.32	-3.95	-5.15	-5.15	1.32	1.32	2.50	3.07	2.28	5.15	23.68
RSTR_C	6.39	6.41	6.80	-5.15	-5.15	12.60	12.60	-3.21	-1.72	-2.45	-18.88	6.11
STGL_C	-5.85	-7.02	-7.20	-5.15	-5.15	-2.16	-2.16	14.13	10.42	10.86	22.12	-50.87
SUPPS_C	-35.25	-36.81	-41.83	-5.15	-5.15	-38.64	-38.64	61.90	10.71	30.64	266.22	13.74
TRDE_C	10.49	10.49	10.49	-5.15	-5.15	16.50	16.50	1.09	1.09	1.09	0.00	0.00
WOOG_C	0.10	0.89	1.05	-5.15	-5.15	6.59	6.59	-1.67	0.53	0.21	-6.92	5.80
Total	-0.49	-0.71	-0.86	-5.15	-5.15	4.52	4.52	2.25	2.38	1.91	6.15	2.37

$$\frac{P^D}{P^M} = \left(\frac{\left(\frac{P_1^D}{P_1^M} - \frac{P_0^D}{P_0^M} \right)}{{P_0^D}\Big/{P_0^M}} \right) * 100\%$$

$$\frac{P^D}{P^E} = \left(\frac{\left(\frac{P_1^D}{P_1^E} - \frac{P_0^D}{P_0^E} \right)}{{P_0^D}\Big/{P_0^E}} \right) * 100\%$$

Where 1 for shock value; and 0 for base value

Key variables:

P^Q: Output price; P^Z: composite commodity price; P^D: domestic commodity price; P^E: imported commodity price; P^M: imported commodity price; Q: output volume; Z: composite commodity quantity; D: domestic commodity quantity; E: exported commodity quantity; M: imported commodity quantity.

4.4.1.5. Impact of Scenario 1 on Household income and Expenditure

In this section we briefly discuss the impact of SIM-1 on household income and expenditure across all categories. This section does not investigate the impact on welfare and inequality.

Damuri and Perdana (2003) address three mechanisms of a policy that could influence household income: (i) direct linkages of primary factor returns, in which the household will receive higher income if their wages increased and lower income in the opposite condition. The variation of household income distribution is dependent on the combination of their factors supply; (ii) the injection effects on income tax adjustment. However, this mechanism is not applicable in this scenario since the model assumes exogenous income tax rates; and (iii) the price effect that contributes to households' purchasing power on final goods. The changes of household budget will affect their real income distribution.

Table 4.6 summarizes the effects of scenario 1 on households' distribution income, expenditure, and saving. The results are consistent to Damuri and Perdana (2003) arguments. The shock has a positive impact on all types of households' actual disposable income[23]. The level of improvements is correlated with their types of occupation status either workers or unclear job[24], which in turn affect their factor returns. The worker types of households' have tendencies on higher disposable income relatively to those of unclear occupation types. The actual disposable income of the respective HH_AGR_L, HH_NAGR_LL, HH_NAGR_HL, HH_NAGU_NA, and HH_NAGU_HL are increased by 3.52%, 4.27%, 3.17%, 3.13%, and 5.64%. Meanwhile the groups of HH_AGR_NL, HH_NAGR_NA, and HH_NAGU_LL are increased only by 1.94%, 1.08%, and 1.47%. These results indicate that the increasing level of household actual disposable income is highly due to the endowed factors of production (labour types and capital) to activities.

Furthermore, the changes of all household budget and saving, excluding non-agricultural-urban household with high wages categories (HH_NAGU_HL), are equal to their level of income distribution. This is because in the model specifications, the relationships of household expenditure, income, and saving are expressed as follows:

$$SH_h = sh\_ratio_h ADIH_h, \qquad h \in H \tag{1}$$

$$sh\_ratio_h = sh\_rin_h(1 + sh\_dum_h sh\_adj), \qquad h \in H \tag{2}$$

$$EH_h = ADIH_h - SH_h, \qquad h \in H \tag{3}$$

We assume that only the richest household groups (HH_NAGU_HL) adjust their saving ratio ($sh\_dum_h = 1$) to clear the saving-investment balance, whilst other household types

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[23] We define actual disposable income as disposable income less transfer payments to institutions'.

[24] The worker types of household include: agricultural household with unskilled labour (HH_AGR_L); non-agricultural-rural household with low wages (HH_NAGR_LL); non-agricultural-rural household with high wages (HH_NAGR_HL); non-agricultural labour-urban household with low wages (HH_NAGU_LL); and non-agricultural labour-urban household with high wages (HH_NAGU_HL). Whilst the unclear occupation types of household are including agricultural-household (HH_AGR_NL), non-agricultural-rural household (HH_NAGR_NA), and non-agricultural-urban household (HH_NAGU_NA).

are fixed. The income tax rates of all households' types are assumed exogenous. Thus, based on above description, the exogenous saving ratio (sh_ratio_h) of those households' types will generate the identical shifts in their expenditure, income, and saving. As a result, the actual disposable income of HH_NAGU_HL increases by 5.64% but the rise of their budget expenditure is lower, which is 4.89%. This is because the saving ratio of this group increases by 4.6%. It implies that this household saving increases relatively higher (10.5%) than its budget percentage change (4.89%). The increase in saving is utilized to adjust the exogenous investment on goods.

Table 4.7 summarises the impact of scenario 1 on household consumption. Total households' demand on aggregate commodities is strongly improved. Across commodity, this shock greatly influences the increased demand of supporting services for transportation (62.90%); other mining (23.69%); hotel (12.09%); textiles (10.70%); and real estate (11.21%). Nevertheless, there are three types of composite goods show a decline: fisheries (-25.62%), other agricultural products (-14.57%), and banking and insurances (-3.26%).

Table 4.6: Impact of Scenario 1 on Household income and Expenditure

Households' Types	$ADIH_h$			EH_h			SH_h			sh_ratio_h		
	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE
HH_AGR_L	171254.15	177284.49	3.52	162021.42	167726.65	3.52	9232.73	9557.84	3.52	0.05	0.05	0.00
HH_AGR_NL	703950.96	717606.80	1.94	642327.17	654787.58	1.94	61623.79	62819.22	1.94	0.09	0.09	0.00
HH_NAGR_LL	476495.04	496859.51	4.27	450508.35	469762.20	4.27	25986.69	27097.31	4.27	0.06	0.06	0.00
HH_NAGR_NA	167662.89	169480.74	1.08	158015.28	159728.53	1.08	9647.61	9752.21	1.08	0.06	0.06	0.00
HH_NAGR_HL	441588.76	455603.42	3.17	385336.98	397566.38	3.17	56251.78	58037.04	3.17	0.13	0.13	0.00
HH_NAGU_LL	671493.46	681352.20	1.47	633498.92	642799.84	1.47	37994.53	38552.36	1.47	0.06	0.06	0.00
HH_NAGU_NA	233824.57	241142.97	3.13	213768.06	220458.71	3.13	20056.51	20684.26	3.13	0.09	0.09	0.00
HH_NAGU_HL	777279.03	821122.50	5.64	672628.57	705483.68	4.89	104650.46	115638.83	10.50	0.14	0.14	4.60

Key variables:

$ADIH_h$: Actual disposable income; EH_h: household budget; SH_h: household saving; sh_ratio_h: adjusted average propensity of saving

Households' types:

HH_AGR_L: agricultural households' with unskilled labour; HH_AGR_NL: agricultural-households' with unclear occupation; HH_NAGR_LL: non-agricultural-rural households' with low wages, HH_NAGR_NA: non-agricultural-rural households' with unclear occupation; HH_NAGR_HL: non-agricultural-rural households' with high wages, HH_NAGU_LL: non-agricultural labour-urban households' with low wages, HH_NAGU_NA: non-agricultural-urban households with unclear occupation, and HH_NAGU_HL: non-agricultural labour-urban households' with high wages.

Table 4.7: The Impact of Scenario 1 on Households Consumption of Commodities Variety

Commodity	HH_AGR_L	HH_AGR_NL	HH_NAGR_LL	HH_NAGR_NA	HH_NAGR_HL	HH_NAGU_LL	HH_NAGU_NA	HH_NAGU_HL	AVG
	% CHANGE								
AGRI_C	7.59	5.94	8.37	5.05	7.23	5.45	7.18	9.00	6.98
AISCOM_C	4.96	3.35	5.72	2.49	4.61	2.88	4.56	6.34	4.36
BANKAS_C	-1.20	-2.71	-0.48	-3.52	-1.53	-3.16	-1.57	0.10	-1.76
CATLE_C	0.46	-1.07	1.19	-1.90	0.13	-1.53	0.08	1.79	-0.11
CHFCC_C	8.04	6.39	8.82	5.49	7.67	5.89	7.63	9.46	7.42
ESTPRV_C	11.85	10.14	12.66	9.22	11.47	9.63	11.43	13.32	11.21
ELEGD_C	10.51	8.82	11.31	7.91	10.14	8.32	10.09	11.96	9.88
FISH_C	-25.20	-26.34	-24.66	-26.96	-25.45	-26.68	-25.48	-24.21	-25.62
FODT_C	3.95	2.37	4.71	1.51	3.60	1.89	3.56	5.32	3.36
FORH_C	1.54	-0.01	2.28	-0.85	1.20	-0.47	1.16	2.88	0.97
GOVTD_C	4.65	3.05	5.41	2.19	4.30	2.58	4.26	6.03	4.06
HTEL_C	12.73	11.00	13.55	10.07	12.35	10.49	12.30	14.21	12.09
INDSHO_C	8.49	6.84	9.28	5.94	8.13	6.34	8.08	9.92	7.88
LANT_C	1.19	-0.35	1.93	-1.19	0.85	-0.82	0.81	2.52	0.62
OAGRI_C	-14.08	-15.39	-13.46	-16.10	-14.37	-15.78	-14.41	-12.95	-14.57
OMINE_C	24.40	22.50	25.30	21.47	23.98	21.93	23.93	26.03	23.69
PPTM_C	8.20	6.54	8.98	5.65	7.83	6.05	7.79	9.62	7.58
RSTR_C	-2.71	-4.20	-2.01	-5.00	-3.04	-4.64	-3.08	-1.43	-3.26
STGL_C	11.33	9.63	12.14	8.71	10.96	9.13	10.91	12.80	10.70
SUPPS_C	63.83	61.33	65.02	59.97	63.28	60.58	63.21	65.99	62.90
WOOG_C	2.61	1.04	3.35	0.19	2.26	0.57	2.22	3.96	

4.4.1.6. Sensitivity Analysis of Scenario 1

Since the parameters used in the model are taken from other studies, it is necessary to investigate the robustness of simulation results with respect to parameters uncertainty (Yusuf, 2008). This is done by implementing a sensitivity analysis of CES or CET parameters and examining the changes of endogenous variables. In this exercise, we choose to vary the import elasticity (CES trade parameters) by 25% decrease and increase (between 1.5 and 2.5) and then check the reliability of results. The model is confirmed to be consistent when the differential effect is small.

Table 4.8 summarizes the sensitivity analysis results of SIM-1 on macroeconomic accounts. It shows that under high and low elasticity, scenario 1 generates a consistent direction (positive) across all endogenous variables excluding the negative sign of capital bill which is considered negligible. Nevertheless, for both high and low elasticity, the simulations generate a variation of values although the differences are small. Nganou (2005) stated that the robustness of simulation results in CGE model is confirmed in two conditions: the small impact differential results of post shock and its consistent signs. Therefore, based on sensitivity results given in Table 4.8, the model is considered robust and consistent.

Table 4.8: Sensitivity Analysis of Scenario 1 on National Income Accounts

Variables	**Import Elasticity = 2 Original Case**	**Import Elasticity = 2.5**	**Import Elasticity = 1.5**
	% Change		
GDP at factor costs	2.42	1.76	2.02
GDPGAP	2.71	1.55	2.10
GDP at market prices from income side	2.67	1.92	2.22
GDP at market prices from expenditure side	2.56	1.86	2.13
Total private consumption	3.02	1.92	2.37
Total investment	0.26	0.07	0.19
Total government consumption	8.54	10.19	9.40
Total export	0.68	0.83	0.62
Total import	0.35	0.69	0.48
Net export	3.92	2.18	2.07
Net indirect tax	9.32	6.39	7.74
Total payment to all workers (WAGEBILL)	4.63	3.39	3.89
Total payment to capital (CAPBILL)	0.01	-0.01	-0.02

4.4.2. Scenario 2: A 10 percent increase in government expenditure ($CGADJ$) with Adjustment in Subsidy Rates to Activities

In scenario 2, we investigate the impact of a 10% increase in government expenditure on Indonesia’s economy. The subsidy rates to activities ($subAArate$) are endogenous to clear the government budget balance. The rests of tax and subsidy rates including government saving are exogenous at the initial level.

4.4.2.1. Impact on Macroeconomic Account

Table 4.9 summarizes the impact of scenario 2 on the macroeconomic accounts and its comparison to SIM-1 results. As expected, scenario 2 results in less improvement on Indonesia’s GDP compared to SIM-1. According to the existing SAM, the government grants subsidy transfers only to sectors namely, agriculture (AGRI_A); fisheries (FISH_A); chemical and petroleum products (CHFCC_A); electricity, city gas, and clean water (ELEGD_A); land transportation (LANT_A); air and sea transportation and communication (AISCOM_A); and public services for national defense, education, health, and others (GOVT_A). Hence, the reduction in subsidy rates to these activities would negatively affect the flow of national supply and demand: the production costs will increase which in turn lead to a drop in equilibrium output and the level of factors demand. It also increases the cost of intermediate inputs inter-industries.

Table 4.9 shows that scenario 2 increases GDP at factor cost only by 1.27%, which is dominated by the increase of its component, total wage bill, by 2.44% while capital bill declines negligibly by -0.02%. In other hand, GDP at market price from income side and expenditure side improve slightly higher by 2.18% and 1.75% respectively. The components of GDP at market price from income side such as household and government consumption, investment, and net exports increased by 1.02%, 10.62%, 1.66%, and 1.21%. The increasing level of total investment 1.66% is due to the increased level of composite goods price index (P_i^Z).

Overall, scenario 2 improves the Indonesia’s macroeconomy. However, from Table 4.9, it can be seen that scenario 2 leads to a less improvement of all GDPs compared to scenario 1. This is because the reduction of subsidy rates across activities would increase the production costs, which in turn, results in a slight increase of aggregate composite prices (P_i^Z) by 1.97%. Thus, the improvement of private consumption in scenario 2 (1.02%) is less pronounced than that of SIM-1 (3.02%).

Table 4.9: The Impact of Scenario 1 and Scenario 2 on National Income Account

Variables	Scenario 1			Scenario 2	
	BASE	SHOCKED	% CHANGE	SHOCKED	% CHANGE
	(Billion Rupiah)			(Billion Rupiah)	
GDP at factor costs	5156935	5281935.23	2.42	5222245	1.27
GDP gap	0.04	0.04	2.71	0.045	11.06
GDP at market prices from income side	5472873	5618878	2.67	5592310	2.18
GDP at market prices from expenditure side	5260984	5395680	2.56	5352868	1.75
Total private consumption	3318105	3418314	3.02	3351949	1.02
Total investment	1508831	1512708	0.26	1533905	1.66
Total government consumption	294566	319709	8.54	325839	10.62
Total export	1487238	1497408	0.68	1514023	1.80
Total import	1347756	1352460	0.35	1372849	1.86
Net export	139482	144949	3.92	141174	1.21
Net indirect tax	104048	113745	9.32	130623	25.54
Total payment to all workers (WAGEBILL)	2692618	2817376	4.63	2758359	2.44
Total payment to capital (CAPBILL)	2464317	2464559	0.01	2463886	-0.02
SG	229473	216656	-5.59	229473	

4.4.2.2. Impact on Gross Output and Value Added

Table 4.10 and 4.11 summarize the impact of scenario 2 on gross output and value added respectively. Overall, scenario 2 improves the output production although the changes are less than under scenario 1. This is due to the effect of a reduction in subsidy rates across activities which eventually raises the aggregate price index of output (PQA_j) by 2.36%; in contrast, the aggregate PQA_j slightly declines by 0.49% in scenario 1. Hence, it leads to a less improvement of total gross output production (1.62%) compared to scenario 1 (2.25%).

Specifically, nine sectors indicate a declinate in output production. These are air and sea communication (AISCOM_A); cattle products (CATLE_A); petrochemical products (CHFCC_A); fossils mining (COMOIL_A); fisheries (FISH_A); households' and other services (INDSHO_A); other mining (OMINE_A); restaurant (RSTR_A); and supporting services for transportation (SUPPS_A) by -2.90%, -0.77%, -0.69%, -2.91%, -3.71%, -1.55%, -7.20%, -7.84%, and -2.89% respectively. These are strongly correlated with the higher price of their output production which 3.04%, 1.53%, 0.24%, 0.26%, 7.48%, 7.88%, 48.69%, 10.68%, and 3.80% respectively. A higher price of output production could be related to either the changes cost of its value added or intermediate input. Table 4.11 shows that excluding the sector of petrochemical products (CHFCC_A), the increased price of output is due to higher cost of value added by 5.23%, 7.64%, -1.09%, 0.35%, 14.42%, 17.12%, 76.77%, 26.13%, 6.03% respectively.

In contrast, the hotel sector (HTEL_A) improves the most by 17.80%, whilst other sectors such as bank and insurances (BANKAS_A); real estates (ESTPRV_A); electricity, city gas, and clean water (ELEGD_A); government services (GOVTD_A); and land transportation (LANT_A) are increased by 4.65%, 1.94%, 5.06%, 4.31%, and 3.81% respectively. These are due to a fall on their value added cost which are -4.91%, -8.69%, -2.00%, -17.24%, -0.10%, -1.65%, and -17.85% percent respectively. Compared to scenario 1, these sectors – excluding banking and insurance (BANKAS_A) – are less improving. This is because the reduction of subsidy rates across activities induces a higher production costs.

Table 4.10: The Impact of Scenario 2 on Activity Gross Domestic Output

Activity	**Industry Gross Domestic Output (QA_j)**			**Price of Gross Domestic Output (PQA_j)**		
	BASE	**SHOCKED**	**% CHANGE**	**BASE**	**SHOCKED**	**% CHANGE**
AGRI_A	577097	587254	1.76	1	1.01	0.93
AISCOM_A	325709	316254	-2.90	1	1.03	3.04
BANKAS_A	268190	280669	4.65	1	0.93	-6.99
CATLE_A	351964	349261	-0.77	1	1.02	1.53
CHFCC_A	1274343	1265531	-0.69	1	1.00	0.24
COMOIL_A	616125	598205	-2.91	1	1.00	0.26
CONS_A	1243976	1246586	0.21	0.98	1.01	2.88
ESTPRV_A	286491	292040	1.94	1	0.99	-1.20
ELEGD_A	124491	130788	5.06	0.98	0.91	-7.39
FISH_A	244882	235793	-3.71	1	1.08	7.48
FODT_A	1173301	1223174	4.25	1	0.97	-2.66
FORH_A	62143	62552	0.66	1	1.09	8.53
GOVTD_A	493287	514538	4.31	1	1.00	-0.10
HTEL_A	39603	46653	17.80	1	0.97	-2.96
INDSHO_A	279477	275153	-1.55	1	1.08	7.88
LANT_A	265679	275792	3.81	1	0.94	-5.83
OAGRI_A	220411	224867	2.02	1	1.01	1.24
OMINE_A	99298	92152	-7.20	1	1.49	48.69
PPTM_A	1579245	1643357	4.06	1	0.97	-2.59
RSTR_A	285032	262683	-7.84	1	1.11	10.68
STGL_A	336199	379025	12.74	1	0.96	-3.97
SUPPS_A	48418	47017	-2.89	1	1.04	3.80
TRDE_A	999123	1022462	2.34	0.97	0.93	-4.06
WOOG_A	211879	219730	3.71	1	0.97	-3.13
Total	11406362	11591536	1.62	1.00	1.02	2.36

Table 4.11: The Impact of Scenario 2 on Value Added

Activity	Volume of Value Added (VA_j)			Value Added Price (PVA_j)		
	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE
AGRI_A	377515	384160	1.76	1	1.02	2.41
AISCOM_A	184908	179541	-2.90	1	1.05	5.23
BANKAS_A	174958	183100	4.65	1	0.91	-8.69
CATLE_A	129760	128763	-0.77	1	1.08	7.64
CHFCC_A	541374	537631	-0.69	1	0.99	-1.09
COMOIL_A	485997	471862	-2.91	1	1.00	0.35
CONS_A	427655	428553	0.21	1	1.01	0.90
ESTPRV_A	198081	201917	1.94	1	0.98	-2.00
ELEGD_A	127591	134045	5.06	1	0.83	-17.24
FISH_A	134055	129079	-3.71	1	1.14	14.42
FODT_A	286708	298895	4.25	1	0.92	-8.53
FORH_A	40074	40337	0.66	1	1.14	13.97
GOVTD_A	330641	344885	4.31	1	1.00	-0.10
HTEL_A	23451	27626	17.80	1	0.95	-4.91
INDSHO_A	141973	139777	-1.55	1	1.17	17.12
LANT_A	105917	109949	3.81	1	0.82	-17.85
OAGRI_A	128807	131411	2.02	1	1.03	2.65
OMINE_A	63134	58591	-7.20	1	1.77	76.77
PPTM_A	430990	448487	4.06	1	0.97	-3.27
RSTR_A	116147	107040	-7.84	1	1.26	26.13
STGL_A	108712	122560	12.74	1	0.94	-6.12
SUPPS_A	26498	25731	-2.89	1	1.06	6.03
TRDE_A	499883	511560	2.34	1	0.93	-6.76
WOOG_A	72105	74777	3.71	1	0.92	-7.62

4.4.2.3. Impact on Employed Factors

The impact of scenario 2 on employed factors is presented in Table 4.12. The changes of production cost in activity specific are determined from its corresponding level of employed factors. In addition, in this simulation, we assume fixed wages of labour types and capital rent. Hence, the shock induces only the adjustment in capital stock; number of labour composite; and labour composite wage.

Compared to scenario 1, this simulation indicates a less improvement in aggregate demand of labour composite (3.78%) but negligible changes on capital stock (0.00%). Nevertheless, the demand of capital stock varies across activities. There are 8 sectors which indicate a decline. These are bank and insurances (-4.42%); petrochemical products (-1.76%); fossils mining (-1.42%); electricity, city gas, and clean water (-13.04%); food and tobaccos (-4.63%), trade (-4.57%); woods products (-4.18%); and land transportation (-14.70%) which is contracted the most. In contrast, other sectors experience a positive demand on capital stock especially in fisheries (10.19%); forestry (14.74%); hotel (12.04%); restaurant (16.26%);

households' and other services (15.33%); and other mining (64.08%) which is improved the most.

In labour composite demand, there are 10 sectors which indicate a decline. These are: air and sea communication (-11.06%); cattle products (-3.78%); fossils mining (-5.37%); construction (-0.82%); fisheries (-23.55%); forestry (-18.62%); households' and other services (-11.15%); other mining (-24.00%); restaurant (-10.25%); and supporting services for transportation (-4.57%); Fisheries and other mining sectors constitute the most severed fall in labour composite employment. Conversely, other sectors experience a positive impact on labour composite demand where electricity, city gas, and clean water sector (ELEG_A) indicates the highest demand (279.60%). Overall, Table 4.12 shows that the hotel sector benefits the most for both of factors movement effects where the demand of capital and labour composite increased by 12.04% and 27.18% respectively.

Table 4.12: The Impact of Scenario 2 on Employed Factors *(LAB_j and K_j)*

Activity	Labour Composite (LAB_j)			Capital (K_j)		
	BASE	SHOCKED	% CHANGE	BASE	SHOCKED	% CHANGE
AGRI_A	356465	362224	1.62	21051	21942	4.24
AISCOM_A	68100	60569	-11.06	116808	119370	2.19
BANKAS_A	53146	68474	28.84	121813	116425	-4.42
CATLE_A	91495	88033	-3.78	38265	40879	6.83
CHFCC_A	166589	169503	1.75	374785	368198	-1.76
COMOIL_A	60075	56848	-5.37	425923	415035	-2.56
CONS_A	200904	199257	-0.82	226751	229316	1.13
ESTPRV_A	45543	49640	9.00	152538	152414	-0.08
ELEGD_A	16371	62144	279.60	111220	96715	-13.04
FISH_A	49457	37813	-23.55	84598	93216	10.19
FODT_A	120241	141792	17.92	166467	158762	-4.63
FORH_A	15275	12431	-18.62	24799	28454	14.74
GOVTD_A	286212	298579	4.32	44429	46306	4.22
HTEL_A	9279	11801	27.18	14172	15878	12.04
INDSHO_A	86104	76501	-11.15	55869	64434	15.33
LANT_A	87258	94464	8.26	18660	15916	-14.70
OAGRI_A	106334	107882	1.46	22473	23539	4.74
OMINE_A	46746	35526	-24.00	16388	26889	64.08
PPTM_A	179195	195340	9.01	251795	253493	0.68
RSTR_A	104242	93554	-10.25	11905	13840	16.26
STGL_A	45829	56326	22.91	62884	66570	5.86
SUPPS_A	20445	19511	-4.57	6053	6234	2.98
TRDE_A	441454	455961	3.29	58429	55761	-4.57
WOOG_A	35860	40284	12.34	36245	34729	-4.18
Total	2692618	2794457	3.78	2464317	2464317	0.00

4.4.2.4. Impact on Price and Volume of Commodities

Table 4.13 presents scenario 2 impact on price and volumes. In scenario 2, we assume that the world price index of export and import are also exogenous. Hence, the changes of the export (P_i^E) and import (P_i^M) price are completely determined by the changes in exchange rates.

In this scenario, the level of exchange rate still indicates an appreciation (-1.46%) although it is lower than scenario 1 result. In overall, the shock shifts up the relative aggregate domestic-import (P_i^D/P_i^M) price ratios by 3.75% which signaled import and domestic goods substitution. It reflects that imported goods are cheaper to purchase, which in turn increases the share of import relatively to domestic input to produce final output (Z_i). These effects are due to the subsidy cuts that influence a higher cost at domestic production which in turn increases its price at consumer side. A higher price of domestically produced commodity leads to a higher demand on import relatively to volumes of domestic goods. Table 4.13 shows that the aggregated volume of import ($\sum_i M_i$) increases by 3.37% while domestic input ($\sum_i D_i$) increases only by 1.45%. A higher demand for trade input of domestic-import goods improves the production of aggregate composite goods ($\sum_i Z_i$) by 1.66%.

Furthermore, across commodity, the effects are related to the complex linkages of the changes of final demand, market prices, and production constraints. Five types of imported goods show a drop in volumes: cattle products (-7.12%); hotel (-0.70%); land transportation (-3.84%); paper and metal equipment (-0.18%); textiles (-0.37%); and woods (-2.30%). Other commodities indicate an increase in import volumes, i.e. air and sea communication (3.18%), petrochemical products (3.23%), fisheries (18.20%), restaurant (13.50%), and supporting services for transportation (11.22%). Other mining and forestry constitute the largest improvement in import by 72% and 31.81% respectively.

In terms of export, there are 12 types of commodities which indicate a contraction in volumes, i.e. agricultural (-1.57%), air and sea communication (-3.32%), cattle products (-5.14%), petrochemical products (-5.27%), fossils mining (-4.82%), fisheries (-23.73%), forestry (-23.73%), households and other services (-16.64%), other agricultural (-1.91%), restaurant (-25.87%), and supporting services for transportation (-11.20%); and other mining which has the largest reduction (-58.64%). Rests of exported commodities are increased substantially where real estate and hotel experience the largest improvement by 15.28% and 68.24% respectively.

In domestic market, there are 6 types of both domestic (D_i) and composite goods (Z_i) that indicate a volume contraction. These are cattle products (-0.76% and -0.68%); fisheries (-3.49% and -3.48%); households and other services (-1.50% and -0.84%); restaurant (-7.03% and -6.32%); fossils mining (-1.42% and -0.13%); and other mining (-6.68% and -0.24%). These tendencies are caused by the increasing level of its price index in domestic market.

Table 4.13: The Impact of Scenario 2 on Prices and Quantities of Commodities (% Change)

Commodity	P^Q	P^Z	P^D	P^E	P^M	P^D/P^E	P^D/P^M	Q	Z	D	E	M
AGRI_C	0.93	0.77	0.94	-1.46	-1.46	2.40	2.40	1.76	2.10	1.77	-1.57	6.78
AISCOM_C	3.04	2.74	3.76	-1.46	-1.46	5.34	5.34	-2.90	0.44	-1.53	-9.88	9.18
BANKAS_C	-6.99	-6.89	-7.08	-1.46	-1.46	-5.72	-5.72	4.65	4.03	4.45	19.20	-7.12
CATLE_C	1.53	1.49	1.53	-1.46	-1.46	3.01	3.01	-0.77	-0.68	-0.76	-5.14	5.36
CHFCC_C	0.24	0.01	0.71	-1.46	-1.46	2.19	2.19	-0.69	1.66	0.25	-2.60	4.71
COMOIL_C	0.26	0.38	1.03	-1.46	-1.46	2.50	2.50	-2.91	-0.13	-1.42	-4.82	3.63
CONS_C	2.88	2.88	2.88	-1.46	-1.46	4.43	4.43	0.21	0.21	0.21	0.00	0
ESTPRV_C	-1.20	-1.25	-1.21	-1.46	-1.46	0.27	0.27	1.94	1.99	1.91	2.90	2.44
ELEGD_C	-7.39	-7.39	-7.39	-1.46	-1.46	-6.03	-6.03	5.06	5.06	5.06	0.00	0
FISH_C	7.48	7.60	7.61	-1.46	-1.46	9.20	9.20	-3.71	-3.48	-3.49	-17.87	15.09
FODT_C	-2.66	-2.91	-3.01	-1.46	-1.46	-1.56	-1.56	4.25	3.31	3.51	8.42	0.29
FORH_C	8.53	8.49	8.60	-1.46	-1.46	10.21	10.21	0.66	0.99	0.79	-15.79	22.42
GOVTD_C	-0.10	-0.10	-0.06	-1.46	-1.46	1.38	1.38	4.31	4.48	4.39	2.98	7.39
HTEL_C	-2.96	-3.95	-6.30	-1.46	-1.46	-4.91	-4.91	17.80	4.52	9.82	23.27	-0.70
INDSHO_C	7.88	7.55	7.90	-1.46	-1.46	9.50	9.50	-1.55	-0.84	-1.50	-16.64	18.12
LANT_C	-5.83	-5.83	-5.85	-1.46	-1.46	-4.50	-4.50	3.81	3.71	3.76	15.35	-5.28
OAGRI_C	1.24	1.30	1.49	-1.46	-1.46	3.01	3.01	2.02	2.92	2.53	-1.91	8.76
OMINE_C	48.69	44.20	49.10	-1.46	-1.46	51.31	51.31	-7.20	-0.24	-6.68	-58.64	113.66
PPTM_C	-2.59	-2.56	-3.04	-1.46	-1.46	-1.56	-1.56	4.06	2.09	3.10	8.05	-0.18
RSTR_C	10.68	10.75	11.17	-1.46	-1.46	12.85	12.85	-7.84	-6.32	-7.03	-25.87	18.34
STGL_C	-3.97	-5.31	-5.68	-1.46	-1.46	-4.30	-4.30	12.74	7.89	8.75	20.46	-0.37
SUPPS_C	3.80	3.10	4.34	-1.46	-1.46	5.85	5.85	-2.89	0.51	-1.88	-11.20	10.02
TRDE_C	-4.06	-4.06	-4.06	-1.46	-1.46	-2.68	-2.68	2.34	2.34	2.34	0.00	0
WOOG_C	-3.13	-3.69	-3.74	-1.46	-1.46	-2.27	-2.27	3.71	2.27	2.39	8.89	-2.30
Total	2.35	1.97	2.23	-1.46	-1.46	3.75	3.75	1.62	1.66	1.45	3.31	3.37

$$\frac{P^D}{P^M} = \left(\frac{\left(\frac{P_1^D}{P_1^M} - \frac{P_0^D}{P_0^M} \right)}{P_0^D \big/ P_0^M} \right) * 100\%$$

$$\frac{P^D}{P^E} = \left(\frac{\left(\frac{P_1^D}{P_1^E} - \frac{P_0^D}{P_0^E} \right)}{P_0^D \big/ P_0^E} \right) * 100\%$$

Where 1 for shock value; and 0 for base value

Key variables:

P^Q: Output price; P^Z: composite commodity price; P^D: domestic commodity price; P^E: imported commodity price; P^M: imported commodity price; Q: output volume; Z: composite commodity quantity; D: domestic commodity quantity; E: exported commodity quantity; M: imported commodity quantity**.**

4.4.2.5. Impact on Household Income and Expenditure

Table 4.14 presents scenario 2 effects on household income, expenditure, and saving. Here we allow two groups of households, non-agricultural-urban households with low (HH_NAGU_LL) and high wages (HH_NAGU_HL), to adjust their saving ratio; and let the other types of household saving exogenously fixed. We expect that fiscal expansion would increase the level of real income households' such that only these representatives could afford to adjust their saving for the sake of investment on goods.

The results indicate that household income is improved for all categories but lower than that under scenario 1. A reduction of subsidy rates to activities influences the reduction of output production. Thus, producers will reduce the costs of factor production which in turn lead to a decline in factors return to households. In addition, contrary to SIM-1 results, the changes of household income are not directly correlated to their status of occupation: clear or unclear occupation. Table 4.14 shows that the actual disposable income of agricultural households' with unskilled labour (HH_AGR_L); agricultural households' with unclear occupation (HH_AGR_NL); non-agricultural rural households with unclear occupation (HH_NAGR_NA); and non-agricultural-rural households with high wages (HH_NAGR_HL) have tendencies on a higher improvement by 2.63%, 2.83%, 2.67%, and 2.29% respectively. For the rest of groups, i.e. non-agricultural rural households with low wages (HH_NAGR_LL); non-agricultural labour urban households with high wages (HH_NAGU_HL); non-agricultural urban households with low wages (HH_NAGU_LL); and non-agricultural urban households with unclear job (HH_NAGU_NA) are experiencing lower improvement of actual income which are 1.50%, 1.05%, 0.86%, and 0.94% respectively. Clearly, the reduction of subsidies tends to depress the income of richest households (represented as those who have higher wages and live in urban areas) higher than poor households. In other words, these results imply that subsidies mostly benefit households who have a lower level of income.

On the other hand, the changes of household budget and saving for all types, excluding non-agricultural-urban households with low (HH_NAGU_LL) and high wages (HH_NAGU_HL), are equal to their level of income distribution. This is due to the assumption given in scenario 2 where both of these groups are allowed to adjust their saving ratio ($sh\_dum_h = 1$) whilst the other groups are held fixed. Table 4.14 shows that the actual income of HH_NAGU_LL and HH_NAGU_HL increases by 0.86% and 1.05% respectively. However, their spending budget on goods and services decreases by -0.10% and -1.45%. The saving ratios increase by 15.87% reflecting a sharp increase in the saving by 16.88% and 17.10% which are utilized to adjust the exogenous investment on goods.

Furthermore, table 4.15 presents the effects of scenario 2 on varieties of household consumption. Overall, total private consumption on aggregate commodities increases. Specifically, scenario 2 influences the largest improvement of households' demand on electricity, city gas, and clean water (9.50%); bank and insurances (8.92%); and land transportation (7.69%). However, there are 8 types of commodities which severe a demand contraction, i.e. other mining (-29.67%), restaurant (-8.43%), forestry (-6.53%), fisheries (-5.75%), households' and other services (-5.70%), supporting services for transportation (-1.63%), air and sea communication (-1.29%), and cattle products (-0.08%). The changes of household consumption are due to linkages of household income and changes in each type of composite commodity price.

Table 4.14: The Impact of Scenario 2 on Household Income and Expenditure

Households' Types	$ADIH_h$			EH_h			SH_h			sh_ratio_h		
	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE
HH_AGR_L	171254	175765	2.63	162021	166289	2.63	9233	9476	2.63	0.05	0.05	0.00
HH_AGR_NL	703951	723836	2.83	642327	660471	2.83	61624	63364	2.83	0.09	0.09	0.00
HH_NAGR_LL	476495	483663	1.50	450508	457286	1.50	25987	26378	1.50	0.06	0.06	0.00
HH_NAGR_NA	167663	172136	2.67	158015	162231	2.67	9648	9905	2.67	0.06	0.06	0.00
HH_NAGR_HL	441589	451698	2.29	385337	394158	2.29	56252	57539	2.29	0.13	0.13	0.00
HH_NAGU_LL	671493	677254	0.86	633499	632846	-0.10	37995	44408	16.88	0.06	0.07	15.89
HH_NAGU_NA	233825	236020	0.94	213768	215775	0.94	20057	20245	0.94	0.09	0.09	0.00
HH_NAGU_HL	777279	785442	1.05	672629	662894	-1.45	104650	122549	17.10	0.14	0.16	15.89

Key variables:

$ADIH_h$: Actual disposable income; EH_h: household budget; SH_h: household saving; sh_ratio_h: adjusted average propensity of saving

Households' types:

HH_AGR_L: agricultural households' with unskilled labour; HH_AGR_NL: agricultural-households' with unclear occupation; HH_NAGR_LL: non-agricultural-rural households' with low wages, HH_NAGR_NA: non-agricultural-rural households' with unclear occupation; HH_NAGR_HL: non-agricultural-rural households' with high wages, HH_NAGU_LL: non-agricultural labour-urban households' with low wages, HH_NAGU_NA: non-agricultural-urban households, and HH_NAGU_HL: non-agricultural labour-urban households' with high wages.

Table 4.15: The Impact of Scenario 2 on Household Consumption of Commodities by Variety

Commodity	**HH_AGR_L**	**HH_AGR_NL**	**HH_NAGR_LL**	**HH_NAGR_NA**	**HH_NAGR_HL**	**HH_NAGU_LL**	**HH_NAGU_NA**	**HH_NAGU_HL**	**AVG**
	PCHANGE								
AGRI_C	1.85	2.04	0.73	1.88	1.51	-0.87	0.17	-2.20	0.64
AISCOM_C	-0.10	0.08	-1.20	-0.07	-0.44	-2.77	-1.75	-4.08	-1.29
BANKAS_C	10.23	10.43	9.02	10.27	9.86	7.29	8.41	5.85	8.92
CATLE_C	1.13	1.32	0.01	1.16	0.79	-1.57	-0.54	-2.89	-0.08
CHFCC_C	2.63	2.82	1.50	2.66	2.28	-0.11	0.93	-1.46	1.41
ESTPRV_C	3.93	4.13	2.79	3.97	3.58	1.16	2.22	-0.20	2.70
ELEGD_C	10.82	11.03	9.60	10.86	10.45	7.87	8.99	6.42	9.50
FISH_C	-4.61	-4.44	-5.66	-4.58	-4.93	-7.16	-6.19	-8.41	-5.75
FODT_C	5.72	5.91	4.55	5.75	5.36	2.90	3.97	1.51	4.46
FORH_C	-5.40	-5.22	-6.44	-5.37	-5.72	-7.92	-6.96	-9.16	-6.53
GOVTD_C	2.74	2.93	1.61	2.77	2.39	0.00	1.04	-1.35	1.51
HTEL_C	6.86	7.06	5.68	6.89	6.50	4.01	5.09	2.61	5.59
INDSHO_C	-4.57	-4.39	-5.62	-4.54	-4.89	-7.11	-6.14	-8.36	-5.70
LANT_C	8.99	9.19	7.79	9.02	8.62	6.08	7.19	4.65	7.69
OAGRI_C	1.32	1.51	0.21	1.35	0.98	-1.38	-0.35	-2.71	0.12
OMINE_C	-28.83	-28.69	-29.61	-28.80	-29.07	-30.72	-30.00	-31.66	-29.67
PPTM_C	5.33	5.53	4.17	5.36	4.98	2.52	3.59	1.14	4.08
RSTR_C	-7.33	-7.16	-8.35	-7.30	-7.64	-9.80	-8.86	-11.02	-8.43
STGL_C	8.39	8.59	7.20	8.42	8.02	5.50	6.60	4.08	7.10
SUPPS_C	-0.45	-0.26	-1.54	-0.42	-0.78	-3.10	-2.09	-4.41	-1.63
WOOG_C	6.57	6.77	5.39	6.60	6.21	3.73	4.81	2.33	5.30

4.4.2.6. Sensitivity Analysis of Scenario 2

Table 4.16 shows the sensitivity analysis results of scenario 2 on the macroeconomic accounts for robustness checking. Similar to scenario 1, we vary the trade elasticity by 25% decrease and increase (between 1.5 and 2.5) and then check the sign and size of each value.

Under high and low elasticity, scenario 2 also generates a consistent sign (positive) across all endogenous variables excluding the negative direction of capital bill which is considered negligibly small. For both high and low elasticity, the simulations generate small impact differential results of post shock. Therefore, based on these results, the model is confirmed robust and consistent.

Table 4.16: Sensitivity Analysis Results of Scenario 2 (% Change)

Variables	Import Elasticity = 2 Original Case	Import Elasticity = 2.5	Import Elasticity = 1.5
GDP at factor costs	1.27	1.48	0.50
GDP gap	11.06	11.70	12.55
GDP at market prices from income side	2.18	2.44	1.50
GDP at market prices from expenditure side	1.75	1.98	1.01
Total private consumption	1.02	2.16	0.79
Total investment	1.66	0.37	0.43
Total government consumption	10.62	8.94	6.69
Total export	1.80	1.76	1.14
Total import	1.86	1.91	1.20
Net export	1.21	0.26	0.53
Net indirect tax	25.54	26.54	26.20
Total payment to all workers (WAGEBILL)	2.44	2.88	0.97
Total payment to capital (CAPBILL)	-0.02	-0.05	-0.00

4.4.3. Scenario 3: A 10 percent increase in government expenditure ($CGADJ$) with Adjustment in Output Tax Rates

In scenario 3, we examine the effects of a 10% increase in government expenditure on Indonesia's economy. The output tax rates are endogenous to compensate for the additional expenditure in public goods and services. The rests of the tax and subsidy rates including government saving are exogenous at the initial level.

In this scenario, we expect that higher taxes on output production create higher distortion in their relative prices. It influences producers to lower the production volumes and thus creating a lower income at the national level (Damuri and Perdana, 2003). It implies labour market adjustments that could lead to a negative effect on household income and expenditure (Damuri and Perdana, 2003).

4.4.3.1. Impact on Macroeconomic Account

Table 4.17 summarizes the impact of scenario 3 on macroeconomic accounts and its comparison to scenario 1 and scenario 2 results. Scenario 3 leads to negative effect on Indonesia's economy performance. GDP at factor cost falls by -1.97% whilst both GDP at market prices, from income and expenditure side drop by -0.46% and -1.21% respectively. The reason is clear: The output tax rate is embodied in the output price system. Hence, the increase in output tax rates directly increases the output prices, which in turn, leads to higher prices of goods in final market. As a result, the equilibrium output falls. However, this effect may be offset by the injection of government spending on goods and services that shifts up the aggregate demand.

The decline in GDP at factor cost is strongly due to the fall of one of the components, total wage bill, by -3.81% while capital bill increases negligibly by 0.05%. It implies that SIM-3 depresses the industry demand for labour which would reduce the factors return to households. Hence, this effect indirectly leads to a reduction in total private purchasing power which is reflected from a drop of private consumption by -2.47%. The other components of GDP at market prices from income side such as investment and net export are also declined by -1.07%, and -0.67% respectively.

Table 4.17: The Impact of All Simulations on National Income Account

Variables	**Scenario 1**	**Scenario 2**	**Scenario 3**
	% CHANGE	% CHANGE	% CHANGE
GDP at factor costs	2.42	1.27	-1.97
GDP gap	2.71	11.06	19.61
GDP at market prices from income side	2.67	2.18	-0.46
GDP at market prices from expenditure side	2.56	1.75	-1.21
Total private consumption	3.02	1.02	-2.47
Total investment	0.26	1.66	-1.07
Total government consumption	8.54	10.62	11.91
Total export	0.68	1.80	0.01
Total import	0.35	1.86	0.08
Net export	3.92	1.21	-0.67
Net indirect tax	9.32	25.54	36.10
Total payment to all workers (WAGEBILL)	4.63	2.44	-3.81
Total payment to capital (CAPBILL)	0.01	-0.02	0.05
SG	-5.59	-	-

4.4.3.2. Impact on Gross Output and Value Added

Tables 4.18 and 4.19 present the impact of scenario 3 on gross domestic output and value added across activities. The increase in output tax rate has a negative effect on aggregate sectors. It raises the cost of production that leads to a contraction in production volumes. Table 4.20 shows that the total output production declines by -0.98% while its aggregate price (PQA_j) increases by 1.90%.

Nevertheless, by looking at specific industries, there are six sectors which indicate an improvement on output production. Textiles (STGL_A), hotel (HTEL_A), households' and other services (INDSHO_A), and real estate (ESTPRV_A) sector indicate the highest expansion by 28.22%, 28.39%, 12.54%, and 6.75%; meanwhile, public services (GOVTD_A) and construction (CONS_A) sector only improve slightly, by about 0.08%. Rests of sectors are contracted where sector of supporting services for transportation (SUPPS_A) suffers the most. For example, the decline in output production of agricultural (AGRI_A); air and sea communication (AISCOM_A); fossils mining (COMOIL_A); and fisheries (FISH_A) sectors also indicate a fall in their respective cost of value added by -7.34%, -5.02%, -1.21%, -1.27%. In other words, the contraction of these outputs could be related to the variation of intermediate input between industries. However, Table 4.19 indicates that a drop in output production for some sectors may not be directly related to the increased cost per unit of their value added input. The distributional effects can also be influenced by the complex interaction of the changes in aggregate demand, and constraint shifts of intermediate input prices inter-industries.

Table 4.18: Impact of Scenario 3 on Activity Gross Domestic Output

Activity	Volume of Gross Domestic Output (QA_j)			Price of Gross Domestic Output (PQA_j)		
	BASE	SHOCKED	% Change	BASE	SHOCKED	% Change
AGRI_A	577097	576604	-0.09	1	0.94	-6.47
AISCOM_A	325709	325405	-0.09	1	0.99	-1.43
BANKAS_A	268190	248283	-7.42	1	1.22	21.97
CATLE_A	351964	351165	-0.23	1	0.98	-2.00
CHFCC_A	1274343	1222499	-4.07	1	1.02	1.84
COMOIL_A	616125	607801	-1.35	1	0.99	-1.11
CONS_A	1243976	1244991	0.08	0.98	0.96	-1.72
ESTPRV_A	286491	305823	6.75	1	0.89	-10.82
ELEGD_A	124491	119990	-3.62	0.98	1.09	10.76
FISH_A	244882	242011	-1.17	1	0.97	-3.06
FODT_A	1173301	1102099	-6.07	1	1.02	1.89
FORH_A	62143	59196	-4.74	1	1.22	22.24
GOVTD_A	493287	493695	0.08	1	1.03	3.16
HTEL_A	39603	50845	28.39	1	0.96	-4.48
INDSHO_A	279477	314528	12.54	1	0.76	-23.92
LANT_A	265679	254030	-4.38	1	1.11	10.47
OAGRI_A	220411	210205	-4.63	1	1.05	5.09
OMINE_A	99298	97169	-2.14	1	1.10	10.18
PPTM_A	1579245	1544421	-2.21	1	1.01	1.24
RSTR_A	285032	269775	-5.35	1	1.04	3.73
STGL_A	336199	431089	28.22	1	0.93	-7.00
SUPPS_A	48418	40968	-15.39	1	1.22	22.17
TRDE_A	999123	980073	-1.91	0.97	0.86	-11.47
WOOG_A	211879	201474	-4.91	1	1.04	3.92
TOTAL	11406362	11294140	-0.98	1.00	1.02	1.90

Table 4.19: Impact of Scenario 3 on Value Added

ACTIVITY	Value Added Price (PVA_j)			Volume of Value Added (VA_j)		
	BASE	SHOCKED	% Change	BASE	SHOCKED	% Change
AGRI_A	1	0.93	-7.34	377515.4	375281.6	-0.59
AISCOM_A	1	0.95	-5.02	184907.8	187200.4	1.24
BANKAS_A	1	1.28	27.89	174958.4	187899.4	7.40
CATLE_A	1	1.00	-0.23	129760	129342.4	-0.32
CHFCC_A	1	1.06	5.69	541374.3	545510.3	0.76
COMOIL_A	1	0.99	-1.21	485997.4	488020.4	0.42
CONS_A	1	0.89	-10.73	427655.1	428654	0.23
ESTPRV_A	1	0.85	-14.89	198080.9	185233.1	-6.49
ELEGD_A	1	1.16	15.75	127591.3	128584.9	0.78
FISH_A	1	0.99	-1.27	134054.8	132463.8	-1.19
FODT_A	1	1.17	16.47	286707.7	280670.9	-2.11
FORH_A	1	1.36	35.56	40073.65	40055.48	-0.05
GOVTD_A	1	1.05	4.90	330641	354605.9	7.25
HTEL_A	1	0.93	-7.40	23450.72	23945.22	2.11
INDSHO_A	1	0.52	-48.00	141973.2	143269.9	0.91
LANT_A	1	1.34	34.40	105917.4	106076.3	0.15
OAGRI_A	1	1.08	8.06	128807.1	127119.7	-1.31
OMINE_A	1	1.17	16.84	63134.19	63358.95	0.36
PPTM_A	1	1.08	7.73	430989.9	431267.7	0.06
RSTR_A	1	1.10	10.10	116147.1	116836.5	0.59
STGL_A	1	0.87	-13.39	108712.3	110092.8	1.27
SUPPS_A	1	1.39	39.29	26497.85	36813.79	38.93
TRDE_A	1	0.76	-23.64	499882.7	497837.7	-0.41
WOOG_A	1	1.03	2.81	72105.2	71966.71	-0.19
Average	1	1.04	3.86			2.08

4.4.3.3. Impact on Employed Factors

Table 4.20 presents the impact of scenario 3 on employed factors. A higher tax rate on outputs will induce an increase in their prices. These changes will then influence the producers to reallocate the production factors. Analogous to previous simulations, under this scenario we assume wages of labour specific and rent of capital as exogenous. Whilst, stock of capital, number of labour composite, and labour composite wage are endogenously determined to clear the factors market.

Overall, compared to scenario 1 and scenario 2, this simulation indicates the smallest increase in labour composite demand by only 0.96% and the effect on the stock of capital remains negligible (0.00%). Nevertheless, the results vary across industries. There are 10 sectors which indicate a contraction: agriculture (AGRI_A); air and sea communication (AISCOM_A); cattle products (CATLE_A); fossils mining (COMOIL_A); construction (CONS_A); real estates (ESTPRV_A); fisheries (FISH_A); households' and other services

(INDSHO_A); trade (TRDE_A); and timber products (WOOG_A). Conversely, the rest of sectors expand. These changes would trigger factor substitution in favour of labour composite. This is reflected by the expansion in labour composite for the corresponding sectors, excluding cattle products (CATLE_A) and timber products (WOOG_A), which also indicate a drop by -0.11% and -7.49% respectively. Furthermore, Table 4.22 indicates that hotel (HTEL_A) and textiles (STGL_A) sectors benefit the most from both of factors movement effects where the demand of capital and labour composite are increased.

Table 4.20: The Impact of SIM-3 on Employed Factors (LAB_j and K_j)

Activity	**Labour Composite (LAB_j)**			**Capital (K_j)**		
	BASE	**SHOCKED**	**% CHANGE**	**BASE**	**SHOCKED**	**% CHANGE**
AGRI_A	356465	357778	0.37	21051	19,480	-7.46
AISCOM_A	68100	74387	9.23	116808	110,783	-5.16
BANKAS_A	53146	28028	-47.26	121813	144,151	18.34
CATLE_A	91495	91395	-0.11	38265	38,071	-0.51
CHFCC_A	166589	141281	-15.19	374785	379,784	1.33
COMOIL_A	60075	64822	7.90	425923	414,888	-2.59
CONS_A	200904	228673	13.82	226751	202,488	-10.70
ESTPRV_A	45543	83568	83.49	152538	138,514	-9.19
ELEGD_A	16371	5862	-64.19	111220	124,021	11.51
FISH_A	49457	50000	1.10	84598	82,503	-2.48
FODT_A	120241	91515	-23.89	166467	182,027	9.35
FORH_A	15275	8887	-41.82	24799	32,005	29.06
GOVTD_A	286212	284353	-0.65	44429	46,619	4.93
HTEL_A	9279	13407	44.49	14172	16,840	18.83
INDSHO_A	86104	148159	72.07	55869	32,682	-41.50
LANT_A	87258	78329	-10.23	18660	23,967	28.44
OAGRI_A	106334	99774	-6.17	22473	23,147	3.00
OMINE_A	46746	43322	-7.32	16388	18,728	14.28
PPTM_A	179195	157957	-11.85	251795	265,132	5.30
RSTR_A	104242	97591	-6.38	11905	12,399	4.15
STGL_A	45829	71626	56.29	62884	69,801	11.00
SUPPS_A	20445	15685	-23.28	6053	7,131	17.80
TRDE_A	441454	448806	1.67	58429	43,742	-25.14
WOOG_A	35860	33173	-7.49	36245	35,417	-2.29
Total	2692618	2718379	0.96	2464317	2464317	0.00

4.4.3.4. Impact on Price and Volume of Commodities

Table 4.21 presents scenario 3 impact on price and volumes. Similar to the previous simulations, here we also assume that the world price index of export and import are exogenous. Hence, the changes of domestically export (P_i^E) and import (P_i^M) price are influenced by the changes in exchange rates (local currency per foreign currency).

Intuitively, the presence of higher output tax rates has a direct effect on higher prices on goods due to the increasing cost of production. However, the higher prices are offset by the increase in government expenditure on composite goods which at the end raises the aggregate demand. Under scenario 3, the results indicate that the prices of domestically produced commodities considerably increase. Hence, producers will favour to increase the shares of imported commodities relatively with domestic goods in order to produce composite goods. This leads to a raise in import price which in turn depreciates the exchange rate. Table 4.21 shows that under this simulation, the overall composite prices (P_i^Z) increase by 2.05% and the domestic prices increase by 2.11%. Meanwhile, the exchange rate depreciates by 0.41%.

In terms of volume absorptions, the aggregate demand for all types of goods: composite goods ($\sum_i Z_i$), domestic goods ($\sum_i D_i$), import ($\sum_i M_i$), and export ($\sum_i E_i$) indicate a reduction. The demand for aggregate domestic goods falls by -1.12% is higher than import (-0.33%). This is due to the price effect which is reflected from the relative aggregate domestic-import (P_i^D/P_i^M) price ratios by 1.70%. Therefore, it triggers substitution between imports and domestic goods. In other words, the fall of import is less than domestic goods. Taken together, these effects result in a drop in composite goods by -1.04%. Furthermore, a higher increase in domestic price (P_i^D) to export price (P_i^E) would also lead to a small drop in export volumes (-0.40%).

However, across commodities specific, the results vary. There are 11 types of imported goods that show an improvement in volumes. These are bank and assurances 38.27%); food and beverages (0.26%); forestry (43.50%); government services (6.47%); land transportation (17.23%); other agricultural (7.09%); other mining (19.28%); paper products (1.06%); restaurant (3.06%); supporting services for transportation (37.26%); and timber products (6.22%). These are due to an increase in the specific price ratio between domestic price and its corresponding import price (P_i^D/P_i^M). The rests commodities indicate a contraction in import volumes. In terms of export, there are 8 types of commodities which indicate an increase in volumes, i.e. agricultural (14.33%); air and sea communication (2.03%); cattle products (4.03%); real estates (33.06%); fisheries (5.35%); hotel (37.43%); households and other services (93.42%); and textiles (48.20%). As mentioned earlier, the export competitiveness of each type of commodity is influenced by the increase in its price ratio (P_i^D/P_i^E). Finally, in the domestic market, there are 6 types of both domestic (D_i) and composite goods (Z_i) that indicate an improvement in volumes. These are construction

(0.08% and 0.08%); real estates (5.35% and 1.78%); government services (0.34% and 0.52%); hotel (12.91% and 2.43%); households and other services (12.22% and 10.34%); and textiles (16.52% and 14.05%).

Table 4.21: The Impact of Scenario 3 on Prices and Quantities of Commodities (% Change)

Commodity	P^Q	P^Z	P^D	P^E	P^M	P^D/P^E	P^D/P^M	Q	Z	D	E	M
AGRI_C	-6.47	-5.91	-6.34	0.41	0.41	-6.68	-6.68	-0.09	-1.01	-0.11	14.33	-13.08
AISCOM_C	-1.43	-0.79	-1.06	0.41	0.41	-1.50	-1.50	-0.09	-1.07	-0.53	2.03	-3.42
BANKAS_C	21.97	21.50	22.45	0.41	0.41	22.00	22.00	-7.42	-5.58	-7.03	-37.75	38.27
CATLE_C	-2.00	-1.84	-1.87	0.41	0.41	-2.30	-2.30	-0.23	-0.30	-0.23	4.03	-4.71
CHFCC_C	1.84	1.96	2.71	0.41	0.41	2.28	2.28	-4.07	-1.37	-2.79	-7.47	1.71
COMOIL_C	-1.11	-0.51	-0.82	0.41	0.41	-1.20	-1.20	-1.35	-2.81	-2.20	-0.16	-4.58
CONS_C	-1.72	-1.34	-1.34	0.41	0.41	-1.70	-1.70	0.08	0.08	0.08	-	-
ESTPRV_C	-10.82	-9.29	-10.84	0.41	0.41	-11.16	-11.16	6.75	1.78	5.35	33.06	-16.93
ELEGD_C	10.76	11.18	11.18	0.41	0.41	10.75	10.75	-3.62	-3.62	-3.62	-	-
FISH_C	-3.06	-3.00	-3.00	0.41	0.41	-3.40	-3.40	-1.17	-1.29	-1.28	5.35	-7.87
FODT_C	1.89	3.07	3.25	0.41	0.41	2.78	2.78	-6.07	-4.84	-5.18	-10.68	0.26
FORH_C	22.24	22.82	23.09	0.41	0.41	22.60	22.60	-4.74	-4.09	-4.51	-36.72	43.50
GOVTD_C	3.16	3.34	3.43	0.41	0.41	2.98	2.98	0.08	0.52	0.34	-5.82	6.47
HTEL_C	-4.48	-4.64	-9.17	0.41	0.41	-9.57	-9.57	28.39	2.43	12.91	37.43	-7.62
INDSHO_C	-23.92	-23.03	-23.67	0.41	0.41	-24.01	-24.01	12.54	10.34	12.22	93.42	-35.16
LANT_C	10.47	11.08	11.14	0.41	0.41	10.65	10.65	-4.38	-4.21	-4.31	-22.21	17.23
OAGRI_C	5.09	5.49	5.85	0.41	0.41	5.37	5.37	-4.63	-2.97	-3.63	-13.63	7.09
OMINE_C	10.18	10.00	10.75	0.41	0.41	10.25	10.25	-2.14	-0.61	-1.95	-19.72	19.28
PPTM_C	1.24	1.34	1.75	0.41	0.41	1.39	1.39	-2.21	-0.79	-1.60	-4.57	1.06
RSTR_C	3.73	4.46	4.59	0.41	0.41	4.17	4.17	-5.35	-4.78	-5.02	-12.81	3.06
STGL_C	-7.00	-10.19	-11.15	0.41	0.41	-11.46	-11.46	28.22	14.05	16.52	48.20	-8.76
SUPPS_C	22.17	19.46	25.62	0.41	0.41	25.09	25.09	-15.39	-3.03	-12.31	-44.20	37.26
TRDE_C	-11.47	-10.87	-10.87	0.41	0.41	-11.26	-11.26	-1.91	-1.91	-1.91	-	-
WOOG_C	3.92	4.98	5.10	0.41	0.41	4.67	4.67	-4.91	-2.83	-3.04	-11.86	6.22
Total	1.88	2.05	2.11	0.41	0.41	1.70	1.70	-0.98	-1.04	-1.12	-0.40	-0.33

$$\frac{P^D}{P^M} = \left(\frac{\left(\frac{P_1^D}{P_1^M} - \frac{P_0^D}{P_0^M} \right)}{P_0^D \Big/ P_0^M} \right) * 100\%$$

$$\frac{P^D}{P^E} = \left(\frac{\left(\frac{P_1^D}{P_1^E} - \frac{P_0^D}{P_0^E} \right)}{P_0^D \Big/ P_0^E} \right) * 100\%$$

Where 1 for shock value; and 0 for base value

Key variables:

P^Q: Output price; P^Z: composite commodity price; P^D: domestic commodity price; P^E: imported commodity price; P^M: imported commodity price; Q: output volume; Z: composite commodity quantity; D: domestic commodity quantity; E: exported commodity quantity; M: imported commodity quantity.

4.4.3.5. Impact on Households Income and Expenditure

Table 4.22 summarises the impact of scenario 3 on household income, expenditure, and saving. Under this scenario, we only allow the representative household of non-agricultural-urban households with high wages (HH_NAGU_HL) to adjust their saving ratio; and let the rest types of household saving exogenously fixed.

We expect that this scenario may lead to a negative effect on household income and expenditure because of two main reasons. First, a higher output tax rates indirectly increases the prices of final goods purchased by the households' which result in a fall in their real consumption. Second, it induces the cost of production to increase. This triggers producers to lower the wage bills and thus reducing the private income.

As expected, the results indicate that household income drops for all types. The actual disposable income of agricultural households with unskilled labour (HH_AGR_L); agricultural households' with unclear occupation (HH_AGR_NL); non-agricultural rural households' with low wages (HH_NAGR_LL); non-agricultural rural households' with unclear occupation (HH_NAGR_NA); non-agricultural-rural households with high wages (HH_NAGR_HL); non-agricultural urban households' with low wages (HH_NAGU_LL); non-agricultural urban households' with unclear job (HH_NAGU_NA); and non-agricultural labour urban households' with high wages (HH_NAGU_HL) are reduced by -1.67%, -2.25%, -3.75%, -0.83%, -2.34%, -1.31%, -2.94%, and -4.40%. The rural households with unclear occupation (HH_NAGR_NA) has the smallest fall in their income.

Furthermore, similar with SIM-1, the magnitude changes of expenditure and saving for all types of household budget and saving, excluding non-agricultural-urban households with high wages (HH_NAGU_HL), are identical with the level of income distribution. For instance, the changes of total expenditure and saving for HH_AGR_L; HH_AGR_NL; HH_NAGR_LL; HH_NAGR_NA; HH_NAGR_HL; HH_NAGU_LL; and HH_NAGU_NA are -1.67%, -2.25%, -3.75%, -0.83%, -2.34%, -1.31%, -2.94% respectively. This is due to the assumption of which only HH_NAGU_HL is allowed to adjust their saving ratio ($sh\_dum_h = 1$) in order to clear the saving-investment balance. Table 24 shows that actual income of HH_NAGU_HL falls by -4.40%. However, their total consumption declines lower by -3.41%. The saving ratio strongly declines by -6.70% reflecting a sharp reduction in saving by -10.81%.

Table 4.23 presents the impact of SIM-3 on private consumption across final commodities. In sum, total private consumption on aggregate commodities declines. However, there is indication of expansion for some types of goods and services. The largest improvement of households' demand is given to households and other services by 26.91%. Whilst, the other types of commodities namely agricultural, real estates, fisheries, hotel, and textiles are improved by 3.83%, 7.69%, 0.71%, 2.45%, and 8.77% respectively. The variations of household consumption can be explained from the distribution effects of household income and prices of goods.

Table 4.22: The Impact of Simulation 3 on Household Distribution Income and Expenditure

Household Types	$ADIH_h$			EH_h			SH_h			sh_ratio_h		
	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE	BASE	SHOCKED	PCHANGE
HH_AGR_L	171254	168403	-1.67	162021	159324	-1.67	9233	9079	-1.67	0.05	0.05	0.00
HH_AGR_NL	703951	688143	-2.25	642327	627903	-2.25	61624	60240	-2.25	0.09	0.09	0.00
HH_NAGR_LL	476495	458644	-3.75	450508	433631	-3.75	25987	25013	-3.75	0.06	0.06	0.00
HH_NAGR_NA	167663	166272	-0.83	158015	156704	-0.83	9648	9568	-0.83	0.06	0.06	0.00
HH_NAGR_HL	441589	431242	-2.34	385337	376308	-2.34	56252	54934	-2.34	0.13	0.13	0.00
HH_NAGU_LL	671493	662686	-1.31	633499	625190	-1.31	37995	37496	-1.31	0.06	0.06	0.00
HH_NAGU_NA	233825	226942	-2.94	213768	207476	-2.94	20057	19466	-2.94	0.09	0.09	0.00
HH_NAGU_HL	777279	743047	-4.40	672629	649707	-3.41	104650	93341	-10.81	0.14	0.13	-6.70

Key variables:

$ADIH_h$: Actual disposable income; EH_h: household budget; SH_h: household saving; sh_ratio_h: adjusted average propensity of saving

Household types:

HH_AGR_L: agricultural households with unskilled labour; HH_AGR_NL: agricultural-households with unclear occupation; HH_NAGR_LL: non-agricultural-rural households with low wages, HH_NAGR_NA: non-agricultural-rural households with unclear occupation; HH_NAGR_HL: non-agricultural-rural households with high wages, HH_NAGU_LL: non-agricultural labour-urban households with low wages, HH_NAGU_NA: non-agricultural-urban households, and HH_NAGU_HL: non-agricultural labour-urban households with high wages.

Table 4.23: The Impact of Scenario 3 on Household Consumption of Commodities Variety (% Change)

Commodity	HH_AGR_L	HH_AGR_NL	HH_NAGR_LL	HH_NAGR_NA	HH_NAGR_HL	HH_NAGU_LL	HH_NAGU_NA	HH_NAGU_HL	AVG
AGRI_C	4.52	3.90	2.30	5.40	3.80	4.89	3.16	2.66	3.83
AISCOM_C	-0.88	-1.47	-2.98	-0.04	-1.57	-0.53	-2.17	-2.64	-1.54
BANKAS_C	-19.07	-19.55	-20.78	-18.38	-19.63	-18.78	-20.12	-20.50	-19.60
CATLE_C	0.18	-0.41	-1.94	1.03	-0.51	0.54	-1.12	-1.60	-0.48
CHFCC_C	-3.56	-4.13	-5.60	-2.74	-4.23	-3.21	-4.81	-5.27	-4.19
ESTPRV_C	8.40	7.76	6.11	9.32	7.65	8.79	6.99	6.48	7.69
ELEGD_C	-11.55	-12.07	-13.42	-10.80	-12.16	-11.23	-12.70	-13.12	-12.13
FISH_C	1.37	0.78	-0.77	2.24	0.68	1.74	0.06	-0.42	0.71
FODT_C	-4.59	-5.15	-6.61	-3.78	-5.25	-4.25	-5.83	-6.28	-5.22
FORH_C	-19.94	-20.41	-21.63	-19.26	-20.49	-19.65	-20.98	-21.36	-20.46
GOVTD_C	-4.84	-5.41	-6.86	-4.04	-5.50	-4.50	-6.08	-6.53	-5.47
HTEL_C	3.12	2.52	0.94	4.00	2.41	3.50	1.78	1.30	2.45
INDSHO_C	27.75	27.00	25.05	28.84	26.87	28.21	26.09	25.49	26.91
LANT_C	-11.47	-11.99	-13.34	-10.72	-12.08	-11.15	-12.62	-13.04	-12.05
OAGRI_C	-6.78	-7.33	-8.75	-5.99	-7.42	-6.44	-7.99	-8.43	-7.39
OMINE_C	-10.60	-11.13	-12.49	-9.84	-11.22	-10.28	-11.76	-12.19	-11.19
PPTM_C	-2.96	-3.53	-5.02	-2.14	-3.63	-2.61	-4.22	-4.68	-3.60
RSTR_C	-5.86	-6.42	-7.86	-5.06	-6.51	-5.53	-7.09	-7.53	-6.48
STGL_C	9.49	8.85	7.18	10.42	8.74	9.89	8.07	7.55	8.77
SUPPS_C	-17.68	-18.17	-19.42	-16.98	-18.25	-17.39	-18.75	-19.14	-18.22
WOOG_C	-6.33	-6.88	-8.31	-5.53	-6.97	-5.99	-7.55	-7.99	-6.94

4.4.3.6. Sensitivity Analysis of Scenario 3

We conduct a sensitivity analysis by varying the import elasticity in order to check the robustness of scenario 3 results. Table 4.24 presents the sensitivity analysis results of SIM-3 on the macroeconomic accounts. We choose in experimenting a decrease and an increase of the import elasticity by 25% (between 1.5 and 2.5). We then examine the sign and size of results. If the trade elasticity reduces the sensitivity of trade to changes in the relative price would fall.

Apparently, the effects of changes in import elasticity are quite large especially in the case of higher elasticity. All macroeconomic accounts, excluding real investment and capital bills, generate a contrast sign by which they are tend to be positively improved. In the case of lower elasticity, however, the results are less sensitive where only GDP at market price from expenditure side and real investment give a contradicted sign. McDaniel and Balistreri (2003) found that the wide-ranging sensitivity with respect to trade elasticity is highly dependent to the degree of firm heterogeneity: the more disaggregated the sectors, the greater substitutability there is between varieties. We also suspect that these results could be due to the colliding mechanisms in which the effects of expansionary public goods on Indonesia's macroeconomic are offset by the contractions of higher *ad valorem* tax rates. In other words, the increase in aggregate demand leads to a drop in prices of goods which in turn improves the national income account. However, these outcomes are suppressed by the presence of an increase in *ad valorem* tax rates. Thus, it indicates that the changes of elasticity in scenario 3 could sensitively generate a different result. Since the elasticity used in this model is adopted from other studies, we suggest that this value should be precisely weighed for each type of traded commodity based on Indonesia's economy.

Table 4 24: Sensitivity Analysis Results of Scenario 3 (% Change)

Variables	Import Elasticity = 2 Original Case	Import Elasticity = 2.5	Import Elasticity = 1.5
GDP at factor costs	-1.97	0.639	-1.43
GDPGAP	19.61	16.686	19.98
GDP at market prices from income side	-0.46	2.042	0.15
GDP at market prices from expenditure side	-1.21	1.387	-0.62
Total private consumption	-2.47	1.261	-3.20
Total investment	-1.07	-2.423	3.01
Total government consumption	11.91	20.315	10.60
Total export	0.01	3.156	-0.55
Total import	0.08	2.898	-0.38
Net export	-0.67	5.644	-2.12
Net indirect tax	36.10	38.476	39.44
Total payment to all workers (WAGEBILL)	-3.81	1.125	-2.73
Total payment to capital (CAPBILL)	0.05	0.108	0.00

4.5. Conclusion

In this chapter we use the standard CGE model developed in Chapter 3 to examine the impacts of implementing specific fiscal policies on Indonesia's main macroeconomic indicators and to their consequences by examining how different institutions and sectors in the economy are affected as a result. Three simulations were conducted in order to compensate a 10% expansion in exogenous public spending. The first simulation is the impact of a 10% increase in government expenditure with the adjusted government deficit and balance of payment. This scenario ensures that the government can only borrow to finance the extra expenditure without having any change in tax revenue. The second simulation is a simultaneous 10% increase in government expenditure and 10% reduction in the subsidy rate to activities. Under this scenario, the extra government expenditure is compensated by a reduction in exogenous subsidy payments to activities and its endogenous saving. The third simulation is a simultaneous 10% increase in government expenditure and 10% increase in *ad valorem* tax rate. Here, we compensate the additional public expenditures by increasing the *ad valorem* tax rate such that the burden of budget deficit could be relaxed.

The results show that different scenarios of fiscal policies would affect the economy's performance. The increase in public expenditure shifts up the equilibrium output. We present that scenario 1 generates the strongest impact due to the static nature of the model for which it does not consider the deficit payment in the future. The financing scheme of lowering subsidy rates to activities given in scenario 2 resulted in less improvement on Indonesia's GDP compared to scenario 1. This is because a subsidy cut directly increases the cost of production which at the end reduces national income. However, we also found that fiscal expansion with higher output tax revenue under scenario 3 resulted in the opposite results. The sectors were pressurized by higher taxes which creates deindustrialization, low employment, and thus reduces equilibrium national income and output.

We perform a sensitivity analysis to check the robustness of simulations results by varying the import elasticity. The results indicate that scenario 1 and scenario 2 reveal a small sensitivity and generate consistent sign for most of the endogenous variables, which implies that the model is robust. However, in scenario 3, the results are sensitive with respect to the variation of import elasticity. We argue that these are due to the large number of disaggregated sectors provided in the data set and the colliding effects of which the expansionary of public goods are offset by higher *ad valorem* tax rates.

Chapter 5

Constructing Indonesia’s Energy-SAM

5.1. Introduction

Integrating energy technology details within CGE model for energy analysis has been considered as a mediation to reconcile divergent results between the ‘bottom-up’ engineering and macroeconomic – usually called ‘top-down’ – perspectives (Wing, 2008)[25]. The impact analysis of energy policies within the context of conventional top-down framework (mainly CGE models) usually overestimates the economy’s adjustments of an energy system (Proenca and Aubyn, 2009). This is because it ignores the technological shifts induced by price changes (Proenca and Aubyn, 2009). Contrary to top-down models, the bottom-up energy models, which underestimate the economy’s adjustments induced by the energy policy shocks, are a partial equilibrium representation of the energy sector that focused on the cost minimization problems of detailed energy technologies to satisfy the final energy demand (Proenca and Aubyn, 2009; Wing, 2008; Bohringer and Rutherford, 2008). In bottom-up models, energy demand is determined only from a simple aggregate macroeconomic framework; but energy supply is usually derived from specific energy system models which represent the transformation linkages of energy input-output processes (Wing, 2008). By looking at above strengths and weaknesses, therefore, we attempt to develop a hybrid-CGE model by incorporating the electricity technological explicitness of bottom-up model with the conventional top-down model (or standard CGE model) given in Chapter 3.

Hybrid-CGE models are commonly constrained by several limitations of the SAM data set to numerically calibrate the model. The first issue is related to the typical aggregated account of a set of energy types (industries and commodities). For instance, in the official Indonesian SAM for 2008, all types of energy fossils[26] sectors (oil, coal, and natural gas mining), usually known as primary energy types, are pooled together with geothermal and metal ores in a single account namely the fossils and metal ores mining sector. Refineries products are aggregated together with chemical, fertilizer, clays, and cements products in a single account. Electricity is pooled together with other utilities such as drinkable water and city gas products. We argue that the set comprising three energy sectors in the existing SAM will not be sufficiently applicable to calibrate the hybrid-CGE model for specific energy analysis in Indonesia. Therefore, these sectors need to be further disaggregated into specific types of energy in order to have a robust analytical result.

Second, the official Indonesian SAM is principally based on a one-to-one relationship between activity output (and price) and commodity supply (and price). In other words, it

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[25] For detailed explanations about “bottom-up” and “top-down” models see Wing (2008), Manne *et al.* (1995), Paltsev *et al.* (2005).

[26] These are usually known as primary energy types.

does not permit an activity to produce multiple types of commodity, or conversely, multiple activities to produce a homogenous type of commodity. These relationships are essential to have more accurate picture of energy-economy flows especially among energy industries and commodities (Choumert *et al.*, 2006). For example, electricity is a homogenous commodity generated from various types of generation technology such as conventional (fossil fuels) and renewables plant (solar, wind, geothermal, nuclear, and so on). In contrast, a refinery industry can produce multi types of petroleum commodities such as gasoline, diesel oil, liquid petroleum gas, kerosene, asphalt, and others. Third, the SAM does not specifically record the factor contribution of natural resources that are strongly related to the climate problem. These values are approximated as the shares of capital input to activity (Wing, 2001). Wing (2008) defined these resource factors as:

> "Land area with incident insolation or atmospheric boundary-layer flow in the cases of solar and wind, topographically-determined hydrostatic potential in the case of hydroelectricity, or geologically-determined hot dry rock in the case of geothermal energy" (p. 563).

This chapter aims to extend the existing Indonesia's SAM by disaggregating the specific types of energy industry and commodity as well as factor of natural resources. This data set will then be used to calibrate the hybrid-CGE model for specific energy policies that is explained in detail in Chapter 6. The energy types are grouped into three sets: (1) primary energy (energy fossils) which is extracted by mining activity; (2) petroleum products which are produced by the refinery industry; and (3) electricity which is produced from multiple power plants (conventional and renewables). The activity-commodity relationship of each classification is then determined as follows. Any activity of fossil mining produces a homogenous commodity (a one-to-one relationship). The refinery industry produces multiple types of petroleum products (a one-to-multi relationship). And each activity of generation technology produces a homogenous electricity commodity (a multi-to-one relationship). The dimension level of energy disaggregation of each set is highly dependent on the data availability. For the energy disaggregation method, we follow Wissema (2006) and Wing (2008) that are basically based on the shares approach. To our findings, we are the first to construct an energy-SAM for Indonesia by disaggregating the specific energy types and the factor of natural resources following the above terminologies.

This chapter is organized as follows. Section 5.2 briefly discusses the current energy accounts in the official Indonesian SAM 2008 and the proposed energy types which will be disaggregated. Section 5.3 describes in detail the construction of disaggregating specific energy for each set of energy types, from how these types are mapped, the data availability, the introduction of natural resources factor as shares of capital input to energy sectors, and the step-by-step construction. Finally, chapter 5.4 presents conclusions and briefly discusses how to update the standard CGE model for policy analysis related to energy and carbon dioxide emissions.

5.2. The Energy Sector in the Official Indonesian SAM 2008

The existing Indonesian SAM 2008 has 24 activities (and commodities) accounts. Among these accounts, there are only three main accounts which comprise energy aggregate sectors (or commodities), namely: (1) mining account; (2) chemical account; and (3) utility account. Based on the available data, we determine the elements of energy specific which are grouped in above set accounts as follows. Primary energy types (coal, crude oil, natural gas) and geothermal energy, are pooled in mining account. We disaggregate these energy types for both activity and commodity and ensure the activity-commodity relationship where each industry produces a single type of commodity. Secondary energy commodities (particularly petroleum products: subsidized gasoline, subsidized kerosene, subsidized diesel, non-subsidized gasoline, subsidized and non subsidized liquid petroleum gas, and liquid natural gas, are grouped in the chemical account. However, we keep its production activity, which is refinery industry, in a single account to ensure a single-to-multiple relationship between refinery output (and price) and its corresponding commodity supply (and price). Finally, the activities (and commodities) of electricity and city gas are pooled in the utility account. The latter follows a one-to-one relationship of activity output (and price) and commodity supply (and price), whilst, for electricity industry, we follow Wing's (2008) approach by splitting this sector into three activity accounts, namely: generation, transmission, and distribution. The generation account is then further disaggregated into several types of power plants which are conventional (aggregated fossil fuels), geothermal, and hydro power plant. While electricity commodity account remains in a single account. Therefore, in contrast to refinery products, in the electricity sector we permit a multiple-to-single relationship between electricity activities and its corresponding commodity.

5.3. The Energy Data

To update the details of energy activity (and commodity) into the existing SAM, we employ the data source compiled by the National Energy Council. This data set is compiled by consolidating the information obtained from (a) the Input-Output Table of 2008 and 2005, (b) the Input-Output of Small and Middle Business Table 2003, (c) The Handbook of Energy and Economic Statistics of Indonesia 2008, (d) The State Expenditure Budget from the Ministry of Finance, (e) The National Statistics of Electricity, (f) The Statistics of City Gas given from the State-Owned Gas Company, (g) data of subsidized gasoline from the Ministry of Mineral and Energy Resources, (h) and other data sources which were obtained from the forum group discussion meetings or direct interview to the head of energy sector stakeholders.

The compiled data records almost all types of energy sectors and covers the details of their balance sheet of expenditure and receipt transaction. The structural framework of the compiled data is similar to that of SAM. It is a square matrix of which column total of expenditure equal to total row of the receipt account. However, there are four aspects which differ from the SAM, namely that (1) the compiled data does not distinguish activity and commodity from the production sector; (2) labour is only classified into eight groups; (3) the households are only represented in a single account; and (4) there is no record of import tariff for each imported demand. The schematic structure of this compiled data is shown in Table 5.1.

Table 5.1: The Schematic Structure of the Compiled Data from National Energy Council

				Expenditure					
				Endogenous Account			Exogenous Account		Total
				Production Sector	Production Factors	Institution	ROW	Exogenous	
				1	2	3	4	5	6
receipt	Endogenous Account	Production Sector	1	Intermediate Inputs		Institution consumption	Export	Investment and subsidy	Total production sector income
		Production Factors	2	Value added distribution					Factor Income
		Institution	3		Factor Income to institution		Transfer from abroad		Institution Income
	Exogenous Account	ROW	4	Imports					Total import demand
		Exogenous	5	`Sales tax	Fixed capital consumption	Institution saving			Exogenous Income
	Total		6	Total expenditure of production sector	Factor expenditure	Institution expenditure	Total import supply	Exogenous Expenditure	

Furthermore, the compiled data records 44 types of production sectors which obtained by disaggregating the 24 activity accounts in the existing Indonesian SAM in year 2008. The sectors mapping between the existing SAM and the compiled data is presented in Table 5.2. Metal ores mining, coal mining, oil mining, natural gas mining and geothermal mining are subsets of a sector in the existing SAM, namely ‘Coal, Metal Ores, and Oil Mining’ (COMOIL_A). Chemical industry, bio-ethanol industry, and biodiesel industry, other oil industry, subsidized gasoline industry, subsidized bio-gasoline industry, kerosene industry, subsidized bio-diesel industry, non-subsidized industry, and LNG industry are subsets of a sector, namely ‘Chemical, Fertilizer, Goods from Clay and Cement’ (CHFCC_A). Subsidized electricity, non-subsidized electricity, hydro power plant, city gas, and clean water are subsets of a sector, namely ‘electricity, city gas and clean water’ (ELEGD_A). Finally, train services and land transportation are subsets of a sector, namely ‘land transportation’ (LANT_A).

Table 5.2: The Mapping Sectors

24 Activities in the Existing SAM 2008		**44 Activities in the Compiled Data**	
No	Sector	No	Sector
1	Agriculture Food Crops	1	Agriculture Food Crops
2	Agriculture for Other Crops	2	Agriculture for Other Crops
3	Cattle and the Outcomes	3	Cattle and the Outcomes
4	Forestry and Hunting	4	Forestry and Hunting
5	Fishery	5	Fishery
6	Coal, Metal Ores, and Oil Mining (COMOIL_A)	6	Metal Ores Mining
		7	Coal Mining
		8	Oil Mining
		9	Natural Gas Mining
		10	Geothermal Mining
7	Other Mining and Excavations	11	Other Mining and Excavations
8	Food, Drink, and Tobacco	12	Food, Drink, and Tobacco
9	Spinning, Textile, Garment, and Leather Industries	13	Spinning, Textile, Garment, and Leather Industries
10	Wood and Goods from Wood	14	Wood and Goods from Wood
11	Paper, Printing, Transport Equipment, and Goods from Metal and Industry	15	Paper, Printing, Transport Equipment, and Goods from Metal and Industry
12	Chemical, Fertilizer, Goods from Clay and Cement (CHFCC_A)	16	Chemical Industry
		17	Bio-Ethanol Industry
		18	Bio-Diesel Industry
		19	Other Oil Industries
		20	Subsidized Gasoline Industry
		21	Subsidized Bio-Gasoline Industry
		22	Kerosene Industry
		23	Subsidized Diesel Industry
		24	Subsidized Bio-Diesel Industry
		25	Non Subsidized Gasoline Industry
		26	Subsidized LPG Industry
		27	Non Subsidized LPG Industry
		28	LNG Industry
13		29	Conventional Power Plant

24 Activities in the Existing SAM 2008		44 Activities in the Compiled Data	
No	Sector	No	Sector
	Electricity, Gas, and Drinkable Water (ELEGD_A)		(Aggregated Fossil Fuels Generation)
		30	Geothermal Power Plant
		31	Hydro Power Plant
		32	City Gas
		33	Clean Water
14	Construction	34	Construction
15	Trade	35	Trade
16	Restaurant	36	Restaurant and Hotel
17	Hotel		
18	Land Transportation (LANT_A)	37	Train Transportation
		38	Land Transportation
19	Air, Sea, and Communication Transportation	39	Air, Sea, and Communication Transportation
20	Supporting Services for Transportation and Warehouse	40	Supporting Services for Transportation and Warehouse
21	Bank and Assurance	41	Bank and Assurance
22	Real Estate, and Private Services	42	Real Estate, and Private Services
23	Government and Defence, Education, Health, Film, and Other Social Services	43	Government and Defence, Education, Health, Film, and Other Social Services
24	Individual Services, Households, and Other Services	44	Individual Services, Households, and Other Services

As mentioned previously, the compiled data has 2 limitations: (1) it does not record the import tariff for all production sectors; and (2) the imported demand for a given commodity differs a lot from the existing SAM. Table 5.3 compares the import demand and import tariff of COMOIL_C commodity recorded in the existing SAM and the compiled data[27]. From Table 4, it can be seen that the total import for COMOIL_C commodity in the existing SAM is 134,406.64 billion Rp. However, in the compiled data, it is 24,773.80 billion Rp. The discrepancy between these two values reached almost six folds. Furthermore, the total import tariff revenue of COMOIL_C in the existing SAM is 561.07 billion Rp. However, in the compiled data, there is no record of this tariff.

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[27] Due to the limited space of table presentation, we only present an example of import and tariff discrepancy of COMOIL_C given in the existing SAM and compiled data. These discrepancies appear for all types of imported energy commodities.

Table 5.3: Comparing the Values of Import and Import Tariff Between the Existing SAM and the Compiled Data (Billion Rp)

		Expenditure					
Receipt	**ROW**	**Activity in the existing SAM**	**Types of COMOIL_C in the compiled data**				
		COMOIL_C	Metal Ores Mining	Coal Mining	Oil Mining	Natural Gas Mining	Geothermal Mining
	Import	134,406.64	2,340.97	2,174.37	19,445.68	139.25	105.34
	Total import	134,406.64	24,773.80				
	Import Tariff Revenue	561.07	NA	NA	NA	NA	NA
	Total import tariff	561.07	-	-	-	-	-

**NA means not available*

5.4. Constructing the Energy-SAM

In this section, we describe a step-by-step construction of the energy-SAM by carefully paying attention to the activity-commodity link for each set of energy types: primary energy, petroleum products, and electricity. We use the compiled data as our main resource because it has a square matrix format similar to the existing SAM.

In a first step, we disaggregate the activity (and commodity) of energy types. Traditionally there is a one-to-one relationship between activity output (price) and commodity supply (price). As previously mentioned, because of the discrepancy in import demand and import tariff for energy sector account, as a result, their total expenditure (column side) is not equal to its relevant total receipt (row side). Therefore, in a second step, we eliminate the residuals by assuming a rough approximation for each energy tariff (and import) such that the energy-SAM balance is obtainable. For consistency check, we compare these results to the energy balance in year 2008. For example, we determine coal tariff so that its total supply (or demand) of coal goods in the energy-SAM is approximately equal to the given energy statistics. This approach is preferable over applying a SAM balancing method in order to avoid the effect of changes on other entry cells. In a third step, we add an account of resources factor which is derived from applying a proportion of capital input to the relevant energy activity. In a fourth step, we follow Wing (2008) approach to disaggregate the electricity activity into types of generation technologies, transmission, and distribution. Nevertheless, the electricity commodity remains as a single account. Finally, we adopt method by Choumert *et al.* (2006) to aggregate all refinery activities but keeping the disaggregated accounts of refinery commodities. That way, for petroleum products, we permit a single-to-multiple relationship between its activity output and the relevant commodity supply.

5.4.1. The First Step: Disaggregating the Energy Types

This section discusses the first step of constructing the Energy-SAM by which we disaggregate the activity (and commodity) of energy types following the traditional one-to-one relationship between activity output (price) and commodity supply (price). In the compiled data, the total expenditure of mining commodity (intermediate input) used in its corresponding differs from the existing SAM. Table 5.4 presents an example of statistic discrepancies between existing SAM and compiled data for intermediate input cost of COMOIL_C (and its subsets) to each mining sector.

Table 5.4: Statistic Discrepancies of Intermediate Input Cost of Mining Sector between Existing SAM and Compiled Data (Billion Rupiah)

		Expenditure					
	Mining Commodity	**Mining Activity in the Existing SAM**	**Mining Activity in the Compiled Data**				
			Metal Seeds Mining	Coal Mining	Oil Mining	Natural Gas Mining	Geothermal Mining
Receipt	Metal Seeds Mining		21,007.03	-	-	-	-
	Coal Mining		391.57	8,217.35	0.46	0.38	0.01
	Oil Mining		-	-	21,404.18	10,414.45	316.01
	Natural Gas Mining		-	-	161.62	2,161.72	30.40
	Geothermal Mining		-	-	-	-	-
	Total	**83,490.17**	21,398.60	8,217.35	21,566.26	12,576.55	346.42
			64,105.18				

The total intermediate input cost of the Coal, Metal Seeds, and Oil Mining account (COMOIL_C) for its corresponding activity (COMOIL_A) in the existing SAM is 83,490.17 billion Rp. However, the sum of this cost in the compiled data gives a value 64,105.18 billion Rp. This difference might arise from (1) the weighting process of the compiled data used to obtain a balance system; and (2) the absence of import tariff in each production sector. Thus, by directly using the values of 64,105.18 billion Rp. into the existing SAM will disrupt the balance system. Taking this issue into consideration, we use a weighting approach to update the existing SAM in order to balance the total expenditure and its corresponding receipt.

The method works as follows. First calculate the share of input cost for each subset of the energy sector account in the compiled data. Then multiply this share to the corresponding set in the existing SAM to obtain the new value for each subset in the existing SAM. For example, as presented in Table 5.4, the compiled data records the intermediate input cost of COMOIL_C to each mining activity are: Rp. 21,398.60 billion; Rp. 8,217.35 billion; Rp.

21,566.26 billion; Rp. 12,576.55 billion; and Rp. 346.42 billion, respectively. We then calculate their share by using the shares approach as follows:

$$Share\ of\ COMOIL\_C\ cost = {C_i}/{\sum_i C_i}$$

Where: C_i is the COMOIL_C cost to the i-th mining sector.

Thus, the shares of COMOIL_C cost in each mining activity are: 0.33, 0.13, 0.34, 0.20, and 0.01, respectively. Finally, use these shares to calculate the COMOIL_C cost for each mining activity account in the existing SAM by multiplying each of them to the cell of SAM ("COMOIL_C", "COMOIL_A") which is Rp. 83,490.17 billion. As a result, the intermediate cost of COMOIL_C input to each type of mining activity is: Rp. 27,869.40 billion; Rp. 10,702.22 billion; Rp. 28,087.76 billion; Rp. 16,379.62 billion; and Rp. 451.17 billion, respectively. The COMOIL_A in the existing SAM has now been disaggregated into the subsets of mining sector namely: (1) metal seeds, (2) coal, (3) oil, (4) natural gas, and (4) geothermal. These approaches are also implemented to disaggregate the other energy sectors in the existing SAM for both the row and the column side.

5.4.2. Second Step: Balancing the Traditional Energy-SAM

This section discusses the second step of constructing the Energy-SAM by which we eliminate the discrepancies of the values of import demand and import tariff for energy sector account such that the energy-SAM balance is obtainable.

As previously mentioned, the compiled data does not record the import tariff account of each energy type. To balance the energy-SAM, we use the information of energy import given in the compiled data and roughly approximate the import tariff for each mining sector in the existing SAM. This is done by calculating the share of import for each subset of COMOIL_C in the compiled data, and then multiplying them with the total import tariff revenue of COMOIL_C in the existing SAM (Rp. 561.07 billion). We adopt this approach by the consideration that the share of import demand for each subset of COMOIL_C reflects its share in import tariff revenue. These approaches are also applied to all energy types. Table 5.5 presents the estimated imports and import tariff revenues of energy mining commodities.

Table 5.5: Import Values and Tariff Revenue in the Existing SAM (Billion Rp)

		Expenditure				
		COMOIL_C				
Receipt	ROW	Metal Ores Mining	Coal Mining	Oil Mining	Natural Gas Mining	Geothermal Mining
	Import	12,998.69	12,073.66	107,976.15	773.23	584.91
	Import Tariff	54.26	50.40	450.73	3.23	2.44

By employing the values of import tariff revenue provided in Table 5.5 into the Energy-SAM, thus, it will generate residuals between total row and its relevant total column of an energy account. Table 5.6 shows the example of an unbalanced total expenditure and income of COMOIL_C in the Energy-SAM.

Table 5.6: The Values of Import and Import Tariff Revenue in the Energy-SAM (Billion Rp)

		Expenditure				
		COMOIL_C				
Receipt		Metal Ores Mining	Coal Mining	Oil Mining	Natural Gas Mining	Geothermal Mining
	Metal Seeds Mining Activity	161,677.16				
	Coal Mining Activity		105,619.51			
	Oil Mining			260,965.34		
	Natural Gas Mining				85,226.96	
	Geothermal Mining					2,636.50
	Sales tax	5,387.42	3,591.61	10,916.97	3,237.17	109.73
	Import	12,998.69	12,073.66	107,976.15	773.23	584.91
	Import Tariff	54.26	50.40	450.73	3.23	2.44
	Total expenditure	180,117.53	121,335.19	380,309.19	89,240.58	3,333.58
	Total receipt	183,181.27	116,749.58	343,592.39	128,050.22	2,762.61
	Residuals	**-3,063.74**	**4,585.61**	**36,716.80**	**-38,809.64**	**570.96**

In Table 5.6, the column total (expenditure) and its corresponding row (receipt) of each mining commodity account is unbalanced. Thus, in order to maintain a balance system in the updated SAM, we eliminate these residuals by taking them directly and reallocate them to a certain cell. Because the compiled data has a bias information with respect to trade accounts (import, export, and tariff), we opt to reallocate these residuals into the import (or export) entry cell. The explanation of these reallocations is given as follows:

1) In the metal ores mining commodity account, we take the residual of Rp, -3,063.74 billion and add it to its export cell. Hence the export of metal seeds mining commodity is reduced

from Rp. 42,279.90 billion to Rp. 39,216.16 billion. We choose this option so that it does not distract the transaction value in other accounts.

2) In the coal mining commodity account, we take the remainder of Rp. 4,585.61 billion and add it to its export cell. Hence the export of coal mining commodity is increased from Rp. 69,682.76 billion to be Rp. 74,268.37 billion.
3) In the oil mining commodity account, we take the residual of Rp. 36,716.80 billion and add it to its corresponding export cell. Hence the export of oil mining commodity is increased from Rp. 129,142.04 billion to be Rp. 165,858.84 billion.
4) In the natural gas mining commodity account, we reduce the intermediate input cost of natural gas mining commodity from Liquid Natural Gas (LNG) activity account as equal as the residual of Rp. 36,716.80 billion. Hence the intermediate input cost of natural gas mining commodity for the LNG activity declines from Rp. 94,475.58 billion to Rp. 55,665.94. Thus, the domestic production of LNG reduces from Rp. 211,032.75 billion to Rp. 172,223.12.
5) In the geothermal mining commodity account, we simply reduce imports as equal as the remainder. This is because according to the Indonesia energy balance 2008, the import of geothermal mining is zero. Thus the import cost for this mining in the updated SAM is lowered from Rp. 584.91 billion to be Rp. 13.95 billion.
6) Finally, we also apply the approach of (5) to achieve balance in the commodity accounts comprising of (a) chemical; (b) bioethanol; (c) biodiesel; (d) other oil; (e) subsidized gasoline; (f) subsidized bio-gasoline; (g) kerosene; (h) subsidized diesel; (i) subsidized bio-diesel; (j) non-subsidized gasoline; (k) subsidized LPG; (l) non-subsidized LPG; (m) LNG; (n) subsidized electricity; (o) non-subsidized electricity; (p) hydro power plant; (q) city gas; and (r) clean water.

As results, the traditional Energy-SAM for Indonesia in year 2008 is obtained.

5.4.3. Final Step: Disaggregating the Technology Details of Electricity Sector

Within a CGE modelling framework, the electricity sector has been targeted as the sector that most contributed to reduce global carbon dioxide emissions (Sue Wing, 2004). By switching (combining) power generation technology, i.e. from conventional coal to hydro power plant, which is emission-free, this sector has a substantial capability to reduce greenhouse gas emissions. The CGE model designed for green electricity promotion and environmental analysis is therefore ought to be calibrated on a fitted SAM for Indonesia that explicitly provides a technology for electricity production.

However, the official Indonesia SAM 2008 does not record these accounts in details. The account of the electricity sector is simply organized in terms of a one-to-one relationship between the electricity industry and its homogenous commodity supply. Sue Wing (2008) argued that this dataset could bias the results of CGE approach due to the overly simplistic representation of electricity production function by which the electricity is actually generated from multi-types of power plant.

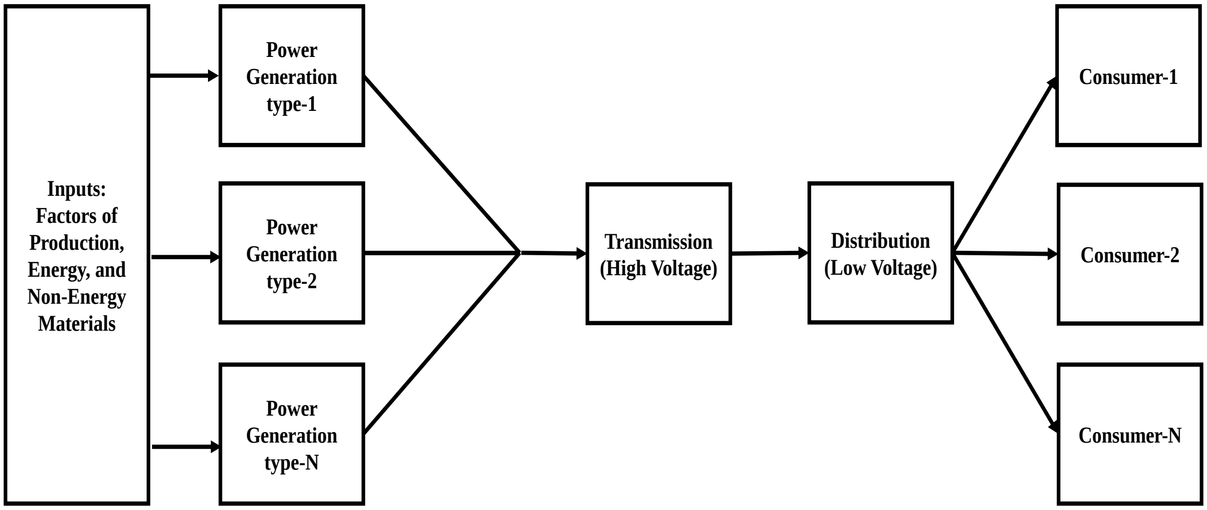
In this section, we disaggregate the technology details of the electricity sector in the SAM by employing a number of additional engineering statistics, so that the SAM enables to calibrate the distinct characteristics of the power production structure in the CGE model. Nevertheless, this is difficult because engineering and economic datasets are rarely consistent to each other. Thus, the integration of these databases requires plausible judicious assumptions and procedures (Sue Wing, 2008).

In order to avoid such problematic issues, we follow Sue Wing's (2008) approach, which addressess the problems via a mathematical scheme that integrates the engineering databases with the SAM dataset. This methodology is simple, transparent, and robust (Sue Wing, 2008).

5.4.3.1. The Fundamental Framework of Electricity System

To successfully overcome the challenge of disaggregating an activity account in the SAM, it is necessary to fully understand how this activity supplies its output to the final consumers. In the case of a power market, electricity is generated by utilizing various primary energy types, both renewable and non-renewables. Electricity is then transmitted to consumers through a high-voltage wire or grid network and distributed through a low-voltage grid to final consumers. The mechanism of this integrated industry is often called a generation-transmission-distribution system, which is shown in Figure 5.1.

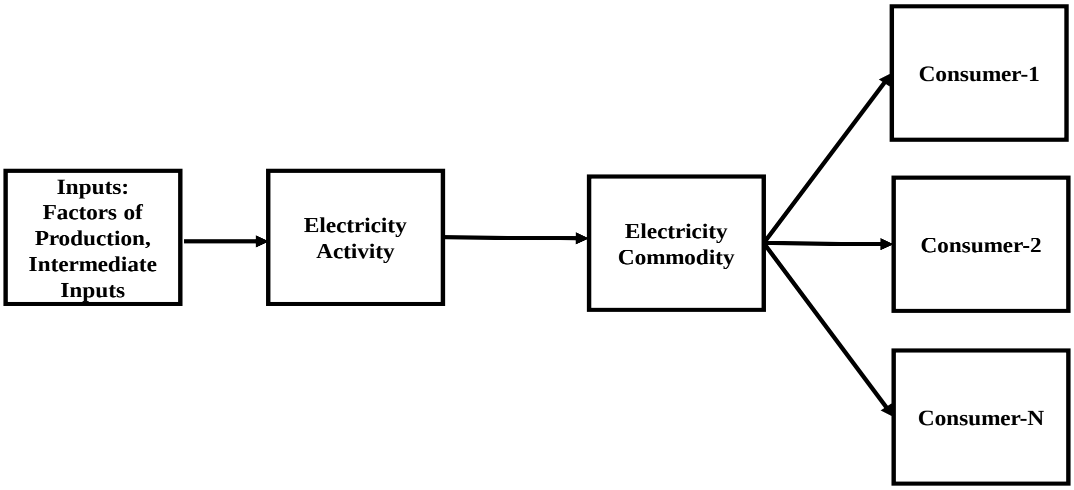
Figure 5.1: Electricity System Network



In contrast to other commodities, electricity cannot be stored effectively. Thus, the supply and demand for electricity must be kept in balance dynamically (Hu and Hu, 2013). An excess of demand (or shortage of a supply) will distort national economic development. Because of these characteristics, the supply and demand of electricity is known as one of the most complicated systems in world (Hu and Hu, 2013).

In the existing SAM for Indonesia, however, the transaction behaviour of electricity market is treated identically to other activities' accounts – i.e. agricultural, manufacture, mining, and so on, where commodity is only produced from the corresponding activity. The transaction flows of electricity activity-commodity given in the existing SAM for Indonesia are not in accordance to the framework illustrated in Figure 5.1. In other words, the activities of power generation, transmission, and distribution are aggregated into a single account. Figure 5.2 illustrates the economy flow of electricity market in the existing SAM for Indonesia.

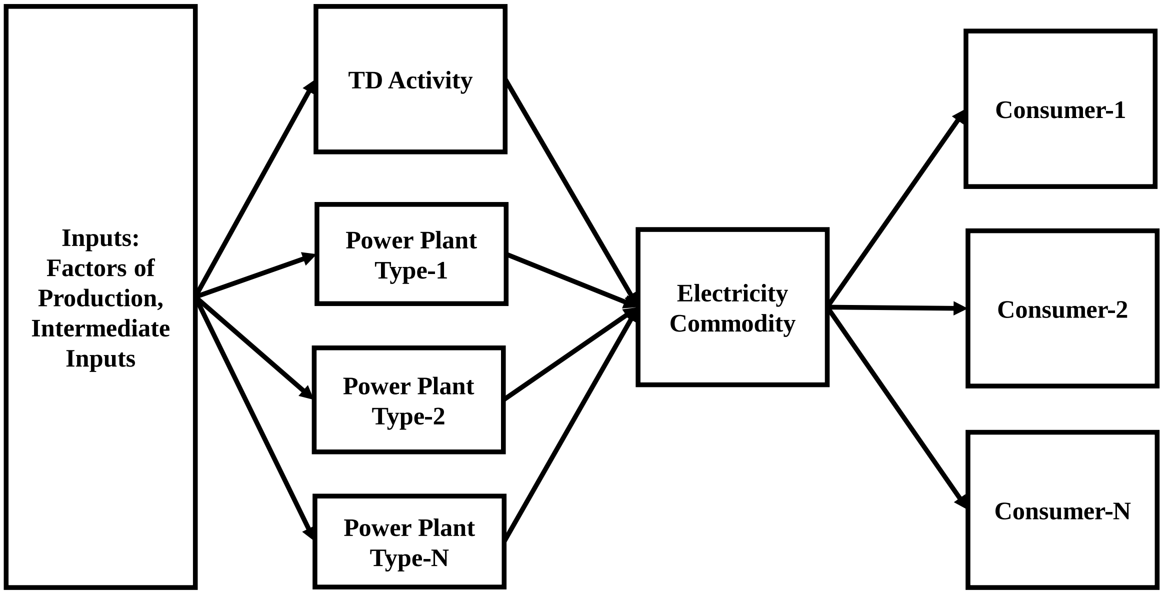
Figure 5.2: Economy Flow of Electricity Market in SAM



In this section, we attempt to first reconciling the power system framework shown in Figure 5.1 with the SAM framework. To do so, we slightly modify Figure 5.1, in which each activity is an element of the electricity set: $\{\text{Generation}, \text{Transmission}, \text{Distribution}\} \in \mathit{electricity}$; and each activity is assumed to produce electricity proportionally (Wing, 2008). This is because in the SAM framework, all activity accounts usually allocate their gross output production to the relevant commodity cell account. To our findings, there is no literature that employs the transaction flows of output production from activity-to-activity, although this framework is possible in the SAM.

For the sake of simplification, since the activities of both transmission and distribution are responsible to dispatch the electricity output to consumers, we thus aggregate them into a single account namely: TD Activity. In a next step, we disaggregate the generation activity into a number of discrete technologies: (i) conventional power plant which is the aggregated generation of coal-fired, coal-steam, oil-fired, and gas-fired power plants; (ii) hydro plant; and (iii) geothermal plant. Figure 5.3 illustrates the modified power system framework that will be employed in the SAM.

Figure 5.3: The Structure of Power System in SAM



Based on Figure 5.3, we further disaggregate the electricity activity account as discussed step-by-step in the following section.

5.4.3.2. Disaggregating the Electricity Activity Account

It is helpful to first introduce the double-entry principle of the electricity account in Indonesia's official SAM, in which the corresponding row (electricity demand or receipt) and column (electricity supply or expenditure) sums must balance. This principle can be written mathematically as follows:

$$QA_{EL} = \sum_{f \in F} FA_{f,EL} + \sum_{i \in C} X_{i,EL}\,, \qquad EL \subset j \in A \tag{1}$$

$$Q_{EL} = QA_{EL}, \qquad EL \subset i \in C \tag{2}$$

Where QA_{EL} denotes total electricity output; $FA_{f,EL}$ is the f-th factors used in the electricity sector; and $X_{i,EL}$ is the i-th intermediate input used in the electricity sector. Eq (2) represents a one-to-one relationship between electricity activity output (QA_{EL}) and its domestic commodity supply (Q_{EL}) (single activity to produce a single type of commodity).

To distinguish the GEN (electricity generation) and TD (transmission and distribution) accounts from the electricity activity account, the above principles are extended such that QA_{EL} is the sum of electricity produced from its component activities ($ACT = \{GEN, TD\}$) which can be rewritten as follows:

$$QA_{EL} = QA_{GEN} + QA_{TD} = \sum_{ACT} QA_{ACT} \tag{3}$$

Following the zero profit condition, the production of each constituent output (QA_{ACT}) is equal to the sum of its inputs (factors production ($FA_{f,ACT}$) and intermediate goods ($X_{i,ACT}$)):

$$QA_{ACT} = \sum_{f \in F} FA_{f,ACT} + \sum_{i \in C} X_{i,ACT,} \qquad ACT \subset j \in A \tag{4}$$

To maintain the SAM balance, two conditions must be satisfied:

i) The sum of the factor inputs used in each constituent activity ($FA_{f,ACT}$) is equal to the f-th factor used in electricity sector in the official SAM:

$$FA_{f,EL} = \sum_{ACT \subset j \in A} FA_{f,ACT}, \qquad f \in F, \quad EL \subset j \in A \tag{5}$$

ii) The sum of the i-th type of intermediate used in each constituent activity ($X_{i,ACT}$) is equal to the i-th intermediate input used in the electricity sector:

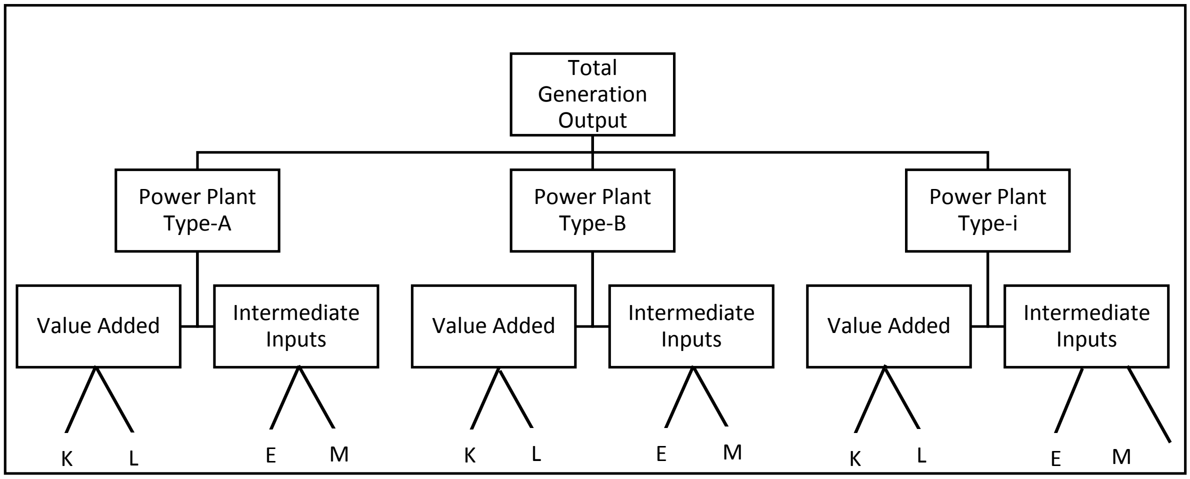
$$X_{i,EL} = \sum_{ACT \subset j \in A} X_{i,ACT}, \qquad i \in C, \quad EL \subset j \in A \tag{6}$$

In addition, since TD activity functions only as a network connection to dispatch the electricity generated from GEN activity, we do not separate ($X_{i,ACT}$) into energy and non-energy goods. In other words, we assume that the activity of TD does not require any specific quantity of each type of energy inputs.

5.4.3.3. Disaggregating The Activity of Electricity Generation (GEN) Account

In this section, we discuss the process of how to distinguish GEN activity into several power plant activities so that the SAM can actually characterize those electricity goods generated from multi-types power plant. Figure 5.4 presents the production structure of the electricity sector based on engineering (bottom-up) perspective. It shows that each type of generation plant utilizes the inputs of factors production (capital and labour) and intermediate commodities (energy and non-energy), to produce a homogenous electricity commodity.

Figure 5.4: Electricity Production Structure in Bottom-Up Perspective



Note: Capital (K), Labour (L), Energy (E), Other inputs (M)
Source: Sue Wing (2008): Author's modification

Based on Figure 5.4, we disaggregate the GEN activity account into a number of power plant types. Thus, QA_{GEN} is obtained from the sum of each generation technologies output (QA_{tech}) as follows:

$$QA_{GEN} = \sum_{tech \subset j \in A} QA_{tech} \tag{7}$$

Where QA_{GEN} is obtained from the shares of QA_{EL}:

$$QA_{GEN} = GEN\_shareQA_{EL} \tag{8}$$

Following the zero profit condition, the output produced from each QA_{tech} is equal to the sum of its inputs requirement (factors production ($FA_{f,tech}$) and intermediate goods ($X_{i,tech}$)):

$$QA_{tech} = \sum_{f \in F} FA_{f,tech} + \sum_{i \in C} X_{i,tech}\,, \qquad tech \subset j \in A \tag{9}$$

$$Q_{ELC} = \sum_{tech \subset j \in A} QA_{tech,ELC,} \qquad ELC \subset i \in C \tag{10}$$

Where QA_{tech} is the electricity production from $tech$-th type of power plant; $FA_{f,tech}$ and $X_{i,EL}$ are the respective f-th factors and i-th type of intermediate inputs used in the $tech$-th type of power plant. Equation (10) represents a multi-to-one relationship between QA_{tech} and its domestically commodity supply (Q_{EL}) (multi-activities but produce a single type of commodity).

QA_{tech}, $FA_{f,tech}$, and $X_{i,tech}$ are obtained from the respective shares of QA_{GEN}, $FA_{f,GEN}$, and $X_{i,GEN}$ as follows:

$$QA_{tech} = QA\_share_{tech} QA_{GEN}, \quad tech \subset j \in A \tag{11}$$

$$FA_{f,tech} = FA\_share_{f,tech} FA_{f,GEN}, \quad f \in F, \quad tech\&GEN \subset j \in A \tag{12}$$

$$X_{i,tech} = X\_share_{i,tech} X_{i,GEN} \quad , \quad i \in C, \quad tech\&GEN \subset j \in A \tag{13}$$

Where QA_share_{tech} is the share of output generated from each $tech$-th type of power plant; $FA\_share_{f,tech}$ is the share of production factors used in each $tech$-th type of power plant; and $X\_share_{i,tech}$ is the shares of intermediate goods used in each $tech$-th type of power plant.

To maintain the SAM balance, two conditions must be satisfied:

i) The sum of $FA_{f,tech}$ must be equal to f-th factors used in GEN activity ($FA_{f,GEN}$):

$$FA_{f,GEN} = \sum_{tech \subset j \in A} FA_{f,tech,} \qquad f \in F, \quad GEN \subset j \in A \tag{14}$$

ii) The sum of $X_{i,tech}$ must be equal to the i-th intermediate inputs used in the electricity sector ($X_{i,GEN}$):

$$X_{i,GEN} = \sum_{tech \subset j \in A} X_{i,tech} \qquad , i \in C, \quad GEN \subset j \in A \tag{15}$$

Furthermore, the activity of each power plant is characterized distinctly based on its primary energy input (fossil fuels), i.e. a coal-fired power plant requires greater quantities of coal material input compared to a hydro power plant. Thus, we categorize $X_{i,tech}$ into two classifications: primary energy (e) and non-primary energy (ne) material inputs.

Eq. 15 can then be extended as follows:

$$X_{e,GEN} = \sum_{tech \subset j \in A} X_{e,tech}, \qquad e \subset i \in C, \quad GEN \subset j \in A \tag{16a}$$

$$X_{ne,GEN} = \sum_{tech \subset j \in A} X_{ne,tech}, \qquad ne \subset i \in C, \quad GEN \subset j \in A \tag{16b}$$

5.4.3.4. Specifying The Natural Resources Input of Renewable Technologies

The conversion of primary energy inputs to generate electricity is restricted to conventional generating technologies, i.e. coal-fired power plant, gas-fired power plant, and diesel-fired power plant. Renewable types of power plants such as hydro, wind, and solar power plant do not utilize fossil inputs, but convert the inputs of so-called "fixed-factor" natural resources (such as water debits, wind speed, the intensities of photovoltaic cells, and so on) to electricity.

Although there is no reliable information to value these factors, their values should somehow be identified in the SAM. According to Wing (2008), these resources are defined as:

"Land area with incident insolation or atmospheric boundary-layer flow in the cases of solar and wind, topographically-determined hydrostatic potential in the case of hydroelectricity, or geologically-determined hot dry rock in the case of geothermal energy" (p. 563).

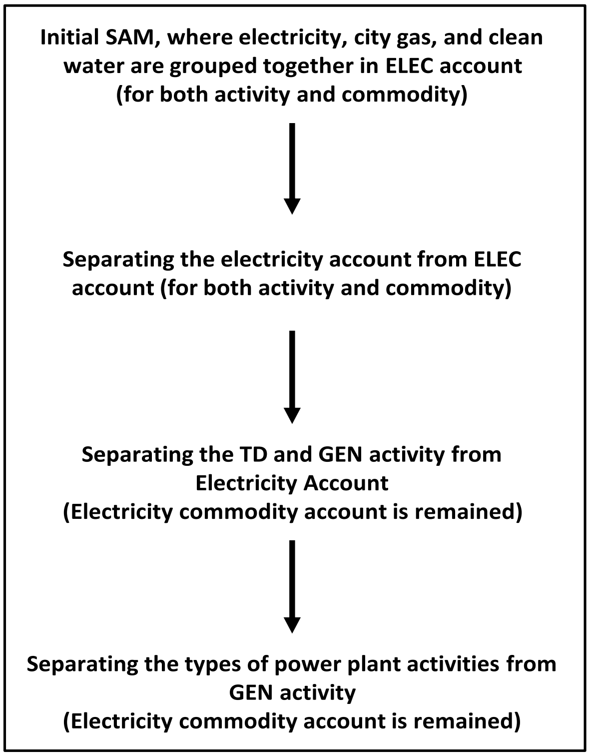
Wing (2008) suggests that the value of natural resources inputs should be estimated as a share of capital input. This is because the aggregated capital account in the SAM represents the non-labour or assets categories, i.e. land, machineries, and other equipment. We adopt this suggestion by assuming resources input shares of 5% of total capital costs among all fossil fuels as well as renewable technologies. Based on this assumption, the production factors in SAM are classified into three broad types: capital, labour, and natural resources.

5.4.3.5. The Availability and Limitations of Additional Databases

A number of statistical databases are needed to identify the above equations (eq. 1 – 16), i.e. the statistics of electricity input-output – including electricity production from each generation technology, that must be accurately matched to transaction flows given in SAM dataset. Unfortunately, no such information is available for specific factors and intermediate inputs expenditures to separate TD and GEN activities. Baughman and Bottaro (1976) stated that assessing the costs in TD activities is complex because they are related to numerous components such as constructions, mounting, voltage levels, geographic constraints, and other technical operations. Therefore, it is difficult to precisely determine the average costs of each equipment category. It indeed becomes more problematic to match this equipment to the relevant intermediate commodity in the SAM, i.e. the costs of electricity poles which made from steel and concrete should be grouped into the steel and cement raw materials accounts.

In this section, we discuss the available databases, their limitations, and the assumptions to solve the lack of data. The process to disaggregate the electricity account into TD and types of power plant activities is illustrated in Figure 5.5.

Figure 5.5: The Processes of Disaggregating Electricity Activity in SAM



In a preliminary process, we use the compiled data constructed by the National Energy Council (2011)[28] to separate the electricity account (for both activity and commodity) from the ELEC account. In the compiled data, the electricity sector already distinguishes into three classifications: (1) subsidized electricity; (2) non-subsidized electricity; and (3) hydro power plants. To obtain a single electricity account, these classifications are simply aggregated into a single account. We then estimate the cost shares of each input, i.e. production factors and intermediate inputs. These shares are then used to modify the transaction records of electricity account in the energy-SAM proportionally, by multiplying each of these shares to the electricity account of both activity and commodity in the Energy-SAM.

The second stage is to distinguish TD and GEN activities from electricity activity by following the framework given in subsection 5.4.3.2. In this treatment, we employ the available electricity statistics published by the state-owned power company (PLN (2009)), given in Table 5.7. This table presents the operational costs (in Rp. trillion) of each power plant and TD activity, i.e. the costs to purchase the additional power (including rent of diesel engines), fuel inputs, maintenance, labour wages, depreciation, and others.

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[28] This database is not public but is available on a request.

Table 5.7 presents two difficulties. First, the costs categories are not compatible with the input costs classified in SAM. To solve this problem, we map the electricity production cost categories given in Table 5.7 to the input categories in SAM (Table 5.8). We then assume that the cost shares approximation of each specification is applied equally with the relevant types of inputs (production factors and intermediate inputs). Although this assumption is justified roughly, it is necessary to permit this condition; otherwise, the equations given in previous section cannot be identified (Wing, 2008). As a result, we estimate the share costs in TD and GEN activities in year 2008 as follows:

1. The cost shares of intermediate commodity inputs ($X_{i,tech} \quad , i \in C, ACT \subset j \in A$):
   - Electricity: $X_{electricity,GEN} = 0$; $X_{electricty,TD} = X_{electricity,EL} \quad , electricity \subset i \in C$; $\{GEN, TD\} \in ACT \subset j \in A$
   - Types of primary energy (e): $X_{e,GEN} = 0.96X_{e,EL}; X_{e,TD} = 0.04X_{e,EL} \quad , e \subset i \in C$; $\{GEN, TD\} \in ACT \subset j \in A$
   - Other intermediate commodities: $X_{ne,GEN} = 0.73X_{ne,EL}$; $X_{ne,TD} = 0.27X_{ne,EL} \quad , e \subset i \in C$; $\{GEN, TD\} \in ACT \subset j \in A$
2. The cost shares of production factors ($FA_{f,tech} \quad , f \in F, ACT \subset j \in A$):
   - Capital: $FA_{K,GEN} = 0.75FA_{K,EL}; FA_{K,TD} = 0.25FA_{K,EL} \quad , K \subset f \in F, \{GEN, TD\} \in ACT \subset j \in A$
   - o-th types of labour: $FA_{o,GEN} = 0.15FA_{o,EL}; FA_{o,TD} = 0.85FA_{o,EL} \quad , o \subset f \in F, \{GEN, TD\} \in ACT \subset j \in A$

Table 5.7: The Operational Costs of GEN (Types of Plants) and TD Activities (in trillion Rp.)

Type of Activity	Additional Power Purchasing	Fuel input	Maintenance	Depreciation	Others	Employment	Total
1. Total GEN costs	-	103.31	5.57	8.55	0.50	1.29	119.22
2. Total TD costs	20.74	4.47	2.05	2.82	4.24	7.06	41.38
Total Electricity Costs	20.74	107.78	7.62	11.37	4.74	8.34	160.60
Shares of GEN costs	0	0.96	0.73	0.75	0.10	0.15	0.74
Shares of TD costs	1	0.04	0.27	0.25	0.90	0.85	0.26

Source: PLN Statistics, 2009; author modifications

Table 5.8: The Costs Specification Mapping

No.	Costs Specification of GEN and TD Activity Based on PLN Statistics (2009)	Costs Specification of GEN and TD Activity in SAM
1.	Additional electricity	Intermediate input: electricity
2.	Fuels	Intermediate input: types of primary energy
3.	Maintenance	Other intermediate inputs
4.	Depreciation	Production Factor: capital
5.	Employment	Production Factors: all types of labour

The second problem, as shown in Table 5.9, arises because the electricity statistics record a surplus between electricity receipt and its expenditure in year of 2008 by about Rp. 3.61 trillion. This deviation is obviously unmatched to the principal of SAM dataset where the total receipts should equal its corresponding expenditure. Table 5.10 illustrates the framework of separating GEN and TD activity accounts. It shows that there are discrepancies between total receiptd and expenditured in these activities ($QA_{ACT} \neq \sum_{f\in F} FA_{f,ACT} + \sum_{i\in C} X_{i,ACT}$, $ACT = \{GEN, TD\}$), which are expressed as follows:

i) $QA_{GEN} = 0.96X_{e,EL} + 0.73X_{ne,EL} + 0.75FA_{K,EL} + 0.15FA_{o,EL} = XX \neq XX'$

ii) $QA_{TD} = X_{electricity,,EL} + 0.04X_{e,EL} + 0.27X_{ne,EL} + 0.25FA_{K,EL} + 0.85FA_{o,EL}$
$= XY \neq XY'$

Where: $i = \{electricity, e, ne\} \in C$, and $f = \{K, o\} \in F$

Some modellers have proposed the SAM balancing method to achieve the square matrix account of the SAM, i.e. Wing (2008) and Hosoe *et al.* (2010) suggested the approach of minimizing the deviations of an adjusted cell value from the original one. However, this method can lead to changes in values among other cells in SAM and the results may be dubious since the original SAM has already been constructed by the help of matrix balancing method (Hosoe *et al.*, 2010). Therefore, we choose to maintain all other cell values original and assume that $XX = XX' + subsidy$ and $XY = XY'$. In other words, the total input costs of GEN (or TD) activity equals the total receipts of domestically GEN (or TD) supply.

Table 5.9: The Value Discrepancies of Electricity Receipt and Expenditure

Description	Trillion Rp.
Electricity Receipt	
Electricity Sales	84.25
Connecting Cost	0.59
Subsidy	78.58
Others	0.79
Total Receipt	164.21
Electricity Expenditure	
Additional Power Purchasing	20.74
Fuels	107.78
Maintenance	7.62
Employment	8.34
Depreciation	11.37
Others	4.74
Total Expenditure	160.60
Net Surplus	**3.61**

Source: PLN Statistics, 2009

Table 5.10: The Scheme Framework of Separating TD and GEN Activity

	Electricity Activity		Other Activities	Electricity Commodities	Other Commodities	Factors	Other Accounts	Total
	GEN Activity	TD Activity						
GEN Activity	-	-	-	XX'	-	-	(subsidy)	$XX' + subsidy$
TD Activity	-	-	-	XY'	-	-	-	XY'
Other Activities	-	-	-	-	Not change	-	-	Not change
Electricity Commodities	-	$X_{electricity,,EL}$	Not change	-	-	-	Not change	Not change
Primary Energy commodities	$0.96X_{e,EL}$	$0.04X_{e,EL}$	Not change	-	-	-	Not change	Not change
Other Commodities	$0.73X_{ne,EL}$	$0.27X_{ne,EL}$	Not change	-	-	-	Not change	Not change
Capital Factors	$0.75FA_{K,EL}$	$0.25FA_{K,EL}$	Not change	-	-	-	Not change	Not change
Types of Labour Factors	$0.15FA_{o,EL}$	$0.85FA_{o,EL}$	Not change	-	-	-	Not change	Not change
Other Accounts	-	-	-	Not change	Not change	Not change	Not change	Not change
Total	XX	XY	Not change	Not change	Not change	Not change	Not change	

Source: Own calculation

Finally, we disaggregate the types of power generation from GEN activity by operationalizing the methodology proposed in subsection 1.3. We use the statistics of power plants' operational costs published by the state-owned power company (PLN) (2009) presented in Table 5.11.

Table 5.11: Operational Costs of Power Plants (Trillion Rp)

Power Plants	Maintenance	Depreciation	Others	Employment	Total
Hydro Plant	0.23	0.83	0.05	0.18	1.41
Coal-fired Plant	1.07	2.73	0.12	0.28	31.27
Diesel-fired Plant	1.65	0.66	0.09	0.48	20.81
Gas-fired Plant	1.41	1.20	0.04	0.11	17.51
Geothermal Plant	0.05	0.20	0.01	0.06	2.53
Coal-Steam Plant	1.16	2.93	0.19	0.18	45.68
Total Generation Costs	5.57	8.55	0.50	1.29	119.22
Shares of Hydro Plant	0.04	0.10	0.10	0.14	0.01
Shares of Coal-fired Plant	0.19	0.32	0.24	0.22	0.26
Shares of Diesel-fired Plant	0.30	0.08	0.17	0.37	0.17
Shares of Gas-fired Plant	0.25	0.14	0.08	0.09	0.15
Shares of Geothermal Plant	0.01	0.02	0.02	0.05	0.02
Shares of Coal-Steam Plant	0.21	0.34	0.38	0.14	0.38
Total Shares	1.00	1.00	1.00	1.00	1.00

Source: PLN Statistics (2009); Author's modifications

The methods to disaggregate the generation technology are similar to that of the GEN and TD disaggregation. The types of operational costs for each generating technologies provided in statistics data are firstly mapped with the cost structure given in the SAM. However, since it is intuitively implausible to assume that the shares of fossil fuel inputs are equally applied to all type of generating technologies, we exclude these shares. Therefore, the cost shares of each input (except fossil fuel inputs) in the statistics are used to estimate the relevant input types used in each generation technology activity in the SAM.

On the other hand, to obtain the shares of fossil fuel inputs for each conventional technology, we use the statistics of fuel consumption by type of power plant published by the PLN statistics (2009) presented in Table 5.12.

Table 5.12: Fuel Inputs by Types of Power Plant

Fuel Input (unit)	Hydro Plant	Geothermal Plant	Coal-fired Plant	Gas-fired Plant	Gas-steamed Plant	Diesel-fired Plant	Total
Oil (kilolitres)	-	-	2.83	1.71	4.27	2.51	11.32
Coal (tons)	-	-	21.00	-	-	-	21.00
Natural Gas (mmscf)	-	-	0.01	0.02	0.15	-	0.18
Oil Shares	-	-	0.25	0.15	0.38	0.22	1.00
Coal Shares	-	-	1.00	-	-	-	1.00
Natural Gas Shares	-	-	0.05	0.11	0.84	-	1.00
Natural Resources Shares*	0.20	0.20	-	-	-	-	

Source: PLN Statistics, 2009; Author Modifications

**) Sue Wing (2008) justification*

Finally, we adopt Wing's (2008) assumption that the share of natural resources input for each renewable technology is 5% of the capital cost.

5.5. Conclusion

In this chapter, we constructed a hypothetical energy-SAM for the year 2008 which will be used to initialize the hybrid-CGE model for specific energy policies that is explained in detail in Chapter 6. This construction is done by disaggregating the types of energy sectors and factor of natural resources given in the existing Indonesian SAM in year 2008. To do so, we employ compiled data developed by the National Energy Council. However, since there are statistic discrepancies between the compiled data and the existing SAM, we opt to roughly approximate a number of values of energy accounts such that the energy-SAM is balanced. As a consistency check, we compare these results to the statistics of Indonesia's energy balance in the year 2008.

In the energy-SAM for Indonesia in year 2008, we also introduce a bottom-up framework for the electricity sector by explicitly incorporating the generation technology such that the energy-SAM can characterize the electricity production from multi-types of power plant (fossil fuels based generation, hydro generation, and geothermal generation). However, due to the limited information, we employ the cost shares approach to estimate each input cost needed to produce an electricity output from each of generation technology. The information of these cost shares is obtained from Indonesia's Electricity Statistics published by PLN (2009).

Chapter 6
The Extended CGE Model for Specific Energy Analysis

6.1. Introduction

The promotion of clean energy production is currently recognized as one of the top economic priorities of Indonesia’s government to combat climate change. Under the Copenhagen Accord (2009), the government has reiterated its commitments to reduce Indonesia’s greenhouse gas (GHG) emissions by 26% by 2020 and to boost the utilization of renewable energy by 25% of total energy production by 2025 (Ardiansyah *et al*., 2012). Generally, the expansion of clean energy production can be achieved based on two key strategies (or reforms). First, all types of renewable energy output – i.e. biofuel products and the electricity output produced from renewable power plants – are subsidised so that their production cost declines. And second, carbon taxes are levied on fossil fuels – i.e. gasoline, coal, gas, and electricity produced from conventional power plants – which contain pollutant emitter. These policy actions would, in turn, affect the economy’s equilibrium, thereby leading to supply and demand adjustments across commodities (Allan *et al*., 2008).

It is widely acknowledged that to investigate these impacts CGE models are more appropriate than partial equilibrium models (Allan *et al*., 2008; Orlov, 2012). Indeed, CGE models have become the best-known approach for economy-wide analysis of energy and climate issues at national or regional levels (Devarajan and Robinson, 2002; Allan *et al*., 2008; Beausejour *et al*., 1995; Bergman, 1990; Bohringer and Loschel, 2006; Conrad and Schroder, 1991; Goulder and Pizer, 2006; Lee and Roland-Holst, 1997; Conrad, 1999). CGE models have an advantage to investigate in detail the changes of representatives’ incomes and expenditure that result from the adjustments of various options such as carbon tax and energy pricing policies to reduce the level of carbon emissions in a particular region (Sue Wing, 2009). The can simultaneously characterize the equilibrium shifts of a particular economy in which market demand equals supply across all sectors. For example, by employing a CGE framework, the economy’s path of adjustment of increasing the level of renewable generations can be easily assessed (Allan *et al*., 2008). Therefore, we choose to employ a CGE framework to analyse the impacts of reducing CO_2 emissions in Indonesia under two different schemes: (i) increasing the clean energy production by introducing a feed-in tariff (subsidy); and (ii) introducing a carbon tax in order to reduce the production of fossil energy which strongly emits pollutants.

In this chapter, we discuss the construction of CGE model for specific energy analysis with emphasis on contracting the ‘dirty’ fuels and promoting zero-emission energy production. We specifically develop a hybrid CGE model that incorporates energy technologies – particularly power plants. This will enable us to identify the magnitude of the impact of different level of carbon taxes on fossil fuel (or subsidy on renewable energy) on Indonesia's economy. The hybrid CGE model is an extended version of the standard CGE model given in chapter 3. The modifications are briefly explained as follows:

(i) We distinguish the nested structure between energy and non-energy producing sectors by which we allow substitution between energy and production factors as well as substitution among energy types. These modifications are justified according to Hudson and Jorgenson (1974), Berndt and Wood (1975), and Griffin and Gregory (1976) studies who econometrically estimated that energy is substitutable with labour and capital. Furthermore, we classify the relationship between activity output (and price) and commodity supply (and price) for each set of industry. For example, in the fossil energy and non-energy producing industries we only permit a one-to-one relationship between activity and its relevant commodity. However, for the refinery industry, we allow the activity to produce multiple commodities (a single-to-multiple relationship). Finally, for the electricity generation industry, we allow a multi-to-single relationship where any power technology activity will produce a single type of commodity (electricity).

(ii) We incorporate carbon emission unit and its taxation features into the standard CGE model in order to assess the effects of carbon emission taxes on fossil fuel utilization by industries and representative agents[29]. However, following Deravajan *et al.* (2011), the terms of 'carbon emission' only refer to emissions of fossil fuels and its refined fuels; we exclude the emissions generated from other activities, i.e. land use in agriculture and deforestation. Furthermore, the carbon emission is generated from consumption on final energy goods such as household types and government as well as industries (used as the intermediate inputs or factor inputs).

The rest of this paper is organised as follows: Section 6.2 presents in detail the extended CGE model for energy analysis including the closure choices. The standard structure of output production given in Chapter 3 is modified by incorporating substitution possibilities between energy and production factors and also among energy types. We also feature the expressions of carbon emission and its taxation into the model. Nevertheless, the expressions of other representative agents' behaviours as well as trade aggregations and closures remain identical to the benchmark specifications. Finally, Section 6.3 presents the conclusions.

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[29] These approaches have been applied by numerous recent studies within the context of CGE modelling analysis for climate and energy policies. For instances, the Indonesia-E3 (Economy-Equity-Environment) model (Yusuf and Resosudarmo, 2007; Yusuf and Resosudarmo, 2008 and Yusuf and Ramayandi, 2008); GLOBE_EN (Energy) model (Mcdonald and Thierfeld, 2008); the modified STAGE model (Orlov *et al.*, 2013) and a modified CGE model developed by the International Food Policy Research Institute, IFPRI, (Devarajan *et al*., 2009 and Deravajan *et al*., 2011).

6.2. The Hybrid CGE Model

This section introduces the hybrid CGE model for specific energy analysis. It incorporates the specific energy flows across industries as well as carbon emissions and its taxation. This model is a modified version of the benchmark CGE model presented in Chapter 3; it is calibrated to the energy-SAM for 2008 given in Chapter 5. The economy's flow in the energy-CGE framework is identical to the benchmark model since it covers the system equations of representative behaviour; transfers among institutions; output production and linkages inter-industries; saving-investment balance; and treatments of traded goods and services.

6.2.1. Production of Gross Domestic Output

We employ nested functions to capture the structural characteristics of a specific industry to produce its output. According to Orlov *et al.* (2013), Paltsev *et al.* (2005), Burniaux *et al.* (1992), and Burniaux and Truong (2002), 'top-down' nested structures distinguish between energy (excluding electricity generation) and non-energy producing sectors. The differences are explained as follows.

For non-energy sectors, we allow two possibilities of energy substitution: inter-fuel substitution and fuel-factor substitution (between the energy composite and production factors). However, for the energy producing sectors – such as fossil fuels and refineries – we follow Burniaux and Truong (2002), in which a complementary function (Leontief) is assumed to reflect the relationship of inter-fuel and fuel-factor[30]. The nesting choice between capital and energy composite is arguably preferable than between labour and energy composite (Schoutheete, 2012). This is because the aggregation of energy and capital can indicate the new technologies embodied in capital goods to affect the trends of energy substitution and energy saving. Hence, it is assumed that firms choose to optimize the energy-capital bundle.

Furthermore, in the electricity sector, we apply a hybrid nested structure – combining the 'top-down' and 'bottom-up' perspectives – following Wing's (2006) approach where electricity activity is represented by an array of generation technologies (power plants). A hybrid model is aimed to take into account the aspects of technology substitution. Wing (2006) stated that incorporating the hybrid model into the CGE framework facilitates an accurate accounting for electricity production from conventional (fossil fuels) and renewables (hydro and geothermal) at the sub-sector level. The input requirements and output productions in each type of power technology can be separately identified (Wing, 2006).

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[30] The issue of energy-capital complementarity and substitutability has been a major controversy in some economic literatures of energy modelling (Allan *et al.*, 2008; Vinals, 1984; Burniaux *et al.*, 1992). However, we justify the non-substitution possibilities (complementarity) between inter-fuel and fuel-factor in non-energy producing sectors based on Burniaux and Truong (2002) and Orlov *et al* (2013) models.

The detailed modifications of nested structure for each set of producing sector are further explained below.

6.2.1.1. Non-Energy Producing Structure

The classifications of non-energy producing sectors are based on the Indonesia’s energy-SAM in year 2008. These sectors are: Agriculture Food Crops; Agriculture for Other Crops; Cattle and the Outcomes; Forestry and Hunting; Fishery; Other Mining and Excavations; Food, Drink, and Tobacco; Spinning, Textile, Garment, and Leather Industries; Wood and Goods from Wood; Paper, Printing, Transport Equipment, and Metal Products; Construction; Trade; Air, Sea, and Communication Supporting Services for Transportation and Warehouse; Bank and Assurance; Real Estate, and Private Services; Government and Defence, Education, Health, Film, and Other Social Services; Individual Services, Households, and Other Services; and electricity transmission (and distribution). We include the activity of electricity transmission (and distribution) as non-energy producing sector because this activity is only related to non-energy service (administration) management.

We modify Orlov *et al.* (2013) and Paltsev *et al.* (2005) to determine the nested structure of these sectors[31]. Figure 6.1 presents the nested structure of the non-energy producing sector. Generally, each non-energy producing industry generates its output by using intermediate inputs and production factors. We assume that producers will minimize these costs subject to the constraints imposed by production technology in a perfectly competitive market (marginal revenue equals marginal cost). The production technologies are specified using a CES function. The degree of input combinations depends on the elasticities that reflect the trade-offs between these inputs. Since this study does not econometrically estimate elasticities, we obtain them from the literature.

The nested structure for non-energy producing sectors is similar to that implemented in the standard model. The only difference is that we allow substitution for inter-fuel and energy aggregate-capital. Let the set of non-energy producing sectors is denoted by indices $j \in NE \subset A, \quad NE \cap Energy = \emptyset$.

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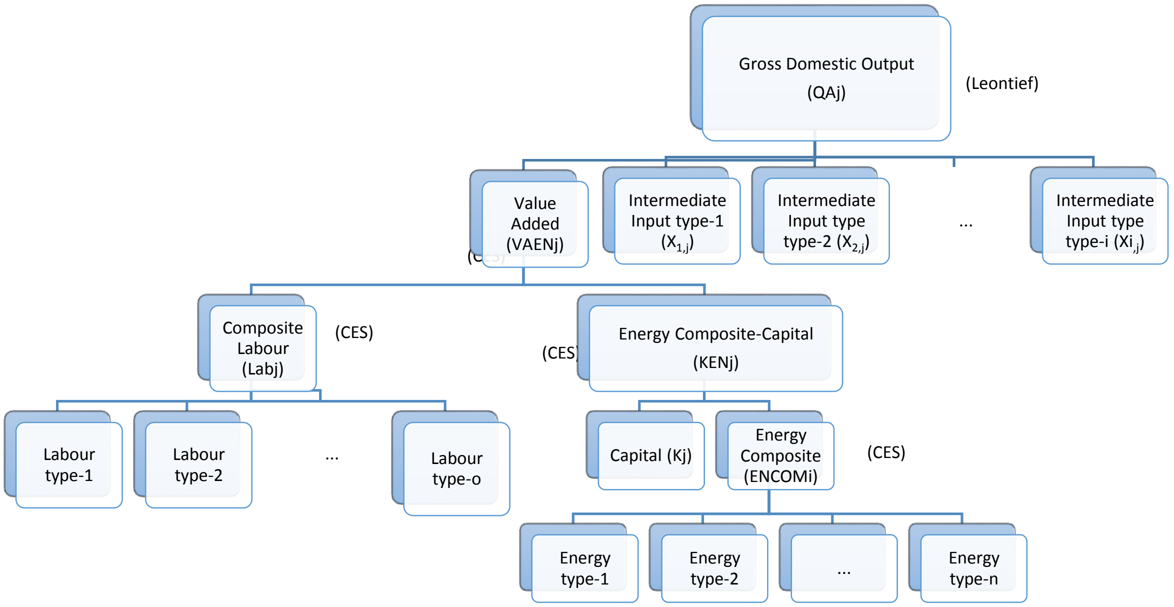
[31] Orlov *et al.* (2013) assumes the substitution possibilities between intermediate inputs and value added-energy composite. However, based on our justification, we presume that raw material inputs are not substitutable with the aggregate factors; it is more plausible to assume a complementarity relationship between these types of inputs. According to Allan *et al.* (2008), the judgment of choosing the combination of the nested production structure is considerably acceptable since none of these models have been actually tested for the chosen assumptions.

Figure 6.1: The Nested Structure for Non-Energy Producing Sectors ($j \in NE \subset A$)



At the top level, j-th non-energy domestic output is produced by a fixed coefficient (Leontief) function between intermediate commodities and the aggregate of value added-energy composite ($VAEN_j$). Because the Energy-SAM data set records subsidies given to the j-th industry, we add the level of subsidy rate $subA_j$ to the price of gross domestic output.

Let QA_j be the gross domestic output of j-th non-energy industry; i denotes the element of intermediate commodities, excluding energy inputs ($i \in NEC \subset C, NEC \cap Energy = \emptyset$), used in j-th non-energy industry; $X_{i,j}$ denotes the intermediate input of the i-th non-energy commodity used by the j-th non-energy industry; $ax_{i,j}$ denotes the coefficient of minimum requirements of the i-th non-energy intermediate input to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEN_j$ to produce one unit of QA_j; p_j^{VAEN} denotes the price of $VAEN_j$; and p_i^Z denotes the price of i-th final (composite) non-energy goods. We assume that the j-th industry produces QA_j by minimizing the cost inputs of $X_{i,j}$ and $VAEN_j$ following a Leontief production function:

Top stage:

$$\min_{VAEN_j, X_{i,j}} C_j = p_j^{VAEN} VAEN_j + \sum_{i \in NEC \subset C} p_i^Z \, X_{i,j} \,, \qquad j \in NE \subset A \tag{1'}$$

Subject to:

$$QA_j = min\left(\frac{X_{i,j}}{ax_{i,j}}, \frac{VAEN_j}{ava_j}\right), \qquad i \in NEC \subset C, \qquad j \in NE \subset A \qquad (2')$$

Equation (2’) implies that $X_{i,j} = ax_{i,j}QA_j$; and $VAEN_j = ava_jQA_j$. We rearrange equation (1’) as follows:

$$C_j = \left(p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j}\right) QA_j, \quad j \in NE \subset A$$

The subsidy rate on j-th production ($subA\_rate_j$) is added to the price index p_j^{QA} such that $C_j = (1 + subA\_rate_j)p_j^{QA}QA_j$. Hence, the relationships are given as follows:

$$X_{i,j} = ax_{i,j}QA_j, \qquad i \in NEC \subset C, \qquad j \in NE \subset A \qquad (1)$$

$$VAEN_j = ava_jQA_j, \qquad j \in NE \subset A \qquad (2)$$

$$(1 + subA\_rate_j)p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j}, \qquad j \in NE \subset A \qquad (3')$$

Furthermore, we redefine the variable of $subA\_rate_j$ into the average subsidy across activities ($subAArate$) and the specific subsidy rate of activity ($subArate_j$), which are obtained from the relationships below:

$$subAArate = \frac{1}{card(A)} \sum_{j \in NE \subset A} sub\_rateA_j$$

$$subA\_rate_j = subAArate\ (subArate_j), \qquad j \in NE \subset A$$

Thus, eq. (3’) is rewritten as follows:

$$\left(1 + (subAArate)\ (subArate_j)\right) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j},$$

$$j \in NE \subset A \qquad (3)$$

Equation (3) represents the unit cost of j-th non-energy industry to produce an output (QA_j) which is obtained from the weighted sum of the prices of value added-energy composite and intermediate commodities.

We define the relationship between the activity output (and price) and its relevant commodity supply (and price) as follows:

$$Q_i = \sum_{j \in NE \subset A} TRANS\_Coef_{j,i} QA_j, \qquad i \in NEC \subset C \qquad (4)$$

$$P_j^{QA} = \sum_{i \in NEC \subset C} TRANS\_Coef_{j,i} P_i^{Q}, \qquad j \in NE \subset A \tag{5}$$

Where:

$TRANS\_Coef_{j,i} = \frac{QQ_{j,i}}{QA_j}$, is the Input-Output coefficients; and

$QQ_{j,i}$: Output of the j-th non-energy activity for the i-th non-energy commodity.

Identically to the nesting structure in the standard model, for non-energy industries we allow a one-to-one relationship in which each activity produces a single type of commodity, thus $TRANS\_COEF_{j,i} = 1$.

At the second stage, the j-th non-energy industry minimizes the input cost combination of capital-energy composite and composite labour within a Cobb-Douglas function to produce the aggregate value added-energy composite ($VAEN_j$). Let P_j^{LAB} and P_j^{KEN} be the respective price of composite labour and capital-energy composite of j-th non-energy industry; LAB_j and KEN_j be the number of composite labour and capital-energy input of j-th non-energy industry respectively; $\delta_{LAB,j}$ be the share parameter of labour composite by j-th industry ($0 \leq \delta_{LAB,j} \leq 1$); $\delta_{KEN,j}$ be the share parameter of capital-energy composite by j-th industry ($0 \leq \delta_{KEN,j} \leq 1$); $\delta_{LAB,j} + \delta_{KEN,j} = 1$; and sva_j be the efficiency parameter of the j-th $VAEN$.

The j-th non-energy industry problem to minimize cost of $VAEN_j$ is therefore defined as follows:

Second stage:

$$\min_{Lab,KEN} \left(P_j^{LAB} LAB_j + P_j^{KEN} KEN_j\right), \qquad j \in NE \subset A$$

Subject to:

$$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \quad \delta_{LAB,j} + \delta_{KEN,j} = 1, \quad j \in NE \subset A \tag{6}$$

The solution of the above problem yields the j-th industry demand for capital-energy composite and composite labour:

$$KEN_j = \delta_{KEN,j} \frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j \in NE \subset A \tag{7}$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{P_j^{LAB}} VAEN_j, \qquad j \in NE \subset A \tag{8'}$$

The price index of value added P_j^{VAEN} is the unit cost of VAEN production and is obtained from a weighted sum of the price of composite labour and composite capital-energy:

$$P_j^{VAEN} = \frac{P_j^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \qquad j \in NE \subset A \qquad (9')$$

Next, we introduce the price adjustment terms of composite labour to enable its price variation across industries[32]. Thus, the price of composite labour across activities is defined as follows:

$$P_j^{LAB} = PDIST_j^{LAB} P^{LAB}$$

Where $PDIST_j^{LAB}$ is the adjustment factor for price of labour composite, and P^{LAB} is the aggregate price of labour composite, which together determine the activity level price of labour composite, P_j^{LAB}. We assume $P^{LAB} = 1$.

Based on the above definitions, equations (8' – 9') are rewritten as follows:

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j \in NE \subset A \qquad (8)$$

$$P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \qquad j \in NE \subset A \qquad (9)$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, we arbitrarily choose to eliminate eq. 9 in order to maintain balance between total equations and endogenous variables. Hence, the income-expenditure accounting identity in the supply-demand equilibrium system can be obtained.

At the third stage, we specify two kinds of aggregation. The labour composite is determined by a CES function over types of labour within a cost minimization problem. Let $L_{o,j}$ be the o-th type of labour used in j-th non-energy industry; p_o^L be the wage of o-th labour; $\gamma_{o,j}$ be the share parameter of o-th labour used by j-th industry $(0 \leq \gamma_{o,j} \leq 1)$; sl_j be the efficiency parameter of composite labour used by the j-th industry; and β_j be the substitution parameter of $L_{o,j}$ $(-1 \leq \beta_j \leq \infty,\ \beta_j \neq 0)$.

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[32] We do not introduce the price adjustment of the capital-energy composite because the eenergy composite is classified as goods inputs that are combined together with capital factor.

Third stage (Left Side):

$$\min_{L_{o,j}} \sum_{o \in LBR} p^L_{o,j} L_{o,j}\,, \qquad j \in NE \subset A$$

subject to:

$$LAB_j = \; sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad j \in NE \subset A \tag{10'}$$

By solving the above minimization problem, the labour demand solution for NE-th industry is given as follows:

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_j}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{P^L_{o,j}}{P^{LAB}_j} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR, \qquad j \in NE \subset A \tag{11'}$$

The price index of industry's composite labour (P^{LAB}_j) is obtained from the weighted sum of different types of o-th type of labour wage rates (P^L_o):

$$P^{LAB}_j = \frac{\sum_{o \in LBR} p^L_{o,j} L_{o,j}}{LAB_j}, \qquad j \in NE \subset A \tag{12'}$$

Denoting the elasticity of substitution by σ^L_j we have: $\beta_j = \frac{1}{\sigma^L_j} - 1$. The parameter value of β_j is obtained from Decaluwé *et al* (2012) since in this research we do not econometrically estimate this value. Tthe robustness of the results generated from using these values will be tested through a sensitivity analysis.

Here, we introduce the terms of labour wage adjustment to enable the variation of wages across activities. Thus, we need to define the additional variables, p^L_o and $PDIST^L_{o,j}$, such that: $p^L_{o,j} = PDIST^L_{o,j} p^L_o$ where $PDIST^L_{o,j}$ is the adjustment factor for the wage of labour type, and p^L_o is the aggregate wage of labour types which together determine the industry wage $p^L_{o,j}$.

Based on the energy-SAM data set, total supply of labour's type is obtained from total labour's demand to activities and abroad (L_ROW_o) as follows:

$$\sum_{j \in A} L_{o,j} + \; L_{o,ROW} + LU_o = LS_o, \qquad o \in LBR, \quad ROW \in INS$$

We assume there is unemployed labour LU_o. Thus, the aggregate wage of labour type is estimated as: $p^L_o = \frac{total\ labour\ type\ value\ in\ SAM}{LS_o}$.

We assume $p^L_{o,j} = 1$ and $P^L_{o,ROW} = p^L_o$. Thus $p^L_{o,j} = {}^{SAM(o,j)}\!\big/_{L_{o,j}}$ where $SAM(o,j) = L_{o,NE}$ and $SAM(o,ROW) = L\_ROW_o$.

To test the zero gaps, we estimate:

$Cost\_gap(o,j) = PDIST^L_{o,j} p^L_o L_{o,j} - SAM(o,j)$

Therefore, based on these definitions, equations (10' – 12') are rewritten as follows:

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad j \in NE \subset A,$$

$$\sum_{o \in LBR} \gamma_{o,j} = 1\,, \qquad \beta_j = \frac{1}{\sigma^L_j} - 1 \tag{10}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{PDIST^L_{o,j} P^L_o}{PDIST^{LAB}_j P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR, \quad j \in NE \subset A \tag{11}$$

$$PDIST^{LAB}_j P^{LAB} LAB_j = \sum\nolimits_{o \in LBR} PDIST^L_{o,j} P^L_o L_{o,j}\,, \qquad j \in NE \subset A \tag{12}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, one of the above equations is redundant. We arbitrarily choose to eliminate eq. 10 from the model specifications.

Furthermore, the aggregate of capital-energy composite is determined by a Cobb-Douglas function over capital and energy composite within a cost minimization problem. Let P^{ENCOM}_j and P^K_j be the respective price of composite energy and capital of j-th non-energy industry; $ENCOM_j$ and K_j be the inputs of composite energy and capital to j-th non-energy industry; $\chi_{ENCOM,j}$ be the share parameter of energy composite by j-th non-energy industry ($0 \le \chi_{ENCOM,j} \le 1$); $\chi_{K,j}$ be the share parameter of capital by j-th non-energy industry ($0 \le \chi_{K,j} \le 1$); $\chi_{ENCOM,j} + \chi_{K,j} = 1$; and $sken_j$ be the efficiency parameter of the j-th capital-energy composite. Hence, the j-th non-energy industry problem to minimize cost of aggregate capital-energy composite is estimated as follows:

Third stage (Right Side):

$$\min_{ENCOM,K} \left(P^{ENCOM}_j ENCOM_j + P^K_j K_j \right), \qquad j \in NE \subset A$$

Subject to:

$$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}} K_j^{\chi_{K,j}}, \qquad \chi_{ENCOM,j} + \chi_{K,j} = 1, \qquad j \in NE \subset A \qquad (13)$$

The solution of the above optimization problem yields the j-th industry demand for energy composite and capital:

$$ENCOM_j = \chi_{ENCOM,j} \frac{P_j^{KEN}}{P_j^{ENCOM}} KEN_j, \qquad j \in NE \subset A \qquad (14)$$

$$K_j = \chi_{K,j} \frac{P_j^{KEN}}{P_j^{K}} KEN_j, \qquad j \in NE \subset A \qquad (15')$$

The price index of the capital-energy composite P_j^{KEN} is the unit cost of capital-energy composite production, and is obtained from a weighted sum of the prices of energy composite and of capital:

$$P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + P_j^K K_j}{KEN_j}, \qquad j \in NE \subset A \qquad (16')$$

We introduce capital rent adjustment to obtain the specific capital rent across j-th non-energy industries. Thus, we need to define the additional variables: P^K and $PDIST_j^K$ such that: $P_j^K = PDIST_j^K P^K$ where $PDIST_j^K$ is the adjustment factor of capital rent, and P^K is the aggregate capital rent which together determine the j-th industry's level of capital rent, P_j^K.

Based on the energy-SAM data set, the total supply of capital stock is obtained from the sum of capital demand for activities and rest of world (ROW) (K_ROW) as follows:

$$KS = \sum_{j \in NE \subset A} K_j + K\_ROW$$

We assume there is no unemployed capital: $KU = 0$. Thus, the aggregate capital rent is obtained as: $P^K = \frac{total\ capital\ value\ in\ SAM}{KS}$.

However, due to lack information on real (physical) capital stock at specific activity (K_{NE}) and rest of world (ROW) (K_ROW) in the given year of Energy-SAM, we then assume that:

$$P_j^K = {}^{SAM(K,j)}\!\big/_{K_j} \text{ and } P_{ROW}^K = 1$$

where $SAM(K,j) = K_j$. Thus, P_j^K is equal to 1. To test these relationships, in the model we estimate the cost gap, which should be zero:

$$Cost\_GAP(K,j) = PDIST_j^K P^K K_j - SAM(K,j)$$

Therefore, based on above definitions, equations (15' – 16') are rewritten as follows:

$$K_j = \chi_{K,j} \frac{P_j^{KEN}}{PDIST_j^K P^K} KEN_j, \qquad j \in NE \subset A \tag{15}$$

$$P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + PDIST_j^K P^K K_j}{KEN_j}, \qquad j \in NE \subset A \tag{16}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' law condition, one of the above equations is redundant. We arbitrarily choose to eliminate eq. 16 from the model specifications.

Finally, at bottom stage, the energy composite is determined by a CES function over types of energy $(i \in energyc \subset C,\ NEC \cap Energyc = \emptyset)$ within a cost minimization problem. Let $X_{i,j}$ be the type of energy used in j-th non-energy industry; p_i^Z be the price of final energy goods; $\kappa_{i,j}$ be the share parameter of energy type used by j-th non-energy industry $(0 \le \kappa_{i,j} \le 1)$; sen_j be the efficiency parameter of energy composite used by the j-th non-energy industry; and ϕ_j be the substitution parameter of $X_{i,j}$ $(-1 \le \phi_j \le \infty, \phi_j \neq 0)$. In addition, in this stage we introduce the ad-valorem tax fuel[33], $TAXFUEL_{i,j}$ where:

$TAXFUEL_{i,j} = 0\ if\ i \in \{non-fuel\ types\} \subset energyc \subset C,$
$j \in NE \subset A;\ and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,$
$j \in NE \subset A$

Bottom Stage:

$$\min_{X_{i,j}} \sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}, \qquad j \in NE \subset A$$

subject to:

$$ENCOM_j = sen_j \left\{ \sum_{i \in energyc \subset C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}}, \qquad j \in NE \subset A \tag{17}$$

By solving the above minimization problem, the energy demand solution for j-th industry is as follows:

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[33] For detailed explanations of introducing the tax fuel, see sub section 6.2.2.2.

$$X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}}\right) ENCOM_j \left(\frac{\left(1+TAXFUEL_{i,j}\right)p_i^Z}{P_j^{ENCOM}}\right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$$

$$j \in NE \subset A \qquad (18)$$

The price index of industry's energy composite (P_j^{ENCOM}) is obtained from the weighted sum of different type of energy price (p_i^Z):

$$P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1+TAXFUEL_{i,j}\right)p_i^Z X_{i,j}}{ENCOM_j}, \qquad j \in NE \subset A \qquad (19)$$

Denoting the elasticity of substitution by σ_j^{energy} we have: $\phi_j = \frac{1}{\sigma_j^{energy}} - 1$. The parameter value of ϕ_j is obtained from Paltsev, *et al* (2005); Orlov (2012); and Orlov, *et al* (2013)). The robustness of the results generated from using these values will then be tested through a sensitivity analysis.

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, one of the above equations is redundant. We arbitrarily choose to eliminate eq. 19 from the model specifications.

6.2.1.2. Energy Producing Structure

We separate the types of energy producing industry into three subsets, namely: (i) primary energy (fossil fuel) including geothermal mining[34] ($j \in fossil \subset energy \subset A,\ energy \cap NE = \emptyset$); (ii) secondary energy (refinery products) ($j \in refinery \subset energy \subset A,\ energy \cap NE = \emptyset$); and (iii) generation technology (power plants) ($j \in elect \subset energy \subset A,\ energy \cap NE = \emptyset$). Hence, the nested structures for energy producing sectors are distinguished according to above subsets. Following Burniaux and Truong (2002), we assume a complementarity (Leontief) relationship between inter-fuel and capital-energy composite for all types of energy producing sectors.

6.2.1.2.1. Fossil Fuel Nested Structure

The nested structure for fossil fuel production is similar to the non-energy producing sector. The difference, is that we assume no substitution possibilities (Leontief function) between

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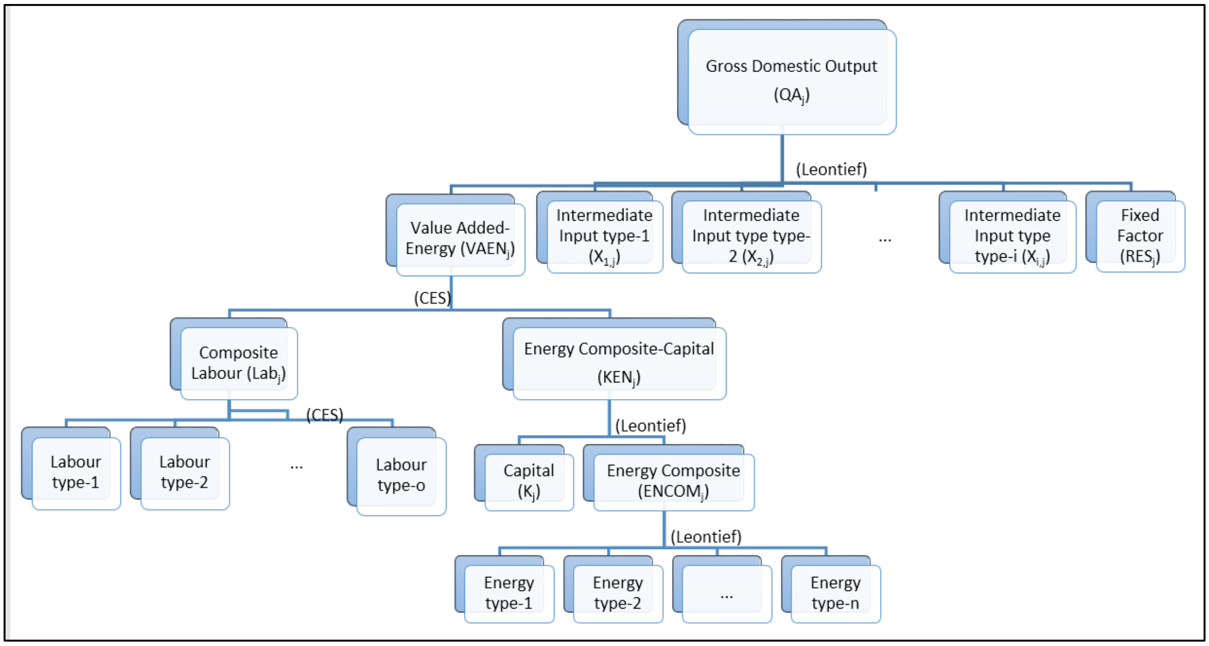
[34] Based on the compiled energy data set, geothermal activity is categorised as a mining activity where its production output is supplied to the geothermal power plant. Thus, because the production process of this mining activity is similar to that of fossil mining production structure – of which it requires the natural resources located beneath the land's soil – we grouped this activity with the fossil fuel production subset.

capital and energy composite as well as inter-fuel. We modify Orlov *et al* (2013) to determine the nested structure of these sectors. We allow a fixed factor of natural resources of each type of fossil fuel, i.e. oil resources factor for oil sector, coal resources for coal mining, and natural gas resources for gas mining. These factors characterize the resource constraints due to the fact that fossil output production is highly dependent on the availability of these resource stocks (RTI, 2008).

Figure 6.2 presents the nesting structure of fossil fuel sectors. The first two levels as well as the stage of labour composite in fossil fuel producing sectors are identical with those of non-energy producing sectors. The difference is that we include the fixed factor of natural resource at the top stage. Let the subset of fossil fuel producing sectors is denoted by indices ($j \in fossil \subset energy \subset A,\ energy \cap NE = \emptyset$).

Figure 6.2: The Nested Structure for Fossil Fuel Producing Industry
($j \in fossil \subset energy \subset A$)



Thus, at the top level, the domestic output of the j-th fossil industry is produced by a fixed coefficient (Leontief) function between intermediate non-energy commodities ($i \in NEC \subset C,\ NEC \cap energyc = \emptyset$), the aggregate of value added-energy composite ($VAEN_j$) and the fixed factor of resources (RES_j). By employing a similar approach for non-producing structures, the results are given as follows. Equations (20) – (22) determine the fixed proportion of non-energy intermediate inputs ($X_{i,j}$); value added-energy composite ($VAEN_j$); and fixed resources to produce the domestic output of j-th fossil industry (QA_j).

The subsidy rate on j-th fossil mining production, $(subAArate)$ $\left(subArate_j\right)$ is added to the price index p_j^{QA} such that $C_j = \left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA}\, QA_j$. Equation (23) represents the unit cost of j-th industry to produce QA_j which is obtained from the weighted sum of the prices of value added-energy composite, intermediate commodities, and the fixed factor.

$$X_{i,j} = ax_{i,j} QA_j\,, \qquad i \in NEC \subset C, \qquad j \in fossil \subset energy \subset A \tag{20}$$

$$VAEN_j = ava_j QA_j\,, \qquad j \in fossil \subset energy \subset A \tag{21}$$

$$RES_j = nat_j QA_j\,, \qquad j \in fossil \subset energy \subset A \tag{22}$$

$$\begin{aligned} &\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA} \\ &= p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j} + PDIST_j^{RES} p^{RES} nat_j, \\ &j \in fossil \subset energy \subset A \end{aligned} \tag{23}$$

Where $ax_{i,j}$ denotes the coefficient of minimum requirements of i-th non-energy intermediate input to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEN_j$ to produce one unit of QA_j; nat_j denotes the coefficient of minimum requirements of the natural resources RES_j; p_i^Z denotes the price of i-th final (composite) non-energy goods; p_j^{VAEN} denotes the price of $VAEN_j$; and p^{RES} denotes the factor price of RES_j.

Furthermore, we define the relationship between the j-th output (and price) and its relevant commodity supply (and price) as follows:

$$Q_i = \sum_{j \in fossil \subset energy \subset A} TRANS\_Coef_{j,i} QA_j\,, \qquad i \in fossilc \subset energyc \subset C \tag{24}$$

$$P_j^{QA} = \sum_{i \in fossilc \subset energyc \subset C} TRANS\_Coef_{j,i} P_i^Q\,, \qquad j \in fossil \subset energy \subset A \tag{25}$$

Where:

$TRANS\_Coef_{j,i} = \frac{QQ_{j,i}}{QA_j}$, are the Input-Output coefficients; and

$QQ_{j,i}$: Output of the j-th activity for the i-th commodity.

For fossil fuel industries we allow a one-to-one relationship in which each activity ($j \in fossil \subset energy \subset A$) produces a single type of its relevant commodity ($i \in fossilc \subset energyc \subset C$), thus $TRANS\_Coef_{j,i} = 1$.

At the second stage, the aggregate of value added-energy composite ($VAEN_j$) is defined by the two arguments of Cobb-Douglas function over capital-energy composite and composite labour; that is identical to that of non-energy producing structure. Hence, the results are given as follows. Equation (26) determines the constraint of $VAEN_j$ production. Equation (27) – (28) represent the solution of the $fossil$-th industry demand for capital-energy composite (KEN_j) and composite labour respectively (LAB_j). Equation (29) determines the price index of P_j^{VAEN} that is obtained from a weighted sum combination of price of composite LAB_j and KEN_j:

$$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}} \;, \delta_{LAB,j} + \delta_{KEN,j} = 1,$$
$$j \in fossil \subset energy \subset A \qquad (26)$$

$$KEN_j = \delta_{KEN,j} \frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j \in fossil \subset energy \subset A \qquad (27)$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j \in fossil \subset energy \subset A \qquad (28)$$

$$P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \qquad j \in fossil \subset energy \subset A \qquad (29)$$

Where P_j^{LAB} and P_j^{KEN} denotes the respective price of composite labour and capital-energy composite of j-th industry; $\delta_{LAB,j}$ denotes the share parameter of labour composite by j-th industry ($0 \leq \delta_{LAB,j} \leq 1$); $\delta_{KEN,fossil}$ be the share parameter of capital-energy composite by j-th industry ($0 \leq \delta_{KEN,j} \leq 1$); $\delta_{LAB,fossil} + \delta_{KEN,j} = 1$; sva_j be the efficiency parameter of the j-th $VAEN$; and $PDIST_j^{LAB}$ is the adjustment factor for price of composite labour. Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, we arbitrarily choose to eliminate eq. (29) such that the balance between total equations and endogenous variables can be obtained.

At the third stage, the labour composite (LAB_j) is determined by a CES function over labour types within a cost minimization problem which is identical to that of non-energy producing structure. Thus, the results are given as follows. Equation (30) determines the constraint of LAB_j production. Equation (31) represents the solution of the j-th industry demand for labour types ($L_{o,j}$). Equation (32) determines the price index of labour composite ($PDIST_j^{LAB} P^{LAB}$) that is obtained from a weighted sum combination of wage of labour types ($PDIST_{o,j}^{L} P_o^{L}$).

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad j \in fossil \subset energy \subset A,$$

$$\beta_j = \frac{1}{\sigma_j^l} - 1, \qquad \sigma_j^l > 1 \tag{30}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_{fossil}}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_{NE} \left(\frac{PDIST_{o,j}^{L} P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR,$$

$$j \in fossil \subset energy \subset A \tag{31}$$

$$PDIST_j^{LAB} P^{LAB} LAB_j = \sum\nolimits_{o \in LBR} PDIST_{o,j}^{L} P_o^L L_{o,j}, \qquad j \in fossil \subset energy \subset A \tag{32}$$

Where $\gamma_{o,j}$ is the share parameter of o-th labour used by j-th fossil industry ($0 \leq \gamma_{o,j} \leq 1$); sl_j is the efficiency parameter of composite labour used by the j-th fossil industry; and β_j be the substitution parameter of $L_{o,j}$ ($-1 \leq \beta_j \leq \infty,\ \beta_j \neq 0$). Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, we arbitrarily choose to eliminate eq. (32) to obtain the balance between total equations and endogenous variables. In addition, the parameter value of β_j is obtained from Decaluwé *et al* (2012). The robustness of the results generated from using these values will then be tested through a sensitivity analysis.

Furthermore, the aggregate of capital-energy composite is determined by a Leontief function over capital and energy composite within a cost minimization problem. Let KEN_j be the aggregate of capital-energy composite of j-th fossil industry; P_j^{ENCOM} and P_j^K be the respective price of composite energy and capital of j-th fossil industry; $ENCOM_j$ and K_j be the respective inputs of composite energy and capital to j-th fossil industry; ak_j denotes the coefficient of minimum requirements of capital input to produce one unit of KEN_j; and $aencom_j$ denotes the coefficient of minimum requirements of the $ENCOM_j$ to produce one unit of KEN_j. Hence, the j-th fossil industry problem to minimize cost of aggregate capital-energy composite is estimated as follows:

Third stage (Right Side):

$$\min_{K_j, ENCOM_j} C_j = p_j^K K_j + p_j^{ENCOM} ENCOM_j, \qquad j \in fossil \subset energy \subset A \tag{33'}$$

Subject to:

$$KEN_j = min\left(\frac{K_j}{ak_j}, \frac{ENCOM_j}{aencom_j}\right), \quad j \in fossil \subset energy \subset A \qquad (34')$$

Equation (34') implies that $K_j = ak_jKEN_j$; and $ENCOM_j = aencom_jKEN_j$. We rearrange equation (33') as follows:

$$C_j = \left(p_j^K ak_j + p_j^{ENCOM} aencom_j\right)KEN_j, \quad j \in fossil \subset energy \subset A$$

Hence, the relationships are given as follows:

$$K_j = ak_jKEN_j, \quad j \in fossil \subset energy \subset A \qquad (33)$$

$$ENCOM_j = aencom_jKEN_j, \quad j \in fossil \subset energy \subset A \qquad (34)$$

$$p_j^{KEN} = PDIST_j^K P^K ak_j + p_j^{ENCOM} aencom_j, \quad j \in fossil \subset energy \subset A \qquad (35)$$

Equation (35) represents the unit cost of j-th fossil industry to produce the aggregate capital-energy composite (KEN_j) which is obtained from the weighted sum of the prices of capital and energy composite.

Finally, at bottom stage, the energy composite is also determined by a Leontief function over types of energy commodity ($i \in energyc \subset C$) within a cost minimization problem. Let $X_{i,j}$ be the type of energy commodity used in j-th fossil industry; p_j^Z be the price of final energy goods; $ax_{i,j}$ denotes the coefficient of minimum requirements of each type of energy commodity input to produce one unit of energy composite, $ENCOM_j$. In this stage we introduce the ad-valorem tax on fuel, $TAXFUEL_{i,j}$ where:

$TAXFUEL_{i,j} = 0\ if\ i \in \{non - fuel\ types\} \subset energyc \subset C,$
$j \in fossil \subset energy \subset A;$
$and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C, \quad j \in fossil \subset energy \subset A$

Bottom Stage:

$$\min_{X_{i,j}} CENCOM_j = \sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j},$$

$$j \in fossil \subset energy \subset A \qquad (36')$$

Subject to:

$$ENCOM_j = min\left(\frac{X_{i,j}}{ax_{i,j}}\right), \quad i \in energyc \subset C,$$

$$j \in fossil \subset energy \subset A \qquad (37')$$

By rearranging equation (36’) we obtain:

$$CENCOM_j = \sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j}\, ENCOM_j,$$
$$j \in fossil \subset energy \subset A$$

Hence, the relationships are given as follows:

$$X_{i,j} = ax_{i,j} ENCOM_j, \qquad i \in energyc \subset C,\ \ j \in fossil \subset energy \subset A \qquad (36)$$

$$p_j^{ENCOM} = \sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j}\,,\ \ j \in fossil \subset energy \subset A \qquad (37)$$

Equation (37) represents the unit cost of j-th fossil mining industry to produce energy composite ($ENCOM_j$) which is obtained from the weighted sum of the prices of energy types.

6.2.1.2.2. Refinery Nested Structure

The nested production structure for refinery industry ($j \in refinery \subset energy \subset A$, $energy \cap NE = \emptyset$) is identical to that of fossil fuel industries. However, there are some differences.

The refinery industry depends strongly on crude oil input – generated from oil mining industry – to produce petroleum products which cannot be replaced by other types of intermediate inputs. However, it is not dependent on the fixed factor of oil resources (RTI, 2008). In the energy-SAM data set, there are 12 types of refinery products: bio-ethanol, bio-diesel, subsidised gasoline, subsidised bio-gasoline, kerosene, subsidised diesel, subsidised bio-diesel, non-subsidised bio-diesel, non-subsidised gasoline, subsidised LPG, non-subsidised LPG, LNG, and other oil products. Due to this principle, we modify the top stage of nested structure for fossil industries by excluding the fixed factor of natural resources input. But we are allowing the intermediate input of crude oil commodity – as the most essential input – in fixed proportion to produce petroleum products.

Therefore, at the top stage, the domestic output of the j-th refinery industry is produced by a fixed coefficient (Leontief) function of intermediate commodities (excluding energy types) ($i \in NEC \subset C$); the aggregate of value added-energy composite ($VAEN_j$); and the intermediate input of crude oil commodity. Again, by employing an approach similar to fossil fuel producing structures, the results are given as follows. Equation (38) – (40) determine the fixed proportion of intermediate inputs ($X_{i,j}$); value added-energy composite ($VAEN_j$); and the intermediate input of crude oil commodity to produce the domestic output of refinery industry (QA_j) respectively. Equation (41) represents the unit cost of refinery industry to produce QA_j

which is obtained from the weighted sum of the prices of value added-energy composite, intermediate commodities (excluding energy goods), and crude oil input[35].

$$X_{i,j} = ax_{i,j}QA_j, \quad i \in NEC \subset C, \quad j \in refinery \subset energy \subset A \tag{38}$$

$$VAEN_j = ava_j QA_j, \quad j \in refinery \subset energy \subset A \tag{39}$$

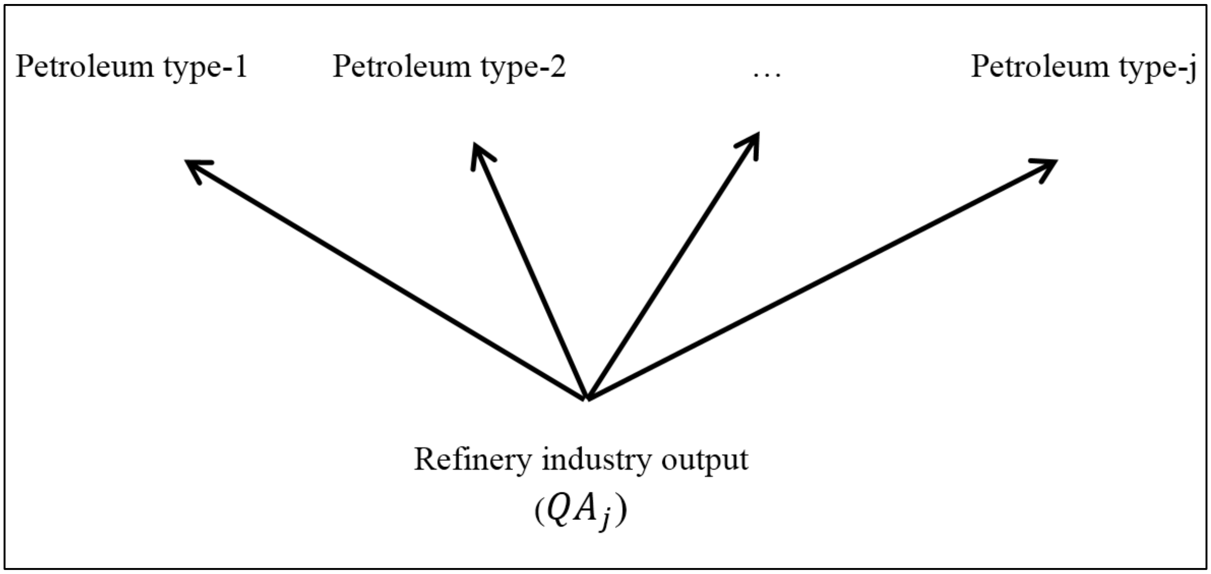
$$X_{oil,j} = ax_{oil,j}QA_j, \quad oil \in energy \subset C, \quad j \in refinery \subset energy \subset A \tag{40}$$

$$\Big(1 + (subAArate)\,\big(subArate_j\big)\Big) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j} + \big(1 + TAXFUEL_{oil,j}\big) p_{oil}^Z ax_{oil,refinery}, \quad oil \in energy \subset C \quad j \in refinery \subset energy \subset A \tag{41}$$

Where $ax_{i,j}$ denotes the coefficient of minimum requirements of non-energy intermediate input to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEN_j$ to produce one unit of QA_j; $ax_{oil,j}$ denotes the coefficient of minimum requirements of the crude oil input to produce one unit of QA_j; p_i^Z denotes the price of i-th final (composite) non-energy goods; and p_j^{VAEN} denotes the price of $VAEN_j$.

Furthermore, because refinery industry produces several types of petroleum products, hence we characterise a one-to-multiple relationship between activity output (and price) and its commodity supply (and price). Figure 6.3 illustrates the relationship between refinery's industry output and its petroleum products.

Figure 6.3: Structure of Petroleum Products



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[35] We impose the ad-valorem tax fuel to the use of crude oil.

In the model, we define the above relationship as follows:

$$Q_i = \sum_{j \in refinery \subset energy \subset A} TRANS\_Coef_{j,i} QA_j,$$
$$i \in refineryc \subset energyc \subset C \qquad (42)$$

$$P_j^{QA} = \sum_{i \in refineryc \subset energyc \subset C} TRANS\_Coef_{j,i} P_i^{Q}\,, \qquad j \in refinery \subset energy \subset A \quad (43)$$

Where:

$TRANS\_Coef_{j,i} = \frac{QQ_{j,i}}{QA_j}$, is the Input-Output coefficients; and

$QQ_{j,i}$: Output of the refinery activity for the i-th refinery commodity (petroleum product).

For refinery industry we allow a one-to-multi relationship in which each activity produces multi types of petroleum products, thus: $TRANS\_Coef_{j,i} \neq 1,\ \ j \neq i$.

The above equations (eq. (42) – (43)) determine the relationship between refinery activity output (single) and its multi commodity supplies. It is simply fixed shares relationship where there is no substitution among commodities allowed here.

Finally, of the last three stages (second – bottom stage), the specifications are similar to that of fossil fuel producing structures. The differences are by which we change the subset of '$fossil$' with '$refinery$'; and also taking the intermediate input of crude oil to be used at top stage of refinery producing structure. This rearrangement would plausibly portray the actual condition of which crude oil is used as raw material for refinery industry.

At second stage, the aggregate of value added-energy composite ($VAEN_j$) is defined by a two argument of Cobb-Douglas function over capital-energy composite and composite labour. Equation (44) determines the constraint of $VAEN_j$ production. Equation (45) – (46) represent the demand of the j-th refinery industry for capital-energy composite (KEN_j) and composite labour respectively (LAB_j). Equation (47) determines the price index of P_j^{VAEN} that is obtained from a weighted sum combination of price of composite LAB_j and KEN_j. Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, we arbitrarily choose to eliminate eq. (47) such that the balance between total equations and endogenous variables can be obtained.

$$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \qquad \delta_{LAB,j} + \delta_{KEN,j} = 1,$$
$$j \in refinery \subset energy \subset A \qquad (44)$$

$$KEN_j = \delta_{KEN,j} \frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j \in refinery \subset energy \subset A \tag{45}$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j \in refinery \subset energy \subset A \tag{46}$$

$$P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \qquad j \in refinery \subset energy \subset A \tag{47}$$

Where P^{LAB} and P_j^{KEN} is the respective price of composite labour and capital-energy composite of j-th refinery industry; $\delta_{LAB,j}$ is the share parameter of labour composite by j-th refinery industry ($0 \leq \delta_{LAB,j} \leq 1$); $\delta_{KEN,j}$ is the share parameter of capital-energy composite by j-th industry ($0 \leq \delta_{KEN,j} \leq 1$); $\delta_{LAB,j} + \delta_{KEN,j} = 1$; sva_j is the efficiency parameter of the j-th $VAEN$; and $PDIST_j^{LAB}$ is the adjustment factor for price of labour composite.

At the third stage (left side), the labour composite (LAB_j) is determined by a CES function over labour types within a cost minimization problem. The results are given as follows. Equation (48) determines the constraint of LAB_j production. Equation (49) represents the demand of the j-th refinery industry for labour types ($L_{o,j}$). Equation (50) determines the price index of labour composite ($PDIST_j^{LAB} P^{LAB}$) that is obtained from a weighted sum combination of wage of labour types ($PDIST_{o,j}^{L} P_o^L$). Due to Walras' Law condition, we arbitrarily choose to eliminate eq. (50) to obtain the balance between total equations and endogenous variables.

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad j \in refinery \subset energy \subset A,$$

$$\beta_j = \frac{1}{\sigma_j^l} - 1, \qquad \sigma_j^l > 1 \tag{48}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_{NE} \left(\frac{PDIST_{o,j}^{L} P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR,$$

$$j \in refinery \subset energy \subset A \tag{49}$$

$$PDIST_j^{LAB} P^{LAB} LAB_j = \sum\nolimits_{o \in LBR} PDIST_{o,j}^{L} P_o^L L_{o,j}, \; j \in refinery \subset energy \subset A \tag{50}$$

Where $\gamma_{o,j}$ is the share parameter of o-th labour used by j-th refinery industry ($0 \leq \gamma_{o,j} \leq 1$); sl_j is the efficiency parameter of composite labour used by the j-th refinery industry; and β_j be the substitution parameter of $L_{o,j}$ ($-1 \leq \beta_j \leq \infty, \beta_j \neq 0$).

Furthermore, at the third stage (right side), the aggregate of capital-energy composite is determined by a Leontief function over capital and energy composite within a cost minimization problem. Let KEN_j be the aggregate of capital-energy composite of j-th refinery industry; P_j^{ENCOM} and P^K be the respective price of composite energy and capital of j-th refinery industry; $ENCOM_j$ and K_j be the respective inputs of composite energy and capital to j-th refinery industry; ak_j be the coefficient of minimum requirements of capital input to produce one unit of KEN_j; and $aencom_j$ be the coefficient of minimum requirements of the $ENCOM_j$ to produce one unit of KEN_j. Hence, the results are given as follows.

Equation (51) – (52) represent the capital (K_j) and energy composite ($ENCOM_j$) used by j-th refinery industry, respectively. Equation (53) represents the unit cost of j-th refinery industry to produce the aggregate capital-energy composite (KEN_j) which is obtained from the weighted sum of the prices of capital and energy composite.

$$K_j = ak_j KEN_j, \qquad j \in refinery \subset energy \subset A \tag{51}$$

$$ENCOM_j = aencom_j KEN_j, \qquad j \in refinery \subset energy \subset A \tag{52}$$

$$p_j^{KEN} = PDIST_j^K P^K ak_j + p_j^{ENCOM} aencom_j, \qquad j \in refinery \subset energy \subset A \tag{53}$$

Finally, at the bottom stage, the energy composite is also determined by a Leontief function over types of energy within a cost minimization problem. Let $X_{i,j}$ be the type of energy used ($i \in energyc \subset C$) in j-th refinery industry; p_i^Z be the price of final energy goods; $ax_{i,j}$ denotes the coefficient of minimum requirements of each type of energy input to produce one unit of energy composite, $ENCOM_j$. In addition, in this stage we introduce the ad-valorem tax fuel, $TAXFUEL_{i,j}$ where:

$$TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel\; types\} \subset energyc \subset C,$$
$$j \in refinery \subset energy \subset A;$$
$$and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel\; types\} \subset energyc \subset C,$$
$$j \in refinery \subset energy \subset A$$

The results are given as follows. Equation (54) represents the energy used by j-th industry. Equation (55) represents the unit cost of j-th industry to produce energy composite ($ENCOM_j$) which is obtained from the weighted sum of the prices of energy types.

$$X_{i,j} = ax_{i,j} ENCOM_j, \qquad i \neq oil \in energyc \subset C,$$

$$j \in refinery \subset energy \subset A \tag{54}$$

$$\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{ENCOM} = \sum_{i \neq oil \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j,}$$

$$j \in refinery \subset energy \subset A \tag{55}$$

6.2.1.2.3. Electricity Generation Structure

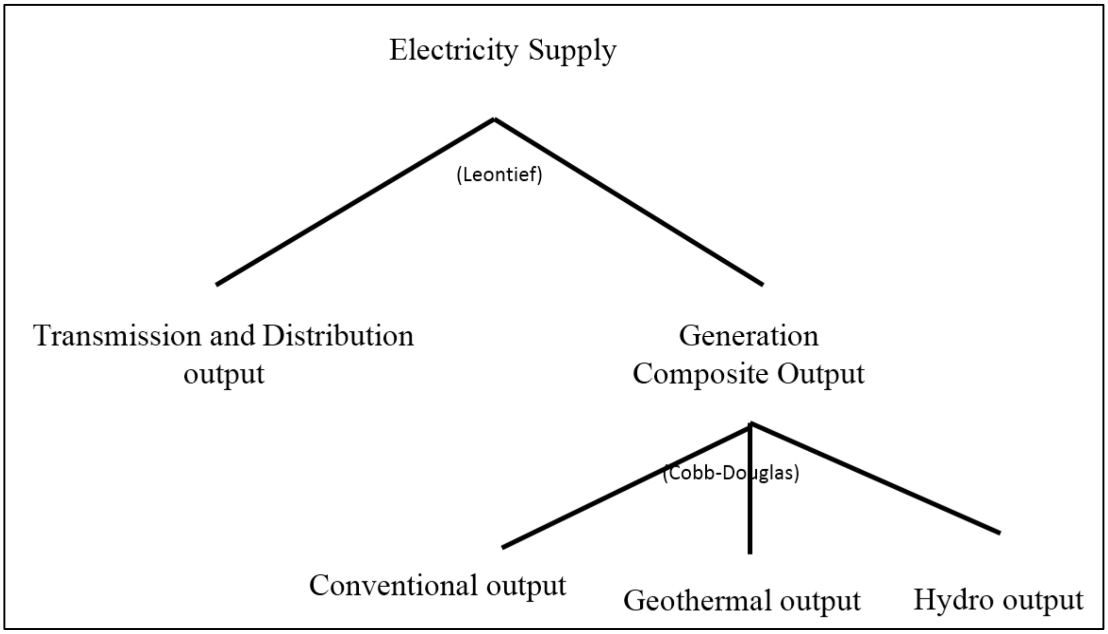
The expansion of clean energy technology has been expected as a crucial factor in mitigating the future climate change (Wing, 2006). Wing (2004) addressed that within the CGE framework analysis, the largest drop on carbon emissions will come from the electricity sector. This section attempts to introduce the nested structure of electricity generation in detail.

In the traditional SAM data set, the account of electricity sector is obtained from the aggregation of three related activities: generation, transmission, and distribution (Wing, 2006). Generation activity comprises of types of electricity technology that use inputs of production factors and specific fuels (or renewable resources) to generate electricity output; whilst, transmission and distribution are related to non-energy service activities (Wing, 2006).

Following Wing (2006) we employ a hybrid modeling approach – integrating top-down macroeconomic models and bottom-up engineering models – in which we disaggregate the electricity sector into activities of transmission (and distribution) and electricity technologies: conventional fossil, geothermal and hydro power plant. These technologies are chosen based on the available Indonesian Energy-SAM in year 2008. We do not include other generation technologies such as solar, nuclear, wind, and so on because these generations were not existed in the base year data set.

Figure 6.4 illustrates the production process of the j-th electricity industry ($j \in elect \subset energy \subset A$) to generate the homogenous electricity supply. The electricity supply is determined from the fixed shares of transmission (and distribution) and generation composite output. Whilst, the generation composite output ($GEN_j,\ \ j \in tech \subset elect \subset energy \subset A$) is defined by three arguments of Cobb-Douglas function over conventional, geothermal, and hydro power plants.

Figure 6.4: Structure of Electricity Sector



We use the Leontief function to define the relationship between the activities of transmission (and distribution) and generation composite output (and price) and their relevant electricity supply (and price) as follows. Equation (56) represents the fixed shares of transmission (and distribution) output to electricity supply. Equation (57) represents the fixed shares of generation composite output to electricity supply. Equation (58) represents the price of electricity supply which is obtained from the weighted sum of the prices of transmission (and distribution) and generation composite:

$$TAD_i = atd_i Q_i, \qquad i \in electc \subset energyc \subset C \tag{56}$$

$$GEN_i = agen_i Q_i, \qquad i \in electc \subset energyc \subset C \tag{57}$$

$$p_i^Q = p_i^{TAD} atd_i + p_i^{GEN} agen_i, \qquad i \in electc \subset energyc \subset C \tag{58}$$

where TAD_i is the electricity supplied from the transmission (and distribution) activity output; GEN_i be the electricity supplied from the generation composite activity output; atd_i be the fixed coefficient of TAD_i; and $agen_i$ is the fixed coefficient of GEN_i; p_i^{TAD} and p_i^{GEN} be the respective price of TAD_i and GEN_i; Q_i and p_i^Q is the quantity and price of electricity supply, respectively.

To determine the relationship between electricity activities output (multi-types) and its homogenous electricity supply (single type), we apply a fixed share by Leontief function (Eq. 56 – 58) instead of using a standard input-output coefficient – i.e. by employing the $TRANS\_Coef_{j,i}$ – into above. In other words, the standard input-output approach may not be available in the case of introducing the hybrid model in electricity generation since we have to define the aggregated power plant outputs (equation (57)).

However, by implementing the usual Leontief function like above we can actually define the fixed shares of generation composite load: aggregated electricity outputs from conventional, geothermal, and hydro power plants. The fixed shares will then be determined by the relationship of $GEN_i = agen_i Q_i,\ i \in electc \subset energyc \subset C$.

Furthermore, the generation activity minimizes the production cost of its power plants – conventional, geothermal, and hydro – within a simplified CES function, a Cobb-Douglas function, to produce the load composite output (GEN_i)[36]. Equation (59) represents the constraint of generation composite load.

$$\min_{QA_{j,i}} \sum_{j \in tech \subset elect \subset energy \subset A} P_{j,i}^{QA} QQA_{j,i}, \qquad i \in electc \subset energyc \subset C$$

Subject to:

$$GEN_i = sgen_i \prod_{j \in tech \subset elect \subset energy \subset A} QQA_{j,i}^{\delta_{j,i}} \quad , \qquad \sum_{j \in tech \subset elect \subset energy \subset A} \delta_{j,i} = 1,$$
$$i \in electc \subset energyc \subset C \tag{59}$$

The solution of the above problem yields the optimum load of each type of generation technology:

$$QQA_{j,i} = \delta_{j,i} \frac{p_i^{GEN}}{P_{j,i}^{QQA}} GEN_i, \qquad j \in tech \subset elect \subset energy \subset A,$$
$$i \in electc \subset energyc \subset C \tag{60}$$

The price index of the generation composite load p_i^{GEN} is the unit cost of GEN_i production and is obtained from a weighted sum combination of the prices of each generation technology:

$$P_i^{GEN} = \frac{1}{GEN_i} \sum_{j \in tech \subset elect \subset energy \subset A} P_{j,i}^{QQA} QQA_{j,i}, \qquad i \in electc \subset energyc \subset C \tag{61}$$

Where $P_{j,i}^{QQA}$ and $QQA_{j,i}$ denote the price and quantity of each generation load supply, respectively; p_i^{GEN} and GEN_i denote the price and quantity of generation composite load; $\delta_{j,i}$ is the share parameter of each generation load supply ($0 \le \delta_{j,i} \le 1\ , \sum_{tech \in A} \delta_{tech,electc} = 1$); and $sgen_i$ is the efficiency parameter of generation composite load. Walras law states that the

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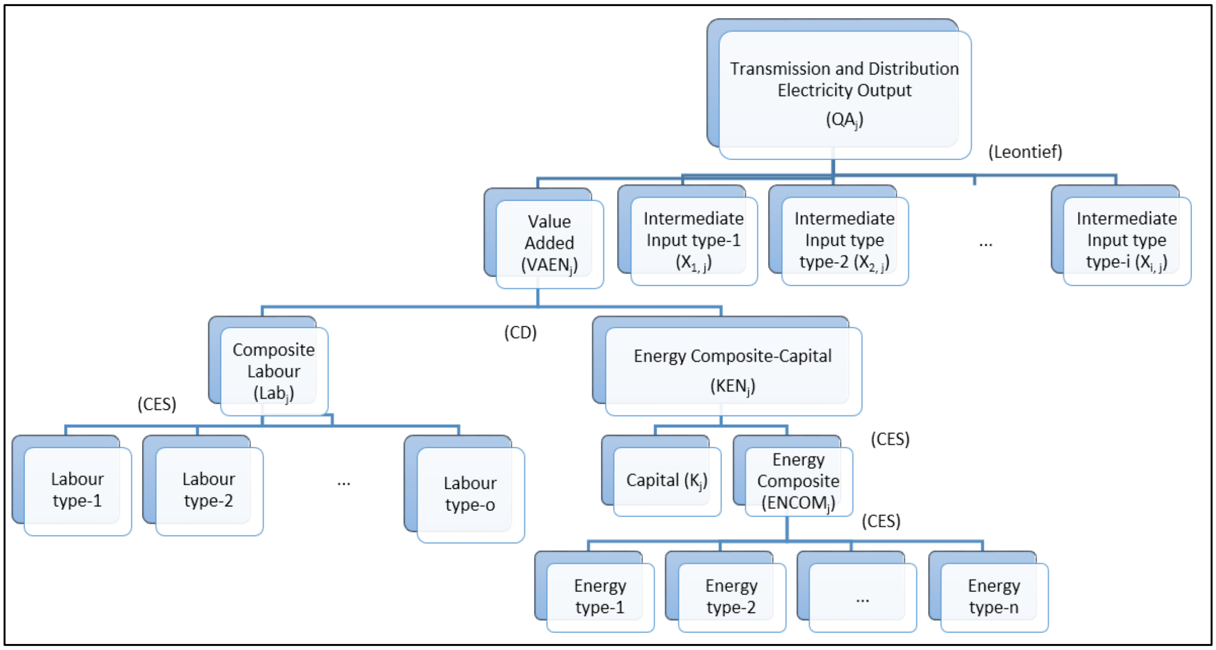
[36] Due to a lack of information, we assume that the CES parameter of substitutions among these technologies is limited to zero ($\rho \to 0$) such that the elasticity of substitution is unity ($\sigma = \frac{1}{1+\rho} = 1$). This function is generally a Cobb-Douglas function.

equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law, we arbitrarily choose to eliminate eq. (59) to obtain the balance between total equations and endogenous variables. Thus, the optimum generation load of electricity supply from each technology – i.e. conventional, geothermal, and hydro plants – is estimated from equations (59 – 61).

A. Transmission and Distribution

The detailed production structure of transmission (and distribution) is represented in Figure 6.5. Since the activities of transmission and distribution are related only to non-energy services, we assume that the production structure is similar to that of non-energy producing sectors. Therefore, the specifications for all stages (top – bottom stage) of this activity are identical to the non-energy producing structures.

Figure 6. 5: Structure of Transmission (and Distribution) Activity
($j \in TD \subset elect \subset energy \subset A$)



At the top stage, the domestic output of transmission (and distribution) industry (QA_j) is produced by a fixed coefficient (Leontief) function of non-energy intermediate inputs and the aggregate of value added-energy composite ($VAEN_j$). By employing similar approach of non-energy producing structures, the results are given as follows. Equation (62) – (63) determine the fixed proportion of intermediate inputs ($X_{i,j}$) and value added-energy composite ($VAEN_j$), respectively. Whilst, equation (64) represents the unit cost of transmission (and distribution) industry to produce QA_j which is obtained from the weighted sum of the prices of value added-energy composite and non-energy intermediate inputs.

$$X_{i,j} = ax_{i,j}QA_j, \qquad i \in NEC \subset C, \qquad j \in TD \subset elect \subset energy \subset A \tag{62}$$

$$VAEN_j = ava_jQA_j, \qquad j \in TD \subset elect \subset energy \subset A \tag{63}$$

$$\Big(1 + (subAArate)\,\big(subArate_j\big)\Big)\,p_j^{QA} = p_j^{VAEN}ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j},$$
$$j \in TD \subset elect \subset energy \subset A \tag{64}$$

Where $ax_{i,j}$ denotes the coefficient of minimum requirements of i-th non-energy intermediate input to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEN_j$ to produce one unit of QA_j; p_i^Z denotes the price of i-th final (composite) non-energy goods; and p_j^{VAEN} denotes the price of $VAEN_j$.

At the second stage, the aggregate of value added-energy composite ($VAEN_j$) is defined by a two argument of Cobb-Douglas function over capital-energy composite and composite labour. Equation (65) determines the constraint of $VAEN_j$ production. Equation (66) – (67) represent the demand of the j-th transmission (and distribution) industry for capital-energy composite (KEN_j) and composite labour respectively (LAB_j). Equation (68) determines the price index of P_j^{VAEN} that is obtained from a weighted sum combination of price of composite LAB_j and KEN_j. Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law condition, we arbitrarily choose to eliminate eq. (68) for balancing the total equations and endogenous variables.

$$VAEN_j = sva_jLAB_j^{\delta_{LAB,j}}KEN_j^{\delta_{KEN,j}}, \qquad \delta_{LAB,j} + \delta_{KEN,j} = 1,$$
$$j \in TD \subset elect \subset energy \subset A \tag{65}$$

$$KEN_j = \delta_{KEN,j}\frac{P_j^{VAEN}}{P_j^{KEN}}VAEN_j, \qquad j \in TD \subset elect \subset energy \subset A \tag{66}$$

$$LAB_j = \delta_{LAB,j}\frac{P_j^{VAEN}}{PDIST_j^{LAB}P^{LAB}}VAEN_j, \qquad j \in TD \subset elect \subset energy \subset A \tag{67}$$

$$P_j^{VAEN} = \frac{PDIST_j^{LAB}P^{LAB}LAB_j + P_j^{KEN}KEN_j}{VAEN_j}, \qquad j \in TD \subset elect \subset energy \subset A \tag{68}$$

Where P^{LAB} is the respective price of composite labour and P_j^{KEN} is the price of capital-energy composite of the j-th transmission (and distribution) industry; $\delta_{LAB,j}$ is the share parameter of labour composite by the j-th transmission (and distribution) industry ($0 \leq \delta_{LAB,j} \leq 1$); $\delta_{KEN,j}$ is the share parameter of capital-energy composite by the j-th industry ($0 \leq \delta_{KEN,j} \leq 1$); $\delta_{LAB,j} + \delta_{KEN,j} = 1$; sva_{TD} is the efficiency parameter of the j-th $VAEN$; and $PDIST_j^{LAB}$ is the adjustment factor for price of labour composite.

At the third stage (left side), the labour composite (LAB_j) is determined by a CES function over labour types within a cost minimization problem. Equation (69) determines the constraint of LAB_j production. Equation (70) represents the demand of the j-th industry for labour types ($L_{o,j}$). Equation (71) determines the price index of labour composite ($PDIST_j^{LAB} P^{LAB}$) that is obtained from a weighted sum combination of wage of labour types ($PDIST_{o,j}^{L} P_o^L$). Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we choose to eliminate eq. (69) to obtain the balance between total equations and endogenous variables.

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \qquad \sum_{o \in LBR} \gamma_{o,j} = 1, \qquad \beta_j = \frac{1}{\sigma_j^L} - 1,$$
$$j \in TD \subset elect \subset energy \subset A \tag{69}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{PDIST_{o,j}^{L} P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR,$$
$$j \in TD \subset elect \subset energy \subset A \tag{70}$$

$$PDIST_j^{LAB} P^{LAB} LAB_j = \sum\nolimits_{o \in LBR} PDIST_{o,j}^{L} P_o^L L_{o,j},$$
$$j \in TD \subset elect \subset energy \subset A \tag{71}$$

Where $\gamma_{o,j}$ is the share parameter of o-th labour used by j-th industry ($0 \leq \gamma_{o,j} \leq 1$); sl_j is the efficiency parameter of composite labour used by the j-th industry; and β_j be the substitution parameter of $L_{o,j}$ ($-1 \leq \beta_j \leq \infty,\ \beta_j \neq 0$).

At the third stage (right side), the aggregate of capital-energy composite is determined by a Cobb-Douglas function over capital and energy composite within a cost minimization problem. Let P_j^{ENCOM} and P_j^K be the respective price of composite energy and capital of j-th industry; $ENCOM_j$ and K_j be the inputs of composite energy and capital to j-th transmission (and distribution) industry; $\chi_{ENCOM,j}$ be the share parameter of energy composite by j-th industry ($0 \leq \chi_{ENCOM,j} \leq 1$); $\chi_{K,j}$ be the share parameter of capital by j-th industry ($0 \leq$

$\chi_{K,j} \leq 1$); $\chi_{ENCOM,j} + \chi_{K,j} = 1$; and $sken_j$ be the efficiency parameter of the j-th capital-energy composite. Hence, the results are given as follows.

Equation (72) represents the constraint of aggregated capital-energy composite (KEN_j). Equation (73) – (74) represent the demand solution of energy composite ($ENCOM_j$) and capital (K_{TD}) used by j-th industry, respectively. Equation (75) represents the unit cost of j-th transmission (and distribution) industry to produce the aggregate capital-energy composite (KEN_j) which is obtained from the weighted sum of the prices of capital and energy composite. Equation (75) is eliminated due to Walras' Law.

$$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}} K_j^{\chi_{K,j}}, \qquad \chi_{ENCOM,j} + \chi_{K,j} = 1,$$

$$j \in TD \subset elect \subset energy \subset A \tag{72}$$

$$ENCOM_j = \chi_{ENCOM,j} \frac{P_j^{KEN}}{P_j^{ENCOM}} KEN_j, \qquad j \in TD \subset elect \subset energy \subset A \tag{73}$$

$$K_j = \chi_{K,j} \frac{P_j^{KEN}}{PDIST_j^K P^K} KEN_j\,, \qquad j \in TD \subset elect \subset energy \subset A \tag{74}$$

$$P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + PDIST_j^K P^K K_j}{KEN_j}, \qquad j \in TD \subset elect \subset energy \subset A \tag{75}$$

Finally, at the bottom stage, the energy composite is determined by a CES function over types of energy ($i \in energyc \subset C$) within a cost minimization problem. Let $X_{i,j}$ be the type of energy used in j-th transmission (and distribution) industry; p_i^Z be the price of final energy goods; $\kappa_{i,j}$ be the share parameter of energy type used by j-th industry ($0 \leq \kappa_{i,j} \leq 1$); sen_j be the efficiency parameter of energy composite used by the j-th industry; and ϕ_j be the substitution parameter of $X_{i,j}$ ($-1 \leq \phi_j \leq \infty, \phi_j \neq 0$). In addition, in this stage we introduce the ad-valorem tax fuel, $TAXFUEL_{i,j}$ where:

$TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel \; types\} \subset energyc \subset C,$

$j \in TD \subset elect \subset energy \subset A;$

$and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel \; types\} \subset energyc \subset C,$

$j \in TD \subset elect \subset energy \subset A$

The results are given as follows. Equation (76) represents the constraint of energy composite used by j-th transmission (and distribution) industry. Equation (77) represents the demand solution of energy types used by j-th transmission (and distribution) industry. Equation (78) represents the unit cost of j-th transmission (and distribution) industry to produce energy composite ($ENCOM_j$) which is obtained from the weighted sum of the prices of energy types.

$$ENCOM_j = senergy_j \left\{ \sum_{i \in energyc \subset C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}},$$

$$j \in TD \subset elect \subset energy \subset A \qquad (76)$$

$$X_{i,j} = \left(\frac{\kappa_{i,j}}{senergy_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$$

$$j \in TD \subset elect \subset energy \subset A \qquad (77)$$

$$P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j},$$

$$j \in TD \subset elect \subset energy \subset A \qquad (78)$$

Denoting the elasticity of substitution by σ_j^{energy} we have: $\phi_j = \frac{1}{\sigma_j^{energy}} - 1$. The parameter value of ϕ_j is obtained from Paltsev, *et al* (2005); Orlov (2012); and Orlov, *et al* (2013). The robustness of the results generated from using these values will then be tested through a sensitivity analysis.

One of the above equations is redundant. Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' law, we arbitrarily choose to eliminate eq. 76 from the model specifications.

B. Electricity Generation

Following the energy-SAM data set in year 2008, we classify the generation activities into three types of technology: conventional fossil, geothermal, and hydro plant. Figures 6.6 and 6.7 illustrate the production structure from top to bottom of conventional and renewable (geothermal and hydro) technology.

Since renewable generation does not require fossil fuel input, we only combine the capital and electricity within a CES function to produce aggregate capital-electricity. In other words, we eliminate the combination of the energy composite.

Figure 6.6: Structure of Conventional Generation Activity
($j \in conv \subset elect \subset energy \subset A$)

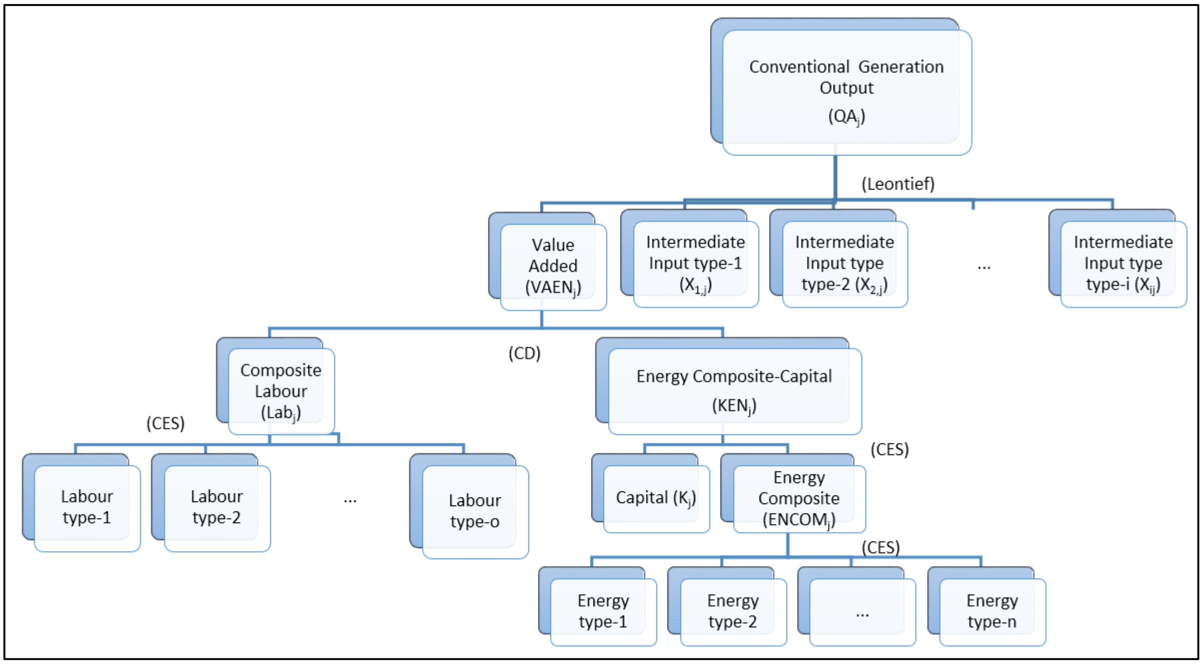


Figure 6.6, the model equations for conventional generation structure (this activity is denoted as $j \in conv \subset elect \subset energy \subset A$) are briefly described as follows.

At the top stage, conventional generation output is produced by a fixed coefficient (Leontief) function between intermediate commodities and the aggregate of value added-energy composite ($VAEN_j$):

$$X_{i,j} = ax_{i,j} QA_j, \quad i \in NEC \subset C, \quad j \in conv \subset elect \subset energy \subset A \tag{79}$$

$$VAEN_j = ava_j QA_j, \quad j \in conv \subset elect \subset energy \subset A \tag{80}$$

$$\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j},$$
$$j \in conv \subset elect \subset energy \subset A \tag{81}$$

Where QA_j is the conventional generation output; $X_{i,j}$ denotes the intermediate input of i-th non-energy commodity used by conventional generation activity; $ax_{i,j}$ denotes the coefficient of minimum requirements of i-th non-energy intermediate input to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEN_j$ to produce one unit of QA_j; p_j^{VAEN} denotes the price of $VAEN_j$; and p_i^Z denotes the price of i-th final (composite) non-energy goods.

At the second stage, the conventional generation activity minimizes the input cost combination of capital-energy composite and composite labour within a Cobb-Douglas function to produce the aggregate of value added-energy composite ($VAEN_j$). Equation (82) determines the constraint of $VAEN_j$ production. Equations (83) – (84) represent the demand of the conventional generation activity for capital-energy composite (KEN_j) and composite labour (LAB_j). Equation (85) determines the price index of P_j^{VAEN} that is obtained from a weighted sum combination of price of composite LAB_j and KEN_j:

$$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \qquad \delta_{LAB,j} + \delta_{KEN,j} = 1,$$
$$j \in conv \subset elect \subset energy \subset A \tag{82}$$

$$KEN_j = \delta_{KEN,j} \frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j \in conv \subset elect \subset energy \subset A \tag{83}$$

$$LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j \in conv \subset elect \subset energy \subset A \tag{84}$$

$$P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \; j \in conv \subset elect \subset energy \subset A \tag{85}$$

Due to Walras' Law, we arbitrarily choose to eliminate eq. 85 to ensure the income-expenditure accounting identity in the supply-demand equilibrium system.

At third stage (left side), labour composite is determined by a CES function over types of labour within a cost minimization problem. The results are given as follows. Equation (86) determines the constraint of LAB_j production. Equation (87) represents the demand of the conventional generation activity for labour types ($L_{o,j}$). Equation (88) determines the price index of labour composite ($PDIST_j^{LAB} P^{LAB}$) that is obtained from a weighted sum combination of wage of labour types ($PDIST_{o,j}^{L} P_o^{L}$). Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we choose to eliminate eq. (86) to obtain the balance between total equations and endogenous variables.

$$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}},$$
$$j \in conv \subset elect \subset energy \subset A, \qquad \sum_{o \in LBR} \gamma_{o,j} = 1\,, \qquad \beta_j = \frac{1}{\sigma_j^L} - 1 \tag{86}$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j^{\frac{\beta_j}{\beta_j+1}}}\right) LAB_j \left(\frac{PDIST_{o,j}^{L} P_o^{L}}{PDIST_j^{LAB} P^{LAB}}\right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR,$$
$$j \in conv \subset elect \subset energy \subset A \tag{87}$$

$$PDIST_j^{LAB} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST_{o,j}^{L} P_o^{L} L_{o,j}, j \in conv \subset elect \subset energy \subset A \tag{88}$$

Where $\gamma_{o,j}$ is the share parameter of o-th labour used by conventional generation activity ($0 \leq \gamma_{o,j} \leq 1$); sl_{TD} is the efficiency parameter of composite labour used by the conventional generation activity; and β_j be the substitution parameter of $L_{o,j}$ ($-1 \leq \beta_{conv} \leq \infty, \quad \beta_j \neq 0$).

At the third stage (right side), the aggregate of capital-energy composite is determined by a Cobb-Douglas function over capital and energy composite within a cost minimization problem. Equation (89) represents the constraint of aggregated capital-energy composite (KEN_j). Equations (90) – (91) represent the demand solution of energy composite ($ENCOM_j$) and capital (K_j) used by conventional generation activity. Equation (92) represents the unit cost of conventional activity to produce the aggregate capital-energy composite (KEN_j) which is obtained from the weighted sum of the prices of capital and energy composite. One of the above equations is redundant. We eliminate equation (92) to obtain the balanced system.

$$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}} K_j^{\chi_{K,j}}, \qquad \chi_{ENCOM,j} + \chi_{K,j} = 1,$$
$$j \in conv \subset elect \subset energy \subset A \tag{89}$$

$$ENCOM_j = \chi_{ENCOM,j} \frac{P_j^{KEN}}{P_j^{ENCOM}} KEN_j, \qquad j \in conv \subset elect \subset energy \subset A \tag{90}$$

$$K_j = \chi_{K,j} \frac{P_j^{KEN}}{PDIST_j^{K} P_j^{K}} KEN_j, \qquad j \in conv \subset elect \subset energy \subset A \tag{91}$$

$$P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + PDIST_j^{K} P_j^{K} K_j}{KEN_j}, \qquad j \in conv \subset elect \subset energy \subset A \tag{92}$$

Where P_j^{ENCOM} and P_j^{K} are the price of composite energy and capital of conventional activity; $ENCOM_j$ and K_j be the inputs of composite energy and capital to conventional activity; $\chi_{ENCOM,j}$ is the share parameter of energy composite by conventional activity ($0 \leq \chi_{ENCOM,j} \leq 1$); $\chi_{K,j}$ is the share parameter of capital by conventional activity ($0 \leq \chi_{K,j} \leq 1$); $\chi_{ENCOM,j} + \chi_{K,j} = 1$; and $sken_j$ is the efficiency parameter of capital-energy composite of the conventional activity.

Finally, at the bottom stage, the energy composite is determined by a CES function over types of energy ($i \in energyc \subset C$) within a cost minimization problem. Let $X_{i,j}$ be the type of energy used in conventional activity; p_i^Z be the price of final energy goods; $\kappa_{i,j}$ be the share parameter of energy type used by conventional activity ($0 \leq \kappa_{i,j} \leq 1$); sen_j be the efficiency parameter of energy composite used by the conventional activity; and ϕ_j be the substitution parameter of $X_{i,j}$ $(-1 \leq \phi_j \leq \infty,\ \phi_j \neq 0)$. In addition, in this stage we introduce the ad-valorem tax fuel, $TAXFUEL_{i,j}$ where:

$TAXFUEL_{i,j} = 0\ if\ i \in \{non - fuel\ types\} \subset energyc \subset C,$
$j \in conv \subset elect \subset energy \subset A;$
$and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,$
$j \in conv \subset elect \subset energy \subset A$

The results are given as follows. Equation (93) represents the constraint of energy composite used by conventional activity. Equation (94) represents the demand solution of energy types used by conventional activity. Equation (95) represents the unit cost of conventional activity to produce energy composite ($ENCOM_j$) which is obtained from the weighted sum of the prices of energy types.

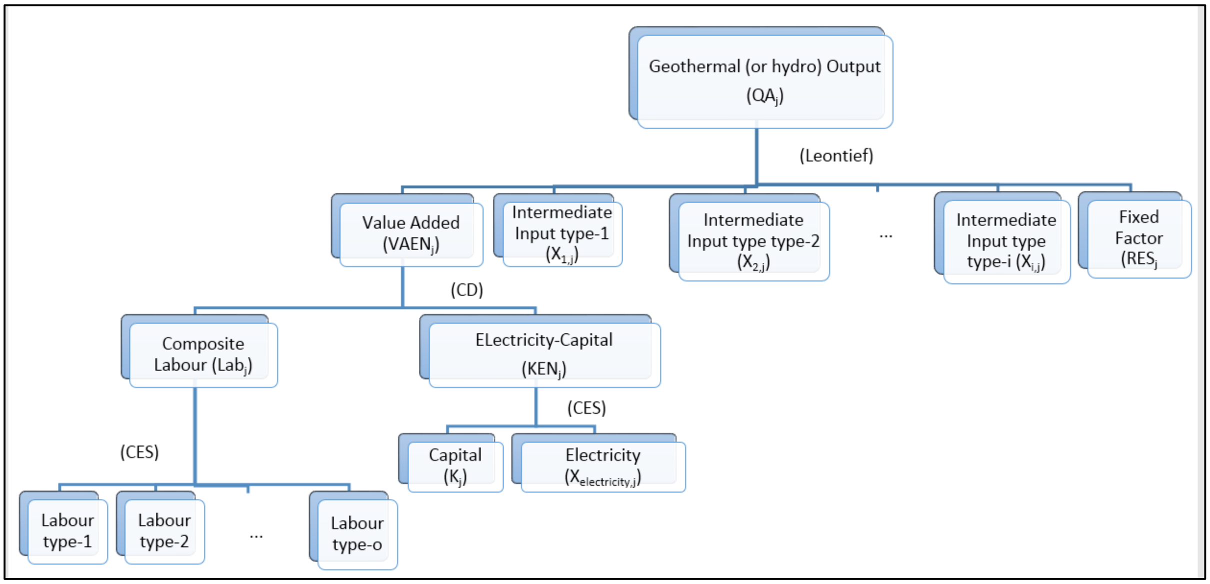
$$ENCOM_j = sen_j \left\{ \sum_{energy \in C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}}, \qquad i \in energyc \subset C \tag{93}$$

$$X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$$
$$j \in conv \subset elect \subset energy \subset A \tag{94}$$

$$P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j},$$
$$j \in conv \subset elect \subset energy \subset A \tag{95}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Due to Walras' Law condition, one of the above equations is redundant. We arbitrarily choose to eliminate eq. 95 from the model specifications. In addition, the parameter value of ϕ_j is obtained from Paltsev, *et al* (2005); Orlov (2012); and Orlov, *et al* (2013). The robustness of the results generated from using these values will then be tested through a sensitivity analysis

Figure 6. 7: Structure of Renewable (Geothermal or Hydro) Generation Activity ($\boldsymbol{j \in renew \subset elect \subset energy \subset A}$)



The model equations for renewable generation (this activity is denoted as $j \in renew \subset elect \subset energy \subset A$) are similar to those of conventional electricity generation. The differences, however, are by which we allow the fixed factor of natural resources of each type of renewable generation, i.e. geological hot dry rock for geothermal generation, and topographically-determined hydrostatic potential for hydro generation (Sue Wing, 2006). Because the SAM data set does not record these factors explicitly, we follow Sue Wing (2006) approximation by which these are estimated as roughly 20% shares of capital input. In addition, we eliminate the specification for the energy composite at the bottom stage since this composite is not required to generate renewable energy.

Therefore, at the top stage, the domestic output of renewable generation is produced by a fixed coefficient (Leontief) function between intermediate commodities, the aggregate of value added-electricity ($VAEL_j$) and the fixed factor of resources (RES_j). Equations (96) – (98) determine the fixed proportion of intermediate inputs ($X_{i,j}$) excluding the input of electricity ($i \neq electricity \in C$); value added- electricity ($VAEL_j$); and fixed resources to produce the domestic output of j-th renewable industry (QA_j). Equation (99) represents the unit cost of j-th renewable industry to produce QA_j which is obtained from the weighted sum of the prices of value added-energy composite, intermediate commodities, and the fixed factor of natural resources:

$$X_{i,j} = ax_{i,j}QA_j, \qquad i \neq elect \in C\ , \qquad j \in renew \subset elect \subset energy \subset A \qquad (96)$$

$$VAEL_j = ava_jQA_j, \qquad j \in renew \subset elect \subset energy \subset A \qquad (97)$$

$$RES_j = nat_jQA_j, \qquad j \in renew \subset elect \subset energy \subset A \qquad (98)$$

$$\Big(1 + (subAArate)\ \big(subArate_j\big)\Big)\, p_j^{QA} = p_j^{VAEL}ava_j +$$

$$\sum_{i \neq electricity \in C} \big(1 + TAXFUEL_{i,j}\big)p_i^Z ax_{i,j} + PDIST_j^{RES}p^{RES}nat_j,$$

$$j \in renew \subset elect \subset energy \subset A \qquad (99)$$

Where $ax_{i,j}$ denotes the coefficient of minimum requirements of i-th intermediate input – excluding electricity input – to produce one unit of QA_j; ava_j denotes the coefficient of minimum requirements of the $VAEL_j$ to produce one unit of QA_j; nat_j denotes the coefficient of minimum requirements of the RES_j; p_i^Z denotes the price of i-th final (composite) goods; p_j^{VAEL} denotes the price of $VAEL_j$; p_j^{RES} denotes the factor price of RES_j; and $TAXFUEL_{i,j} = 0\ if\ i \in \{non - fuel\ types\} \subset energyc \subset C,\ j \in renew \subset elect \subset energy \subset A$; $and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,\ j \in renew \subset elect \subset energy \subset A.$

At the second stage, each j-th renewable activity minimizes the input cost combination of capital-electricity and composite labour within a Cobb-Douglas function to produce the aggregate of value added-electricity ($VAEL_j$). Equation (100) determines the constraint of $VAEL_j$ production. Equations (100) – (101) represent the demand of the conventional generation activity for capital- electricity (KEL_j) and composite labour respectively (LAB_j). Equation (102) determines the price index of P_j^{VAEN} that is obtained from a weighted sum combination of price of composite LAB_j and KEL_j:

$$VAEL_j = sva_jLAB_j^{\delta_{LAB,j}}KEL_j^{\delta_{KEL,j}}, \qquad \delta_{LAB,j} + \delta_{KEL,j} = 1,$$

$$j \in renew \subset elect \subset energy \subset A \qquad (100)$$

$$KEL_j = \delta_{KEL,j}\frac{P_j^{VAEL}}{P_j^{KEL}}VAEL_j, \qquad j \in renew \subset elect \subset energy \subset A \qquad (101)$$

$$LAB_j = \delta_{LAB,j}\frac{P_j^{VAEL}}{PDIST_j^{LAB}P^{LAB}}VAEL_j, \qquad j \in renew \subset elect \subset energy \subset A \qquad (102)$$

$$P_j^{VAEL} = \frac{PDIST_j^{LAB}P^{LAB}LAB_j + P_j^{KEL}KEL_j}{VAEL_j}, \quad j \in renew \subset elect \subset energy \subset A \quad (103)$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we arbitrarily choose to eliminate eq. 103 to ensure the income-expenditure accounting identity in the supply-demand equilibrium system.

At the bottom stage (left side), the labour composite is determined by a CES function over types of labour within a cost minimization problem. The results are given as follows. Equation (104) determines the constraint of LAB_j production. Equation (105) represents the demand of the conventional generation activity for labour types ($L_{o,j}$). Equation (106) determines the price index of labour composite ($PDIST_j^{LAB}P^{LAB}$) that is obtained from a weighted sum combination of wage of labour types ($PDIST_{o,j}^{L}P_o^L$). Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we choose to eliminate eq. (104) to obtain the balance between total equations and endogenous variables.

$$LAB_j = \ sl_j\left\{\sum_{o\in LBR}\gamma_{o,j}{}^{1+\beta_j}L_{o,j}{}^{-\beta_j}\right\}^{-\frac{1}{\beta_j}}, \qquad j \in renew \subset elect \subset energy \subset A,$$
$$\sum_{o\in LBR}\gamma_{o,j} = 1\,, \qquad \beta_j = \frac{1}{\sigma_j^L} - 1 \qquad (104)$$

$$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}}\right)LAB_{conv}\left(\frac{PDIST_{o,j}^{L}P_o^L}{PDIST_j^{LAB}P^{LAB}}\right)^{\frac{-1}{\beta_j+1}}, \qquad o \in LBR,$$
$$j \in renew \subset elect \subset energy \subset A \qquad (105)$$

$$PDIST_j^{LAB}P^{LAB}LAB_j = \sum\nolimits_{o\in LBR}PDIST_{o,j}^{L}P_o^L L_{o,j},$$
$$j \in renew \subset elect \subset energy \subset A \qquad (106)$$

Where $\gamma_{o,j}$ is the share parameter of o-th labour used by conventional generation activity ($0 \leq \gamma_{o,j} \leq 1$); sl_{TD} is the efficiency parameter of composite labour used by the j-th renewable generation activity; and β_j be the substitution parameter of $L_{o,j}$ ($-1 \leq \beta_j \ \leq \infty, \ \ \beta_j \neq 0$).

At the bottom stage (right side), the aggregate of capital-energy composite is determined by a Cobb-Douglas function over capital and electricity within a cost minimization problem. The results are given as follows. Equation (107) represents the constraint of capital-electricity used by $renew$-th generation activity. Equation (108) represents the demand solution of electricity used by $renew$-th generation activity. Equation (109) represents the demand solution of capital used by $renew$-th generation activity. Equation (110) represents the unit cost of $renew$-th activity to produce capital-electricity composite (KEL_j) which is obtained from the weighted sum of the prices of capital and electricity:

$$KEL_j = sken_j X_{electricity,j}^{\chi_{electricity,j}} K_j^{\chi_{K,j}}, \qquad \chi_{electricity,j} + \chi_{K,j} = 1,$$
$$j \in renew \subset elect \subset energy \subset A \tag{107}$$

$$X_{electricity,j} = \chi_{electricity,j} \frac{P_j^{KEL}}{P_{electricity}^{z}} KEL_j,$$
$$j \in renew \subset elect \subset energy \subset A \tag{108}$$

$$K_j = \chi_{K,j} \frac{P_j^{KEL}}{PDIST_j^K P_j^K} KEL_j, \qquad j \in renew \subset elect \subset energy \subset A \tag{109}$$

$$P_j^{KEL} = \frac{P_{electtricity}^{z} X_{electricity,j} + PDIST_j^K P^K K_j}{KEL_{renew}},$$
$$j \in renew \subset elect \subset energy \subset A \tag{110}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law condition, one of the above equations is redundant. We arbitrarily choose to eliminate eq. 110 from the model specifications.

6.2.2. CO$_2$ emissions accounting and its taxation modules

To specificy the CO$_2$ emission and its taxation, we assume that utilizations (absorptions) of fossil and its refinery (petroleum) products emit CO$_2$ due to their combustion. Following Allan et al. (2008), we do not take into account the pollutants from non-CO$_2$ emissions – i.e. methane, sulphuric acid, carbon monoxide emissions – due to the complexity of identifications that are strongly related to combustion conditions and technology. These absorptions cover: the fossil (and petroleum) input in the production process across industries and the final fossil (and petroleum) consumption by households and government. Because of limited information, however, we exclude the emissions generated by agriculture – i.e. land use change – and deforestation.

6.2.2.1. CO$_2$ emissions accounting

Following Mcdonald and Thierfelder (2008), we incorporate the CO$_2$ emission accounting into the CGE model. Suppose the intermediate fuel inputs (fossils and refineries inputs), denoted as $i \in \{fuel\ types\} \subset energyc \subset C$, used by the j-th industry in the production processes are specified as $X_{i,j}$. Hence, the total CO$_2$ emissions, expressed in tons, generated from fuels combustion in each industry ($CO2FIRM_j$), is obtained by the multiplication of $X_{i,j}$ and their emission factor $CO2FAC_i$ as follows:

$$CO2FIRM_j = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2FAC_i \,.\, X_{i,j}\,, \qquad j \in A$$

The total CO$_2$ emission generated from fuel consumption by households and government are obtained as follows:

$$CO2INS = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2FAC_i \,.\left(\sum_{h \in H} CH_{i,h} + CG_i\right)$$

Where $CO2INS$ is the total CO$_2$ emission on final consumption; i is an element of the subset of fuel types (fossils and refineries) commodity; $\sum_{h \in H} CH_{i,h}$ and CG_i are the respective fuel consumption by the households' and government.

In the absence of detailed emission factors by fuel type for Indonesia, we use the available data based on the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006). The emission factors depend on fuel types rather than combustion conditions and technology (Allan *et al.*, 2008). To estimate the total CO$_2$ emissions emitted in Indonesia in the year 2008, the quantity (volume) of fuel domestic consumption is required. We use the available data of domestic oil fuels sales (unit of kilo liters (kl)), crude oil (unit of thousand barrels), coal, natural gas, and LPG consumption (unit of Thousand Barrel Oil Equivalent (BOE)) published in the Handbook of Energy and Economic Statistics of Indonesia, Ministry of Energy and Mineral Resources (2010). Table 6.1 shows the data of emission factors ($^{TonCO_2}/_{TJ}$) and oil fuels volume sales (TJ) for Indonesia in year of 2008[37].

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[37] We convert the unit of oil fuels volume (kilo liters) to Tetra Joule (TJ) so that the total emissions can be calculated.

Table 6.1: CO_2 Emission Factor and Volume Sales by Fuel Types

No.	Fuel Type	CO_2 emission Factor $\left(\frac{TonCO_2}{Terajoules}\right)$	Volume Sales (Terajoules)
1.	Bio-ethanol	70.80	7,096.72
2.	Bio-diesel	70.80	13,190.11
3.	Coal	94.60	458,466.31
4.	Crude Oil	73.30	2,187,141.07
5.	Kerosene	71.90	280,375.41
6.	Liquid Natural Gas (LNG)	64.20	1,394.87
7.	Natural Gas	56.10	208,771.97
8.	Non Subsidised Gasoline ('*Pertamax'*)	69.30	10,571.66
9.	Non Subsidised Liquefied Petroleum Gases (LPG)	63.10	96,160.52
10.	Other Petroleum Products (Other Oils)	73.30	176,335.08
11.	Subsidised Bio-diesel	70.80	19,785.16
12.	Subsidised Bio-gasoline	70.80	1,560.05
13.	Subsidised Gasoline ('*Premium*')	69.30	682,208.69
14.	Subsidised Diesel Oil	74.10	931,479.67
15.	Subsidised Liquefied Petroleum Gases (LPG)	63.10	313,148.78

Source: IPCC (2006); Handbook of Energy and Economic Statistics of Indonesia, Ministry of Energy and Mineral Resources (2008).

Therefore, the overall CO_2 emissions generated from the economy transactions are the sum of the emissions arising from the fuel combustion of industries, households and government:

$$CO2TOTAL = \sum_{j \in A} CO2FIRM_j + CO2INS$$

6.2.2.2. CO_2 Emission Taxation

Because we only consider the emissions that result from fuel combustions, the CO_2 emission tax be imposed as an ad-valorem fuel tax (Yusuf, 2008). The burden of this tax is then incorporated to the burning of fuel inputs by industries and the final fuel consumption by representative agents (households and government).

The government revenue from a CO_2 emission tax ($IGCO2$) is obtained by multiplying the tax rate ($TAXCO2$) and total CO_2 emissions ($CO2TOTAL$):

$$IGCO2 = TAXCO2.CO2TOTAL$$

$$= TAXCO2 \sum_{i \in \{fuel\ types\} \subset energyc \subset C} \left(\sum_{j \in A} CO2FIRM_{i,j} + \sum_{h \in H} CO2H_{i,h} + CO2G_i \right)$$

Where $IGCO2$ is the government revenue collected from CO$_2$ emission tax; $TAXCO2$ (in Rp / ton CO$_2$) is the specific CO$_2$ emission tax; $CO2FIRM_{i,j}$ is the CO$_2$ emission generated from each type of fuel used by j-th industry; $CO2H_{i,h}$ is the CO$_2$ emission generated from each type of fuel used by h-th households'; and $CO2G_i$ is the CO$_2$ emission generated from each type of fuel used by government. This revenue is equivalent to the ad-valorem fuel tax imposed across users (industry, households, and government):

$$IGCO2 = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} p_i^Z \left(\sum_{j} TAXFUEL_{i,j} X_{i,j} + \sum_{h \in H} TAXFUEL_{i,h} CH_{i,h} \right.$$
$$\left. + TAXFUEL_{i,gov} CG_i \right)$$

Where p_i^Z denotes the market price index of each fuel and $TAXFUEL_{i,user}$ denotes the ad-valorem tax fuel for users that are j-th industry, h-th households, and government. The relationship between $TAXCO2$ and $TAXFUEL_{fuel,user}$ is then expressed as follows:

$$TAXFUEL_{i,j} = \frac{TAXCO2.\, CO2FIRM_{i,j}}{p_i^Z X_{i,j}}, \qquad i \in \{fuel\ types\} \subset energyc \subset C,$$
$$j \in A$$

$$TAXFUEL_{i,h} = \frac{TAXCO2.\, CO2H_{i,h}}{p_i^Z CH_{i,h}}, \qquad i \in \{fuel\ types\} \subset energyc \subset C, \qquad h \in H$$

$$TAXFUEL_{i,gov} = \frac{TAXCO2.\, CO2G_i}{p_i^Z CG_i}, \qquad i \in \{fuel\ types\} \subset energyc \subset C,\ \ gov \in INS$$

The above expressions imply that $TAXFUEL_{fuel,user}$ does not depend only on the carbon content of each fuel type, but also on economic variables such as fuel prices and volumes (Yusuf, 2008).

Therefore, in the next step, we suppose that the government imposes an ad-valorem fuel tax on the utilization of energy input in the j-th industry production structure; and final fuel consumption by h-th households and government.

For the j-th non-energy industry, we add $TAXFUEL_{i,j}$ to the bottom stage of their production structure. The energy demand solution for j-th non-energy industry is then rearranged as follows:

$$X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$$

$j \in NE \subset A$

Where:

$TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel \; types\} \subset energyc \subset C,$

$j \in NE \subset A;$ $and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel \; types\} \subset energyc \subset C,$

$j \in NE \subset A$

The price index of an industry's energy composite (P_j^{ENCOM}) is obtained from the weighted sum of different type of energy price (p_i^Z):

$$P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j}, \qquad j \in NE \subset A$$

For the j-th industry, we add $TAXFUEL_{energy,fossil}$ to the bottom stage of their production structure. The unit cost of $fossil$-th industry to produce energy composite ($ENCOM_{fossil}$) is then rearranged as follows:

$$\Big(1 + (subAArate)\left(subArate_j\right)\Big) p_j^{ENCOM} = \sum_{i \neq oil \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j,}$$

$j \in fossil \subset energy \subset A$

Where:

$TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel \; types\} \subset energyc \subset C,$

$j \in fossil \subset energy \subset A;$

$and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel \; types\} \subset energyc \subset C, \quad j \in fossil \subset energy \subset A$

For the $refinery$ industry, we add $TAXFUEL_{i,j}$ that is identical to that of $fossil$-th industry:

$$\Big(1 + (subAArate)\left(subArate_j\right)\Big) p_j^{ENCOM} = \sum_{i \neq oil \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j,}$$

$j \in refinery \subset energy \subset A$

Where:

$TAXFUEL_{i,j} = 0\ if\ i \in \{non - fuel\ types\} \subset energyc \subset C,$

$j \in refinery \subset energy \subset A;$

$and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,$

$j \in refinery \subset energy \subset A$

Finally, at bottom stage of conventional electricity generation activity, we add the $TAXFUEL_{i,j}$ to the bottom stage of their production structure. The energy demand solution for the conventional generation industry is then rearranged as follows:

$$X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}}\right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}}\right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$$

$j \in conv \subset elect \subset energy \subset A$

Where:

$TAXFUEL_{i,j} = 0\ if\ i \in \{non - fuel\ types\} \subset energyc \subset C,$

$j \in conv \subset elect \subset energy \subset A;$

$and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,$

$j \in conv \subset elect \subset energy \subset A$

The price index of this industry's energy composite (P_j^{ENCOM}) is obtained from the weighted sum of different types of energy prices (p_i^Z):

$$P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j},$$

$j \in conv \subset elect \subset energy \subset A$

Furthermore, we introduce $TAXFUEL_{i,h}$ to the representative households' demand function as follows:

$$\left(1 + TAXFUEL_{i,h}\right) P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h, \qquad i \in C, \qquad h \in H$$

Where:

$TAXFUEL_{i,h} = 0\ if\ i\!: \{non\ fuel\ types\} \in energy \subset C;\ and$

$TAXFUEL_{i,h} \neq 0\ if\ i\!: \{fuel\ types\} \in energy \subset C$

For the public spending on fuel commodities, we also add $TAXFUEL_{i,gov}$. Thus, the equation for total government expenditure is rearranged as follows:

$$EG = \sum_{i\in C}\left(1 + TAXFUEL_{i,gov}\right)P_i^Z CG_i + \sum_{i\in C}(subQArate)(subQrate_i)P_i^Q Q_i$$
$$+\sum_{j\in A}(subAArate)\left(subArate_j\right)P_j^{QA} QA_j \;+ \sum_{in\in INS} TR_{in,gov}$$

Where:

$TAXFUEL_{i,gov} = 0 \; if \; i\colon\{non\; fuel\; types\} \in C;\; and$

$TAXFUEL_{i,gov} \neq 0 \; if \; i\colon\{fuel\; types\} \in C$

6.2.3. Government Behaviour

The specifications to describe government behaviour are similar to those of the standard model[38]. The difference is that we add the collection of CO_2 emission tax ($IGCO2$) as described above.

Thus, in the modified model, the government earns income from total institutions' transfers and taxes. This is expressed as follows:

$$IG = \sum_{i\in C}(vatArate)(vatrate_i)P_i^Q Q_i + \sum_{i\in CM}(tarifArate)(tarifrate_i)P_i^M M_i$$
$$+ \sum_{in\in INS} TR_{gov,in} + TAXCO2.CO2TOTAL \qquad (111)$$

Where IG denotes the government total income; $(vatArate)(vatrate_i)$ denotes *ad valorem* tax rate of the i-th gross domestic supply in terms of value $\left(P_i^Q Q_i\right)$; $(tarifArate)(tarifrate_i)$ denotes tariff's rate of the i-th imported goods in terms of value $(P_i^M M_i)$; and $TR_{gov,in}$ denotes government transfer income from institutions'.

Whilst government's expenditure and saving are given as follows:

$$EG = \sum_{i\in C}\left(1 + TAXFUEL_{i,gov}\right)P_i^Z CG_i + \sum_{i\in C}(subQArate)(subQrate_i)P_i^Q Q_i$$
$$+\sum_{j\in A}(subAArate)\left(subArate_j\right)P_j^{QA} QA_j \;+ \sum_{in\in INS} TR_{in,gov} \qquad (112)$$

$$CG_i = CGIN_i\overline{CGADJ}, \qquad i \in C \qquad (113)$$

$$TR_{h,gov} = TRG\_share_{h,gov}TRG\_barCPI, \qquad h \in H, gov \in INS \qquad (114a)$$

$$TR_{in,gov} = TRG\_share_{in,gov}TRG\_bar, \qquad in \neq h \in INS \qquad (114b)$$

Government saving (SG) is therefore defined as follows:

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[38] For detailed explanations of government behaviour see section 3.2.2.

$$SG = IG - EG \tag{115}$$

Where EG denotes total public expenditure; CG_i denotes government spending on each goods and services; $(subQArate)(subQrate_i)$ denotes the subsidy rate of i-th domestic supply $(P_i^Q Q_i)$; $(subAArate)(subArate_j)$ denotes the subsidy rate of j-th industry gross output $(P_j^{QA} QA_j)$; $TR_{in,gov}$ denotes government transfer payments to institutions'; $CGIN_i$ denotes initial government expenditure of i-th final goods; $TRG\_share_{in,gov}$ denotes the fixed proportion of government transfer payments to each institution; TRG_bar denotes total transfer payments; and SG denotes government saving.

6.2.4. Households Behaviour

The specifications to define household behaviour are similar to those of the standard model[39]. The differences are that we introduce: (i) the ad-valorem fuel tax, $TAXFUEL_{i,h}$, to the representative households' demand function as described in section 6.2.2.2; and (ii) the households' fixed factor income of natural resources extracted by the fossil mining activities.

Thus, in the modified model, the income sources obtained by the h-th type of households are expressed as follows:

$$IH_h = IHL_h + IHK_h + IHRES_h + \sum_{in \in INS} TR_{h,in}, \qquad h \in H \tag{116}$$

$$IHL_h = \sum_{o \in LBR} IHL\_share_{h,o} P_o^L \left(\sum_{j \in A} PDIST_{o,j}^L \, L_{o,j} + L_{o,ROW} \right), \qquad h \in H \tag{117}$$

$$IHK_h = IHK\_share_h P^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right), \;\; h \in H, \;\; ROW \in IN \tag{118}$$

$$IHRES_h = IHRES\_share_h P^{RES} \left(\sum_{j \in fossil \subset A} PDIST_j^{RES} RES_j + \sum_{j \in renew \subset A} PDIST_j^{RES} RES_j \right), \qquad h \in H \tag{119}$$

Where IH_h denotes total income of the h-th type of households; IHL_h denotes labour income of the h-th type of households'; IHK_h denotes capital income of the h-th type of households;

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[39] For detailed explanations of households' behaviour see section 3.2.3.

$IHRES_h$ denotes natural resources income of the h-th type of households; $TR_{h,in}$ denotes transfer income of the h-th type of households from the in-th institutions'; $IHL\_share_{h,o}$ denotes the share of the o-th type of labour income received by h-th type of households; IHK_share_h denotes the share of capital income received by h-th type of households; $IHRES\_share_h$ denotes the share of natural resources income received by h-th type of households; L_ROW_o denotes the o-th type of labour supply from ROW used in j-th industry; and K_ROW denotes the abroad capital supply used in j-th industry.

The government collects income tax and CO_2 emission tax from households due to the final consumption of 'dirty' fuel commodities. According to the standard model, the income taxes are represented as transfer payment to the government ($TR_{gov,h}$). The disposable income households (DIH_h) is as follows:

$$DIH_h = IH_h - TR_{gov,h} - TAXCO2 \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2H_{i,h}, \qquad h \in H,$$

$$gov \in INS \tag{120}$$

Where $CO2H_{fuel,h}$ is the CO_2 emission generated from each type of fuel used by the h-th household.

Households' transfer payments to institutions, other than the government, are specified in equation (121a):

$$TR_{in,h} = TRH\_share_{in,h} DIH_h, \qquad in \neq gov \in INS, \qquad h \in H \tag{121a}$$

Household income tax is regarded as household transfer payment to government:

$$TR_{gov,h} = (HAtaxrate\ )(Htaxrate_h)\ IH_h, \qquad h \in H \tag{121b}$$

Where $TRH\_share_{in,h}$ denotes the shares of the h-th households' transfer payment to the in-th institutions'; and $(HAtaxrate\ )(Htaxrate_h)$ denotes income tax rate of h-th households' respectively.

Furthermore, the subtractions of households' transfer payments yield the actual disposable income ($ADIH_h$) of the h-th type of household as follows:

$$ADIH_h = DIH_h - \sum_{in \neq gov \in INS} TR_{in,h}, \qquad h \in H \tag{122}$$

The constant average propensities to save of households are given in equation (123):

$$SH_h = sh\_ratio_h ADIH_h, \qquad h \in H \tag{123}$$

The ratio of the constant average propensities to save is allowed to adjust endogenously:

$$sh\_ratio_h = sh\_rin_h(1 + sh\_dum_h sh\_adj), \qquad h \in H \tag{124}$$

Where SH_h denotes saving of the h-th type of households'; sh_ratio_h denotes the adjusted average propensity for saving of the h-th type of households; sh_rin_h denotes the initial value of average propensity for saving of the h-th type of households; sh_dum_h : 0, if $sh\_ratio_h = sh\_rin_h$, i.e. no change in saving ratio; sh_dum_h: 1, if sh_ratio_h is allowed to adjust, in which case sh_adj is the endogenous adjustment of sh_ratio_h.

Therefore, the budget of household consumption of final goods (EH_h) is then obtained from their actual disposable income less saving (SH_h) (equation (125)).

$$EH_h = ADIH_h - SH_h, \qquad h \in H \tag{125}$$

In this modified model, we introduce $TAXFUEL_{i,h}$ to the representative households' demand function. Hence, by solving the optimization problem with a Cobb-Douglas utility function, the solution to which yields the corresponding demand function:

$$\left(1 + TAXFUEL_{i,h}\right) P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h, \qquad i \in C, \qquad h \in H \tag{126}$$

Where:

$$TAXFUEL_{i,h} = 0 \; if \; i\colon \{non \; fuel \; types\} \in energy \subset C; \; and$$
$$TAXFUEL_{i,h} \neq 0 \; if \; i\colon \{fuel \; types\} \in energy \subset C.$$

6.2.5. Consumer Price Index (CPI)

According to the standard model, CPI is adjusted from the total price index of i-th households (equation (127)), which is obtained from the homogeneity relationship of i-th final goods price (equation (128)).

$$PI_h = \prod_{i \in C} (P_i^Z)^{CH\_share_{i,h}}, \qquad h \in H \tag{127}$$

$$CPI = \sum_{h \in H} w_h PI_h \tag{128}$$

Where w_h is the weight of commodity purchased by the h-th of households.

6.2.6. Enterprise Behaviour

In this modified model, all descriptions for enterprises are similar to that of standard model. The difference is that we assume that enterprises receive income from the extraction of natural resources beneath the land's soil. The enterprise income (IB) is therefore obtained from total of enterprise capital supply (IBK), fixed resources ($IBRES$), and enterprise transfer income from the in-th institutions ($TR_{b,in}$):

$$IB = IBK + IBRES + \sum_{in \in INS} TR_{b,in} \tag{129}$$

$$IBK = IBK\_shareP^{K}\left(\sum_{j \in A} PDIST_j^{K} K_j + K_{ROW}\right), \qquad ROW \in INS \tag{130}$$

$$IBRES = IBRES\_shareP^{RES}\left(\sum_{j \in fossil \subset A} PDIST_j^{RES} RES_j + \sum_{j \in renew \subset A} PDIST_j^{RES} RES_j\right) \tag{131}$$

Where IBK_share and $IBRES\_share$ denote the share of capital and resources income received by enterprise.

Enterprise disposable income (DIB) is expressed as follows:

$$DIB = IB - TR_{gov,b}, \qquad gov\ and\ b \in INS \tag{132}$$

Enterprise transfer payments to institutions excluding government are assumed to adjust proportionally to their disposable income ($TRB\_share_{in,b}$) (equation (133a)); whilst the enterprise transfer payments to government are enterprise income tax (equation (133b)).

$$TR_{in,b} = TRB\_share_{in,b} DIB, \qquad in \neq gov \in INS \tag{133a}$$

$$TR_{gov,b} = (Btaxrate)IB, \qquad b \in INS \tag{133b}$$

These subtractions yield the actual disposable income of enterprise ($ADIB$) as follows:

$$ADIB = DIB - \sum_{in \neq gov \in INS} TR_{in,b} \tag{134}$$

Finally, enterprise saving (SB) is thus simply equal to the actual disposable income:

$$SB = ADIB \tag{135}$$

6.2.7. Rest of World (ROW)

In the modified model, all descriptions for ROW are similar to that of standard model. ROW total outflow is generated from total import, institutions’ income transfers to ROW, and ROW endowments of factors supply to domestic industries:

$$IROW = \sum_{i\in CM} P_i^M M_i + \sum_{in\in INS} TR_{ROW,in} + \sum_{o\in LBR} RL\_share_o P_o^L \left(\sum_{j\in A} PDIST_{o,j}^L L_{o,j} + L_{o,ROW} \right)$$
$$+ \ RK\_shareP^K \left(\sum_{j\in A} PDIST_j^K K_j + K_{ROW} \right), \qquad ROW \in INS \qquad (136)$$

Where $IROW$ denotes ROW total outflow; M_i denotes import of the i-th goods; $TR_{ROW,in}$ denotes transfer income from in-th institutions to ROW; CM denotes the exported and imported commodities; and respective RL_share_o and RK_share denote the shares of the o-th foreign labour and capital used domestically.

ROW total inflow is determined from total of exports, ROW payment transfers to institutions', payment to labour and capital employed by ROW (equation (137)).

$$EROW = \sum_{i\in CE} P_i^E E_i + \sum_{in\in INS} TR_{in,ROW} + \sum_{o\in LBR} P_o^L L_{o,ROW} + P^K K_{ROW},$$
$$ROW \in INS \qquad (137)$$

Where $EROW$ denotes ROW total inflow; E_i denotes export of the i-th goods; $TR_{in,ROW}$ denotes transfer payment from RoW to institutions; and CE denotes the exported and imported commodities.

ROW transfer payments to institutions ($TR_{in,ROW}$) are determined from a fixed proportion of ROW total transfer payments ($TROW\_bar$) as follows:

$$TR_{in,ROW} = TRW\_share_{in,ROW}(EXR)TROW\_bar, \qquad ROW \notin in \in INS \qquad (138a)$$

$$TR_{ROW,ROW} = 0 \qquad (138b)$$

Where $TRW\_share_{in,ROW}$ denotes the shares of ROW transfer payments to the in-th institutions excluding ROW; and EXR denotes the exchange rate (domestic currency unit per foreign currency unit).

The ROW saving ($SROW$) is determined from residual between ROW outflow and inflow:

$$SROW \ = EROW - IROW \qquad (139)$$

Finally, the price relationships in terms of local and ROW currency between export and import commodities:

$$P_i^E = (EXR)P_i^{EW}, \qquad i \in CE \qquad (140)$$

$$P_i^M = (EXR)P_i^{MW}, \qquad i \in CM \qquad (141)$$

Where P_i^{MW} denotes imported price of the i-th goods in terms of foreign currency (exogenous); P_i^{EW} denotes exported price of the i-th goods in terms of foreign currency (exogenous); P_i^M denotes imported price of the i-th goods in terms of domestic currency; P_i^E denotes exported price of the i-th goods in terms of domestic currency.

6.2.8. Investment

All descriptions for investment are similar to that of standard model. The final demand of the i-th investment commodity is given as follows:

$$CINV_i = CINVIN_i(1 + INVADJ), \qquad i \in C \tag{142}$$

Where $CINVIN_i$ denotes the initial investment demand of the i-th commodity; $INVADJ$ denotes the investment adjustment index ($INVADJ$=0 if investment is fixed; otherwise if it is allowed to adjust endogenously).

The Walras identity is then determined from the saving-investment balance as follows:

$$WALRASRES = \sum_{h \in H} SH_h + +SB + SG + SROW - \sum_{i \in C} P_i^Z CINV_i \tag{143}$$

Where $WALRASRES$ denotes the Walras residual.

6.2.9. The Armington Aggregations

Finally, all descriptions to define Armington's aggregations are similar to that of the standard model. In terms of trade aggregations (export and import), we assume that all energy goods do not generate CO_2 emission since there are no processes of fuels burning. Hence, in this modified model, the equations of Armington's aggregations are similar to the standard model of which we do not incorporate the CO_2 emission tax. The respective of the i-th Armington's composite goods (Z_i), demand function of import (M_i) and domestic goods (D_i) are specified as follows:

$$Z_i = sz_i\left(\delta_{mi}{}^{1+\Phi_i} M_i{}^{-\Phi_i} + \delta_{di}{}^{1+\Phi_i} D_i{}^{-\Phi_i}\right)^{-\frac{1}{\Phi_i}},$$

$$i \in CM \cap CD, \qquad \Phi = \frac{1}{\sigma^z} - 1, \qquad \sigma^z > 1 \tag{144}$$

$$M_i = \left(\frac{\delta_{mi}}{sz_i{}^{\frac{\Phi_i}{1+\Phi_i}}}\right) Z_i \left\{\frac{\left(1 + (tarifArate)(tarifrate_i)\right) P_i^M}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}}, \qquad i \in CM \cap CD \tag{145}$$

$$D_i = \left(\frac{\delta_{di}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}} \right) Z_i \left\{ \frac{P_i^D}{P_i^Z} \right\}^{-\frac{1}{1+\Phi_i}}, \qquad i \in CM \cap CD \tag{146}$$

The price index of the composite commodity (P_i^Z) is obtained as:

$$P_i^Z Z_i = \big(1 + (tarifArate)(tarifrate_i)\big) P_i^M M_i + P_i^D D_i, \qquad i \in CM \cap CD \tag{147}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, we exclude eq. 110 from the model specifications.
For an industry that does not use imported goods, the relationship of domestically produced goods and composite goods is written as follows:

$$Z_i = D_i, \qquad i \in CD \ \& \notin CM \tag{148}$$

$$P_i^Z = P_i^D, \qquad i \in CD \ \& \notin CM \tag{149}$$

Furthermore, the respective of the i-th gross domestic output (Q_i); the i-th transformation of export (E_i) and domestic commodity are specified as follows:

$$Q_i = sq_i \big({\omega_{e,i}}^{1-\mu_i} (E_i)^{\mu_i} + {\omega_{d,i}}^{1-\mu_i} (D_i)^{\mu_i} \big)^{\frac{1}{\mu_i}}, \qquad i \in CE \cap CD,$$

$$\mu = \frac{1}{\sigma^q} + 1, \qquad \sigma^q > 0 \tag{150}$$

Nevertheless, for industry that produces only domestic commodities no exports transformation is needed and the relationship is simply written as follows:

$$Q_i = D_i, \qquad i \in CD \ \& \notin CE \tag{151}$$

$$E_i = \frac{\omega_{ei}}{{sq_i}^{\mu_i / \mu_i - 1}} Q_i \left\{ \frac{P_i^E}{\big(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\big) P_i^Q} \right\}^{\frac{1}{\mu_i - 1}},$$

$$i \in CE \cap CD \tag{152}$$

$$D_i = \frac{\omega_{di}}{{sq_i}^{\varsigma_i / \varsigma_i - 1}} Q_i \left\{ \frac{P_i^D}{(1 + vat_i - subQ_i) P_i^Q} \right\}^{\frac{1}{\varsigma_i - 1}}, \qquad i \in CE \cap CD \tag{153}$$

The price index of domestically produced commodity (P_i^q) is determined below:

$$\big(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\big) P_i^Q Q_i = P_i^D D_i + P_i^E E_i,$$

$$i \in CE \cap CD \tag{154}$$

Walras law states that the equilibrium in *n* markets is obtained by the the equilibrium in (*n*-1) markets. Thus, due to Walras' Law, eq. 150 is arbitraly excluded from the model specifications.

For an industry that produces only domestic commodities the price index of P_i^q is simply written as follows:

$$\left(1 + (vatArate)(vatrate_i) - (subQArate)(subQrate_i)\right)P_i^Q = P_i^D, \\ i \in CD \ \& \ \notin CE \tag{155}$$

6.2.10. Market-clearing

The market-clearing conditions that correspond to the equilibrium between supply and demand in all goods markets are as follows:

$$Z_i = \sum_{h \in H} CH_{i,h} + CG_i + CINV_i + \sum_{j \in A} X_{i,j}, \qquad i \in C \tag{156}$$

The factor market-clearing conditions:

$$\sum_{j \in A} K_j + K_{ROW} + KU = KS, \qquad ROW \in INS \tag{157}$$

$$\sum_{j \in fossil \subset A} RES_j + \sum_{j \in renew \subset A} RES_j + RESU = RESS \tag{158}$$

$$\sum_{j \in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o, \qquad o \in LBR, \qquad ROW \in INS \tag{159}$$

Where KS denotes total capital supply; $RESS$ denotes total resources supply; KU denotes unused or excessive capital stock; LU_o denotes the o-th unemployed labour; and LS_o denotes total supply of o-th labour.

6.2.11. Closures

The closure choices used in this CGE-energy model are similar to the standard CGE model specified in Chapter 3. For capital and labour closures we assume that capital and labour are mobile across industries with fixed (exogenous) rent and wages. The labour market equilibrium is obtained from the endogenous adjustment of unemployment rates, whilst the capital market equilibrium is achievable through the endogenous adjustment of aggregated capital rent. For saving-investment closure, we assume the exogenous institution saving. Thus the actual investment goods adjust to obtain the balance. For the open-economy model, we choose the flexible exchange rate regime by which the Indonesian exchange rate is endogenous but having fixed the foreign saving such that the inflow-outflow deficit (or surplus) cleared. Finally, for the government balance, we assume that all net tax rates are exogenously determined but public saving is endogenous to clear the balance.

Some closures, are added in this modified model since new equations and endogenous variables have been introduced into the system, including the fixed tax on fossil fuel used by activities and institutions (households and government). We also assume that the adjusted resources rent across fossil and renewable ($PDIST_j^{RES}$) activities and the total resources supply ($RESS$) are exogenously determined. The fixed resources used by the j-th fossil (including geothermal) and renewable industry (RES_j) adjust to ensure market clearing of each industry. However, we assume no unused resources ($RESU = 0$); the price of aggregated resources (P^{RES}) adjusts to ensure overall market clearing.

6.3. Conclusion

This chapter aimed to explain a detailed construction of the features of the CGE-energy model for Indonesia's economy. The model extends the standard CGE model given in Chapter 3. The model is calibrated to the hypothetical energy-SAM dataset for the year 2008 explained in Chapter 5. The modifications mainly relate to expanding the energy production structures and the introduction of CO_2 emission tax on dirty fuel consumption.

Since the total number of equations is not equal to the total number of endogenous variables, we use a set of closure rules that are closely related to the actual condition of Indonesia's economy. All closure rules used in the standard CGE model in Chapter 3 are implemented in this CGE-energy model, and some closures that relate to CO_2 emission tax and natural resources factor are added.

I will now apply the extended CGE-energy model to examine fiscal policies to promote clean energy utilization in Indonesia.

Appendix 6.A: List of equations of the Modified CGE model

Eq. No	**Equations and their description**	**No. of Eqs.**	**End. Var.**
Domestic Production Block			
1. *j*-th Non-Energy Producing Structure ($j \in NE \subset A, \quad NE \cap Energy = \emptyset$)			
A. Top Stage: Activity Output (Gross Domestic Output) B. We assume a Leontief function:			
1.	The intermediate input of i-th non-energy commodity ($i \in NEC \subset C, NEC \cap Energy = \emptyset$) used by j-th non-energy industry: $X_{i,j} = ax_{i,j}QA_j, \; i \in NEC \subset C, \quad j \in NE \subset A$	26x26	$X_{i,j}$
2.	The j-th value added-energy composite (VAEN) used: $VAEN_j = ava_jQA_j, \quad j \in NE \subset A$	26	QA_j
3.	The price of j-th non-energy domestic output: $\left(1+(subAArate)\left(subArate_j\right)\right)p_j^{QA} = p_j^{VAEN}ava_j + \sum_{i \in NEC \subset C} p_i^{Z}ax_{i,j}, \quad j \in NE \subset A$	26	p_j^{VAEN}
4.	The relationship between non-energy activity output and its commodity supply: $Q_i = \sum_{j \in NE \subset A} TRANS\_Coef_{j,i}QA_j, \quad i \in NEC \subset C$	26	Q_i
5.	The relationship between non-energy activity price and its commodity price: $P_j^{QA} = \sum_{i \in NEC \subset C} TRANS\_Coef_{j,i}P_i^{Q}, \quad j \in NE \subset A$	26	P_j^{QA}

Eq. No	**Equations and their description**	**No. of Eqs.**	**End. Var.**
	Total no. of equations	780	

C.	Second stage: Value Added-Energy Composite (VAEN) from combination of (LAB) Labour Composite and Capital-Energy Composite (KEN) We assume a Cobb-Douglas function:		
6.	$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \quad \delta_{LAB,j} + \delta_{KEN,j} = 1, \quad j \in NE \subset A$	26	$VAEN_j$
7.	The demand solution of j-th non-energy industry for capital-energy composite used: $KEN_j = \delta_{KEN,j} \dfrac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j \in NE \subset A$	26	KEN_j
8.	The demand solution of j-th non-energy industry for composite labour factor used: $LAB_j = \delta_{LAB,j} \dfrac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j \in NE \subset A$	26	LAB_j
9.	Zero profit condition: $P_j^{VAEN} = \dfrac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \qquad j \in NE \subset A$	0	Redundant
	Total no. of equations	78	

D. Third stage (Left Side): The choice of labour factor We assume a CES production function:			
10.	$LAB_j = sl_j\left\{\sum_{o\in LBR}\gamma_{o,j}{}^{1+\beta_j}L_{o,j}{}^{-\beta_j}\right\}^{-\frac{1}{\beta_j}}, \quad j\in NE\subset A,$ $\sum_{o\in LBR}\gamma_{o,j}=1, \quad \beta_j=\frac{1}{\sigma_j^L}-1$	0	redundant
11.	The *o*-th labour used: $L_{o,j}=\left(\frac{\gamma_{o,j}}{sl_j{}^{\frac{\beta_j}{\beta_j+1}}}\right)LAB_j\left(\frac{PDIST^L_{o,j}P^L_o}{PDIST^{LAB}_jP^{LAB}}\right)^{\frac{-1}{\beta_j+1}}, \quad o\in LBR, \quad j\in NE\subset A$	16X26	$L_{o,j}$
12.	Zero profit condition: $PDIST_j^{LAB}P^{LAB}LAB_j=\sum_{o\in LBR}PDIST^L_{o,j}P^L_oL_{o,j}, \quad j\in NE\subset A$	26	$PDIST_j^{LAB}$
	Total no. of equations	432	

E. Third stage (Right Side): The choice of Capital and Energy Composite We assume a Cobb-Douglas function:			
13.	$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}}K_j^{\chi_{K,j}}, \quad \chi_{ENCOM,j}+\chi_{K,j}=1, \quad j\in NE\subset A$	26	KEN_j
14.	The demand solution of j-th non-energy industry for energy composite used:	26	$ENCOM_j$

	$ENCOM_j = \chi_{ENCOM,j} \frac{P_j^{KEN}}{P_j^{ENCOM}} KEN_j, \qquad j \in NE \subset A$		
15.	The demand solution of j-th non-energy industry for capital used: $K_j = \chi_{K,j} \frac{P_j^{KEN}}{PDIST_j^K P^K} KEN_j, \qquad j \in NE \subset A$	26	K_j
16.	Zero profit condition: $P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + PDIST_j^K P^K K_j}{KEN_j}, \qquad j \in NE \subset A$	0	Redundant
	Total no. of equations	78	

F.	Bottom stage: The choice of Energy Goods We assume a CES production function:		
17.	$ENCOM_j = sen_j \left\{ \sum_{i \in energyc \subset C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}}, \qquad j \in NE \subset A$	0	redundant
18.	The demand solution of j-th non-energy industry for intermediate energy input used: $X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{(1 + TAXFUEL_{i,j}) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C, \qquad j \in NE \subset A$	17x26	$X_{i,j}$

	$TAXFUEL_{i,j} = 0 \; if \; i \in \{non-fuel\; types\} \subset energyc \subset C,$ $j \in NE \subset A; \; and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel\; types\} \subset energyc \subset C,$ $j \in NE \subset A$		
19.	Zero profit condition: $P_j^{ENCOM} = \dfrac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j}, \qquad j \in NE \subset A$ $TAXFUEL_{i,j} = 0 \; if \; i \in \{non-fuel\; types\} \subset energyc \subset C,$ $j \in NE \subset A; \; and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel\; types\} \subset energyc \subset C,$ $j \in NE \subset A$	26	P_j^{ENCOM}
	Total no. of equations	468	

2. Energy Producing Structure			
2.1. *j*-th fossil mining industry (including geothermal mining) structure ($j \in fossil \subset energy \subset A, \; energy \cap NE = \emptyset$)			
A. Top Stage: Activity Output (Gross Domestic Output) We assume a Leontief function:			
20.	The intermediate input of i-th commodity – excluding energy goods – used by j-th fossil mining industry: $X_{i,j} = ax_{i,j} QA_j, \; i \in NEC \subset C, \; j \in fossil \subset energy \subset A$	26x4	$X_{i,j}$
21.	The Value Added-Energy Composite (VAEN) used by the j-th fossil mining industry:	4	QA_j

	$VAEN_j = ava_j QA_j , \quad j \in fossil \subset energy \subset A$		
22.	The fixed resources (RES) used by the j-th fossil mining industry: $RES_j = nat_j QA_j , \quad j \in fossil \subset energy \subset A$	4	RES_j
23.	The Price of j-th fossil mining domestic output: $\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j} + PDIST_j^{RES} p^{RES} nat_j,$ $j \in fossil \subset energy \subset A$	4	p_j^{VAEN}
24.	The relationship between activity output and commodity supply: $Q_i = \sum_{j \in fossil \subset energy \subset A} TRANS\_Coef_{j,i} QA_j , \quad i \in fossilc \subset energyc \subset C$	4	Q_i
25.	The relationship between activity price and commodity price: $P_j^{QA} = \sum_{i \in fossilc \subset energyc \subset C} TRANS\_Coef_{j,i} P_i^Q , \quad j \in fossil \subset energy \subset A$	4	P_j^{QA}
	Total no. of equations	124	

B.	Second stage: Value Added-Energy Composite (VAEN) from combination of (LAB) Labour Composite and Capital-Energy Composite (KEN) We assume a Cobb-Douglas function:		
26.	$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}} , \delta_{LAB,j} + \delta_{KEN,j} = 1, \quad j \in fossil \subset energy \subset A$	4	$VAEN_j$
27.	The demand solution of j-th fossil mining industry for capital-energy composite used:	4	KEN_j

	$KEN_j = \delta_{KEN,j} \dfrac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \quad j \in fossil \subset energy \subset A$		
28.	The demand solution of j-th fossil mining industry for composite labour factor used: $LAB_j = \delta_{LAB,j} \dfrac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \quad j \in fossil \subset energy \subset A$	4	LAB_j
29.	Zero profit condition: $P_j^{VAEN} = \dfrac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \quad j \in fossil \subset energy \subset A$	0	Redundant
	Total no. of equations	12	

	C. Third stage (Left Side): The choice of labour factor We assume a CES production function:		
30.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \quad j \in fossil \subset energy \subset A,$ $\beta_j = \dfrac{1}{\sigma_j^l} - 1, \quad \sigma_j^l > 1$	0	redundant
31.	The o-th labour used: $L_{o,j} = \left(\dfrac{\gamma_{o,j}}{sl_{fossil}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_{NE} \left(\dfrac{PDIST_{o,j}^{L} P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \quad o \in LBR, \quad j \in fossil \subset energy \subset A$	16X4	$L_{o,j}$

32.	Zero profit condition: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST_{o,j}^{L} P_o^L L_{o,j}\,, \quad j \in fossil \subset energy \subset A$	4	$PDIST_j^{LAB}$

D.	Third stage (Right Side): The choice of Capital and Energy Composite We assume a Leontief function:		
33.	The capital used by j-th fossil mining industry: $K_j = ak_j KEN_j, \quad j \in fossil \subset energy \subset A$	4	K_j
34.	The energy composite (ENCOM) used by j-th fossil mining industry: $ENCOM_j = aencom_j KEN_j, \quad j \in fossil \subset energy \subset A$	4	$ENCOM_j$
35.	The Price of j-th fossil mining capital-energy composite: $p_j^{KEN} = PDIST_j^K P^K ak_j + p_j^{ENCOM} aencom_j, \quad j \in fossil \subset energy \subset A$	4	p_j^{KEN}
	Total no. of equations	80	

E.	Bottom stage: The choice of Energy Goods We assume a Leontief production function:		
36.	The energy used by $fossil$-th industry: $X_{i,j} = ax_{i,j} ENCOM_j, \quad i \in energyc \subset C, \quad j \in fossil \subset energy \subset A$	17x4	$X_{i,j}$
37.	The Price of j-th fossil mining energy composite:	4	p_j^{ENCOM}

	$p_j^{ENCOM} = \sum_{i\in energyc\subset C} \left(1+TAXFUEL_{i,j}\right)p_i^{Z} ax_{i,j}\,, \qquad j \in fossil \subset energy \subset A$ $TAXFUEL_{i,j} = 0\ if\ i \in \{non-fuel\ types\} \subset energyc \subset C,$ $j \in fossil \subset energy \subset A;$ $and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C, \quad j \in fossil \subset energy \subset A$		
	Total no. of equations	72	

2.2. Refinery Industry Structure ($\boldsymbol{j \in refinery \subset energy \subset A,\ energy \cap NE = \emptyset}$)			
A. Top Stage: Activity Output (Gross Domestic Output) We assume a Leontief function:			
38.	The intermediate input of i-th commodity – excluding energy goods – used by j-th refinery industry: $X_{i,j} = ax_{i,j}QA_j\,,\ i \in NEC \subset C,\ j \in refinery \subset energy \subset A$	26x1	$X_{NEC,refinery}$
39.	The Value Added-Energy Composite (VAEN) used by the j-th refinery industry: $VAEN_j = ava_j QA_j\,, \qquad j \in refinery \subset energy \subset A$	1	QA_j
40.	The intermediate input of crude oil commodity used by j-th refinery industry: $X_{oil,j} = ax_{oil,j}QA_j\,, \qquad oil \in energy \subset C, \qquad j \in refinery \subset energy \subset A$	1x1	$X_{oil,j}$
41.	The price of j-th refinery domestic output: $\left(1+(subAArate)\left(subArate_j\right)\right)p_j^{QA} = p_j^{VAEN} ava_j$	1	p_j^{VAEN}

	$+\sum_{i\in NEC\subset C} p_i^Z ax_{i,j} + \left(1+TAXFUEL_{oil,j}\right)p_{oil}^Z ax_{oil,refinery}, \qquad oil\in energy\subset C$ $j\in refinery\subset energy\subset A$		
42.	The relationship between activity output and commodity supply: $Q_i = \sum_{j\in refinery\subset energy\subset A} TRANS\_Coef_{j,i} QA_j\,, \qquad i\in refineryc\subset energyc\subset C$	12	Q_i
43.	The relationship between activity price and commodity price: $P_j^{QA} = \sum_{i\in refineryc\subset energyc\subset C} TRANS\_Coef_{j,i} P_i^Q\,, \qquad j\in refinery\subset energy\subset A$	1	P_j^{QA}
	Total no. of equations	42	

B.	Second stage: Value Added-Energy Composite (VAEN) from combination of (LAB) Labour Composite and Capital-Energy Composite (KEN) We assume a Cobb-Douglas function:		
44.	$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \qquad \delta_{LAB,j}+\delta_{KEN,j}=1, \qquad j\in refinery\subset energy\subset A$	1	$VAEN_j$
45.	The demand solution of j-th refinery industry for capital-energy composite used: $KEN_j = \delta_{KEN,j}\frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \qquad j\in refinery\subset energy\subset A$	1	KEN_j
46.	The demand solution of j-th refinery industry for composite labour factor used: $LAB_j = \delta_{LAB,j}\frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \qquad j\in refinery\subset energy\subset A$	1	LAB_j

47.	Zero profit condition: $P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \quad j \in refinery \subset energy \subset A$	0	Redundant
	Total no. of equations	3	

	C. Third stage (Left Side): The choice of labour factor We assume a CES production function:		
48.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \quad j \in refinery \subset energy \subset A, \quad \beta_j = \frac{1}{\sigma_j^l} - 1, \quad \sigma_j^l > 1$	0	redundant
49.	The o-th labour used: $L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_j}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_{NE} \left(\frac{PDIST_{o,j}^L P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \quad o \in LBR, \quad j \in refinery \subset energy \subset A$	16X1	$L_{o,j}$
50.	Zero profit condition: $PDIST_j^{LAB} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST_{o,j}^L P_o^L L_{o,j}, \quad j \in refinery \subset energy \subset A$	1	$PDIST_j^{LAB}$
	Total no. of equations	17	

D.	Third stage (Right Side): The choice of Capital and Energy Composite We assume a Leontief function:		
51.	The capital used by *j*-th refinery industry: $K_j = ak_j KEN_j, \quad j \in refinery \subset energy \subset A$	1	K_j
52.	The energy composite (ENCOM) – excluding crude oil – used by *j*-th refinery industry: $ENCOM_j = aencom_j KEN_j, \qquad j \in refinery \subset energy \subset A$	1	$ENCOM_j$
53.	The price of *j*-th refinery's capital-energy composite: $p_j^{KEN} = PDIST_j^K P^K ak_j + p_j^{ENCOM} aencom_j, \qquad j \in refinery \subset energy \subset A$	1	p_j^{KEN}
	Total no. of equations	3	

E.	Bottom stage: The choice of Energy Goods We assume a Leontief production function:		
54.	The energy used – excluding crude oil – by *j*-th refinery industry: $X_{i,j} = ax_{i,j} ENCOM_j, \qquad i \neq oil \in energyc \subset C, \qquad j \in refinery \subset energy \subset A$	16x1	$X_{i,j}$
55.	The price of *j*-th refinery energy composite: $\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{ENCOM} = \sum_{i \neq oil \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z ax_{i,j},$ $j \in refinery \subset energy \subset A$ $TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel\ types\} \subset energyc \subset C,$ $j \in refinery \subset energy \subset A;$	1	p_j^{ENCOM}

<table>
<tr><td></td><td>$and\ TAXFUEL_{i,j} \neq 0\ if\ i \in \{fuel\ types\} \subset energyc \subset C,$
$j \in refinery \subset energy \subset A$</td><td></td><td></td></tr>
<tr><td></td><td>Total no. of equations</td><td>17</td><td></td></tr>
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<tr><td colspan="4">2.3. Electricity industry structure ($j \in elect \subset energy \subset A$)</td></tr>
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$TAD_i = atad_i Q_i, \quad i \in electc \subset energyc \subset C$</td><td>1</td><td>$Q_i$</td></tr>
<tr><td>57.</td><td>The fixed shares of generation composite output to electricity supply:
$GEN_i = agen_i Q_i, \quad i \in electc \subset energyc \subset C$</td><td>1</td><td>$GEN_i$</td></tr>
<tr><td>58.</td><td>The price of electricity supply which is obtained from the weighted sum of the prices of transmission (and distribution) and generation composite:
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<tr><td colspan="4">Introducing the hybrid model of electricity load</td></tr>
<tr><td>59.</td><td>The choice of generation composite load
We assume a Cobb-Douglas function:
$GEN_i = sgen_i \prod_{j \in tech \subset elect \subset energy \subset A} QQA_{j,i}^{\delta_{j,i}} \quad , \quad \sum_{j \in tech \subset elect \subset energy \subset A} \delta_{j,i} = 1,$
$i \in electc \subset energyc \subset C$</td><td>0</td><td>redundant</td></tr>
<tr><td>60.</td><td>The optimum load of each type of generation technology:</td><td>3</td><td>$QQA_{j,i}$</td></tr>
</table>

	$QQA_{j,i} = \delta_{j,i} \frac{p_i^{GEN}}{P_{j,i}^{QQA}} GEN_i\,, \qquad j \in tech \subset elect \subset energy \subset A, \qquad i \in electc \subset energyc \subset C$		
61.	Price index of generation composite load: $P_i^{GEN} = \frac{1}{GEN_i} \sum_{j \in tech \subset elect \subset energy \subset A} P_{j,i}^{QQA} QQA_{j,i}\,, \qquad i \in electc \subset energyc \subset C$	1	P_i^{GEN}
A. Transmission and Distribution ($\boldsymbol{j \in TD \subset elect \subset energy \subset A}$)			
Top Stage: Activity Output (Gross Domestic Output) **We assume a Leontief function:**			
62.	The intermediate input of i-th commodity – excluding energy goods – used by transmission (and distribution) activity: $X_{i,j} \ = \ ax_{i,j} QA_j, \ i \in NEC \subset C\,, \ j \in TD \subset elect \subset energy \subset A$	26x1	$X_{i,j}$
63.	The Value Added-Energy Composite (VAEN) used: $VAEN_j = \ ava_j QA_j, \qquad j \in TD \subset elect \subset energy \subset A$	1	QA_j
64.	The Price of j-th transmission (and distribution) domestic output: $\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^Z ax_{i,j},$ $j \in TD \subset elect \subset energy \subset A$	1	p_j^{VAEN}
	Total no. of equations	28	

Second stage: Value Added-Energy Composite (VAEN) from combination of (LAB) Labour Composite and Capital-Energy Composite (KEN) We assume a Cobb-Douglas function:			
65.	$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \quad \delta_{LAB,j} + \delta_{KEN,j} = 1, \quad j \in TD \subset elect \subset energy \subset A$	1	$VAEN_j$
66.	The demand solution of capital-energy composite used: $KEN_j = \delta_{KEN,j} \dfrac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \quad j \in TD \subset elect \subset energy \subset A$	1	KEN_j
67.	The demand solution of composite labour factor used: $LAB_j = \delta_{LAB,j} \dfrac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \quad j \in TD \subset elect \subset energy \subset A$	1	LAB_j
68.	Zero profit condition: $P_j^{VAEN} = \dfrac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \quad j \in TD \subset elect \subset energy \subset A$	0	redundant
	Total no. of equations	3	
Third stage (Left Side): The choice of labour factor We assume a CES production function:			
69.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \quad \sum_{o \in LBR} \gamma_{o,j} = 1, \quad \beta_j = \dfrac{1}{\sigma_j^L} - 1,$ $j \in TD \subset elect \subset energy \subset A$	0	redundant
70.	The o-th labour used:	16X1	$L_{o,j}$

	$L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j^{\frac{\beta_j}{\beta_j+1}}}\right) LAB_j \left(\frac{PDIST^{L}_{o,j} P^{L}_{o}}{PDIST^{LAB}_{j} P^{LAB}}\right)^{\frac{-1}{\beta_j+1}}, \quad o \in LBR, \quad j \in TD \subset elect \subset energy \subset A$		
71.	Zero profit condition: $PDIST^{LAB}_{j} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST^{L}_{o,j} P^{L}_{o} L_{o,j}\,,\ j \in TD \subset elect \subset energy \subset A$	1	$PDIST^{LAB}_{j}$
	Total no. of equations	17	
Third stage (Right Side): The choice of Capital and Energy Composite We assume a Cobb-Douglas function:			
72.	$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}} K_j^{\chi_{K,j}}, \quad \chi_{ENCOM,j} + \chi_{K,j} = 1, \quad j \in TD \subset elect \subset energy \subset A$	1	K_j
73.	The demand solution of energy composite used: $ENCOM_j = \chi_{ENCOM,j} \frac{P^{KEN}_{j}}{P^{ENCOM}_{j}} KEN_j, \quad j \in TD \subset elect \subset energy \subset A$	1	$ENCOM_j$
74.	The demand solution of j-th transmission (and distribution) industry for capital used: $K_j = \chi_{K,j} \frac{P^{KEN}_{j}}{PDIST^{K}_{j} P^{K}} KEN_j\,, \quad j \in TD \subset elect \subset energy \subset A$	1	P^{KEN}_{j}
75.	Zero profit condition: $P^{KEN}_{j} = \frac{P^{ENCOM}_{j} ENCOM_j + PDIST^{K}_{j} P^{K} K_j}{KEN_j}, \quad j \in TD \subset elect \subset energy \subset A$	0	redundant
	Total no. of equations	3	

Bottom stage: The choice of Energy Goods We assume a CES production function:			
76.	$ENCOM_j = \ senergy_j \left\{ \sum_{i \in energyc \subset C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}}, \qquad j \in TD \subset elect \subset energy \subset A$	0	redundant
77.	The demand solution of intermediate energy input used: $X_{i,j} = \left(\frac{\kappa_{i,j}}{senergy_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \qquad i \in energyc \subset C,$ $j \in TD \subset elect \subset energy \subset A$ $TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel \; types\} \subset energyc \subset C,$ $j \in TD \subset elect \subset energy \subset A;$ $and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel \; types\} \subset energyc \subset C,$ $j \in TD \subset elect \subset energy \subset A$	17x1	$X_{i,j}$
78.	Zero profit condition: $P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j}, \qquad j \in TD \subset elect \subset energy \subset A$ $TAXFUEL_{i,j} = 0 \; if \; i \in \{non - fuel \; types\} \subset energyc \subset C,$ $j \in TD \subset elect \subset energy \subset A;$ $and \; TAXFUEL_{i,j} \neq 0 \; if \; i \in \{fuel \; types\} \subset energyc \subset C,$	1	P_j^{ENCOM}

	$j \in TD \subset elect \subset energy \subset A$		
	Total no. of equations	19	
B. Electricity Generation (Power Plant)			
B.1. Structure of Conventional Generation Activity ($\boldsymbol{j \in conv \subset elect \subset energy \subset A}$)			
Top Stage: Activity Output (Gross Domestic Output) We assume a Leontief function:			
79.	The intermediate input of i-th commodity – excluding energy goods – used by conventional activity: $X_{i,j} = ax_{i,j} QA_j,\ i \in NEC \subset C,\ j \in conv \subset elect \subset energy \subset A$	17x1	$X_{i,j}$
80.	The Value Added-Energy Composite (VAEN) used: $VAEN_j = ava_j QA_j, \quad j \in conv \subset elect \subset energy \subset A$	1	$VAEN_j$
81.	The price of conventional generation domestic output: $\left(1 + (subAArate)\left(subArate_j\right)\right) p_j^{QA} = p_j^{VAEN} ava_j + \sum_{i \in NEC \subset C} p_i^{Z} ax_{i,j},$ $j \in conv \subset elect \subset energy \subset A$	1	p_j^{QA}
	Total no. of equations	19	
Second stage: Value Added-Energy Composite (VAEN) from combination of (LAB) Labour Composite and Capital-Energy Composite (KEN) We assume a Cobb-Douglas function:			
82.	$VAEN_j = sva_j LAB_j^{\delta_{LAB,j}} KEN_j^{\delta_{KEN,j}}, \quad \delta_{LAB,j} + \delta_{KEN,j} = 1, \quad j \in conv \subset elect \subset energy \subset A$	1	$VAEN_j$
83.	The demand solution of capital-energy composite used:	1	KEN_j

	$KEN_j = \delta_{KEN,j} \frac{P_j^{VAEN}}{P_j^{KEN}} VAEN_j, \quad j \in conv \subset elect \subset energy \subset A$		
84.	The demand solution of composite labour factor used: $LAB_j = \delta_{LAB,j} \frac{P_j^{VAEN}}{PDIST_j^{LAB} P^{LAB}} VAEN_j, \quad j \in conv \subset elect \subset energy \subset A$	1	LAB_j
85.	Zero profit condition: $P_j^{VAEN} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEN} KEN_j}{VAEN_j}, \; j \in conv \subset elect \subset energy \subset A$	0	redundant
Third stage (Left Side): The choice of labour factor We assume a CES production function:			
86.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} {\gamma_{o,j}}^{1+\beta_j} {L_{o,j}}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}},$ $j \in conv \subset elect \subset energy \subset A, \quad \sum_{o \in LBR} \gamma_{o,j} = 1, \quad \beta_j = \frac{1}{\sigma_j^L} - 1$	0	redundant
87.	The *o*-th labour used: $L_{o,j} = \left(\frac{\gamma_{o,j}}{{sl_j}^{\frac{\beta_j}{\beta_j+1}}} \right) LAB_j \left(\frac{PDIST_{o,j}^{L} P_o^L}{PDIST_j^{LAB} P^{LAB}} \right)^{\frac{-1}{\beta_j+1}}, \quad o \in LBR, \quad j \in conv \subset elect \subset energy \subset A$	16X1	$L_{o,j}$
88.	Zero profit condition:	1	$PDIST_j^{LAB}$

	$PDIST_j^{LAB} P^{LAB} LAB_j = \sum_{o \in LBR} PDIST_{o,j}^{L} P_o^{L} L_{o,j}\,, \qquad j \in conv \subset elect \subset energy \subset A$		
	Total no. of equations	17	
Third stage (Right Side): The choice of Capital and Energy Composite We assume a Cobb-Douglas function:			
89.	$KEN_j = sken_j ENCOM_j^{\chi_{ENCOM,j}} K_j^{\chi_{K,j}}, \qquad \chi_{ENCOM,j} + \chi_{K,j} = 1, \qquad j \in conv \subset elect \subset energy \subset A$	1	KEN_j
90.	The demand solution of energy composite used: $ENCOM_j = \chi_{ENCOM,j} \frac{P_j^{KEN}}{P_j^{ENCOM}} KEN_j, \qquad j \in conv \subset elect \subset energy \subset A$	1	$ENCOM_j$
91.	The demand solution of conventional industry for capital used: $K_j = \chi_{K,j} \frac{P_j^{KEN}}{PDIST_j^{K} P_j^{K}} KEN_j, \qquad j \in conv \subset elect \subset energy \subset A$	1	K_j
92.	Zero profit condition: $P_j^{KEN} = \frac{P_j^{ENCOM} ENCOM_j + PDIST_j^{K} P_j^{K} K_j}{KEN_j}, \qquad j \in conv \subset elect \subset energy \subset A$	0	redundant
	Total no. of equations	3	
Bottom stage: The choice of Energy Goods We assume a CES production function:			

93.	$ENCOM_j = sen_j \left\{ \sum_{i \in energyc \subset C} \kappa_{i,j}^{1+\phi_j} X_{i,j}^{-\phi_j} \right\}^{-\frac{1}{\phi_j}}, \quad j \in conv \subset elect \subset energy \subset A$	1	$ENCOM_j$
94.	The demand solution of intermediate energy input used: $X_{i,j} = \left(\frac{\kappa_{i,j}}{sen_j^{\frac{\phi_j}{\phi_j+1}}} \right) ENCOM_j \left(\frac{\left(1 + TAXFUEL_{i,j}\right) p_i^Z}{P_j^{ENCOM}} \right)^{\frac{-1}{\phi_j+1}}, \quad i \in energyc \subset C,$ $j \in conv \subset elect \subset energy \subset A$ $TAXFUEL_{i,j} = 0 \ if \ i \in \{non - fuel\ types\} \subset energyc \subset C,$ $j \in conv \subset elect \subset energy \subset A;$ $and\ TAXFUEL_{i,j} \neq 0 \ if \ i \in \{fuel\ types\} \subset energyc \subset C,$ $j \in conv \subset elect \subset energy \subset A$	17x1	$X_{i,j}$
95.	Zero profit condition: $P_j^{ENCOM} = \frac{\sum_{i \in energyc \subset C} \left(1 + TAXFUEL_{i,j}\right) p_i^Z X_{i,j}}{ENCOM_j}, \quad j \in conv \subset elect \subset energy \subset A$ $TAXFUEL_{i,j} = 0 \ if \ i \in \{non - fuel\ types\} \subset energyc \subset C,$ $j \in conv \subset elect \subset energy \subset A;$ $and\ TAXFUEL_{i,j} \neq 0 \ if \ i \in \{fuel\ types\} \subset energyc \subset C,$ $j \in conv \subset elect \subset energy \subset A$	0	redundant
	Total no. of equations	18	

B.2. Structure of Renewable (Geothermal and Hydro) Generation Activity ($\boldsymbol{j\in renew\subset elect\subset energy\subset A}$)			
Top Stage: Activity Output (Gross Domestic Output) We assume a Leontief function:			
96.	The intermediate input of i-th commodity – excluding electricity goods – used by renewable generation activity: $X_{i,j} = ax_{i,j}QA_j,\ i\neq elect\in C,\ j\in renew\subset elect\subset energy\subset A$	43x2	$X_{i,j}$
97.	The Value Added- electricity ($VAEL_j$) used: $VAEL_j = ava_jQA_j, \quad j\in renew\subset elect\subset energy\subset A$	2	QA_j
98.	The fixed factor of natural resources used: $RES_j = nat_jQA_j, \quad j\in renew\subset elect\subset energy\subset A$	2	RES_j
99.	The price of renewable generation domestic output: $\left(1+(subAArate)\left(subArate_j\right)\right)p_j^{QA} = p_j^{VAEL}ava_j + \sum_{i\neq electricity\in C}\left(1+TAXFUEL_{i,j}\right)p_i^{Z}ax_{i,j} + PDIST_j^{RES}p^{RES}nat_j, \quad j\in renew\subset elect\subset energy\subset A$ Where: $TAXFUEL_{i,j}=0\ if\ i\in\{non-fuel\ types\}\subset energyc\subset C,$ $j\in renew\subset elect\subset energy\subset A;\ and\ TAXFUEL_{i,j}\neq 0\ if\ i\in\{fuel\ types\}\subset energyc\subset C,$ $j\in renew\subset elect\subset energy\subset A$	2	p_j^{QA}
	Total	40	

Second stage: Value Added-Electricity ($VAEL_j$) from combination of (LAB_j) Labour Composite and Capital-Electricity (KEL_j) We assume a Cobb-Douglas function:			
100.	$VAEL_j = sva_j LAB_j^{\delta_{LAB,j}} KEL_j^{\delta_{KEL,j}}, \quad \delta_{LAB,j} + \delta_{KEL,j} = 1, \quad j \in renew \subset elect \subset energy \subset A$	2	$VAEN_j$
101.	The demand solution of capital-energy composite used: $KEL_j = \delta_{KEL,j} \frac{P_j^{VAEL}}{P_j^{KEL}} VAEL_j, \quad j \in renew \subset elect \subset energy \subset A$	2	KEN_j
102.	The demand solution of composite labour factor used: $LAB_j = \delta_{LAB,j} \frac{P_j^{VAEL}}{PDIST_j^{LAB} P^{LAB}} VAEL_j, \quad j \in renew \subset elect \subset energy \subset A$	2	LAB_j
103.	Zero profit condition: $P_j^{VAEL} = \frac{PDIST_j^{LAB} P^{LAB} LAB_j + P_j^{KEL} KEL_j}{VAEL_j}, \quad j \in renew \subset elect \subset energy \subset A$	0	redundant
	Total no. of equations	6	
Bottom stage (Left Side): The choice of labour factor We assume a CES production function:			
104.	$LAB_j = sl_j \left\{ \sum_{o \in LBR} \gamma_{o,j}{}^{1+\beta_j} L_{o,j}{}^{-\beta_j} \right\}^{-\frac{1}{\beta_j}}, \quad j \in renew \subset elect \subset energy \subset A,$ $\sum_{o \in LBR} \gamma_{o,j} = 1, \quad \beta_j = \frac{1}{\sigma_j^L} - 1$	0	redundant

105.	The *o*-th labour used: $L_{o,j} = \left(\frac{\gamma_{o,j}}{sl_j^{\frac{\beta_j}{\beta_j+1}}}\right) LAB_{conv} \left(\frac{PDIST^L_{o,j}P^L_o}{PDIST^{LAB}_j P^{LAB}}\right)^{\frac{-1}{\beta_j+1}}, \quad o \in LBR,\ \ j \in renew \subset elect \subset energy \subset A$	16X2	$L_{o,j}$
106.	Zero profit condition: $PDIST^{LAB}_j P^{LAB} LAB_j = \sum_{o \in LBR} PDIST^L_{o,j} P^L_o L_{o,j}\,, \quad j \in renew \subset elect \subset energy \subset A$	2	$PDIST^{LAB}_j$
	Total no. of equations	34	
Bottom stage (Right Side): The choice of Capital and Energy Composite We assume a CES production function:			
107.	$KEL_j = sken_j X_{electricity,j}^{\chi_{electricity,j}} K_j^{\chi_{K,j}}, \quad \chi_{electricity,j} + \chi_{K,j} = 1, \quad j \in renew \subset elect \subset energy \subset A$	2	KEL_j
108.	The demand solution of electricity input used: $X_{electricity,j} = \chi_{electricity,j} \frac{P^{KEL}_j}{P^z_{electricity}} KEL_j, \quad j \in renew \subset elect \subset energy \subset A$	2	$X_{electricity,j}$
109.	The demand solution of capital used: $K_j = \chi_{K,j} \frac{P^{KEL}_j}{PDIST^K_j P^K_j} KEL_j, \quad j \in renew \subset elect \subset energy \subset A$	2	K_j
110.	Zero profit condition: $P^{KEL}_j = \frac{P^z_{electtricity} X_{electricity,j} + PDIST^K_j P^K K_j}{KEL_{renew}}, \quad j \in renew \subset elect \subset energy \subset A$	0	redundant

	Total no. of equations	6	

Government Block			
111.	Total government revenue: $IG = \sum_{i \in C}(vatArate)(vatrate_i)P_i^Q Q_i + \sum_{i \in CM}(tarifArate)(tarifrate_i)P_i^M M_i + \sum_{in \in INS} TR_{gov,in} + TAXCO2.CO2TOTAL$	1	IG
112.	Total government expenditure: $EG = \sum_{i \in C}\left(1 + TAXFUEL_{i,gov}\right)P_i^Z CG_i + \sum_{i \in C}(subQArate)(subQrate_i)P_i^Q Q_i + \sum_{j \in A}(subAArate)\left(subArate_j\right)P_j^{QA} QA_j + \sum_{in \in INS} TR_{in,gov}$ Where: $TAXFUEL_{i,gov} = 0\ if\ i\colon\{non - fuel\ types\} \in C\ \ ;\ and$ $TAXFUEL_{i,gov} \neq 0\ if\ i\colon\{fuel\ types\} \in C$	1	EG
113.	Public spending on i-th final goods: $CG_i = CGIN_i\overline{CGADJ}, \qquad i \in C$	43	CG_i
114.	Government spending on public services: $TR_{h,gov} = TRG\_share_{h,gov}(CPI)TRG\_bar, \qquad h \in H, \qquad gov \in INS$ $TR_{b,gov} = TRG\_share_{b,gov}TRG\_bar, \qquad b \in INS$	11x1	$TR_{in,gov}$

	$TR_{gov,gov} = TRG_{share_{gov,gov}} TRG\_bar, \qquad gov \in INS$ $TR_{ROW,gov} = TRG\_share_{ROW,gov} TRG\_bar, \qquad ROW \in INS$		
115.	Government saving: $SG = IG - EG$	1	SG
	Total no. of equations	57	

Households Block			
116.	Total income of the h-th household: $IH_h = IHL_h + IHK_h + IHRES_h + \sum_{in \in INS} TR_{h,in}, \qquad h \in H$	8	IH_h
117.	Labour income of the h-th household: $IHL_h = \sum_{o \in LBR} IHL\_share_{h,o} P_o^L \left(\sum_{j \in A} PDIST_{o,j}^L L_{o,j} + L_{o,ROW} \right), \qquad h \in H$	8	IHL_h
118.	Capital income of the h-th household: $IHK_h = IHK\_share_h P^K \left(\sum_{j \in A} PDIST_j^K K_j + K_{ROW} \right), \qquad h \in H, \qquad ROW \in INS$	8	IHK_h
119.	Household income due to the extraction of natural resources:	8	$IHRES_h$

	$IHRES_h = IHRES\_share_h P^{RES} \Bigg(\sum_{j \in fossil \subset A} PDIST_j^{RES} RES_j$ $+ \sum_{j \in renew \subset A} PDIST_j^{RES} RES_j \Bigg), \quad h \in H$		
120.	Disposable income of the h-th household: $DIH_h = IH_h - TR_{gov,h} - TAXCO2 \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2H_{i,h}, \quad h \in H, \quad gov \in INS$	8	DIH_h
121.	The the h-th household transfer payments to institution’s: $TR_{in,h} = TRH\_share_{in,h} DIH_h, \quad in \neq gov \in INS, \quad h \in H$ $TR_{gov,h} = (HAtaxrate)(Htaxrate_h)\, IH_h, \quad h \in H$	11x8	$TR_{in,h}$
122.	Actual disposable income of the h-th household: $ADIH_h = DIH_h - \sum_{in \neq gov \in INS} TR_{in,h}, \quad h \in H$	8	$ADIH_h$
123.	The h-th household saving: $SH_h = sh\_ratio_h ADIH_h, \quad h \in H$	8	SH_h
124.	Adjusted average propensity for saving of the h-th households: $sh\_ratio_h = sh\_rin_h(1 + sh\_dum_h sh\_adj), \quad h \in H$	8	sh_ratio_h
125.	Consumption budget of the h-th household: $EH_h = ADIH_h - SH_h, \quad h \in H$	8	EH_h

126.	Final demand of the h-th household: We assume a Cobb-Douglas utility function $P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h, \quad i \in NEC \subset C, \quad h \in H$ $\left(1 + TAXFUEL_{i,h}\right) P_i^Z CH_{i,h} = CH\_share_{i,h} EH_h, \quad i \in energy \subset C, \quad h \in H$ $TAXFUEL_{i,h} = 0 \; if \; i\!:\{non\; fuel\; types\} \in energy \subset C;\; and$ $TAXFUEL_{i,h} \neq 0 \; if \; i\!:\{fuel\; types\} \in energy \subset C$	43x8	$CH_{i,h}$
	Total no. of equations	352	

Consumer Price Index (CPI)			
127.	Price index of h-th households: $PI_h = \prod_{i \in C} {P_i^Z}^{CH\_share_{i,h}}, \quad h \in H$	8	PI_h
128.	CPI: $CPI = \sum_{h \in H} w_h PI_h$	1	P^{LAB}
	Total no. of equations	9	

Enterprise			
129.	Total enterprise income: $IB = IBK + \sum_{in \in INS} TR_{b,in}, \qquad b \in INS$	1	IB
130.	Capital income of enterprise: $IBK = IBK\_shareP^{K} \left(\sum_{j \in A} PDIST_j^{K} K_j + K_{ROW} \right), \qquad ROW \in INS$	1	IBK
131.	Enterprise income due to the extraction of natural resources: $IBRES = IBRES\_shareP^{RES} \left(\sum_{j \in fossil \subset A} PDIST_j^{RES} RES_j + \sum_{j \in renew \subset A} PDIST_j^{RES} RES_j \right)$	1	$IBRES$
132.	Disposable income of enterprise: $DIB = IB - TR_{gov,b}, \qquad gov\ and\ b \in INS$	1	DIB
133.	Enterprise transfer payment to in-th institutions: $TR_{in,b} = TRB\_share_{in,b} DIB, \qquad in \neq gov \in INS$ $TR_{gov,b} = (Btaxrate) IB, \quad b \in INS$	11x1	$TR_{in,b}$
134.	Actual disposable income of enterprise: $ADIB = DIB - \sum_{in \neq gov \in INS} TR_{in,b}$	1	$ADIB$
135.	Saving of enterprise:	1	$INVADJ$

	$SB = ADIB$		
	Total no. of equations	17	

Export, Import and The Balance of Payments Constraint Block			
136.	RoW total outflow: $IROW = \sum_{i\in CM} P_i^M M_i + \sum_{in\in INS} TR_{ROW,in} + \sum_{o\in LBR} RL\_share_o P_o^L \left(\sum_{j\in A} PDIST_{o,j}^L L_{o,j} + L_{o,ROW}\right)$ $+ \ RK\_share P^K \left(\sum_{j\in A} PDIST_j^K K_j + K_{ROW}\right), \qquad ROW \in INS$	1	$IROW$
137.	RoW total inflow: $EROW = \sum_{i\in CE} P_i^E E_i + \sum_{in\in INS} TR_{in,ROW} + \sum_{o\in LBR} P_o^L L_{o,ROW} + P^K K_{ROW}, \qquad ROW \in INS$	1	$EROW$
138.	ROW transfer payment to institutions': $TR_{in,ROW} = TRW\_share_{in,ROW}(EXR)TROW\_bar, \qquad ROW \notin in \in INS$ $TR_{ROW,ROW} = 0$ is treated as exogenous	11x1	$TR_{in,ROW}$
139.	Current account deficit: $SROW = EROW - IROW$	1	$SROW$
140.	The price of export for the i-th of commodities: $P_i^E = (EXR)P_i^{EW}, \qquad i \in CE$	28	P_i^E

141.	The price of import for the i-th of commodities: $P_i^M = (EXR)P_i^{MW}, \qquad i \in CM$	37	P_i^M
	Total no. of equations	88	

Investment Block			
142.	Final demand of the i-th investment commodities: $CINV_i = CINVIN_i(1 + INVADJ), \qquad i \in C$	43	$CINV_j$
143.	Saving-Investment identity used for Walras law $WAL\_RES = \sum_{h \in H} SH_h + SB + SG + SROW - \sum_{i \in C} P_i^Z CINV_i$	1	WAL_RES
	Total no. of equations	44	

Production of composite good			
144.	Armington's production function: $Z_i = sz_i \left({\delta_{m,i}}^{1+\Phi_i} {M_i}^{-\Phi_i} + {\delta_{d,i}}^{1+\Phi_i} {D_i}^{-\Phi_i} \right)^{-\frac{1}{\Phi_i}}, \qquad i \in CM \cap CD \;, \Phi = \frac{1}{\sigma^z} - 1, \qquad \sigma^z > 1$	0	redundant
145.	The final goods production by only utilizes the input of domestic commodities (not imported): $Z_i = D_i, \qquad i \in CD \;\&\; \notin CM$	6	D_i
146.	The i-th import commodity used:	37	M_i

	$M_i = \left(\frac{\delta_{mi}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}}\right) Z_i \left\{\frac{\left(1+(tarifArate)(tarifrate_i)\right)P_i^M}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}}, \qquad i \in CM \cap CD$		
147.	The i-th domestic commodity used: $D_i = \left(\frac{\delta_{di}}{{sz_i}^{\frac{\Phi_i}{1+\Phi_i}}}\right) Z_i \left\{\frac{P_i^D}{P_i^Z}\right\}^{-\frac{1}{1+\Phi_i}}, \qquad i \in CM \cap CD$	37	D_i
148.	Zero profit condition: $P_i^Z Z_i = \left(1+(tarifArate)(tarifrate_i)\right)P_i^M M_i + P_i^D D_i, \qquad i \in CM \cap CD$	37	P_i^Z
149.	Zero profit condition in which the industry only utilizes the input of domestic commodities (not imported): $P_i^Z Z_i = P_i^D\ D_i, \qquad i \in CD\ \&\ \notin CM$	6	P_i^Z
	Total no. of equations	127	

Division of gross production to domestic and exports sales			
150.	Armington's transformation equation: $Q_i = sq_i\left({\omega_{e,i}}^{1-\mu_i}(E_i)^{\mu_i} + {\omega_{d,i}}^{1-\mu_i}(D_i)^{\mu_i}\right)^{\frac{1}{\mu_i}}, \qquad i \in CE \cap CD, \qquad \mu = \frac{1}{\sigma^q}+1 \qquad ,\sigma^q > 0$	0	redundant
151.	Gross Domestic Output in the case where the industry produces only domestic commodities (not exported): $Q_i = D_i, \qquad i \in CD\ \&\ \notin CE$	15	P_i^D
152.	The i-th export commodity:	28	E_i

	$E_i = \frac{\omega_{ei}}{sq_i^{\mu_i/\mu_i-1}} Q_i \left\{\frac{P_i^E}{\left(1+(vatArate)(vatrate_i)-(subQArate)(subQrate_i)\right)P_i^Q}\right\}^{\frac{1}{\mu_i-1}},$ $i \in CE \cap CD$		
153.	The i-th domestic commodity supply: $D_i = \frac{\omega_{di}}{sq_i^{\varsigma_i/\varsigma_i-1}} Q_i \left\{\frac{P_i^D}{\left(1+(vatArate)(vatrate_i)-(subQArate)(subQrate_i)\right)P_i^Q}\right\}^{\frac{1}{\mu_i-1}},$ $i \in CE \cap CD$	28	P_i^D
154.	Zero profit condition: $\left(1+(vatArate)(vatrate_i)-(subQArate)(subQrate_i)\right)P_i^Q Q_i = P_i^D D_i + P_i^E E_i,$ $i \in CE \cap CD$	28	P_i^Q
155.	Zero profit condition in the case where the industry produces only for domestic commodities (not exported): $\left(1+(vatArate)(vatrate_i)-(subQArate)(subQrate_i)\right)P_i^Q = P_i^D, \quad i \in CD \ \& \ \notin CE$	15	P_i^Q
	Total no. of equations	168	

Market Clearing Conditions Block			
156.	Total supply equals with the total demand: $Z_i = \sum_{h \in H} CH_{i,h} + CG_i + CINV_i + \sum_{j \in A} X_{i,j}, \ \ i \in C$	43	Z_i
157.	Capital factor market-clearing conditions:	1	P^K

	$\sum_{j \in A} K_j + K_{ROW} + KU = KS, \qquad ROW \in INS$		
158.	Resource factor market-clearing conditions: $\sum_{j \in fossil \subset A} RES_j + \sum_{j \in renew \subset A} RES_j + RESU = RESS$	1	
159.	Labour factor market-clearing conditions: $\sum_{j \in A} L_{o,j} + L_{o,ROW} + LU_o = LS_o, \qquad o \in LBR, \qquad ROW \in INS$	16	P_o^L
	Total no. of equations	61	

Appendix 6.B: List of all variables appearing in the CGE model (Alphabetical Orders)

Notation used for the variable	Set, Subset, and Element Notation	Number of Variables		Definition of the Variable
		Endogenous	Exogenous	
$ADIB$		1		Actual disposable income of enterprise
$ADIH_h$	$h \in H$	8		Actual disposable income of the h-th type of households
$Btaxrate$			1	Income tax rate of enterprise
$CO2H_{i,h}$	$i \in \{fuel\ types\} \subset energyc \subset C$		12*8	CO_2 emissions generated in h-th households' used of dirty fuel
$CO2TOTAL$		1		Total CO_2 emissions generated
CG_i	$i \in C$	43		Government demand of the i-th composite goods
$CH_{i,h}$	$i \in C, \quad h \in H$	43*8		The h-th household final demand of the i-th composite goods
$CINV_i$	$i \in C$	43		Investment demand of the i-th composite goods
CPI			1	Consumer Price Index
D_i	$i \in C$	43		The i-th domestic commodity
DIB		1		Disposable income of enterprise
DIH_h	$h \in H$	8		Disposable income of the h-th type of households
E_i	$i \in C$	28		The i-th exported commodity
EG		1		Total government expenditure
EH_h	$h \in H$	8		Consumption budget of the h-th household
$ENCOM_j$	$j \in NE \subset A$	26		Energy composite used in in NE-th activity
$ENCOM_j$	$j \in fossil \subset energy \subset A$	4		Energy composite used in in $fossil$-th activity (including geothermal)
$ENCOM_j$	$j \in refinery \subset energy \subset A$	1		Energy composite used in in $refinery$-th activity
$ENCOM_j$	$j \in elect \subset energy \subset A$	2		Energy composite used in in $elect$-th activity
$EROW$		1		RoW total inflow

EXR			1	Exchange rate: units of domestic currency per unit of foreign currency
GEN_i	$i \in electc \subset energyc \subset C$	1		Generation composite output to electricity supply
$HAtaxrate$			1	Average tax rate of h-th household income
IB		1		Total enterprise income
IBK		1		Capital income of enterprise
$IBRES$		1		Resources income of enterprise
IG		1		Total government revenue
IH_h	$h \in H$	8		Total income of the h-th type of households
IHK_h	$h \in H$	8		Capital income of the h-th type of households
IHL_h	$h \in H$	8		Labour income of the h-th type of households
$INVADJ$		1		The investment adjustment index ($INVADJ$=0 if investment is fixed; otherwise if it is allowed to adjust endogenously)
$IHRES_h$	$h \in H$	8		Resources income of the h-th type of households
$IROW$		1		RoW total outflow
K_j	$j \in NE \subset A$	26		Capital used in NE-th activity
K_j	$j \in fossil \subset energy \subset A$	4		Capital used in $fossil$-th activity (including geothermal)
K_j	$j \in refinery \subset energy \subset A$	1		Capital used in $refinery$-th activity
K_j	$j \in elect \subset energy \subset A$	4		Capital used in $elect$-th activity
K_{ROW}			1	Capital used in abroad
KEN_j	$j \in NE \subset A$	26		Capital-energy composite used in NE-th activity
KEN_j	$j \in fossil \subset energy \subset A$	4		Capital-energy composite used in $fossil$-th activity (including geothermal)
KEN_j	$j \in refinery \subset energy \subset A$	1		Capital-energy composite used in $refinery$-th activity

KEN_j	$j \neq renew \in elect \subset energy \subset A$	2		Capital-energy composite used in $elect$-th activity (excluding renewable generation)
KEL_j	$j \in renew \subset elect \subset energy \subset A$	2		Capital-electricity composite used in $renew$-th generation activity
KS			1	Total of capital supply
KU			1	Unemployed (unused) capital
$L_{o,j}$	$o \in LBR,\ \ j \in NE \subset energy \subset A$	16*26		The o-th labour used in NE-th activity
$L_{o,j}$	$o \in LBR,\ \ j \in fossil \subset energy \subset A$	16*4		The o-th labour used in $fossil$-th activity (including geothermal)
$L_{o,j}$	$o \in LBR,\ \ j \in refinery \subset energy \subset A$	16*1		The o-th labour used in $refinery$-th activity
$L_{o,j}$	$o \in LBR,\ \ j \in elect \subset energy \subset A$	16*4		The o-th labour used in $elect$-th activity
$L_{o,ROW}$	$o \in LBR$		16	The o-th labour used abroad
LAB_j	$j \in NE \subset A$	26		The composite labour in NE-th activity
LAB_j	$j \in fossil \subset energy \subset A$	4		The composite labour in $fossil$-th activity (including geothermal)
LAB_j	$j \in refinery \subset energy \subset A$	1		The composite labour in $refinery$-th activity
LAB_j	$j \in elect \subset energy \subset A$	4		The composite labour in $elect$-th activity
LS_o	$o \in LBR$	16		Total supply of labour types
LU_o	$o \in LBR$		16	Total unemployment of labour types
M_i	$i \in CM \cap CD$	37		The i-th import commodity
P_i^D	$i \in C$	43		Price of the i-th domestically produced commodity
$PDIST_j^K$	$j \in NE \subset A$		26	The adjusted capital rent across NE activities
$PDIST_j^K$	$j \in fossil \subset energy \subset A$		4	The adjusted capital rent across $fossil$ activities (including geothermal)
$PDIST_j^K$	$j \in refinery \subset energy \subset A$		1	The adjusted capital rent across $refinery$ activity

$PDIST_j^K$	$j \in elect \subset energy \subset A$		4	The adjusted capital rent across $elect$-th activities
$PDIST_{o,j}^L$	$j \in NE \subset A$		16*26	The adjusted labour type wages across NE activities
$PDIST_{o,j}^L$	$j \in fossil \subset energy \subset A$		16*4	The adjusted labour type wages across $fossil$ activities (including geothermal)
$PDIST_{o,j}^L$	$j \in refinery \subset energy \subset A$		16*1	The adjusted labour type wages across $refinery$ activity
$PDIST_{o,j}^L$	$j \in elect \subset energy \subset A$		16*4	The adjusted labour type wages across $elect$-th activities
$PDIST_j^{LAB}$	$j \in NE \subset A$	26		The adjusted labour composite wage across NE activities
$PDIST_j^{LAB}$	$j \in fossil \subset energy \subset A$	4		The adjusted labour composite wage across $fossil$ activities (including geothermal)
$PDIST_j^{LAB}$	$j \in refinery \subset energy \subset A$	1		The adjusted labour composite wage across $refinery$ activities
$PDIST_j^{LAB}$	$j \in elect \subset energy \subset A$	4		The adjusted labour composite wage across $elect$-th activities
$PDIST_j^{RES}$	$j \in fossil \subset energy \subset A$		4	The adjusted resources rent across $fossil$ activities
$PDIST_j^{RES}$	$j \in renew \subset elect \subset energy \subset A$		2	The adjusted resources rent across $renew$ activities
P_i^E	$i \in CE \cap CD$	28		Price of the i-th exported commodity
p_j^{ENCOM}	$j \in NE \subset A$	26		Price of energy composite in NE-th activity
p_j^{ENCOM}	$j \in fossil \subset energy \subset A$	4		Price of energy composite in $fossil$-th activity (including geothermal)
p_j^{ENCOM}	$j \in refinery \subset energy \subset A$	1		Price of energy composite in $refinery$-th activity
p_j^{ENCOM}	$j \neq renew \in elect \subset energy \subset A$	2		Price of energy composite in $elect$-th activity
p_i^{GEN}	$i \in electc \subset energyc \subset C$	1		Price of generation composite output

P_i^{EW}	$i \in CE \cap CD$		28	The price of the i-th of exported commodities in terms of foreign currency
PI_h	$h \in H$	8		Price index of h-th households
P_i^M	$i \in CM \cap CD$	37		Price of the i-th imported commodity
P^K		1		Price of aggregate capital
P_j^{KEN}	$j \in NE \subset A$	26		Price of capital-energy in NE-th activity
P_j^{KEN}	$j \in fossil \subset energy \subset A$	4		Price of capital-energy in $fossil$-th activity (including geothermal)
P_j^{KEN}	$j \in refinery \subset energy \subset A$	1		Price of capital-energy in $refinery$ activity
P_j^{KEN}	$j \neq renew \in elect \subset energy \subset A$	2		Price of capital-energy in $elect$-th activity (excluding renewable generation)
P_j^{KEL}	$j \in renew \subset elect \subset energy \subset A$	2		Price of capital-electricity in $renew$-th generation activity
P_o^L	$o \in LBR$	16		Wages rate of the o-th labour
P^{LAB}		1		Wages rate of the composite labour in aggregated activities
P_i^{MW}	$i \in CM \cap CD$		37	The price of the i-th imported commodities in terms of foreign currency
P_i^Q	$i \in NEC \subset C$	26		Price of the NEC-th domestically produced goods
P_i^Q	$i \in fossilc \subset energyc \subset C$	4		Price of the $fossilc$-th domestically produced goods (including geothermal)
P_i^Q	$i \in refineryc \subset energyc \subset C$	12		Price of the $refineryc$-th domestically produced goods
P_i^Q	$i \in electc \subset energyc \subset C$	1		Price of the $electc$ domestically produced goods
P_j^{QA}	$j \in NE \subset A$	26		Price of gross domestic output of NE-th activity
P_j^{QA}	$j \in fossil \subset energy \subset A$	4		Price of gross domestic output of $fossil$-th activity (including geothermal)

P_j^{QA}	$j \in refinery \subset energy \subset A$	1		Price of gross domestic output of $refinery$ activity
P_j^{QA}	$j \in elect \subset energy \subset A$	4		Price of gross domestic output of $elect$-th activity
$P_{j,i}^{QQA}$	$j \in tech \subset elect \subset energy \subset A$, $i \in electc \subset energyc \subset C$	3*1		Price of gross domestic output of $tech$-th power plant activity
P^{RES}		1		Price of aggregate resources
P_j^{VAEN}	$j \in NE \subset A$	26		Price of value added-energy in NE-th activity
P_j^{VAEN}	$j \in fossil \subset energy \subset A$	4		Price of value added-energy in $fossil$-th activity (including geothermal)
P_j^{VAEN}	$j \in refinery \subset energy \subset A$	1		Price of value added-energy in $refinery$ activity
P_j^{VAEN}	$j \neq renew \in elect \subset energy \subset A$	2		Price of value added-energy in $elect$-th activity(excluding renewable generation)
P_j^{VAEL}	$j \in renew \subset elect \subset energy \subset A$	2		Price of value added-energy in $renew$-th generation activity
P_i^{Z}	$i \in energyc \subset C$	17		Price of the $energy$-th final (composite) goods
P_i^{Z}	$i \in NEC \subset C$	26		Price of the NEC-th final (composite) goods
Q_i	$i \in NEC \subset C$	26		The NEC-th domestic goods
Q_i	$i \in fossilc \subset energyc \subset C$	4		The $fossilc$-th domestic goods (including geothermal)
Q_i	$i \in refineryc \subset energyc \subset C$	12		The $refineryc$-th domestic goods
Q_i	$i \in electc \subset energyc \subset C$	1		The $electc$ domestic goods
QA_j	$j \in NE \subset A$	26		Gross domestic output of NE-th activity
QA_j	$j \in fossil \subset energy \subset A$	4		Gross domestic output of $fossil$-th activity (including geothermal)
QA_j	$j \in refinery \subset energy \subset A$	1		Gross domestic output of $refinery$-th activity
QA_j	$j \in elect \subset energy \subset A$	4		Gross domestic output of $electricity$-th activity

$QQA_{j,i}$	$j \in tech \subset elect \subset energy \subset A$, $i \in electc \subset energyc \subset C$	3*1		Gross domestic output of $tech$-th power plant activity
RES_j	$j \in fossil \subset energy \subset A$	4		The factor resources (RES) used by the $fossil$-th industry (including geothermal)
RES_j	$j \in renew \subset elect \subset energy \subset A$	2		The factor resources (RES) used by the $renew$-th industry
$RESS$			1	Total of resources supply
$RESU$			1	Unemployed (unused) resources
SB			1	Enterprise saving
SG		1		Government saving
SH_h	$h \in H$	8		Household saving
sh_adj		1		The endogenous adjustment of sh_ratio_h
sh_ratio_h	$h \in H$	8		Adjusted average propensity for saving of the h-th type of households
$SubAArate$			1	Average subsidy rate of the j-th activity
$SubQArate$			1	Average subsidy rate of the i-th gross domestic output
$SROW$			1	Current account deficit
$TAXCO2$			1	Tax on CO_2 emissions
$TAXFUEL_{i,j}$	$i \in energyc \subset C$, $j \in NE \subset A$		17*26	Tax of dirty fuel used in the NE-th activity
$TAXFUEL_{i,j}$	$i \in energyc \subset C$, $j \in fossil \subset energy \subset A$		17*4	Tax of dirty fuel used in the $fossil$-th activity (including geothermal)
$TAXFUEL_{i,j}$	$i \in energyc \subset C$, $j \in refinery \subset energy \subset A$		17*1	Tax of dirty fuel used in the $refinery$ activity
$TAXFUEL_{i,j}$	$i \in energyc \subset C$, $j \in elect \subset energy \subset A$		17*4	Tax of dirty fuel used in the $elect$-th activity
$TAXFUEL_{i,gov}$	$i \in energyc \subset C$, $gov \in INS$		17*1	Tax of dirty fuel used in the government institution
$TAXFUEL_{i,h}$	$i \in energyc \subset C$,		17*8	Tax of dirty fuel used in the government institution

	$h \in H$			
$tarifArate$			1	Average import tariff rate of i-th imported commodity
TAD_i	$i \in electc \subset energyc \subset C$	1		Transmission (and distribution) output to electricity supply
$TR_{in,in}$	$in \in INS$	120	1	Transfers between in-th institution's
TRG_bar			1	Total government transfer payments
$TROW\_bar$			1	Total ROW transfer payments
$VAEN_j$	$j \in NE \subset A$	26		The value added-energy output in NE-th activity
$VAEN_j$	$j \in fossil \subset energy \subset A$	4		The value added-energy output in $fossil$-th activity (including geothermal)
$VAEN_j$	$j \in refinery \subset energy \subset A$	1		The value added-energy output in $refinery$-th activity
$VAEN_j$	$j \neq renew \in elect \subset energy \subset A$	2		The value added-energy output in $elect$-th activity (excluding renewable generation)
$VAEL_j$	$j \in renew \subset elect \subset energy \subset A$	2		The value added-electricity output in $renew$-th generation activity
$vatArate$			1	The average *ad valorem* tax rate of the i-th gross domestic output
WAL_RES		1		Saving-Investment identity used for Walras law
$X_{i,j}$	$i \in energyc \subset C, \quad j \in NE \subset A$	17*26		The $energy$-th intermediate commodity input for NE-th activity
$X_{i,j}$	$i \in energyc \subset C,$ $j \in fossil \subset energy \subset A$	17*4		The $energy$-th intermediate commodity input for $fossil$-th activity (including geothermal)
$X_{i,j}$	$i \in energyc \subset C,$ $j \in refinery \subset energy \subset A$	17*1		The $energy$-th intermediate commodity input for $refinery$ activity
$X_{i,j}$	$i \in energyc \subset C,$ $j \in elect \subset energy \subset A$	17*4		The $energy$-th intermediate commodity input for $elect$-th activity
$X_{i,j}$	$i \in NEC \subset C, \quad j \in NE \subset A$	26*26		The NEC-th intermediate commodity input – excluding energy goods – for NE-th activity

$X_{i,j}$	$i \in NEC \subset C,$ $j \in fossil \subset energy \subset A$	26*4		The NEC-th intermediate commodity input – excluding energy goods – for $fossil$-th activity
$X_{i,j}$	$i \in NEC \subset C,$ $j \in refinery \subset energy \subset A$	26*1		The NEC-th intermediate commodity input – excluding energy goods – for $refinery$-th activity
$X_{i,j}$	$i \in NEC \subset C,$ $j \neq renew \in elect \subset energy \subset A$	26*2		The NEC-th intermediate commodity input – excluding energy goods – for $elect$-th activity
$X_{i,j}$	$i \neq electricity \in C,$ $j \in renew \subset elect \subset energy \subset A$	42*2		The i-th intermediate commodity for $renew$-th generation activity
Z_i	$i \in C$	43		Final output of the i-th composite commodity
TOTAL No:		**3505**	1540	

Appendix 6.C: List of all parameters used in the modified CGE model

Parameters	Set, Subset, and Element Notation	Description and measurement
ak_{fossil}	$j \in fossil \subset energy \subset A$	Coefficient of minimum requirements of the K_{fossil} for one unit of KEN_{fossil}
$ak_{refinery}$	$j \in refinery \subset energy \subset A$	Coefficient of minimum requirements of the $K_{refinery}$ for one unit of $KEN_{refinery}$
$aencom_{fossil}$	$j \in fossil \subset energy \subset A$	Coefficient of minimum requirements of the $ENCOM_{fossil}$ for one unit of KEN_{fossil}
$aencom_{refinery}$	$j \in refinery \subset energy \subset A$	Coefficient of minimum requirements of the $ENCOM_{refinery}$ for one unit of $KEN_{refinery}$
$agen_{electc}$	$i \in electc \subset energyc \subset C$	The fixed shares of generation composite output to electricity supply
$atad_{electc}$	$i \in electc \subset energyc \subset C$	The fixed shares of transmission (and distribution) output to electricity supply
ava_{NE}	$j \in NE \subset A$	Coefficient of minimum requirements of the $VAEN_{NE}$ for one unit of QA_{NE}
ava_{fossil}	$j \in fossil \subset energy \subset A$	Coefficient of minimum requirements of the $VAEN_{fossil}$ for one unit of QA_{fossil}
$ava_{refinery}$	$j \in refinery \subset energy \subset A$	Coefficient of minimum requirements of the $VAEN_{refinery}$ for one unit of $QA_{refinery}$
ava_{elect}	$j \in elect \subset energy \subset A$	Coefficient of minimum requirements of the $VAEN_{elect}$ for one unit of $QA_{electricity}$
$ax_{NEC,NE}$	$i \in NEC \subset C, \quad j \in NE \subset A$	Coefficient of minimum requirements of NEC-th intermediate input – excluding energy goods – for a unit of QA_{NE}
$ax_{NEC,fossil}$	$i \in NEC \subset C,$ $j \in fossil \subset energy \subset A$	Coefficient of minimum requirements of NEC-th intermediate input – excluding energy goods – for a unit of Q_{fossil}

$ax_{NEC,refinery}$	$i \in NEC \subset C,$ $j \in refinery \subset energy \subset A$	Coefficient of minimum requirements of NEC-th intermediate input – excluding energy goods – for a unit of $Q_{refinery}$
$ax_{NEC,elect}$	$i \in NEC \subset C,$ $j \in elect \subset energy \subset A$	Coefficient of minimum requirements of NEC-th intermediate input – excluding energy goods – for a unit of Q_{elect}
$ax_{energy,fossil}$	$i \in energyc \subset C,$ $j \in fossil \subset energy \subset A$	Coefficient of minimum requirements of $energy$-th intermediate input for a unit of Q_{elect}
$ax_{energy,refinery}$	$i \in energyc \subset C,$ $j \in refinery \subset energy \subset A$	Coefficient of minimum requirements of $energy$-th intermediate input for a unit of $Q_{refinery}$
$\beta_{NE} = \frac{1}{\sigma^{l}_{NE}} - 1, \quad \sigma^{l}_{NE} > 1$	$j \in NE \subset A$	Elasticity (CES-composite labour) in NE-th industry (non-energy)
$\beta_{fossil} = \frac{1}{\sigma^{l}_{fossil}} - 1\,, \sigma^{l}_{fossil} > 1$	$j \in fossil \subset energy \subset A$	Elasticity (CES-composite labour) in $fossil$-th industry
$\beta_{refinery} = \frac{1}{\sigma^{l}_{refinery}} - 1 \quad, \sigma^{l}_{refinery} > 1$	$j \in refinery \subset energy \subset A$	Elasticity (CES-composite labour) in $refinery$ industry
$\beta_{j} = \frac{1}{\sigma^{l}_{j}} - 1, \quad \sigma^{l}_{j} > 1$	$j \in A$	Elasticity (CES-composite labour) in j-th industry (non-energy, and energy producing sectors)
$\delta_{di} + \delta_{mi} = 1$	$i \in CM \cap CD$	Import and domestic share parameter of Armington's for i-th composite commodity, $0 \leq \delta_{di} \leq 1$
$\delta_{LAB,NE} + \delta_{KEN,NE} = 1$	$j \in NE \subset A$	Share parameter of capital and labour by NE-th industry, $0 \leq \delta_{KEN,NE} \leq 1$
$\delta_{LAB,fossil} + \delta_{KEN,fossil} = 1$	$j \in fossil \subset energy \subset A$	Share parameter of capital and labour by $fossil$-th industry, $0 \leq \delta_{KEN,fossil} \leq 1$
$\delta_{LAB,refinery} + \delta_{KEN,refinery} = 1$	$j \in refinery \subset energy \subset A$	Share parameter of capital and labour by $refinery$-th industry,

		$0 \leq \delta_{KEN,refinery} \leq 1$
$\delta_{LAB,elect} + \delta_{KEN,elect} = 1$	$j \in elect \subset energy \subset A$	Share parameter of capital and labour by $elect$-th industry, $0 \leq \delta_{KEN,elect} \leq 1$
$\lambda_{tech,electc}$	$j \in tech \subset elect \subset energy \subset A,$ $i \in electc \subset energyc \subset C$	Share parameter of each generation technology to produce $electc$ commodity, $\sum_{tech \in A} \lambda_{tech,electc} = 1$
$\gamma_{o,NE}$	$j \in NE \subset A$	Share parameter of o-th labour used by NE-th industry ($0 \leq \gamma_{o,NE} \leq 1$)
$\gamma_{o,fossil}$	$j \in fossil \subset energy \subset A$	Share parameter of o-th labour used by $fossil$-th industry ($0 \leq \gamma_{o,fossil} \leq 1$)
$\gamma_{o,refinery}$	$j \in refinery \subset energy \subset A$	Share parameter of o-th labour used by $refinery$-th industry ($0 \leq \gamma_{o,refinery} \leq 1$)
$\gamma_{o,elect}$	$j \in elect \subset energy \subset A$	Share parameter of o-th labour used by $electricity$-th industry ($0 \leq \gamma_{o,elect} \leq 1$)
$\kappa_{energy,NE}$	$i \in energyc \subset C,$ $j \in NE \subset A$	Share parameter of energy types used by NE-th industry ($0 \leq \kappa_{energy,NE} \leq 1$)
$\kappa_{energy,elect}$	$i \in energyc \subset C,$ $j \in elect \subset energy \subset A$	Share parameter of energy types used by $elect$-th industry ($0 \leq \kappa_{energy,elect} \leq 1$)
ω_{ei}	$i \in C$	Share parameter of i-th transformation commodity, $0 \leq \omega_{ei} \leq 1$
$\omega_{di} + \omega_{ei} = 1$	$i \in CE \cap CD$	Export and domestic share parameter of Armington's for i-th composite commodity, $0 \leq \omega_{di} \leq 1$
$\phi_{NE} = \frac{1}{\sigma_{NE}^{energy}} - 1$, $\sigma_{NE}^{energy} > 1$	$j \in NE \subset A$	Elasticity (CES-energy composite) in NE-th industry

$\phi_{elect} = \frac{1}{\sigma_{elect}^{energy}} - 1$ $, \sigma_{elect}^{energy} > 1$	$j \in elect \subset energy \subset A$	Elasticity (CES-energy composite) in $elect$-th industry
$\mu_i = \frac{1}{\sigma_i^q} + 1, \quad \sigma_i^q > 0$	$i \in CE \cap CD$	Elasticity (CET-Armington's)
$\Phi_\mathrm{i} = \frac{1}{\sigma_i^z} - 1, \quad \sigma_i^z > 1$	$i \in CM \cap CD$	Elasticity (CES-Armington's)
$\chi_{ENCOM,NE} + \chi_{K,NE} = 1$	$j \in NE \subset A$	Share parameter of energy composite and capital by NE-th industry, $0 \leq \chi_{K,NE} \leq 1$
$\chi_{ENCOM,elect} + \chi_{K,elect} = 1$	$j \neq renew \in elect \subset energy \subset A$	Share parameter of energy composite and capital by $elect$-th industry, $0 \leq \chi_{K,elect} \leq 1$
$\chi_{elect,renew} + \chi_{K,renew} = 1$	$j \in renew \subset elect \subset energy \subset A$	Share parameter of energy composite and capital by $elect$-th industry, $0 \leq \chi_{K,renew} \leq 1$
nat_{fossil}	$j \in fossil \subset energy \subset A$	The fixed resources (RES) used by the $fossil$-th industry
nat_{renew}	$j \in renew \subset elect \subset energy \subset A$	The fixed resources (RES) used by the $renew$-th industry
sen_{NE}	$j \in NE \subset A$	Efficiency parameter of energy composite used by the NE-th industry
sen_{elect}	$j \in elect \subset energy \subset A$	Efficiency parameter of energy composite used by the $elect$-th industry
$sgen_{electc}$	$i \in electc \subset energyc \subset C$	Efficiency parameter of generation composite for $electc$ commodity
$sken_{NE}$	$j \in NE \subset A$	Efficiency parameter of capital-energy composite used by the NE-th industry
$sken_{elect}$	$j \in elect \subset energy \subset A$	Efficiency parameter of capital-energy composite used by the $elect$-th industry

sl_{NE}	$j \in NE \subset A$	Efficiency parameter of composite labour used by the NE-th industry (non-energy producing sectors)
sl_{fossil}	$j \in fossil \subset energy \subset A$	Efficiency parameter of composite labour used by the $fossil$-th industry
$sl_{refinery}$	$j \in refinery \subset energy \subset A$	Efficiency parameter of composite labour used by the $refinery$ industry
sl_{elect}	$j \in elect \subset energy \subset A$	Efficiency parameter of composite labour used by the $elect$-th industry
sl_j	$j \in A$	Efficiency parameter of composite labour used by the j-th industry (non-energy, and energy producing sectors)
sq_i	$i \in C$	Shift parameter of CET transformation of i-th commodity supply
sva_{NE}	$j \in NE \subset A$	Efficiency parameter of $VAEN$ used by the NE-th industry (non-energy producing sectors)
sva_{fossil}	$j \in fossil \subset energy \subset A$	Efficiency parameter of $VAEN$ used by the $fossil$-th industry
$sva_{refinery}$	$j \in refinery \subset energy \subset A$	Efficiency parameter of $VAEN$ used by the $refinery$ industry
sva_{elect}	$j \in elect \subset energy \subset A$	Efficiency parameter of $VAEN$ used by the $elect$-th industry
sz_i	$i \in C$	Shift parameter of Armington's production of i-th final goods

Appendix 6.D: List of Shares, Rates, and Weights

Parameters	Set, Subset, and Element Notation	Description and measurement
$\overline{CGADJ}$		Adjustment factor for government consumption
$CGIN_i$	$i \in C$	Initial government consumption on the i-th types of composite goods
$CH\_share_{i,h}$	$i \in C, \quad h \in H$	Share parameter of Cobb-Douglas utility function of the h-th type of households to consume the i-th composite goods
$CINVIN_i$	$i \in C$	Initial investment demand of the i-th commodity
$Htaxrate_h$	$h \in H$	Specific tax rate adjustment of h-th household
IBK_share		Share of capital income received by enterprise
$IBRES\_share$		Share of resources income received by enterprise
IHK_share_h	$h \in H$	Share of capital income received by h-th type of households
$IHL\_share_{h,o}$	$h \in H, \quad o \in LBR$	Share of the o-th type of labour income received by h-th type of households
$IHRES\_share_h$	$h \in H$	Share of resources income received by h-th type of households
RK_share		Share of the foreign capital used domestically
RL_share_o	$o \in LBR$	Share of the o-th type of foreign labour used domestically
sh_dum_h	$h \in H$	Dummy parameter to allow sh_ratio_h to adjust
sh_rin_h	$h \in H$	Initial value of average propensity for saving of the h-th type of households

$SubArate_{NE}$	$j \in NE \subset A$	Subsidy rate adjustment across NE-th activity
$SubArate_{fossil}$	$j \in fossil \subset energy \subset A$	Subsidy rate adjustment across $fossil$-th activity
$SubArate_{refinery}$	$j \in refinery \subset energy \subset A$	Subsidy rate adjustment across $refinery$-th activity
$SubArate_{elect}$	$j \in elect \subset energy \subset A$	Subsidy rate adjustment across $elect$-th activity
$SubArate_j$	$j \in A$	Subsidy rate adjustment across j-th activity
$SubQrate_i$	$i \in C$	Subsidy rate adjustment across i-th gross domestic output
$tarifrate_i$	$i \in CM$	Import tariff rate adjustment across i-th imported commodity
$TRANS\_Coef_{NE,NEC}$	$j \in NE \subset A, \quad i \in NEC \subset C$	Input-Output coefficients between non-energy output and their commodity supply
$TRANS\_Coef_{fossil,fossilc}$	$j \in fossil \subset energy \subset A,$ $i \in fossilc \subset energyc \subset C$	Input-Output coefficients fossil output and their commodity supply
$TRANS\_Coef_{refinery,refineryc}$	$j \in refinery \subset energy \subset A,$ $i \in refineryc \subset energyc \subset C$	Input-Output coefficients between refinery output and their commodity supply
$TRB\_share_{in,b}$	$in \in INS, \quad b \in INS$	The share of enterprise transfer payment to the in-th institution's
$TRG\_share_{in,gov}$	$in \in INS, \quad gov \in INS$	The share of government transfer payment to the in-th institution's
$TRH\_share_{in,h}$	$in \in INS, \quad h \in H \subset INS$	The share of the h-th type of households transfer payment to non-government institution's
$TRW\_share_{in,ROW}$	$in \in INS, \quad ROW \in INS$	The share of the ROW transfer payment to the in-th institution's

$vatrate_i$	$i \in C$	The *ad valorem* tax rate adjustment across i-th gross domestic output
w_h	$h \in H$	CPI weight as share of each households' expenditure in total expenditure

Appendix 6.E: Value of CES and CET Elasticity

CES and CET Parameter	**Value**	**Source**
β_j	0.8	Decaluwé, *et al* (2012)
ς_i	2	
ρ_j	1.5	
Φ_i	2	
θ_{NE}	0.3 – 0.5	Paltsev, *et al* (2005); Orlov (2012); and Orlov, *et al* (2013)
θ_{TD}	0.3 – 0.5	
θ_{conv}	0.3 – 0.5	

Chapter 7

Policy Experiments Using the Hybrid CGE Model for Energy Analysis in Indonesia

7.1. Introduction

In recent decades, the threat of global warming – that is primarily caused by the atmospheric greenhouse gas emissions – have become a central issue in the world's political and scientific arena. The global average temperature has increased by 0.6^0C over the last century, whilst the CO_2 concentration could rise between 75% - 350% above preindustrial level by the end of the twenty-first century (IPCC, 2010). If the CO_2 emissions are not mitigated, the global temperature could rise by between 1.4 – 5.8^0C by 2100 (IEA, 2009; and Baumert, *et al*., 2005). As a consequence, the climate change can lead to severe problems for the world's population, especially in developing countries, such as sea level rise, extreme weather, flooding, a drop in biodiversity, a lack of water resources, and diseases (Lackner, *et al*., 2012; and Baumert, *et al.*, 2005).

In addressing these issues, numerous international programs and approaches have been proposed to reduce the level of GHG released into the atmosphere that create global warming (Moore, 2012). Among other strategies, carbon abatement as well as the development of clean energy production are becoming one of the priority to mitigate the anthropogenic greenhouse gas (GHG) effect. The common targeted types of GHGs to be reduced are (i) carbon dioxide (CO_2) which is emitted mainly from the fossil fuels combustion; (ii) methane (CH_4) which is emitted from the production of fossil fuels, livestock, and organic waste; (iii) nitrous oxide (N_2O) which is emitted from agricultural and industrial activities as well as the burning of fossil fuels and waste; and (iv) the families of hydrofluorocarbons (HCFs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) which are emitted by industrial processes (Moore, 2012). Nevertheless, compared to other GHGs, CO_2 has a much higher concentration in the atmosphere and is increasing due to the combustion of fossil fuels which is identified as one of the major sources of greenhouse gas emissions (Lackner, *et al*., 2012). Baumert, *et al* (2005) stated that since post industrial revolution, the atmospheric concentrations of CO_2 have increased 35% which is mainly due to fossil fuels combustion and deforestation. Energy sector is considered as the major contributor of GHG emissions (Lackner, *et al.*, 2012). It is generally recognized that in developing countries, the burning of fossil fuel tends to rapidly increase as a result of their economic growth (Lackner, *et al*., 2012). Therefore, it is important to achieve a low carbon development from, i.e., converting fossil-fuel utilization to renewable energies including energy efficiency (Lackner, *et al*., 2012).

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the United Nations World Meteorological Organization (WMO) and the United Nations

Environment Program (UNEP), as key task to develop policies in addressing the climate change issues (Moore, 2012). The United Framework Convention on Climate Change (UNFCCC) was thereafter ratified by the United States and 153 other countries with a goal to voluntarily commit to reducing their GHG emissions within an acceptable level in future period (Moore, 2012). Annual meetings, referred as conferences of the parties (COP), have been held by all parties to discuss their target and action plan to reduce the GHGs; and the following progress updates on current issues and future planning (Moore, 2012). Of all COP meetings, the Kyoto Protocol, adopted in year 1997 and entered into force in year 2005, was considered as the most significant result to achieve the agreed commitment of GHG emission reduction targets for 37 developed countries and the European union (Moore, 2012). The agreed targets were an average reduction of 5% against 1990 emission levels from year 2008 to 2012 (Moore, 2012). In year 2009, the Copenhagen Accord updated the first commitment period of the Kyoto Protocol (Moore, 2012). Approved by 186 countries, the Accord required: (i) countries to increase the mitigation actions in order to keep the increase of global temperatures below 2^0C; (ii) countries to submit their specific GHG emission reduction; and (iii) developed countries to provide financial support to the developing countries for forest conservation, adaptation, technology development and transfer as well as capacity building (Moore, 2012).

The country members (parties) under the UNFCCC are classified into: (i) Annex 1 industrialized-countries that ratified the Kyoto Protocol to meet the reduction targets of their GHG emissions based on year 1990 emission levels; (ii) Annex 2 industrialized- countries that are essentially a subgroup of Annex 1 countries and members of OECD excluding those countries that were still in transition-economies in year 1992. These countries will be commissioned to finance mitigation and adaption expenses of developing countries; and (iii) Non-Annex 1 (developing) countries (Moore 2012; and Bumert et al., 2012. As a group member of non-Annex 1, Indonesia ratified the UNFCCC and adopted the Kyoto Protocol in order to seriously mitigate the climate change (Ministry of Finance, 2008). Under the Copenhagen Accord, the Indonesia's government has voluntarily made a commitment to reduce their national greenhouse gas (GHG) emissions by 26% in year 2020 of which the GHG emissions shares from energy utilization are targeted to be reduced by about 1% (NCCC, 2009). Despite the fact that Indonesia has a huge potential of renewable energy sources, their utilizations are still very low (NCCC, 2009). Therefore, Indonesia is expected to scaling up this clean energy production in order to lowering the national emissions (NCCC, 2009; Ardiansyah *et al.*, 2012).

According to Baumert *et al.* (2005) the emissions growth rate in Indonesia (97%) was fastest among other developing country emitters between the year 1990 – 2002. Indonesia ranked 21st in the total share of world's CO_2 emissions (counted only from fossil fuels combustion). Indonesia's emissions level is strongly influenced by the size of the population and economic growth. Indonesia is currently ranked as the 4th largest population in world with annual economic growth rates around 6-7% (Yusuf and Resosudarmo, 2007; and Baumert et al (2005). The CO_2 emissions are mainly generated by deforestation (48%), the energy sector (21%), and peatland (12%); total Indonesia's GHG emission in year 2000 was 1.72 Gt CO_2e and is projected to reach 2.95 Gt CO_2e under business-as-usual scenarios (NCCC, 2009). Although the largest shares of emissions derived from deforestation and peat fires, emissions from the burning of 'dirty' energy will be growing in line with economic growth, which could cause severe problems in long-run (Ministry of Energy and Mineral Resources, 2011; and Ministry of Finance, 2012).

To meet the emission reduction targets, the Indonesian government has included the energy sector as a priority of its mitigation framework (Ministry Finance, 2012). Fossil fuels are still dominant in Indonesia's energy supply: only about 4% of energy is from renewable sources – of which two thirds coming from hydro and one third from geothermal (Ministry of Finance, 2012). In the electricity generation, fossil fuels still dominate (about 86%) followed by renewable energy sources (3% from geothermal and 9% from hydro) (PLN, 2011a; Ministry of Finance, 2012). These statistics clearly show that the clean energy utilization remains very low compared to their huge potential (Ministry of Finance, 2012). Under Presidential Decree No. 5/2006, the electricity generation from renewable sources should reach 25% by the year 2025.

A feed-in tariff (FIT) plays an important role in addressing climate change. Feed-in tariff is a fixed price for purchases of renewable generation that is paid at a premium rate for each unit of electricity, kilowatt-hour (kWh), transmitted into the grid connection (Mendoca *et al.*, 2010). It is one of the policy schemes aimed to rapidly promote the production of non-emitting renewable energy sources (Rio and Bleda, 2013; and Mendoca *et al.*, 2010). FIT schemes have proven to be the best support mechanism, stable, and has become the most essential policy to reduce the GHG emissions (Mendoca *et al.*, 2010). In Germany, the FIT has successfully enabled to reduce emissions of 79 million tonnes of carbon dioxide equivalent in year 2008. FIT – substantial incentives given to renewable production – are independent from government spending because these schemes are generally financed through tax revenues (Mendoca *et al.*, 2010). FIT guarantees a fixed price for purchases of renewable generation from the producer in a long-term contract (Mendoca *et al.*, 2010; and Bohringer *et al.*, 2012). The price cap is usually set higher than either the average unit cost rate of electricity supplied into the grid connectors, or the average unit cost of the most expensive fuel generators, i.e. natural gas-fired generators (Mendoca *et al.*, 2010; and Bohringer *et al.*, 2012). A well designed FIT should enable to cover the costs of renewable energy development, to provide a reasonable rate of return to investors, and to reduce the risk associated with financing the renewable electricity projects (Bohringer *et al.,* 2012). The government will then regulate power companies to purchase renewable generation from producers at this price cap over the agreed long period of contract (Mendoca *et al*., 2010).

The Indonesia's FITs has been stipulated in the Government Regulation No. 79/2014 on National Energy Policy. It stated that "the selling price of renewable energy must be determined upon the FITs mechanism". The price of each type of renewable sources is fixed by the Minister of Energy and Mineral Resources Regulation No. 04/2012, and ranges from Rp. 656/kWh to Rp. 1,722.5/kWh. In the regulation, the price cap ranges are substantially determined on the types of renewables, level of generated voltage and geographic location. For example, if power company purchases wind or solar generation at medium voltages on any site location in Indonesia, the price will be Rp. 656/kWh. However, if the company purchases biomass or biogas generation at low voltages on east regions of Indonesia, i.e. Maluku or Papua, the price will be escalated up to about Rp. 1,722.5/kWh. Following Bohringer *et al.* (2012), we assume that the price is at the mid-point between these values (Rp. 1,189.25/kWh). Meanwhile, we assume that the average unit cost of electricity generation in year 2011 is Rp. 1,051.14/kWh (PLN 2011b). The FITs therefore translate into a 13.14% subsidy rate to renewable generation technologies. The financing scheme to cover these additional subsidies, however, was not clearly explained in above Regulation.

Imposing carbon taxes – carbon pricing instrument – can also be used as alternative schemes in mitigating the climate change (Bhattacharyya, 2011). Carbon pricing can be introduced in several ways, i.e. the implementation of Emission Trading System (ETS), carbon taxes, offset mechanisms, results-based finance (RBF), and internal carbon prices set by companies. Carbon tax is an explicit tax – in terms of the price per tCO_2e – imposed on the carbon content of the polluter, i.e. the 'dirty' fuels (Hoeller and Wallin, 1991). It is a Pigouvian tax aiming to internalise the externality of climate change (Bhattacharyya, 2011). Pittel *et al.* (2012) point out that a carbon tax increases the price of polluter commodities, such that there are incentives to reduce the utilization of such commodities. The carbon tax scheme is considered to have a number of significant advantages over the Kyoto mechanism: (i) it leads to the reduction of GHG emissions and supports energy efficiency, clean energy production as well as the technological progress; and (ii) it gains a "double dividend" to the government by inducing not only a cleaner environment but also less distorting taxes due to additional revenues raised from carbon taxes (Pittel *et al*., 2012; Orlov, 2012; and Ditya and Resosudarmo, 2016).

However, a carbon tax has some disadvantages. It increases the energy costs which in turn reduces the domestic consumption (and production) (Orlov, 2012). It might also be regressive towards income distribution[40]; as ‘dirty’ fuels are normal goods, thus, imposing carbon taxes to these polluters might disproportionately harm low-income households instead of rich households (Ditya and Resosudarmo, 2016; and Callan *et al.*, 2009). Carbon pricing might also create a “rebound effect”, in that it triggers a higher level of GHG emissions instead of reducing it (Ditya and Resosudarmo, 2016). A rebound effect may occur from two channels. First, the increased price of CO_2-related fuels leads to a higher energy efficiency which in turn increases the energy consumption that offsets the energy saving (Sorrel and Dimitropoulos 2008; and Sorrel 2009). Second, the additional revenue gained from carbon tax could also increase the institutions’ demand for energy (Ditya and Resosudarmo, 2016).

In some countries, a carbon tax has been adopted to mitigate climate change, where its implementation is usually revenue-neutral (other distorting taxes are reduced). Since the 1990s, Norway, Denmark, and Finland imposed fuels taxes based on the level of their carbon content (Bhattacharyya, 2011). In 2015, Norway increased the carbon tax on natural gas and Liquefied Petroleum Gas (from US$41/t$CO_2$e to about US$50/tCO_2e) to promote the production of biogas (World Bank, 2015). The UK, Germany, Switzerland, and Italy have also adopted carbon taxes to meet their commitments to reduce the GHG emissions (IPCC, 2001). In 2014, Chile implemented carbon tax to all power plants with thermal input based higher than 50 MW; the tax level is equivalent to about US$5/t$CO_2$e (World Bank, 2015). France, in 2014, introduced a carbon tax of US$8/t$CO_2$e on the fossil fuels that are not covered by the European Union’s Emission Trading System (ETS); the tax rate increased to US$16/t$CO_2$e in 2015 and US$24/tCO_2e in 2016, and will further rise to US$61/t$CO_2$e in 2020 and US$110/tCO_2e in 2030 (World Bank, 2015). In Portugal, a carbon tax of approximately US$5/t$CO_2$e in 2015, was imposed to all energy products used in non-EU ETS sectors; it covers almost a quarter of the country’s emissions (World Bank, 2015). Switzerland imposed a carbon tax on thermal fuels, excluding fossil motor fuels, which increased from US$62/t$CO_2$e to US$87/tCO_2e in 2016. This adjustment was due to the past result in 2015 of which the emission level lied above the targeted level; the tax rate will be reviewed according to emissions level in 2018 (World Bank, 2015). Overall, in 2014, the total revenues in the world raised through carbon taxes implementation were US$10 billion. The United Kingdom accounted for about a fifth of total revenue, followed by Japan, Finland, Norway, and British Columbia (World Bank, 2015).

In Indonesia, the carbon tax has yet to be implemented. A carbon tax was considered in the Ministry of Finance (2009) report as one of the government’s fiscal strategic framework to

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[40] Based on numerous literature studies, the regressive nature of carbon tax mostly occurrs in developed economies; in developing economies, carbon taxes are either less regressive or progressive (Ditya and Resosudarmo, 2016; Callan et al, 2009; Brannlund and Nordsrtom, 2004; Oladosu and Rose, 2007; Yusuf and Resosudarmo, 2015; and Corong, 2008).

finance the country's action plan to reduce the GHG emissions – regulated in the Presidential Regulation no. 61/2011. The report identified the strategy including "working towards a carbon tax or levy on fossil fuel in parallel with removal over time of energy subsidies and with access to international carbon markets" (Ministry of Finance, 2012). The report argued that a carbon tax can lower the carbon emissions in electricity generation supply and industrial activities as well future investment decisions (Ministry of Finance, 2009).

This study aims to investigate the two key frameworks to reduce Indonesia's GHG emissions: (i) implementing carbon tax on fossil fuels; and (ii) promoting the production of renewable electricity through the FIT. We analyse the effects of these policy instruments, within the context of general equilibrium analysis, on Indonesia's macroeconomy and examine how different institutions and sectors in the economy are affected. More specifically, the key questions to be asked in this analysis are: Would a carbon tax or FIT reduce Indonesia's CO_2 emissions generated from the use of fossil fuels? What would be the impact of a carbon tax compared to the FIT on the Indonesia's economy (on sectoral output, income equity, and demand of energy commodities)? Is a carbon tax progressive or regressive towards income distribution? To our knowledge, this work is the first to analyse the economy-wide impact of introducing the carbon tax and (or) FIT in Indonesia.

Numerous experiments can be implemented using a carbon tax or FIT. For example, Yusuf (2008) investigated the effects of a carbon tax of US$32.6/t$CO_2$e for Indonesia in three different experiments: (i) allowing only the government saving adjustment to obtain a budget surplus, aimed to assess the magnitude of distribution costs when there is no compensation to the increased tax revenues; (ii) testing a double-dividend hypothesis by allowing a revenue-neutral mechanism in which the revenue raised from a carbon tax is compensated by the reduction of *ad valorem* tax rates across commodities; and (iii) allowing carbon tax compensation through the higher transfer payments to households. Ditya and Resosudarmo (2016) implemented a carbon tax of US$10/ton CO_2e for ASEAN countries in three different simulations: (i) allowing the government to increase their expenditure on commodities by an amount equal to the additional revenue raised from the carbon tax; (ii) allowing the government to redistribute 50% of carbon tax revenues in the form of transfer payments to low-income households; and (iii) allowing a double-dividend hypothesis of which the government uses 50% of the revenue raised to lower the indirect tax across industries. Proença and Aubyn (2013) implemented the FITs scheme – expressed as the endogenous ad-valorem output subsidy to renewable generation – to meet the 45% target share of Portugal's electricity production from renewable generations. The subsidy is financed by a lump-sum transfer to households. In other words, the households lump-sum transfer is allowed to adjust in order to compensate the additional subsidies to renewable generations. Bohringer *et al.* (2012) introduced Ontario's

FIT which is financed by the electricity consumers in the province through the endogenous tax of electricity sales. The FIT is set at €22.3/kWh or translated into 81.3% subsidy rate for renewable generations.

By following the approaches advocated in the literature, such as above studies, we carry out a number of scenarios which are principally related to the ways of fiscal schemes in recycling (or neutralizing) the carbon tax or FIT injections. Firstly, we separate our simulations under two main policy instruments, the carbon tax and the FIT. Secondly, for each instrument, we consider some recycling schemes as follows.

On carbon tax implementation, we assume that the Indonesia's government levies a tax of Rp. 100,000/ton CO_2e with three possible revenue-recycling schemes. In the first simulation, we allow the revenue neutralizing scheme by which the revenue raised from carbon tax is neutralize through a reduction in income (labour) tax rates. In other words, the income (labour) tax rate is allowed to adjust so that the government net receipts are in balance. In the second simulation, we allow the government to adjust their spending on goods proportionally in response to the revenue raised from carbon tax. A higher public expenditure is expected to increase the equilibrium output. The third simulation assumes endogenous government saving, without any revenue recycling, to allow a budget surplus. Following Yusuf (2008), this scenario aims to assess the impact of carbon tax on Indonesia's economy when there is no compensating (revenue neutralizing) mechanisms. In the FIT implementation, we assume that the Indonesia's government sets a 15% subsidy rate to renewable generations, in this case hydro and geothermal generation, with two possible financing schemes. Following Bohringer *et al.* (2012), in the fourth simulation, we assume that the FIT is distributed equally among the electricity consumers through the adjusted electricity tax rate. Finally, the fifth simulation assumes the FIT is financed by introducing the carbon tax. The FIT financing options are chosen such that there is no government financing intervention under this condition.

Since the Kyoto Protocol, Indonesia has been strongly seeking for solutions to address its GHG emissions (Ministry of Finance, 2009). Allan *et al.* (2008) argued that climate policy actions to curb the GHG emissions would have effects on a country's economy through, i.e. the price and output adjustments across sectors. The way in which the generated carbon tax revenues are recycled back into the economy is an important factor to meet the country's economic and environmental objectives (Welsch, 1996; Corong, 2008; and Yusuf and Resosudarmo, 2015). The above proposed experiments, grounded in a general equilibrium model, provide some strategic frameworks for climate policy makers, i.e. the revenue-neutralizing scheme through the carbon tax or FIT implementation. Each scenario is set out to empirically examine its impacts on Indonesia's economy as well as the change in emissions which are generated from the fossil fuels utilization.

The restsof this chapter is organised as follows: Section 7.2 discusses a brief overview of the literature studies that assessed the economy-wide impact of implementing the carbon tax or FIT using a CGE model framework. The scenarios provided in these literatures are used to motivate the simulations proposed in our model. Section 7.3 discusses the theoretical model and identification of scenarios motivated in Section 7.2 in the context of the specific model. It refers to the extended CGE model (for energy analysis) explained in Chapter 6 and provides the relevant equations to demonstrate our scenarios and closure rules. Section 7.4 discusses simulation results and sensitivity analysis. Finally, Section 7.5 presents the conclusions.

7.2. Literature Reviews

Various studies have assessed the effects of implementing a specific policy instrument in aiming to mitigate climate change. The instruments include the implementation of carbon taxes; emission trading systems (ETS); a cap-and-trade programs; quota obligation systems with tradable green certificates (TGC); feed-in tariffs (FIT); renewable portfolio standards (RPS); and so on. We focus on carbon taxes and the FITs. This section provides an overview of previous studies that specifically looked at the impact of carbon tax and the FIT. The simulations proposed in our study are motivated by these literatures.

7.2.1. Carbon Tax Studies

A carbon tax usually aims to improve the environment and to reduce tax distortion although the magnitude of its benefit highly depends on the economy’s structure and strategies in recycling the revenue (Goulder, 2002; Orlov, 2012). According to the literature, carbon taxes tend to be regressive in developed countries; and neutral or progressive in developing countries. These distributional implications are considered to be the most important issue on the carbon taxes political agenda (Baranzini *et al.,* 2000). The studies that concerned developed countries are those by Pearson and Smith (1991), Hamilton and Cameron (1994), Cornwell and Creedy (1996), Barker and Kohler (1998), Tiezzi (2001), Bergin *et al.* (2004), Brȁnnlund and Nordstrom (2004), Wier (2005), Oladosu and Rose (2007), Wissema and Dellink (2007), Callan *et al.* (2009), Orlov and Grethe (2012), and Siriwardana *et al.* (2011). Whilst, on developing countries, among the few are those studies by Shah and Larsen (1992), Yusuf (2008), Brenner *et al.* (2007), Corong (2008), Mahmood and Marpaung (2014), and Ditya and Resosudarmo (2016).

Among the earliest studies on developed economies, Pearson and Smith (1991) examined the distributional impacts of a carbon tax on fuel in several European countries (Spain, Italy, France, Netherlands, Germany, Ireland, and the UK). By assessing a sample of the 1988 UK Family Expenditure Survey and the 1985 Eurostat data through the IFS simulation Program for Indirect Taxes, the authors concluded that a carbon tax is strongly regressive in the UK and Ireland but less regressive in the other five countries. They argued that although household spending on energy goods in these countries is weakly related to income, the differences in the distributional incidence are principally related to the pattern of households' energy spending and also affected, to some extent, by the consumption of particular fuels with high carbon content in each country. The increased price of energy due to the carbon tax reduces the volume of domestic energy consumption by about 6.5% within an uneven distribution among households. The percentage reduction in energy consumption amongst low-income households is greater than the high-income households. This is because the poor spends a higher proportion of their income on the taxed energy – for the poorest, the carbon tax accounted for more than 2 percent of their total spending, while the richest less than 1%. By using a more comprehensive model – a sectoral, regionalised, econometric model of the European Union (the energy-environment-economy model, E3ME) – Barker and Kohler (1998) upgraded Pearson and Smith (1991) and found similar findings: the carbon taxation is not nearly so regressive towards the EU's income distribution, where the most regressive impact is on West Germany, the UK and Ireland. If revenue raised from carbon tax is neutralized through lower taxes on labour income, all countries experienced an improvement in real disposable income. The UK, Belgium, Ireland, and West Germany benefited the most. The carbon tax can be progressive if the revenue is recycled through increasing government transfers to lower income households via social security payments.

Hamilton and Cameron (1994) analysed the distributional impacts of a carbon tax for Canada by combining the CGE model developed by Beausejour *et al.* (1992), cost-push methods through the Input-Output model, a detailed energy disposition account, and micro-simulation model of household expenditures. The simulation, taxing the carbon content of fossil fuels by $101.56/ton CO_2e (or adding 6.5 cents to the cost of gasoline per liter), is designed to meet the Rio target in Canada: "stabilizing CO_2 emissions at their 1990 level in year 2000". The authors concluded that the simulated tax is moderately regressive, where the goods spending of the lowest quintile households is increasing between 1.1 – 1.2% higher than the highest quintile. Similar to Hamilton and Cameron (1994), Cornwell and Creedy (1996) examined the distributional impacts of implementing a carbon tax for Australia, using the combination of an input-output approach and a household demand system, to achieve the Toronto target: a reduction in CO_2 emissions at 1998 levels by 2005. By implementing a carbon tax of A$ 113/ ton CO_2e, the study found that the fuel, electricity, food and tobacco sectors faced the largest increases in price. This result suggested that carbon tax is regressive since the lower-income households spend a higher proportion of their budget on these commodities than the higher-income households. The Gini inequality measure increases by 2.16%. Nevertheless, transfer payments can offset the regressive nature of the carbon tax.

Tiezzi (2000) examined the welfare effects of the carbon tax introduced in Italy at the beginning year 1999. The effects are assessed using True Cost of Living index numbers where parameters are obtained from the demand system supplied by the Italian National Statistical Institute from 1985 – 1996. Surprisingly, the results showed that carbon taxation is progressive: the living cost of the poor households was not adversely affected. In other words, the negative impact is increasing towards a higher income groups. The author argued that this implication might be due to the fact that the carbon tax mainly increases the price of transport fuels instead of heating fuels. These changes, in turn, affect the car-owning household groups (or higher-income groups) most. Callan *et al.* (2009) stated that the trend of household expenditure on transport fuels is in line towards their increasing income, as opposed to their spending on heating fuel which is relatively flat.

Bergin *et al.* (2004) analysed the impact of a carbon tax on all fuels consumed in Ireland using a macroeconomic model approach, the ESRI's Medium-Term Model (HERMES) embedded with an energy sub-model[41]. The model showed that a carbon tax of €20/ton CO_2e significantly contributed to the reduction of emissions in year 2010 – about 28% above the 1990 level. The demand elasticities for energy dropped over time, where the largest reduction in emissions derived from the electricity sector and industrial sector, and the smallest drop from the transport sector. Overall the economic cost (contraction in GDP) of implementing the carbon tax is small. The authors proposed four revenue-recycling with the implications as follows. Firstly, if the revenue is used to reduce labour taxes (social-insurance contributions), it improves the welfare – real disposable income increases which in turn improves consumption – and level of GNP. Secondly, reducing the VAT results in a small drop in GDP but distributional advantages since the reduction in nominal wage rates will offset the negative effects of carbon tax. Thirdly, improving lump-sum payments to household is less efficient because it does not reduce the distorted tax and thus it increases the economic cost in long-term. Lastly, increasing lump-sum payments to firm indicated the largest drop in GNP. Moreover, the carbon tax is found to be regressive; therefore, the authors suggested to use 23% of the revenue to increase the welfare payments or to compensate low-income households through investment on energy-saving improvements.

A study for Sweden was conducted by Brännlund and Nordstrom (2004), who analysed consumer response and welfare effects of increasing a carbon tax[42] for various energy goods using an econometric model estimated for pooled cross-section data from the Swedish Family

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[41] The HERMES model was also used in constructing macroeconomic forecasts for Ireland until 2020.

[42] Sweden has implemented carbon tax since 1991.

Expenditure Survey in 1985, 1988, and 1992. Two scenarios of revenue-recycling are considered to neutralize a double increase of CO_2 tax: reducing the general VAT; and reducing the specific VAT on public transport. In the first scenario, petrol demand dropped by about 11% for all household groups and public transport demand dropped by about 5% with ambiguous patterns among different household groups. The authors used the compensated variation (CV) to estimate the welfare effects from the carbon tax reform. The CV is defined as "the amount of money the household needs to be given at the new set of prices in order to attain the pre-reform level of utility" (Brännlund and Nordstrom 2004, p. 222). In other words, the CV refers to the quantity of additional money which has to be given to or to be taken from a household to make them as well-off as before the prices change (Gravelle and Rees, 1987). The authors found that the lowest income quintile faced a welfare drop about SEK 465 whilst the richer households dropped by SEK 1305. However, relative to household expenditure, the welfare loss on poorest households is greater than the richest indicating that the carbon tax is regressive. In the second scenario, the doubling of the CO_2 tax can cover 23% ad valorem subsidy on public transport resulting a 28% drop in its consumer price. This scenario is also found to be regressive although the extra subsidy caused a more uneven distribution of welfare loss: households in urban sites benefited the net subsidy, while those in non-urban sites have to bear the tax burden.

Wier *et al.* (2005) investigated the distributional impacts of direct and indirect CO_2 tax payments by households[43] combining a Danish Input-Output model for 1996 – which is extended with a tax vector – and consumer survey from Statistics Denmark. The results showed that a carbon tax is regressive for both direct and indirect tax payments. The payments are increasing with disposable income but constitute a smaller share of spending as income increases. In direct CO_2 tax payments, the rural households paid the tax more due to higher consumption on heating and electricity, while, lower-income groups paid more due to higher consumption on food and public transport. Ccompared to other Danish taxes, the CO_2 taxes are found to be more regressive. Oladosu and Rose (2007) examined the income distribution impacts of a carbon tax ($25 / ton of carbon) on fossil fuel consumption in the Susquehanna River Basin Region of the United States using a computable general equilibrium model. In contrast to Brännlund and Nordstrom (2004), the tax is found to be progressive both in the short and the long run: higher-income groups lose more because they tend to have higher wages and work in sectors that suffer larger declines in production. In addition, the progressivity nature is also caused by the output production pattern; the increasing lump-sum transfer to

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[43] The authors defined the direct CO_2 tax payments from households as total CO_2 levies per unit of energy final consumed. Whilst, indirect CO_2 tax payments are related to the households' payment on CO_2 generated from total chain of intermediate input used by industries to produce the final household consumption.

lower-income groups; and the declined corporate profits absorbed by richer income groups will offset the regressive effects.

Using a CGE model, Wissema and Dellink (2007) analysed the economy-wide impact of a carbon tax on energy use – ranging from 0 to €30/ton CO_2 – in Ireland. They simulated two kinds of energy taxes: a tax based on carbon content of energy and a uniform energy tax. The estimations suggested that a tax on the carbon content is more efficient in reducing the national emissions because it induces people to switch more from CO_2-based fuels to clean energy. With a uniform energy tax, the use of renewable sources declined because they are taxed at the same rate as 'dirty' fuels. A carbon tax has greater effects on the economy than the uniform energy tax because it is a differentiated tax, which leads to more changes in production and consumption. Both tax types provide incentives to energy efficiency in that the sectoral structure shifts towards less energy-intensive production. From the equivalent variation (EV) approach, the taxes caused welfare to be slightly dropped (1.3%). Equivalent Variation is an approach to calculate how much additional money that has to be given to or taken away to make them as well-off as after the commodity prices change (Gravelle and Rees, 1987). Unfortunately, this study did not examine the distributional income among household groups because it only used a single representative household. Nevertheless, the authors suggested to pay attention to assessing the impacts across different income groups since the carbon tax may lead certain households to poverty.

Callan *et al.* (2009) studied the distributional impacts of imposing a carbon tax (€20/ton CO_2) and revenue recycling in the Republic of Ireland using the SWITCH model – a model of direct taxes and welfare payments – based on the CSO's Survey and Living Conditions. The micro-data survey includes detailed information of household variables such as age, composition, income, employment, and disability, as well as their expenditure on energy utilization for heating, electricity used, and fuels. The analysis, however, does not take into account the indirect effects of carbon tax through the intermediate inputs processing across industries because the indirect analysis requires the Input-Output data. In other words, the study includes only the direct emissions. The results showed that the carbon tax is regressive especially in fuels consumption because rural households consumed more fuel than urban households due to a size condition where the countryside area has longer distances. Furthermore, the authors implemented the revenue recycling scenarios of increasing the social welfare payments and decreased taxes –by increasing tax credits or reducing the income taxes. Increasing social welfare payments benefited mostly to lower-income groups; while, the lower taxes benefited mostly to the upper-income households. The authors suggested that the regressive nature of carbon tax can be addressed through well-developed tax and benefit schemes.

Siriwardana *et al* (2011) investigated the economy-wide impact of taxing the carbon content of energy combustion (ranging from \$15 - \$30/ton CO_2) in Australia based on a static CGE model – ORANI-G developed by Horridge (2000). The model is calibrated to the Australian Input-Output tables for 2005 as well as the carbon emission data from the GHG inventory 2005 published by the Department of Climate Change and Energy Efficiency. The tax reduces the national emissions with a small distortion to the economy (the Australian GDP declines only by 0.68%). The effect on inflation, measured by the change in consumer price index, is also small (0.75%). Nonetheless, the electricity price increased sharply (26%) because in Australian, electricity generation heavily relies on coal. In terms of effects on households, the tax is regressive. A higher price of CO_2 intensive fuels disproportionately affects household spending on energy; lower-income households carry a higher tax burden (3.6%) on energy consumption than rich households (1.4%). Therefore, the authors suggested a revenue-recycling scheme by giving an annual lump-sum payment to all households of \$685 in order to compensate the tax burden.

A study for Russia was done by Orlov and Grethe (2012), who investigated the distributional effects of carbon tax under perfect and imperfect competition (Cournot oligopoly), in the context of CGE model. The model is calibrated to the Global Trade Analysis Project (GTAP) Version 7 database which represents a multi-regional SAM. The authors simulated the implementation of a carbon tax on fossil fuels combustion to meet the national emissions reduction target by 10%, where the revenue is recycled through the reduction of labour taxes under two market conditions: perfect competition and Cournot oligopoly. They find that under perfect competition, the revenue recycling of carbon tax through reduction of labour taxes can obtain a strong double dividend – although the magnitude of the welfare highly depends on the labour supply elasticity and the elasticity of substitution among production factors and energy. Welfare, measured by the EV, is improved by 0.23%; household income increases due to higher return to land via the increasing land supply and improvement of labour income via lower labour taxes and an increased labour supply. The demand for domestically produced fossil fuels and its import declines due to higher consumer prices, which in turn leads to currency depreciation and lower production costs. Domestic products therefore become more competitive compared to imported ones, which leads to improvement in export[44]. However, the production of energy-intensive commodities – i.e. electricity, metals, and chemical products – declines due to higher input costs of energy commodities. A carbon tax is found to be regressive; however, lower labour taxes can compensate the lower-income households so that the regressive effect can be prevented. Under Cournot oligopoly, carbon tax

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[44] Competitiveness is calculated from a percentage change of the ratio of import prices to domestic prices.

increases mark-ups. which leads to welfare losses – measured as EV. The domestic supply is already sub-optimal under imperfect competition, thus a further reduction in domestic demand will lead to higher dead-weight losses. Specifically, the introduction of a carbon tax increases the market power of the gas sector due to the increasing shares of gas demand in the market. The mark-ups of chemical products and metals increase due to less competition; in contrast, the mark-ups of mineral products and petroleum products are declined, thus the pre-existing distortions arising in these markets are partially alleviated. In conclusion, the welfare costs of imposing the carbon tax under Cournot oligopoly is higher than that of the perfect competition.

We also discuss in brief carbon tax studies on developing countries, among the few, as follows. A study for Pakistan was conducted by Shah and Larsen (1992), who analysed the efficiency and equity implications of imposing a carbon tax in some developing countries, especially Pakistan, using the 1984/1985 Household Income and Expenditure Survey and a dynamic factor demand model. The authors argued that the regressive incidence of carbon tax on industrialized countries, where household’s spending on fossil fuel as a proportion of current annual income declined with income, cannot be generalized to developing countries since it would also be affected by institutional factors. Three important cases may have a bearing on the tax-shifting. In the first case, tax can be regressive if the fossil fuel producers have full market power (or either demand or supply for the taxed commodities is perfectly inelastic); hence, the burden of carbon taxes can be fully shifted to households. In the second case, under the assumption of zero forward shifting, the burden of carbon taxes can be fully borne on capital owners if the price of fossil fuels is controlled and legal pass-forward of the tax is forbidden (or supply is completely price inelastic), i.e. through obligation of binding import quotas or rationed foreign exchange. The tax burden on capital income is found to be progressive. In the third case – when a partial forward shifting is likely occurred in Pakistan, the burden of carbon tax for fossil fuels is partially borne by its final users and by capital owners. This tax-shifting case would roughly result in a mixture distribution between the regressive pattern under the former case and progressive pattern under the latter case. The study also examined the welfare effects of four scenarios of revenue-recycling. In the first scenario, when the government lowers labour income tax rates, the welfare gain is very small because taxes are low in developing country like Pakistan. In the second scenario, when the government lowers the corporate income tax, the effects on welfare could be either positive or negative. This is because the increase prices of energy production after tax will affect their final consumption, while the reduction of corporate income will affect saving decisions. Thus, this scenario induces intertemporal inefficiencies by both reducing saving and increasing current consumption. In the third scenario, by assuming no changes in other distorting taxes, the welfare costs are significant although they are relatively small compared to the revenues collected from the carbon tax. In the fourth scenario, which is similar to the third with additional observation of subsidies accounting, the welfare improved. The introduction of carbon tax actually acts to remove subsidies because it leads to an increase of carbon-based fuel prices. Thus, the increasing welfare costs due to carbon taxation on fossil fuels are offset by the welfare gain from the subsidy cut.

Yusuf (2008) investigated the distributional effects of introducing a carbon tax of Rp. 280,000/ton CO_2 and energy price reform (or eliminating the subsidy on fuels) in Indonesia using the Indonesia-E3 (Economy-Equity-Environment) model, which is a type of CGE model. The author found that carbon tax tends to be progressive for all revenue-recycling scenarios. This is mainly driven by the largest contraction in energy-related industries (output reduction), which in turn, affected the rich (and urban) households since they own most of the production factors in these industries. A cut of subsidies to transportation fuels (diesel, and gasoline) also found to be a progressive pattern; in contrast, the scenario of reducing the kerosene subsidy tends to be regressive. The author also found that a uniform transfers scheme (social cash transfers) – implemented in October 2005 – tends to over-compensate the rural-poor households but under-compensate the urban-poor households. Therefore, the author suggested that a well-designed of compensation, i.e. more compensation to urban and less compensation to rural groups, would minimize the poverty incidence in urban location.

Brenner *et al.* (2007) examined the distributional implications of carbon tax of 300 yuan/ metric ton of carbon in China based on the household income and expenditure survey in year 1995. The results suggested that a carbon tax is progressive under two scenarios: with revenue-recycling scheme in the form of a lump-sum compensation to all households or a 'sky trust'[45], and without a revenue-recycling scheme. This progressive incidence is due to pattern of consumption where the higher-income (urban) households spend more on carbon-intensive goods, i.e. energy and industrial goods, than the lower-income (urban) households, whilst the rural household groups spend more on less carbon-intensive, i.e. foods. In other words, the urban households would pay a higher share of their expenditure to the sky trust than rural households. This study, however, does not assess the welfare gains.

Corong (2008) assessed the distributional impacts of imposing a carbon tax of 100 peso/ ton of carbon emissions) during the trade liberalization process in the Philippines within the context of a CGE model. The work analysed the case if the tax revenues are used as a compensation to reduce the trade tariffs or a 0.34% decline in the price of imported commodities. More specifically, the author undertook four scenarios: (i) no carbon tax and the nominal tariff rates are reduced and the revenue loss is compensated through an increase of

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[45] The author defined 'sky trust' as a system of carbon charges in which the revenues are recycled to the public on an equal per capita basis.

household's income tax; (ii) a joint simulation of a tariff rate reduction and a carbon tax of 100 peso/ton CO_2 and the tax revenues are recycled through reduction in household income tax; (iii) that is identical to (ii) but the revenues are recycled through reduction in output tax; and (iv) that is also identical to (ii) but with different Keynesian closures (unemployment is allowed to adjust). The results found that in all carbon-tax scenarios (ii – iv), output across industries declines due to a higher import demand and increased in energy prices which leads to a contraction in domestic production. However, compared to the scenario without a carbon tax (i), the price effects due to a lower import tariff are smaller because they were partially offset by the introduction of carbon tax. As expected, the demand for carbon-based coal and oil and energy-intensive (conventional generation) inputs declines and demand for less carbon-based energy, i.e. hydro and geothermal plant, increases. These changes lead to a reduction in national emissions by approximately 1%. In terms of income distribution, the study revealed the progressive nature of carbon taxation: agricultural workers and blue collar industrial workers experienced the highest reduction in their spending on goods due to their small energy consumption pattern[46]. All households experienced an improvement in their welfare although the lower-income groups gained the least.

Apart from assessing the economic impacts of imposing carbon energy taxes on Pakistan's economy, Mahmood and Marpaung (2014) also investigated the effects, including the possibility of rebound effect, of implementing the simultaneous carbon energy taxes and energy efficiency improvement. By employing a recursive CGE model, they simulated two main scenarios: (i) the shock of carbon tax (at different levels ranging from \$20 - \$80/ton CO_2) with two alternatives of revenue-recycling, which are either adjusting the government spending on public goods or lump-sum transfers to households; and (ii) the shock of simultaneous carbon tax (\$50) and energy efficiency (at different levels) with increase of government spending on public goods to recycle the tax revenue. The findings revealed that all scenarios lead to a GDP contraction and a large reduction of GHG emissions (CO_2, CH_4, N_2O, and SO_2). In scenario (i), the carbon tax of \$80/ ton CO_2 will decrease GDP by 3.59% in year 2050; the primary energy consumption dropped largely by 27.92% and CO_2 20.83%. A lower carbon tax (\$10/ton CO_2) the GDP (and other macroeconomic variables excluding government consumption) reduction is much smaller. Across sectors, this scenario reduces the output of fossil fuels (coal, gas, and petroleum products) and electricity as well as other energy-intensive (i.e. non-metallic mineral products) sectors. In a variant of scenario (i), the results indicated a less contraction to GDP due to the increased investment (or a higher marginal propensity to save) which in turn

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[46] In the study, the author distinguishes the household's types based on their occupation. Thus, we suggest that the agricultural workers and blue collar industrial workers are categorised in lower-income groups; while government workers and professional-headed households are included in upper-income groups.

increases final consumption; nonetheless, the effects on CO_2 emissions and sectoral changes are quite similar to that of the first case. In contrast, scenario (ii) has positive implications for the economy in which the GDP is improving while energy consumption and pollutant emissions decline more than that of both cases in scenario (i). The authors argued that this is induced by the effects of energy efficiency improvement which identical to a higher volume of energy inputs but reduction of their prices, which in turn, it gradually offset the adverse effects of carbon taxation. This study, does not examine the impacts on income distribution since it is only based on a single representative household.

Among recent studies, Nurdianto and Resosudarmo (2016) analysed the economic benefits and losses of implementing carbon tax across ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) using the Inter-Regional System of Analysis for ASEAN (IRSA-ASEAN) model – a multi-region CGE model. The study simulated a uniform carbon tax (US$ 10/ ton CO_2) under three different scenarios of recycling scheme. The first scenario assumes the recycling mechanism in which government consumption increases proportionally with the extra revenues. The second scenario deals with 50% extra compensation in the form of government cash transfers to poor households (both in rural and urban sites). In the third scenario, the government uses 50% of carbon tax revenues to reduce the indirect taxes; this scenario aims to assess a double-dividend hypothesis. Overall, the results suggested that the carbon tax, in short run, can reduce the national emissions in an effective way without a rebound effect. However, a double-dividend might not be always achieved through a combination of the carbon taxation and its revenue-recycling scheme among ASEAN countries. The introduction of a carbon tax would likely result in a fall in GDP. More specifically, Indonesia and Malaysia benefited the most from a carbon tax due to their current fuel subsidies. The carbon tax will act as a compensation mechanism to remove the subsidies by increasing the prices of dirty fuels. In contrast, Vietnam would gain the smallest benefit since the carbon tax will raise costs (in terms of GDP contraction) to their economy. In terms of income distribution, the carbon tax tends to be progressive for all countries except Singapore. The carbon tax can also lead to more poverty; however, poverty can be reduced if the government directly compensates the poor households through cash transfers.

7.2.2. Feed-in Tariff Studies

In this section we briefly discuss studies which analyse the distributional implications of implementing a feed-in tariff (FIT). Compared to studies on carbon tax, the studies on the FIT[47] – in terms of assessing its economy-wide impacts – are still lacking especially in case of

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[47] The studies here are referred to those of a peer-reviewed literature.

developing countries. This paper, to some extent, will be the first attempt in assessing the economy-wide implications of introducing a FIT in Indonesia, within the context of a CGE model.

Bohringer and Loschel (2006) investigated the economic and environment implications of promoting renewable energy in the European Union using a hybrid-CGE model. The scenario aims to meet the EU mandate of increasing the clean energy production up to 30% in year 2020 from the business-as-usual levels in year 2005. The model they used is limited to a detailed bottom-up representation of electricity sector. Hence, the target was translated into at least a 20% increase of renewable energy shares (biomass, wind, and solar) in electricity production. The target is achieved through adjustment of uniform ad-valorem subsidies on renewable productions, which are financed from government (lump-sum) transfers. As results, total electricity production increases by almost 5%, primarily due to a reduction in the electricity price (2.3%). Specifically, electricity produced from fossil fuel-based generation – such as combined hard coal-natural gas, natural gas, and oil – decline by more than 10% in year 2020; in contrast, generation produced from wind and biomass improves by more than 170%, by assuming a fixed electricity production from nuclear, soft coal and hydro generation. Welfare, based on the Hicksian equivalent variation, slightly decreased ranging from -0.03% in 2010 to -0.08% in 2020, which is obviously influenced by the increasing government expenditure on renewable subsidies. This result indicates that a promotion of clean energy production through the endogenous ad-valorem subsidies imposes fewer costs to the European economy. In terms of environmental impact, the improvement of clean energy production reduces carbon emissions in Europe although they are partially offset by an increase of electricity production due to the implicit subsidy of electricity from renewable generation.

A similar work as above, Bohringer *et al.* (2007) investigated the economy impacts of increasing electricity production from renewable energy sources in the European Union through (i) feed-in tariffs (or direct subsidies on renewable energy); and (ii) quota obligation systems with tradable green certificates, based on a static large-scale partial equilibrium model of the EU's electricity market. Four scenarios are simulated as follows. The first scenario mimics the current Member State schemes where the diversified FIT support across different renewable technologies is illustrated. The second scenario illustrates the harmonized regional FITs (or an equal premium for each technology). In contrast to the financing scheme proposed in Bohringer and Loschel (2006), both FIT scenarios in this study are financed through an endogenous tax on electricity output. In the third scenario, the target of higher renewables production is achieved through a quota system which obliges the electricity producers to meet regional targets. This scenario does not involve subsidies and thus no extra tax on electricity is required. However, it raises costs of electricity due to the required level of renewable productions which will be financed via higher electricity prices. Finally, the fourth scenario illustrates an identical scheme to that of the third scenario but with additional allowance of tradable green certificates – in which the certificates could be sold at the market. The results indicated that, in overall, the improvement of clean energy production leads to an increase in electricity prices primarily due to technological substitution from cheaper conventional generation (i.e. fossil fuel-based power plants) to more expensive renewable generation. This increase, in turn, leads to a contraction in electricity demand (by 7.4%). Compared to the diversified FIT (scenario 1), the uniform FIT (scenario 2) induces a smaller increase in the electricity price, which leads to a smaller decline in electricity demand (by 6.2%). This is because the premium provided in uniform FIT is based on the marginal costs of the green supply options across region which the producers to exploit the most cheaper renewable potentials. Finally, in the quota scenario (3 and 4), the results are similar to that of the uniform FIT scenario in that these scenarios also lead to a more efficient adjustment cost to meet the clean production target.

Bohringer *et al.* (2012) analysed the labour market implications of the FIT policy implemented in Ontario within the context of a static multi-region CGE model. The study was conducted in order to answer the critique that promoting green energy production may destroy jobs. In the scenario, the FIT is set at the forecasted average point ($USD 0.223/ kWh or translated into 81.3% subsidy rate on renewable generation) which is financed through an endogenous tax on electricity sales. The results found that the electricity price increases by 13% which, in turn, reduces the electricity demand by about 2.1%. The welfare, measured as Hicksian EV, declines about 0.54%. This welfare loss, however, does yet to consider the environmental benefits (such as health improvement) of closing down the carbon based-generations. In terms of sectoral effects, as expected, the electricity sector faced the largest impact. The electricity output produced from conventional (fossil fuel) generations decreases by 20%, which is offset by the increase of clean energy production. This shift leads to a contraction in the electricity-intensive sectors, i.e. mining and manufacturing, because it induces higher electricity prices and less demand for fossil fuel-related inputs. The estimation results suggested that the FIT scenario improves employment only in the relevant sector of renewable generation and manufacturing sectors – as improvement in clean energy production induces a higher demand for manufacturing equipment required for renewable generation. In the broader labour market, however, the subsidy scheme causes a contraction by which the unemployment rate in Ontario increases by 0.32%. This is mainly triggered from a reduction in real wage due to higher consumer prices.

Proenca and Aubyn (2013) assessed the economic and environmental effects of Portugal's FITs policy to promote clean energy production by employing a hybrid-CGE model.

The scenario aims to meet the national renewable electricity target up to 45% in year 2010 through the FITs scheme where the ad-valorem subsidy to renewable electricity output is allowed to adjust. The subsidies are financed from household lump-sum transfers to electricity producers. The results indicated a shift from conventional (fossil fuel) electricity generation towards carbon-free renewable generation, in which wind power generation contributes the largest share in total renewable generation (48.5%) followed by hydropower (46.3%) and biomass (5.1%). Since the subsidies to renewable production are paid by the households' lump-sum transfers, thus, the FITs scenario has a negligible effect on electricity production costs which results in an almost unchanged electricity price (and output). In terms of macroeconomic implications, the FITs leads to a smaller contraction to the economy, where GDP and welfare (measured as Hicksian EV) decline slightly. These contractions are mainly induced by the decline in real household's income due to extra spending on subsidy payments, which negatively affects their consumption. Finally, in terms of environmental impacts, the promotion of clean energy production through the FITs mechanism results in a large reduction in national CO_2 emissions which is about 31% from benchmark levels.

7.3. Policy Scenarios for Indonesia and Their Impacts

This section discusses the theoretical model and identification of scenarios of implementing a carbon tax and FITs under different revenue-recycling schemes. The scenarios are illustrated within the context of the hybrid CGE model provided in Chapter 6. The model features, in detail, the production structure of energy sectors as well as the technological explicitness of bottom-up energy system for the electricity sector. The solution software is General Algebraic Modelling System (GAMS) with the Mixed Complementarity Problem (MCP) solver, which has the advantage that it accommodates the complementarity slackness of a flexible mathematical representation of market equilibrium conditions (Bohringer and Loschel, 2006). The MCP solver is useful to solve the non-linear equation systems. It specifies complementarity boundary conditions clearly such that the model is solved normally and is calibrated to the initial values in the SAM (Dirkse, 1994). By changing the exogenous variables, the MCP solves the model to obtain a new equilibrium.

As previously mentioned, the scenarios chosen in this study are motivated from the literature reviewed. The simulations concern two main policy instruments: the implementation of a carbon tax; and a FIT. Therefore, for each instrument, we consider a different recycling scheme by executing the model as follows.

In the carbon tax scheme, at the initial equilibrium, we introduce the exogenous injection of carbon tax by which the government collects the tax ($TAXCO2$) of Rp. 100,000/ ton CO_2e on dirty fuels with three possible revenue-recycling scenarios:

1. In scenario 1, we allow a revenue-recycling scheme in which the income (labour) tax rate across activities ($HAtaxrate$) adjusts such that the government net receipts are balance; while rests of taxes and subsidies as well as government saving remain unchanged. We expect a double dividend where both environmental improvement and reduction of the distorting tax system can be achieved
2. In scenario 2, following Ditya and Resosudarmo (2016), we assume that the extra revenue raised from a carbon tax is used to proportionally increase government expenditure on goods and services. Thus, in the model, the adjusted government expenditure across commodities ($CGADJ$) is assumed to be endogenous in order to clear the government net receipts. All taxes and subsidies as well as government saving (SG) remain unchanged. We expect that an increase of public expenditure improves the national income.
3. In scenario 3, following Yusuf (2008), we assume that the extra revenue raised from carbon tax is not returned to the economy or not used for compensation. In other words, the tax revenue is kept as government saving to run a budget surplus. Thus, in the model, government saving (SG) is assumed to be endogenous in order to clear the government net receipts. All taxes and subsidies as well as government expenditure on goods remain unchanged. This scenario intends to investigate the impact of a carbon tax on Indonesia's economy if there is no revenue-neutralizing mechanism.

In the FIT scheme, we assume that the government sets a 15% subsidy rate to renewable generation (hydro and geothermal generation) ($subArate(renew)$) with two possible financing scenarios which do not affect the fiscal sustainability:

4. In scenario 4, we assume that the FIT is paid by electricity consumers through the endogenous electricity tax rate ($vatrate(electc)$). Following Bohringer *et al.* (2012), we expect that this scenario would increase the electricity price which leads to a drop in its demand.
5. Finally, in scenario 5, we assume that the FIT support is financed by a carbon tax adjustment.

The closure choices for all scenarios are similar to that in Chapter 4, which are set as follows.

BOP vs. Exchange Rate Regime

The balance of payments ($SROW$) is fixed and the exchange rate adjusts to ensure $SROW = 0$. This closure setting is selected to reflect the real condition of Indonesia which has had a floating exchange rate regime since 1977 (Bank of Indonesia, 2014). It also ensures that the model avoids capital flow and foreign borrowing. Hence, the model restricts the government to finance its budget deficit by selling treasury bonds to domestic institutions. Lofgren *et al.*

(2002) stated that by fixing the trade balance, *ceteris paribus*, a depreciation of the domestic currency would occur to cover a drop of foreign saving below the exogenous level. Damuri and Perdana, (2003) argued that this closure ensures the private investment unaffected from the endogenous trade balances. Fiscal expansion would therefore push the interest rate to soar. The increased interest rate would reduce investment, which in turn lowers the positive effect on aggregate demand (Damuri and Perdana, 2003).

Investment-Saving Closure

In the model, the actual investment goods ($CINV_i$) and enterprise saving (SB) are exogenous. In terms of household saving, we only allow the richest type of households (non-agricultural-urban households with high wages (HH_NAGU_HL))[48] to adjust their saving ratio ($sh\_dum_h = 1$) but the saving of other household types is assumed fixed. Government saving (SG) is allowed to adjust only in scenario 2 so that the additional revenue from a carbon tax is recycled to obtain budget surplus; whilst in rests of scenarios, the government saving remains unchanged.

Factor Closures

We assume that the capital stock is mobile across activities. Thus, both capital rent of activity specific and distorted rent of capital across activities ($PDIST\_K_j$) are fixed; while stock of capital (K_j) adjusts to ensure clearing of each j-th activity. We assume no excess capital (fully employed capital). Similarly, workers are also assumed to be mobile between industries with fixed wages. Therefore, the adjusted wage of labour types across activities ($PDIST\_L_{o,j}$) and the average wage of labour types (P_o^L) are exogenous. Both employed labour used across activities ($L_{o,j}$) and labour composite (LAB_j) are endogenous. Hence, the labour market is cleared through the adjusted unemployment rates. This setting follows the fact that Indonesia currently faces a massive labour surplus (Yusuf *et al.*, 2008). In addition, we include the factor of natural resources[49] only for fossil mining and renewable electricity generation, i.e. oil resources factor for oil sector, coal resources for coal mining, and natural gas resources for gas mining, geological hot dry rock for geothermal generation, and topographically-determined hydrostatic potential for hydro generation (Sue Wing, 2006). We assume a fixed supply of resources factor ($RES_j,\quad j \in fossil \,\&\, renewable \subset energy \subset A$). The rent of resources adjusts (P_RES) to ensure market clearing.

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[48] We define the richest households' based on the highest income ratio to total income of households given in the SAM classifications.

[49] Due to a limited information, we follow we follow Sue Wing (2006) hypothetical assumption by which the factor of resources is estimated as roughly 20% shares of capital input.

Government Closure

The government closure depends on the selected revenue (in case of introducing the carbon tax) or cost neutralizing (in case of introducing the FIT or subsidy on renewable generations) in each scenario. For example, in the case of scenario 1, all taxes and subsidies rates as well as government saving are exogenous; while government expenditure on commodities adjusts to clear the fiscal balance. In scenario 2, all taxes and subsidies rates as well as government expenditure are exogenous while government saving adjusts to allow a budget surplus so that the government balance is achieved. In scenario 3, all government instruments, excluding *ad valorem* tax rates, remain unchanged. In scenario 4, the electricity tax rates are endogenous but the rests of government variables are exogenous. Finally, in scenario 5, all government instruments, excluding the carbon tax, remain unchanged.

7.4. Simulation Results

This section presents the simulation results of both revenue-recycling scenarios of introducing the carbon tax and cost-neutralizing scenarios of implementing the feed-in tariff. The impacts of these policy shocks on Indonesia's macroeconomy as well as income and output distribution are discussed here.

7.4.1. Simulation 1: Recycling Carbon Tax to Reduce Income Tax

In simulation 1, we examine the impact of implementing a carbon tax of Rp. 100,000/ ton CO_2e on carbon-based fuels, where the revenue raised from carbon tax is recycled through s reduction of labour income tax rates. In other word, the of labour income tax rates adjust to clear the government budget balance. The other tax and subsidy rates as well as government spending on goods and services remain unchanged.

7.4.1.1. Impacts on Macroeconomy and on CO_2 Emissions

Table 7.1 summarizes the macroeconomic impacts of introducing a carbon tax compensated by adjustment in income (labour) tax. The results reveal that recycling the carbon tax through a reduction in labour taxes leads to improvement in all GDPs, (GDP at factor cost) that is calculated from total factors returns, GDP at market price from income side that is obtained from total private consumption, government consumption, investment and net export; and GDP at market price from expenditure side that is the sum of GDP at factor costs and net taxes.

From Table 7.1 it can be seen that the introduction of carbon tax leads to a reduction of labour (income) tax rates by -3.24%, which in turn, leads to the expansion in GDP at market price from income side (1.56%) and GDP at market price from expenditure side (2.04%) are more pronounced than GDP at factor costs (0.58%). These imply that the increase of fuel prices due to a carbon tax is offset primarily by higher household income improvement via labour income tax rate reduction. Thus, it induces a higher domestic demand on goods and services due to improvement in their disposable income, which in turn, increases the aggregate output production. Nevertheless, net exports contract by 5.11% due to a slight reduction in exports by 0.14% while total imports increase by 0.36%. We suspect that these changes are influenced by the expansion in composite final domestic commodities which results in a higher demand of imported goods and services relatively to export. The net indirect tax revenues indicate a strong increase by 74.30%. This implies that substituting carbon tax for labour tax leads to expansions in national output such that the government gains more from the commodity (indirect) taxes. In addition, the net indirect tax is the component to estimate GDP at market price from expenditure side. It is revealed that, although the increase of net indirect tax increases sharply, it does not strongly affect the GDP at market price from expenditure side because the ratio of net indirect tax to the GDP at market price from expenditure side is less than 2%.

In terms of emissions accounting, the results found that there is no rebound effect – in aggregate terms – among energy consumers (households, industries, and government). The largest reduction of CO_2 emissions through lower consumption of fossil energy is obtained by households (-7.52%) followed by industries (-0.14%). The government does not experience any changes to their carbon emissions pattern since in the model the public spending is assumed exogenous. Overall, national carbon emissions drop by -0.64%.

Table 7.1: Simulation 1: Impact on National Income Account

Variables	BASE	SHOCKED	% CHANGE
	(Billions Rupiah)		
GDP at factor costs	5,139,651.22	5,169,437.46	0.58
GDP at market prices from income side	5,472,898.80	5,558,429.72	1.56
GDP at market prices from expenditure side	5,243,713.58	5,350,821.20	2.04
Total private consumption	3,318,104.75	3,323,372.41	0.16
Total investment	1,508,830.58	1,512,092.12	0.22
Total real government consumption	294,566.35	299,400.64	1.64
Total export	1,531,028.46	1,528,910.35	-0.14
Total import	1,391,532.58	1,396,548.33	0.36
Net export	139,495.88	132,362.02	-5.11
Net indirect tax (the total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	104,062.37	181,383.74	74.30
Labour (income) tax rates	0.022	0.021	-3.24
Total payment to all workers (WAGEBILL)	2,692,617.74	2,693,711.90	0.04
Total payment to capital (CAPBILL)	2,447,033.48	2,475,725.56	1.17
Emissions	(Billions Ton CO_2)		
CO_2 emissions from Households	4.13	4.20	-7.52
CO_2 emissions from Industries	55.69	61.17	-0.14
CO_2 emissions from Government	0.50	0.55	
TOTAL CO_2	60.32	65.92	-0.64

7.4.1.2. Impacts on Output and Energy Composite

Table 7.2 presents the implications of simulation 1 on industry's output, the required input of energy composite, and the energy intensity. It reveals that the implementation of a carbon tax with adjustment in labour income tax does not necessarily lead to a rise in input prices or a decline in volumes of composite fuels across industries. For examples, in energy industries – i.e. coal mining, natural gas mining, oil mining, and refinery, the input price of energy composite is sharply increased by 10.10%, 6.16%, 6.11%, 6.08%, respectively. In contrast, for some energy intensive industries – i.e. land transportation, construction, paper products, trade, and textile products, the input price of energy composite tends to fall by -4.95%, -12.81%, -3.58%, -13.18%, -2.21%, respectively. In contrast, the consumption pattern of energy composite in most of these industries (energy and energy-intensive industries) indicate an expansion, although the magnitude changes of output production tend to decline for most of energy-intensive sectors but flat for coal, natural gas, and oil mining sector. For example, conventional power plant indicates the largest contraction by -94.38% but its input of energy composite increases by 7.01%.

The energy consumption pattern across industries can also be seen clearly through their energy intensity – measured by diving total energy requirement by output. Despite a contraction in output production, most of energy-intensive industries – excluding chemical sector – require more energy inputs to produce a unit of output. On the other hand, in energy industries, the changes of both energy intensity and output production are considerably negligible. Orlov (2012) argued that the main factor in determining the magnitude changes of energy intensity is the elasticities of substitution among inter-fuel and factor-fuels as featured in the model. For example, if a Leontief production function is assumed, then the energy intensity remains unchanged because its nesting structure does not allow any substitution possibility (Orlov, 2012).

Therefore, by looking at these trends, it can be suspected that there is an indication of 'local' rebound effect especially in energy-intensive industries, excluding the chemical sector. In other words, instead of improving energy efficiency, the introduction of a carbon tax on polluted fuels compensated by a reduction in labour income tax triggers a higher level of energy consumption thereby offsetting some of the energy saving achieved (Sorrel and Dimitropoulos 2008; and Sorrel 2009). Sorrel (2007) stated that the chosen recycling mechanism of carbon tax, i.e. compensating the carbon tax by lowering the distorted taxes, is very influential to create the incidence of rebound effect through demand responses. By reducing the labour income tax, the households' purchasing power increases, which could induce a higher consumption of energy goods or other closely-associated products.

On the other hand, for non-energy intensive industries that require less fossil fuel inputs, the magnitude of changes of fuels composite, output, and energy intensity varies – although the input price of fuels composite tends to increase. In other words, the fuels consumption pattern across these industries is not necessarily in line with the changes of their output production. We argue that these variations are caused by two channels: (i) the contraction effects of carbon tax are offset by the increased disposable income due to lower labour income tax, which could improve the aggregate demand; and (ii) fuel substitution effects in which industry will favor less polluted (less emission factor) fuels. Fifteen non-energy sectors signalled a reduction in energy composite input, namely air, sea, and communication transportation (-0.95%); bank and assurance (-0.02%); cattle products (-0.17%); fishery (-0.85%); forestry and hunting (-0.22%); geothermal mining (-12.97%); hotel (-0.13%), individual services, households, and other service (-8.77%); agriculture for other crops (-0.13%); other mining and excavations (-2.18%); restaurants (-0.24%); supporting services for transportation and warehouse (-2.70%); train transportation (-1.03%); electricity transmission and distribution (-1.98%); and wood products (-20.34%). In contrast, six sectors that signalled an increase in energy composite input, namely agriculture food crops (0.01%); city gas (0.50%); real estates (0.25%); food and drinks (2.12%); government services and defenses (5.02%); clean water (148.05%). The pattern of fuels composite input in these industries is not in line with their output production. For example, although the energy aggregate inputs in agriculture food crops are increased by 2.12%, its output production signals a slight contraction by 0.44%.

Table 7.2: Simulation 1: Impact on Energy Composite, Output, and Energy Intensity (%CHANGE)

Industry	**Energy Composite**		**Output**		**Energy Intensity** $\boldsymbol{ENCOM}/\boldsymbol{QA}$
	Quantity $(ENCOM)$	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Energy and Energy-Intensive Industry					
Coal Mining	-0.04	10.10	0.00	-0.47	0.00
Natural Gas Mining	0.36	6.16	0.00	-0.16	0.00
Oil Mining	0.38	6.11	0.00	0.23	0.00
Conventional Power Plant (Aggregated Fossil Fuels Generation)	7.01	-5.23	-94.38	93.56	1805.00
Refineries	0.13	6.08	-1.04	0.93	1.05
Chemical	-6.27	7.73	-5.93	3.15	-0.54
Metal Ores Mining	-1.55	0.85	-7.48	5.59	8.08
Land Transportation	4.31	-4.95	-0.39	-1.29	4.91
Construction	13.65	-12.81	-0.01	0.31	14.44
Paper, Printing, Transport Equipment, and Products from Metal	3.99	-3.58	-0.85	0.65	3.96
Trade	13.90	-13.18	-1.00	0.19	15.04
Spinning, Textile, Garment, and Leather Industries	2.50	-2.21	1.07	-0.18	5.54
Non-Energy Intensive Industry					
Agriculture Food Crops	0.01	0.01	-0.50	0.01	0.51
Air, Sea, and Communication Transportation	-0.95	1.51	15.29	-12.18	-14.81
Bank and Assurance	-0.02	0.13	-0.08	-0.37	0.08
Cattle and the Products	-0.17	0.08	0.13	-0.51	-0.30
City Gas	0.50	0.46	-13.83	10.68	16.05
Real Estate, and Private Services	0.25	0.05	0.07	-0.16	-0.07

Table 7.2 (continued)

Industry	Energy Composite		Output		Energy Intensity $ENCOM/QA$
	Quantity ($ENCOM$)	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Fishery	-0.85	0.87	-0.01	-0.10	0.01
Food, Drink, and Tobacco	2.12	-2.02	-0.44	0.44	9.57
Forestry and Hunting	-0.22	0.18	0.18	-0.26	-0.18
Geothermal Mining	-12.97	6.14	-0.03	-0.22	-12.95
Government and Defence, Education, Health, Film, and Other Social Services	5.02	-3.16	-1.86	2.63	7.89
Hotel	-0.13	0.03	8.64	-5.10	-8.06
Hydro Generation	na	na	-0.04	76.76	0.04
Individual Services, Households, and Other Service	-8.77	4.51	0.95	-2.29	-0.94
Agriculture for Other Crops	-0.13	0.22	-2.29	1.91	2.35
Other Mining and Excavations	-2.18	0.52	-0.70	0.07	0.70
Geothermal Generation	na	na	-0.71	-0.15	0.71
Restaurant	-0.24	0.16	-0.17	0.11	0.17
Supporting Services for Transportation and Warehouse	-2.70	1.00	12.16	-9.58	-10.84
Train Transportation	-1.03	0.57	20.88	-12.80	-17.27
Electricity Transmission and Distribution	-1.98	1.39	0.00	0.18	0.00
Clean Water	148.05	-50.90	13.52	-0.08	118.51
Wood and the Products	-20.34	7.85	0.58	-0.38	-20.80

7.4.1.3. Impacts on Employed Factors and Factor-Fuels

Table 7.3 summarizes the impacts of simulation 1 on employed factors and factor-fuels. The results reveal that introducing a carbon tax compensated by a reduction in labour income tax leads to a greater sectoral mobility in labour composite than in the capital stock. The composite labour tends to shift from energy and energy-intensive industries toward non-energy industries. For examples, sectors oil mining, refinery, conventional generation, chemical, and metal mining, the aggregate employment declines by -3.79%, -7.72%, -100%, -11.30%, and -44.94%; while in sector of air, sea, and communication transportation, city gas, geothermal mining, hotel, hydro, and other mining, the aggregate employments increase sharply by 51.91%, 1630.71%, 209.18%, 21.85%, 1935.78%, and 53.11%. We argue that this transition is related to the following linkages. First, at a supply side, the implementation of a carbon tax leads to higher production costs across energy and energy-intensive industries due to their large consumption of fuels relative to non-energy industries. In turn, these changes would affect factor reallocation, by the tendency to reduce the labour costs more than the cost of other factors. Second, at the demand side, the reduced labour income tax increases the households' purchasing power, which would induce a higher consumption of non-energy commodities relative to energy commodities. As a result, workers are assumed to be mobile across industries, these would initiate labour mobility towards non-energy industries.

Furthermore, according to the production nesting model, in the third stage, capital is combined with energy-composite – by using either a Cobb Douglas function for non-energy industry or a complementarity relationship for energy-industry – to produce the capital-energy composite. The results suggest that the changes of capital-energy composite vary across industries. We suspect that these variations are influenced by the reduced labour income tax rates such that the producers obtain the least cost of inputs to produce a unit of output. In the fourth stage, the capital-energy composite is combined with the labour composite using a Cobb-Douglas function to form a value added-energy composite. In energy-intensive sectors (except textiles), the strong reduction in labour costs lead to a decline in the value added-energy composite cost; the conventional generation sector experiences the largest contraction (-94.53%) followed by metal ores mining (-7.46%), and chemical (-5.93%). On the other hand, in most non-energy industries, the value added-energy composite tends to increase due to their higher labour costs. For example, twelve non-energy sectors indicate an expansion in value added-energy composite, including air, sea, and communication transportation (15.25%), cattle products (0.11%), city gas (13.84%), real estates (0.07%), forestry (0.17%), hotel (8.62%), households' services (0.95%), other mining (0.00%), supporting services for transportation (12.14%), train transportation (20.08%), clean water (5.30%), and wood products (0.48%). There are only seven non-energy sectors indicate a slight fall in value added-energy composite, including agriculture food crops (-0.50%), bank and assurance (-0.09%), fishery (-0.01%), food and drinks (-0.44%), government services and defences (-1.86%), agriculture for other crops (-2.29%), and restaurant (-0.05%).

Table 7.3: Simulation 1: Impact on Employed Factors and Factor-Fuels (% Change)

Industry	cost ratio of capital/labor	Capital	Labor	Capital-Energy Composite		Value Added-Energy Composite	
				Volume	Price	Volume	Price
Energy and Energy-Intensive Industry							
Coal Mining	3.72	-0.03	0.34	-0.04	0.14	0.01	0.10
Natural Gas Mining	12.77	0.36	-0.91	0.36	0.05	-0.74	0.55
Oil Mining	8.81	0.38	-3.79	0.38	-0.02	0.00	0.36
Conventional Power Plant (Aggregated Fossil Fuels Generation)	51.73	0.00	-100.00	2.77	-1.42	-94.53	96.84
Refineries	4.55	0.13	-7.72	0.13	0.23	-1.06	1.41
Chemical	1.03	-0.07	-11.30	-3.77	3.70	-5.93	5.86
Metal Ores Mining	5.41	-0.69	-44.94	-0.71	-0.01	-7.46	6.76
Land Transportation	0.21	-1.39	-3.95	3.07	-4.40	-0.38	-0.91
Construction	1.13	0.02	-5.17	3.42	-3.46	-0.01	0.01
Paper, Printing, Transport Equipment, and Products from Metal	1.41	0.04	-3.44	0.70	-0.68	-0.85	0.85
Trade	0.13	0.37	-3.13	7.22	-6.87	-1.07	1.34
Spinning, Textile, Garment, and Leather Industries	1.37	0.23	1.25	0.64	-0.43	1.06	-0.87
Non-Energy Intensive Industry							
Agriculture Food Crops	0.06	0.07	-0.53	0.04	-0.01	-0.50	0.36
Air, Sea, and Communication Transportation	1.72	0.03	51.91	-0.25	0.26	15.25	-15.30
Bank and Assurance	2.29	24.16	-1.13	0.15	-0.03	-0.09	0.19
Cattle and the Products	0.42	0.08	0.21	-0.08	-0.01	0.11	-0.25
City Gas	3.19	0.52	1630.71	0.47	0.47	13.84	14.79
Real Estate, and Private Services	3.35	0.31	-0.71	0.31	-0.05	0.07	0.19
Fishery	1.71	-0.08	-0.32	-0.15	0.06	-0.01	-0.08
Food, Drink, and Tobacco	1.38	0.01	-1.27	0.13	-0.12	-0.44	0.45
Forestry and Hunting	1.62	-0.06	0.79	-0.15	0.09	0.17	-0.24
Geothermal Mining	12.03	-13.38	209.18	-12.66	-0.03	-0.60	-13.69
Government and Defence, Education, Health, Film, and Other Social Services	0.16	1.76	-2.74	2.51	-0.77	-1.86	3.60
Hotel	1.53	0.06	21.85	0.05	1.23	8.62	-8.61

Table 7.3 (continued)

Industry	cost ratio of capital/labor	Capital	Labor	Capital-Energy Composite		Value Added-Energy Composite	
				Volume	Price	Volume	Price
Hydro Generation	32.71	6.40	1935.78	na	na	na	na
Individual Services, Households, and Other Service	0.65	-4.17	4.75	-4.48	0.92	0.95	-5.14
Agriculture for Other Crops	0.21	0.03	-2.75	-0.35	0.41	-2.29	2.36
Other Mining and Excavations	0.35	-0.25	53.11	0.36	0.01	0.00	0.41
Geothermal Generation	24.10	1.02	-59.68	na	na	na	na
Restaurant	0.11	0.18	0.01	-0.19	0.11	-0.05	-0.08
Supporting Services for Transportation and Warehouse	0.30	-2.19	17.68	-2.35	0.65	12.14	-13.93
Train Transportation	0.28	-0.21	61.21	0.18	-0.67	20.08	-20.91
Electricity Transmission and Distribution	2.84	-0.54	3.21	-0.51	-0.12		
Clean Water	0.19	-10.49	10.81	-11.56	1.09	5.30	-15.66
Wood and the Products	1.01	0.60	0.08	0.79	7.19	0.48	0.09

7.4.1.4. Impacts on Commodities

Three types of commodities are distinguished, namely (1) energy commodities, which include fossil energy mining (coal, gas, and crude oil) and petroleum products (bioethanol, biodiesel, kerosene, Liquid Natural Gas (LNG), non-subsidized gasoline, non-subsidized Liquid Petroleum Gas (LPG), subsidized biodiesel, subsidized biogas, subsidized diesel, subsidized gasoline, subsidized LPG, and other refined oil products); (2) energy-intensive commodities, which include electricity, chemical products, metal ores mining, land transportation, construction, trade, textiles, and supporting services for transportation and warehouse; and (3) non-energy-intensive, which include agricultural food crops, air sea and communication transportation, bank and assurances, cattle products, city gas, real estates, fishery, food and drinks, forestry products, geothermal mining, government services, hotel, household services, non-food crops agricultural, other mining, paper and printing products, restaurant, train transportation, clean water, and timber products. Table 7.4 summarizes the impacts of SIM-1 on commodity prices and volumes.

As shown in Table 7.4, the implementation of a differentiated carbon tax on fossil fuel products – based on the level of their carbon content – immediately increases their consumer prices: coal (235.67%), natural gas (66.40%), crude oil (94.48%), bioethanol (8.22%), biodiesel (9.16%), kerosene (127.16%), LNG (7.58%), non-subsidized gasoline (361.95%), non-subsidized LPG (140.55%), subsidized biogas (114.15%), subsidized diesel (124.34%), subsidized gasoline (119.71%), and subsidized LPG (56.35%). The consumer prices of energy-intensive commodities also tend to increase, although by less than energy commodities: electricity (0.09%), chemical (3.19%), metal ores mining (6.61%), construction (0.43%), and trade (0.19%). On the other hand, for non-energy commodities, eleven commodities indicate a decline and 9 commodities indicate an increase. This implies that the consumer prices of most of these commodities tend to fall due to lower fuel costs.

On the supply side, the producer prices of most of energy commodities slightly increase: coal mining (0.22%), crude oil (0.25%), bioethanol (0.25%), biodiesel (0.25%), LNG (0.30%), non-subsidized gasoline (1.12%), other oil products (1.00%), and subsidized biodiesel (0.98%). These slight price increases indicate a rise in their final domestic demand (consumption). However, for non-energy commodities, the producer prices considerably vary.

In terms of domestic (final) consumption, the implementation of carbon tax compensated by a reduction in labour (income) tax does not necessarily reduce the final energy consumption. However, the results also reveal that energy consumption shifts towards less polluting types – indicated by lower emission factors. The domestic consumption of gas and biofuel products increases more than coal and crude oil products such as gasoline and kerosene. For example, the domestic consumption of coal declines by 0.09%, crude oil by 0.13%, kerosene by 0.19%, non-subsidised gasoline by 0.01%, and subsidised gasoline by 1.08%; in contrast, the domestic consumption of bioethanol is more increased by 10.65%, LNG by 2.12%, non-subsidised LPG by 11.36%, subsidised biodiesel by 0.17%, and subsidised by LPG 2.47%. However, for energy-intensive commodities (excluding supporting services for transportation and textiles), their domestic consumption tends to decline.

On the trade side, the price index of exported (P_i^E) and imported (P_i^M) goods and services are determined from the following relationships:

$$P_i^E = (EXR)P_i^{EW}, \qquad i \in CE$$

$$P_i^M = (EXR)P_i^{MW}, \qquad i \in CM$$

Because Indonesia's economy is classified as a small and open, Indonesia does not influence the world price of trade, thus, the world price index of export (P_i^{EW}) and import (P_i^{MW}) are exogenous. This implies that the changes of domestically price of export (P_i^E) and import (P_i^M) are fully determined by the endogenous exchange rate (domestic per foreign currency unit). The results found that simulation 1 leads to a slight depreciation of the currency. Thus, as shown in Table 7.4, the domestic price of exported and imported goods and services rises in line with the depreciated exchange rate (0.36%). In terms of trade volumes, the impact of SIM-1 varies substantially among non-energy commodities. This is due to the trade assumptions in the model: imperfect substitutability between domestic and imported commodity to produce final domestic consumption, as well as imperfect transformation from supply production to obtain domestic and exported commodities. However, for energy commodities, as previously mentioned, domestic demand shifts towards less polluting types which results in a contraction on their imported demand.

Table 7.4: Simulation 1: Impact on Commodity Prices and Volumes (% Change)

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Energy and Energy-Intensive Sector								
Coal	0.22	47.95	0.36	0.01	0.42	0.06	1.93	-0.09
Natural Gas	-0.18	13.31	0.36	0.13	2.98	-0.11	-0.74	-0.12
Crude Oil	0.25	19.33	0.36	0.01	-0.07	-0.04	-0.36	-0.13
Bioethanol	0.25	6.48	0.36	-620.66	na	1919.29	-112.17	10.65
Biodiesel	0.25	1.32	0.36	-0.68	52.88	39.44	-125.81	-0.08
Kerosene	0.00	25.94	0.36	0.00	na	0.00	-0.62	-0.19
LNG	0.30	1.43	0.36	-1.04	-1.12	0.00	-0.60	2.12
Non-Subsidized Gasoline	1.12	73.86	0.36	-1.07	na	-1.05	0.45	-0.01
Non-Subsidized LPG	-1.97	27.90	0.36	12.74	na	0.70	-3.86	11.36
Other Oil Products	1.00	12.03	0.36	-1.04	-2.53	-0.39	1.53	0.75
Subsidized Biodiesel	0.98	21.74	0.36	-0.80	na	-0.76	14.95	0.17
Subsidized Biogas	-4.63	22.79	0.36	630.18	na	7.52	1.92	-0.47
Subsidized Diesel	1.86	25.63	0.36	-0.76	na	-1.03	1.92	0.67
Subsidized Gasoline	2.74	24.69	0.36	-1.94	na	-1.94	15.52	-1.08
Subsidized LPG	4.92	13.48	0.36	-2.59	na	-2.66	6.64	2.47
Electricity	0.23	0.09	0.36	0.00	na	0.03	na	0.25
Chemical	3.44	3.19	0.36	-5.93	-12.23	-4.29	3.44	-2.26
Metal Ores Mining	5.59	6.61	0.36	-7.47	-18.27	-4.21	7.14	-2.97
Land Transportation	-1.29	-1.28	0.36	-0.27	2.55	-0.50	-3.90	-0.62
Construction	0.43	0.43	0.36	-0.01	na	-0.01	na	-0.01
Trade	0.19	0.19	0.36	-1.01	na	-1.01	na	-1.01
Supporting Services for Transportation and Warehouse	-9.58	-8.47	0.36	12.20	31.64	9.87	-12.35	5.30
Spinning, Textile, Garment, and Leather Industries	-0.17	-0.31	0.36	1.07	1.79	0.61	4.50	0.46

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Non-Energy Intensive Sector								
Agriculture Food Crops	0.54	0.53	0.36	-0.50	-12.00	-0.51	-0.19	-0.47
Air, Sea, and Communication Transportation	-11.76	-11.33	0.36	15.29	39.15	10.75	-18.04	5.35
Bank and Assurance	-0.16	-0.15	0.36	-0.07	11.67	0.04	4.32	-0.16
Cattle and the Products	-0.04	-0.04	0.36	0.12	31.24	0.22	-0.35	0.11
City Gas	11.15	11.40	0.36	-13.88	na	-11.38	na	-14.30
Real Estate, and Private Services	-0.14	-0.10	0.36	0.04	2.40	0.03	-1.04	-0.13
Fishery	-0.01	-0.07	0.36	-0.01	2.98	-0.02	-0.31	-0.02
Food, Drink, and Tobacco	0.64	0.47	0.36	-0.44	-0.99	-0.35	-0.16	-0.34
Forestry and Hunting	-0.23	0.02	0.36	0.16	14.92	0.16	-30.45	-0.37
Geothermal Mining	-0.35	-0.11	0.36	4.89	na	0.29	na	-0.05
Government and Defense, Education, Health, Film, and Other Social Services	2.60	2.69	0.36	-1.83	-6.66	-1.64	3.15	-1.51
Hotel	-5.09	-6.71	0.36	9.28	19.36	-8.64	-36.82	-22.91
Individual Services, Households, and Other Service	-2.29	-2.20	0.36	1.02	6.67	0.92	-1.60	0.72
Agriculture for Other Crops	1.91	1.91	0.36	-2.29	-5.75	-1.91	1.54	-1.69
Other Mining and Excavations	0.08	0.06	0.36	-0.68	3.02	-0.70	7.11	-3.20
Paper, Printing, Transport Equipment, and Products from Metal	0.70	0.50	0.36	-0.85	-1.84	-0.60	0.50	-0.34
Restaurant	0.13	0.08	0.36	-0.01	0.26	-0.04	11.33	-0.04
Train Transportation	-12.78	-14.63	0.36	37.63	46.98	9.76	-26.30	8.54
Clean Water	-8.92	-9.11	0.36	13.50	na	4.97	na	5.36
Wood and the Products	-0.353	-0.38	0.36	0.54	1.21	0.15	-1.33	0.14

7.4.1.5. Impact on Income Distribution and Welfare

This section discusses the effects of SIM-1 on household welfare and inequality. The inequality is measured by the Theil-L index, which belongs to the family of generalized entropy inequality measures; Welfare is measured by the Equivalent Variation (EV). Table 7.5 summarises the impacts of simulation 1 on income distribution and welfare.

The Theil-L index is widely used to measure inequality since it satisfied the criteria of good measures of inequality: mean independence, population size independence, symmetry, Pigou-Dalton transfer sensitivity, decomposability, and statistical testability (Hasnain, 2010)[50]. According to Hasnain (2010), the Theil-L index can be decomposed as follows:

$$TL = \sum_{h=1}^{N} \frac{1}{\sum_h N_h} \ln\left(\frac{\sum_h YH_h}{YH_h \sum_h N_h}\right)$$

$$= \sum_h \left(\frac{N_h}{\sum_h N_h}\right) TL_h + \sum_h \frac{N_h}{\sum_h N_h} \ln\left(\frac{N_h / \sum_h N_h}{YH_h / \sum_h YH_h}\right) \qquad (1)$$

Where Y is the total income of the population, YH_h is the income of subgroup, N is total population, and N_h us the population in the subgroup. Due to limited data of population in details, we only take into account the between-groups inequality, that is the second term of right hand side of eq. (1):

$$TL = \sum_h \frac{N_h}{\sum_h N_h} \ln\left(\frac{N_h / \sum_h N_h}{YH_h / \sum_h YH_h}\right)$$

which can be rewritten as:

$$TL = \ln\left(\frac{\sum_h YH_h}{\sum_h N_h}\right) - \frac{\sum_h N_h \ln\left(\frac{YH_h}{N_h}\right)}{\sum_h N_h} \qquad (2)$$

The welfare effect is estimated as the equivalent variation of the representative households. Equivalent variation is the amount of spending that is taken away from consumers after the price change without reducing their maximized utility as they would before the change. In the model the equivalent variation is expressed as follows:

$$EV_h = \left(\frac{PI_h^0}{PI_h^1}\right) EH_h^1 - EH_h^0$$

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[50] For further details, see Hasnain (2010).

where PI_h denotes the household price index; EH_h denotes the household expenditure; and superscripts 0 and 1 represent the situations at pre and post change of commodity price. Thus, change in total welfare (or in economy wide welfare) can be estimated as the percentage change of the sums of EVs across households:

$$TEV = 100\left[\frac{\sum_h EV_h}{\sum_h EH_h^1}\right]$$

Table 7.5 shows that the introduction of a carbon tax in Indonesia compensated by lowering the labour (income) tax rates tends to be neutral (or slightly regressive) in both rural and urban areas. In other words, the impacts of SIM-3 on household welfare are negligible. However, in terms of aggregate welfare – measured as economy-wide EV – SIM-1 results in a slight welfare loss by -0.036%. Regarding income distribution, measured as Theil-L index, the result shows that inequality remains unchanged due to the negligible changes in household welfare.

Table 7.5: Simulation 1: Impact on Income Distribution and Welfare

Household's Group	Initial Total Budget	Budget on Energy Consumption	WELFARE		Inequality	
			VALUE	%CHANGE	BASE	SHOCKED
	Billion Rp					
Rural households' - unclear occupations	158015.28	3528.11	-1582.06	-0.03		
Rural households' - agricultural labors with low income	162021.42	1662.63	-197.2	0.00		
Rural households' – non-agricultural labors with low income	385336.98	7871.47	-321.119	-0.01		
Rural households' – non-agricultural with high income	450508.35	6962.91	-2453.81	-0.05		
Rural Households' - Agricultural Employers	642327.17	8864.30	-1499.11	-0.03		
Urban households' - unclear occupations	213768.06	4859.06	-462.723	-0.01		
Urban households' - low income	633498.92	7775.67	-850.787	-0.02		
Urban households' - high income	672628.57	11447.65	6168.249	0.12		
Total				-0.036	0.136	0.136

7.4.1.6. Sensitivity Analysis

Since the parameters used in the model are 'borrowed' from the literature, it is necessary to check the robustness of simulation results with respect to parameter uncertainty (Yusuf, 2008). Orlov (2012) and Qi *et al.* (2016) argued that the results of implementing price discrimination on specific commodities, i.e. imposing carbon tax on fossil fuel commodities, can be sensitive to model parameterisations such as trade elasticities. The magnitude of the tax-shifting effect between imports and domestic commodities to produce final commodities consumed domestically (and the transformation from domestic supply to domestic and exported commodities) is mainly depending on elasticity of substitution between these commodity types. This is done by implementing a sensitivity analysis of trade parameters and examining the changes of endogenous variables. We vary the import elasticity (CES trade parameters) by a 25% decrease and increase (between 1.5 and 2.5) and then check the reliability of results. Table 7.6 presents the sensitivity analysis results of SIM-1 on macroeconomic accounts.

The sensitivity analysis shows that the changes of trade elasticity of substitution affect the macroeconomic accounts due to a change in trade accounts (export and import as well as the net export). As shown in Table 7.6, under a low elasticity scenario (trade elasticity = 1.5), the contraction in net export are more pronounced than the midpoint scenario (trade elasticity = 2) due to higher import and lower exports. This contraction obviously leads to a fall in GDP at market prices from income side; as well as net indirect tax and total wage bill since the changes in exports and imports would affect the final composite commodities purchased by domestic consumers. However, apart from total investment, under the high elasticity scenario (trade elasticity = 2.5), SIM-1 generates a consistent direction across all endogenous variables.

Table 7.6: Sensitivity Analysis of Simulation 1 on National Income Accounts (% Change)

Variables	Trade Elasticities = 1.5	Trade Elasticities = 2.0	Trade Elasticities = 2.5
GDP at factor costs	0.76	0.58	0.78
GDP at market prices from income side	-0.44	1.56	0.73
GDP at market prices from expenditure side	0.48	2.04	1.73
Total private consumption	1.11	0.16	0.01
Total investment	-2.56	0.22	-2.55
Total net government consumption	3.36	1.64	4.49
Total export	0.78	-0.14	3.63
Total import	2.29	0.36	3.43
Net export	-14.26	-5.11	5.62
Net indirect tax (total expenditures of all commodity taxes, including import tariff, less subsidy on commodities (and activities)	-13.19	74.30	48.76
Total payment to all workers (WAGEBILL)	-0.06	0.04	0.40
Total payment to capital (CAPBILL)	1.65	1.17	1.19

Source: simulation results

7.4.2. Simulation 2: Recycling Carbon Tax to Improve the Public Spending

In simulation 2, we examine the impact of implementing a carbon tax of Rp. 100,000/ton CO_2e on carbon-based fuels where the revenue raised from carbon tax is recycled through an expansion of government expenditures on commodities. In other word, the adjusted government expenditures across commodities ($CGADJ$) is endogenous in order to clear the government budget balance; all tax and subsidy rates are fixed.

7.4.2.1. Impact on Macroeconomic and CO_2 Emission Account

Table 7.7 summarizes the macroeconomic impact of introducing the carbon tax with adjustment in public spending. In the model, we estimate three kinds of GDP, namely GDP at factor cost that is calculated from total factors returns; GDP at market price from income side that is obtained from total private consumption, government consumption, investment and net export; and GDP at market price from expenditure side that is the sum of GDP at factor costs and indirect net taxes.

The implementation of a carbon tax on fossil fuels immediately increases their consumer prices. Thus, the increase of these prices will induce factors to be reallocated particularly in energy-intensive industries (Yusuf, 2008). In turn, the changes in factor markets have an important effect on sectoral and income distribution (Yusuf, 2008). As shown in Table 7.7, the GDP at factor cost slightly falls by -0.006%. This contraction is strongly related to the slight reduction of its component of the total wage bill (-0.049%). In contrast, the total capital bill slight increases (0.043%).

The introduction of a carbon tax is compensated by an increase of public expenditure on commodities by 0.07%. This implies that the negative effect of carbon tax on the economy is offset by an expansion of public expenditure on commodities that shifts up the aggregate demand. This pattern is indicated through the improvement in GDP at market prices by 0.601% from the income side and by 0.292% from the expenditure side. The carbon tax, which is embodied in domestic consumer fuel prices, leads to a drop in both total exported goods (-0.304%) and total imported goods (-0.469%). However, net exports improve by 1.34%. In addition, the introduction of carbon tax also leads to a strong rise in net indirect taxes (45.991%) which leads to a slight increase in the GDP at market prices from the expenditure side. As mentioned earlier, the share of net indirect taxes in GDP at market prices from the expenditure side is only about 1.98%. This implies that although the net indirect tax strongly increases, the GDP at market prices from the expenditure side only increases slightly.

In terms of emissions accounting, there is no rebound effect. The largest reduction of CO_2 emissions through lower consumption of fossil energy commodities are obtained by households (-18.533%) followed by industries (-1.377%). The government experiences the smallest reduction of carbon emission (-0.067%), which can be explained by the chosen revenue-recycling of increasing government expenditures on commodities which increases government consumption of fossil fuels. This increase – especially in energy goods – raises their carbon emissions, which in turn offsets the original reduction of government carbon emission. Overall, the national carbon emissions drop by -1.106%. Regarding Indonesia’s commitment to the UFCCC ratification, of which the national share emissions from energy utilization are targeted to be reduced by about 1%, simulation 2 demonstrates that the target can be achieved through imposing the carbon tax on fossil fuels compensated by an increase in public consumption on goods and services.

Table 7.7: SIM-2 Impacts on National Income Account

Variables	BASE	SHOCKED	% CHANGE
	(Billions Rupiah)		
GDP at factor costs	5,139,651.22	5,139,363.12	-0.006
GDP at market prices from income side	5,472,898.80	5,505,805.87	0.601
GDP at market prices from expenditure side	5,243,713.58	5,259,046.42	0.292
Total private consumption	3,318,104.75	3,361,220.97	1.299
Total investment	1,508,830.58	1,474,576.53	-2.27
Total real government consumption	294,566.35	302,036.19	2.536
Total nominal government consumption	294566.348	294368.423	-0.07
Total export	1,531,028.46	1,526,377.78	-0.304
Total import	1,391,532.58	1,385,013.23	-0.469
Net export	139,495.88	141,364.56	1.34
Net indirect tax (total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	104,062.37	119,683.30	15.011
Total payment to all workers (WAGEBILL)	2,692,617.74	2,691,288.35	-0.049
Total payment to capital (CAPBILL)	2,447,033.48	2,448,074.77	0.043
Emissions	(Billions Ton CO_2)		
CO_2 emissions from Households	4.13	3.54	-14.159
CO_2 emissions from Industries	55.69	55.61	-0.149
CO_2 emissions from Government	0.50	0.50	-0.067
TOTAL CO_2	60.32	59.65	-1.106

7.4.2.2. Impacts on Output and Energy Composite

Table 7.8 presents the impacts of simulation 2 on industries's output and the required industries' input of energy composite as well as the industries' energy intensities. As mentioned earlier, the changes in output (price and volume) are strongly influenced by the changes in energy input costs – indicated by the price of energy composite (P_ENCOM) across industries. The introduction of a carbon tax immediately increases the input price of fuel products, which leads to a rise in the aggregated energy costs (Orlov, 2012). As shown in table 7.8, the input price of the energy composite increases in almost all sectors – especially in energy-intensive industries – which leads to a drop in energy aggregate input. For example, energy composite demand falls in conventional generation (-24%), metal ores mining (-18%), textiles (-13%), construction (-10%), and paper products industry (-4%) since their production is heavily relied on fossil fuel inputs. These changes raise the price (or lower the volumes) of their output; the output price of conventional generation indicates the largest increase. In contrast, the output from renewable electricity increases by 0.39% (hydro) and 5.35% (geothermal). This expansion is due to the technology switching effect from conventional (fossil fuels) generation to renewable (clean) generation.

For most of the non-energy intensive industries that require less fossil fuel inputs, demand for energy composite input falls. The magnitude changes of fuel composite demand across these industries are irrelevant to the changes of their output production. We argue that these variations are determined by two channels: (i) the increasing aggregate demand in economy through the expansion of public consumption of commodities; and (ii) fuel substitution effects in which an industry will favor the less polluting (identified by less emission factor) fuels than the higher carbon-based fuels. In other words, the contraction due to the introduction of a carbon tax on fossil fuels will be offset by an increase of government expenditure on goods and services. In thirteen non-energy sectors, the energy composite input went down, namely supporting services for transportation and warehouses (-102.16%); agricultural for food crops (-49.76%); bank and assurances (-22.09%); electricity transmission and distribution (-21.31%); wood products (-20.34%); forestry and hunting (-10.16%); fishery (-7.55%); food, drink, and tobaccos (-6.73%); other mining (-6.41%); air, sea, and communication transportation (-4.59%); restaurant (-3.07%); government services (-3.61%); and cattle and their products (-1.28%). In contrast, six sectors had an increase in energy composite input, namely clean water (148.05%); agriculture for other crops (44.87%); real estate, and private services (21.75%); city gas (9.21%); hotel (4.03%); and individual services, households, and other service (1.78%). The changes of energy aggregate input among these industries are not in line with their output production. For example, although the aggregated energy inputs in agriculture food crops sharply dropped (-49.76%), their output production still slightly increased (0.12%). This is because food crops are required as raw inputs to produce food and drink commodities.

Furthermore, in terms of energy intensity – measured by the division of total energy requirements by output, I found that the changes in energy intensity substantially vary across industries. For example, the largest decline of energy intensity occurred in supporting services for transportation and warehouse sector (-102.23%) (Table 7.2). It means that this sector requires 102.23% less energy to produce a unit of output. In contrast, the energy intensity of natural gas mining (1.01%) increased by more than coal mining (0.55%) due to a higher demand for energy inputs. Orlov (2012) argued that the main factors in determining the magnitude changes of energy intensity are the elasticity of substitution among inter-fuel and factor-fuels. For example, if a Leontief production function is assumed, then the energy intensity remains unchanged because its nesting structure does not allow any substitution possibility (Orlov, 2012).

Table 7.8: Simulation 2: Impact on Energy Composite, Output, and Energy Intensity (% Change)

Industry	**Energy Composite**		**Output**		**Energy Intensity** $ENCOM/QA$
	Quantity ($ENCOM$)	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Energy and Energy-Intensive Industry					
Coal Mining	-0.68	0.62	-1.23	0.04	0.55
Natural Gas Mining	0.77	0.22	-0.24	0.27	1.01
Oil Mining	-1.76	-0.32	-0.08	0.33	-1.84
Conventional Power Plant (Aggregated Fossil Fuels Generation)	-24.21	27.57	-20.04	1.75	-5.22
Refineries	-0.17	1.08	-0.46	0.59	-0.63
Chemical	-1.57	-1.21	-0.20	0.64	-1.77
Metal Ores Mining	-17.69	17.25	-0.88	-0.02	-16.96
Land Transportation	-0.32	0.29	-0.29	0.66	-0.03
Construction	-10.22	10.85	0.09	0.89	-10.29
Paper, Printing, Transport Equipment, and Products from Metal	-3.59	-3.38	-0.02	-0.46	-3.61
Trade	-1.26	2.11	0.00	0.57	-1.25
Spinning, Textile, Garment, and Leather Industries	-13.34	13.16	-0.56	-0.16	-12.86
Non-Energy Intensive Industry					
Agriculture Food Crops	-49.76	2.44	0.12	-0.04	-49.82
Air, Sea, and Communication Transportation	-4.59	3.76	-1.40	0.03	-3.24
Bank and Assurance	-22.09	7.61	-0.06	-0.64	-22.05
Cattle and the Products	-1.28	8.61	0.01	0.62	-1.29
City Gas	9.21	-11.28	-6.31	0.79	16.57
Real Estate, and Private Services	21.75	-21.98	-1.29	-0.64	23.34
Fishery	-7.55	6.21	-0.07	0.36	-7.48
Food, Drink, and Tobacco	-6.73	-0.42	0.04	0.04	-6.70
Forestry and Hunting	-10.16	-0.19	-3.24	-0.45	-7.15
Geothermal Mining	1.70	-1.02	1.90	0.38	-0.19
Government and Defence, Education, Health, Film, and Other Social Services	-3.61	4.32	0.27	-0.64	-3.87
Hotel	4.03	5.58	2.82	-0.64	1.18

Table 7.8 (continued)

Industry	Energy Composite		Output		Energy Intensity $ENCOM/QA$
	Quantity ($ENCOM$)	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Hydro Generation	na	na	0.39	-1.18	na
Individual Services, Households, and Other Service	1.78	0.19	0.39	0.70	1.38
Agriculture for Other Crops	44.87	-46.13	1.17	0.10	43.20
Other Mining and Excavations	-6.41	0.07	3.58	0.34	-9.64
Geothermal Generation	na	na	5.35	1.724	na
Restaurant	-3.07	9.54	-0.57	0.40	-2.51
Supporting Services for Transportation and Warehouse	-102.16	192.90	-3.35	0.30	-102.23
Train Transportation	-19.89	34.58	5.15	-0.80	-23.81
Electricity Transmission and Distribution	-21.31	10.76	-0.69	0.97	-20.76
Clean Water	148.05	-50.90	13.52	-0.08	118.51
Wood and the Products	-20.34	7.85	0.58	-0.38	-20.80

7.4.2.3. Impacts on Employed Factors and Factor-Fuels

The changes in output reallocates factors across sectors (Yusuf, 2008). In addition, because in the factor closures we assume that capital and workers are mobile between industries within a fixed labour wage and capital rent, thus, the injection of an increase of government spending on goods and services induces only the capital stock and the number of workers. Table 7.9 presents the effects of simulation 2 on employed factors and factor-fuels.

The factor ratio of capital to labour composite ($\frac{K}{LAB}$), shows that most energy-intensive industries are also capital-intensive. These industries, which experience a decline in output due to carbon tax, also have tendency in reducing the capital cost. For example, there are a decrease in capital input for conventional electricity generation (-0.49%), fossils mining (coal (-2.99%) and gas (-0.43%)), refinery (-0.25%), chemical (-0.49%), metal mining (-0.73%), construction (-0.69%), paper products (-0.49%), trade (-0.34%), and textiles (-0.88%)[51]. However, for capital-intensive renewable industries, the demand for capital increases by a lot. We argue that this finding is due to the generation technology switching from fossil fuels plant to renewables (hydro and geothermal) as a result of the carbon tax on fuels.[52] The results also revealed a sharp contraction of employment in the capital-intensive energy (fossil and renewable) sectors such

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[51] These findings are similar to those study of Yusuf (2008).

[52] Based on the bottom-up model framework in electricity production structure, this technology switching is allowed to obtain total output generation.

as conventional generation (-37.31%), hydro generation (-100%) and geothermal generation (-100%). Overall, simulation 2 slightly improves the aggregate employment by 0.09%.

In the third stage of the production structure in the model, capital is combined with energy-composite by using either a Cobb Douglas function (for non-energy industry) or a Leontief function (for energy industry) to produce the capital-energy composite. Some energy-intensive (and energy) sectors contract, i.e. coal mining (-1.15%), natural gas mining (-0.13%), oil mining (-0.19%), conventional power plant (-7.10%), construction (-1.99%), paper products (-0.05%), trade (-0.79%), and textiles -0.06%). Orlov (2012) argued that the magnitude of reduction of capital-energy composite depends on the ratio of capital cost relative to energy input costs. When the energy costs are higher than capital costs, the capital-energy aggregate declines more. For example, the largest decline in capital-energy composite is obtained in conventional generation plants since this industry heavily depends on fossil-fuel combustion; on the contrary, there is only a slight decrease of capital-energy composite in textiles and trade sector since they depend on more capital (the machineries) than on energy input.

In the next stage of the production structure (the fourth stage), the capital-energy composite is combined with the labour composite using a Cobb-Douglas function to form value added-energy composite. In some sectors, the reduction in employment costs decreases the cost of the value added-energy composite; conventional generation sector has the largest contraction (-24.43%) followed by city gas (-6.25%), real estate (-1.94%), and air, sea, and communication transportation (-1.44%).

Table 7.9: Simulation 2: Impact on Employed Factors and Factor-Fuels (% Change)

Industry	**Initial input cost ratio of capital/labor**	**Capital**	**Labor**	**Capital-Energy Composite**		**Value Added-Energy Composite**	
				Volume	Price	Volume	Price
Energy and Energy-Intensive Industry							
Coal Mining	3.72	-2.99	-2.69	-1.15	-0.1	-1.28	0.29
Natural Gas Mining	12.77	-0.43	3.32	-0.13	-5.9	-0.20	0.07
Oil Mining	8.81	0.00	1.13	-0.19	0.0	-0.10	0.16
Conventional Power Plant (Aggregated Fossil Fuels Generation)	51.73	-0.49	-37.31	-7.10	-20.9	-24.43	-0.63
Refineries	4.55	-0.25	0.61	0.00	0.4	1.70	-1.42
Chemical	1.03	-0.49	3.21	0.62	-0.5	1.00	-0.87
Metal Ores Mining	5.41	-0.73	-0.41	0.13	-0.4	-0.87	0.23
Land Transportation	0.21	1.79	-1.33	1.01	-0.8	-0.22	0.88
Construction	1.13	-0.69	2.59	-1.99	2.3	0.73	-0.37
Paper, Printing, Transport Equipment, and Products from Metal	1.41	-0.49	-2.20	-0.05	-0.5	-0.05	0.03
Trade	0.13	-0.34	0.25	-0.79	0.2	-0.10	-0.79
Spinning, Textile, Garment, and Leather Industries	1.37	-0.88	-1.57	-0.06	0.0	-0.45	0.10
Non-Energy Intensive Industry							
Agriculture Food Crops	0.06	-0.41	0.19	-0.54	0.8	0.08	-0.65
Air, Sea, and Communication Transportation	1.72	0.02	-0.44	-1.41	0.5	-1.44	0.32
Bank and Assurance	2.29	-1.07	1.26	-2.60	1.7	-0.19	-0.70
Cattle and the Products	0.42	6.62	-2.59	7.66	-5.6	0.26	2.03
City Gas	3.19	-6.91	-32.12	0.97	-1.6	-6.25	1.34
Real Estate, and Private Services	3.35	-2.29	-4.33	-1.40	-0.8	-1.94	-0.93
Fishery	1.71	0.63	5.13	0.01	0.6	-0.46	1.07
Food, Drink, and Tobacco	1.38	0.07	0.68	0.37	-0.3	0.14	-0.11
Forestry and Hunting	1.62	-5.76	0.92	-5.75	-0.4	-3.25	-0.70
Geothermal Mining	12.03	1.26	153.98	2.22	-0.6	2.44	0.07
Government and Defence, Education, Health, Film, and Other Social Services	0.16	-0.73	0.36	-1.61	0.0	0.22	-0.76
Hotel	1.53	1.55	3.89	0.73	1.8	2.82	-1.11
Hydro Generation	32.71	9.54	-100	n.a	n.a	n.a	n.a
Individual Services, Households, and Other Service	0.65	-0.41	0.84	-0.25	2.1	0.40	1.64

Table 7.9 (continued)

Industry	Initial input cost ratio of capital/labor	Capital	Labor	Capital-Energy Composite		Value Added-Energy Composite	
				Volume	Price	Volume	Price
Agriculture for Other Crops	0.21	0.29	1.27	0.64	-0.3	1.17	0.49
Other Mining and Excavations	0.35	4.60	-1.66	1.91	-0.6	3.59	0.61
Geothermal Generation	24.10	240.44	-100	n.a	n.a	n.a	n.a
Restaurant	0.11	4.51	-0.77	6.27	0.5	-0.22	0.80
Supporting Services for Transportation and Warehouse	0.30	-30.19	-39.60	-7.92	0.9	-3.72	0.76
Train Transportation	0.28	-77.91	9.09	1.75	0.1	5.70	-1.11
Electricity Transmission and Distribution	2.84	-3.57	82.67	-0.48	-0.4	n.a	n.a
Clean Water	0.19	34.15	-2.70	64.57	1.2	13.92	0.58
Wood and the Products	1.01	0.82	1.30	-0.01	209.7	0.61	0.54

7.4.2.4. Impacts on Commodities

According to the SAM dataset, we distinguish three types of commodities: (1) energy commodities which including fossil energy mining (coal, gas, and crude oil) and petroleum products (bioethanol, biodiesel, kerosene, Liquid Natural Gas (LNG), non-subsidized gasoline, non-subsidized Liquid Petroleum Gas (LPG), subsidized biodiesel, subsidized biogas, subsidized diesel, subsidized gasoline, subsidized LPG, and other refined oil products); (2) energy-intensive commodities which including electricity, chemical products, metal ores mining, land transportation, construction, trade, textiles, and supporting services for transportation and warehouse; and (3) non-energy-intensive which including agricultural food crops, air sea and communication transportation, bank and assurances, cattle products, city gas, real estates, fishery, food and drinks, forestry products, geothermal mining, government services, hotel, household services, non-food crops agricultural, other mining, paper and printing products, restaurant, train transportation, clean water, and timber products. Table 7.10 summarizes the impacts of simulation 2 on commodity prices (and volumes).

In the model framework, the carbon tax is embodied in the consumer prices of fossil fuels according to the level of their emission. This imposition immediately increases the consumer prices of those fuel products, namely coal (235.67%), natural gas (66.40%), crude oil (94.48%), bioethanol (8.22%), biodiesel (9.16%), kerosene (127.16%), LNG (7.58%), non-subsidized gasoline (361.95%), non-subsidized LPG (140.55%), subsidized biogas (114.15%), subsidized diesel (124.34%), subsidized gasoline (119.71%), and subsidized LPG (56.35%). However, for energy-intensive commodities (electricity), the consumer price declines. This is because in the model, technology switching from conventional to renewable (clean) generation is allowed resulting in a lower price of electricity. For the other energy-intensive commodities (excluding land transportation), the consumer price also drops mostly due to their lower factor costs (Table 7.3). In contrast, the changes in most consumer prices of non-energy commodities are negligible.

On the supply side, the producer price of most of energy commodities tends to fall: natural gas (-0.34%), crude oil (-0.32%), bioethanol (-0.01%), biodiesel (-0.24%), non-subsidized LPG (-0.13%), subsidized biodiesel (-0.03%), subsidized biogas (-0.51%), subsidized diesel (-0.06%), subsidized gasoline (-2.04%). These price falls are influenced by a sharp decrease in their final domestic demand (consumption). However, for non-energy commodities, the producer price tends to increase. We argue that this improvement is triggered by the increased government spending on goods which, in turn, increases the aggregate demand.

Furthermore, on the trade side, as previously discussed, the world price index of export (P_i^{EW}) and import (P_i^{MW}) are exogenous. Thus, the changes of domestically price of export (P_i^{E}) and import (P_i^{M}) are fully determined by the endogenous exchange rate. Simulation 2 still leads to an appreciation of the home currency. Thus, as shown in Table 7.10, the domestic price of exported and imported goods and services falls in line with the appreciated exchange rate (-0.49%). In terms of trade volumes, the impact of simulation 2 varies substantially, especially for non-energy commodities. This is due to the trade assumptions in the model: imperfect substitutability between domestic and imported commodity to produce final domestic consumption as well as domestic and export transformation function from supply commodities. However, for energy commodities, as previously discussed, the introduction of a carbon tax on fossil fuels leads to an increase in price (or a decline in volume) of final domestic consumption. Therefore, this contraction would in turn lead to a drop of both import and domestic supply of energy goods.

Table 7.10: Simulation 2: Impact on Commodity Prices and Volumes (% Change)

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Energy and Energy-Intensive Sector								
Coal Mining	0.33	235.67	-0.49	-1.24	-2.05	-1.94	-5.91	-0.17
Natural Gas Mining	-0.34	66.40	-0.49	0.02	-0.37	-0.05	-9.28	-0.10
Oil Mining	-0.32	94.48	-0.49	-0.21	-0.08	-0.10	-1.61	-0.58
Bioethanol	-0.01	8.22	-0.49	954.17	n.a	0.00	-100.00	-100.00
Biodiesel	-0.24	9.16	-0.49	-100.00	-82.11	-80.42	0.00	-0.66
Kerosene	0.00	127.16	-0.49	618.28	n.a	0.00	-17.40	-3.71
LNG	1.58	7.58	-0.49	-10.46	1.79	26.48	-65.74	-100.00
Non-Subsidized Gasoline	0.36	361.95	-0.49	0.29	n.a	0.44	1.52	0.25
Non-Subsidized LPG	-0.13	140.55	-0.49	-8.03	n.a	-13.10	12.02	-3.11
Other Oil Products	0.10	56.32	-0.49	-1.33	-1.64	-1.23	-1.52	-0.20
Subsidized Biodiesel	-0.03	105.97	-0.49	57.34	n.a	20.38	-12.56	-2.28
Subsidized Biogas	-0.51	114.15	-0.49	680.14	n.a	-100.00	-100.00	-1.46
Subsidized Diesel	-0.06	124.34	-0.49	0.94	n.a	-0.82	0.02	-0.93
Subsidized Gasoline	-2.04	119.71	-0.49	-0.80	n.a	-3.32	-4.70	-1.37
Subsidized LPG	0.04	56.35	-0.49	26.79	n.a	17.69	-32.93	-2.55
Electricity	0.68	-1.69	-0.49	-1.83	n.a	-1.01	n.a	-0.44
Chemical	-0.60	-0.93	-0.49	-0.19	0.20	-0.25	-0.39	0.32
Metal Ores Mining	0.10	-0.65	-0.49	1.26	2.12	-1.48	0.39	-0.24
Land Transportation	0.60	1.59	-0.49	0.18	-17.53	0.12	1.41	-1.34
Construction	-0.29	-0.29	-0.49	0.07	n.a	0.13	n.a	0.17
Trade	-0.60	-0.61	-0.49	0.14	n.a	-0.05	n.a	-0.01
Supporting Services for Transportation and Warehouse	0.31	-0.89	-0.49	-1.40	-6.77	-1.78	6.24	0.76
Spinning, Textile, Garment, and Leather Industries	-0.19	-0.26	-0.49	-0.32	-0.64	-0.10	2.12	0.84

Table 7.10 (continued)

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Non-Energy Intensive Sector								
Agriculture Food Crops	0.13	0.17	-0.49	0.13	84.80	0.02	0.40	-0.07
Air, Sea, and Communication Transportation	-0.09	0.32	-0.49	-1.58	-1.28	-1.62	-0.85	-2.11
Bank and Assurance	-0.61	-0.07	-0.49	-0.16	-95.44	0.58	28.62	0.56
Cattle and the Products	0.98	0.46	-0.49	0.13	696.51	-0.49	29.80	-0.29
City Gas	0.97	0.15	-0.49	-7.01	n.a	-12.70	n.a	-8.86
Real Estate, and Private Services	-0.54	-1.55	-0.49	-1.39	5.74	-1.32	2.08	0.13
Fishery	0.45	0.64	-0.49	-0.03	-1.97	0.11	-100.00	-0.31
Food, Drink, and Tobacco	0.95	0.15	-0.49	-0.01	-0.02	0.05	-0.37	-0.09
Forestry and Hunting	-0.34	-3.34	-0.49	-3.78	177.45	-3.91	301.01	2.33
Geothermal Mining	0.08	3.09	-0.49	9.47	n.a	1.78	n.a	-0.54
Government and Defense, Education, Health, Film, and Other Social Services	-0.72	-0.61	-0.49	0.38	1.68	0.26	2.22	0.33
Hotel	-0.62	0.63	-0.49	2.77	-2.85	8.20	9.89	11.35
Individual Services, Households, and Other Service	0.72	0.80	-0.49	0.58	41.94	0.16	2.29	0.25
Agriculture for Other Crops	0.13	-0.08	-0.49	0.94	1.25	1.16	-2.49	0.19
Other Mining and Excavations	0.36	1.02	-0.49	2.21	42.54	1.70	3.97	1.03
Paper, Printing, Transport Equipment, and Products from Metal	-0.32	-1.26	-0.49	-0.06	0.05	-0.15	0.11	-0.01
Restaurant	0.42	0.10	-0.49	-0.11	-3.07	0.10	7.83	0.07
Train Transportation	-0.74	1.81	-0.49	84.07	39.66	26.45	308.27	26.97
Clean Water	-0.09	-0.99	-0.49	10.72	n.a	-6.34	n.a	-5.32
Wood and the Products	-0.40	-0.10	-0.49	0.31	1.43	0.06	0.42	0.11

7.4.2.5. Impacts on Income Distribution and Welfare

As previously discussed, inequality is measured from the Theil-L index, and the welfare is measured from the Equivalent Variation (EV). Table 7.11 presents the impacts of simulation 2 on income distribution and welfare.

In general, the introduction of a carbon tax in Indonesia compensated by higher public spending tends to be progressive –higher income groups, especially urban households, are worse off than lower income groups. In other words, the higher income groups bear a higher share of the carbon tax burden.

More specifically, poor rural households tend to gain more than rich households. Relative to the initial total budget of households, the welfare on poorest rural households – i.e. rural households with unclear occupations and rural with agricultural workers with low income – tends to improve more (or to lose less) by 0.08% and -0.13%, respectively; while the higher income groups – i.e. rural households employed in non-agricultural with high income and rural households worked as agricultural employer – tend to lose more (or to improve less) by -024% and 0.06%, respectively. In urban areas, the households experience a welfare loss as their budget increases.

Yusuf (2008) argued that the main reasons behind these results are related to the introduction of a carbon tax on polluting fuel commodities, combined with the consumption pattern as well as factor returns for each households. As revealed in Table 7.5, the higher income groups (in rural and urban areas) spend a larger share of their budget on energy commodities than the poorer households. In rural areas, the poorest households (unclear occupations) spend only about Rp. 3,528.11 billion, while the richest (agricultural employers) spends more than twice as much (about Rp. 8,864.30 billion). In urban areas, the poorest households (unclear occupations) spending on energy commodities is only about Rp. 4859.06 billion, while the richest (high income) spends almost three times as much (about Rp. 1,1447.65 billion). These consumption patterns are influenced by the subsidy for gasoline price in year 2008.

Regarding income distribution, measured as Theil-L index, the result shows that inequality slightly reduces from 0.136 to 0.135. We argue that this slight improvement is due to the progressive nature of simulation 2 where the welfare loss by richest households reduces the inequality gap among households.

Table 7.11: Simulation 2: Impact on Income Distribution and Welfare

Household's Group	Initial Total Budget	Budget on Energy Consumption		WELFARE		Inequality	
				VALUE	%CHANGE	BASE	SHOCKED
	Billion Rp						
Rural households' - unclear occupations	158015.28	3528.11		4254.56	0.08		
Rural households' - agricultural labors with low income	162021.42	1662.63		-6412.49	-0.13		
Rural households' – non-agricultural labors with low income	385336.98	7871.47		1600.65	0.03		
Rural households' – non-agricultural with high income	450508.35	6962.91		-12089.21	-0.24		
Rural Households' - Agricultural Employers	642327.17	8864.30		3169.69	0.06		
Urban households' - unclear occupations	213768.06	4859.06		10464.32	0.20		
Urban households' - low income	633498.92	7775.67		-108.35	-0.002		
Urban households' - high income	672628.57	11447.65		-110980.07	-2.16		
Total					-3.32	0.136	0.135

7.4.2.6. Sensitivity Analysis

To test the robustness of simulation results with respect to parameter uncertainty, we implement a sensitivity analysis of trade parameters and examine the changes of endogenous variables. We vary the import elasticity (CES trade parameters) by a 25% decrease and increase (between 1.5 and 2.5) and then check the reliability of results. Table 7.12 shows the sensitivity analysis results of simulation 2 on macroeconomic accounts.

The sensitivity analysis shows that the changes of trade elasticity of substitution would affect the results of macroeconomic accounts due to a change in trade accounts (export and import as well as the net export). Higher elasticity of trade elasticity induces lower export (and import) but improving the net export (export reduction is less pronounced than import). As shown in table 7.6, by increasing the trade elasticity from 1.5 to 2.5, it is showed that export decreases from 0.03% to -1.64% and import decreases from 0.76% -5.54%. These changes, in turn, would lead to a larger rise in GDP at market prices from income side. Apart from the trade accounts, under high and low elasticity, simulation 2 generates a consistent direction across all endogenous variables.

Table 7.12: Sensitivity Analysis of Simulation 2 on National Income Accounts (% Change)

Variables	Trade Elasticities = 1.5	Trade Elasticities = 2.0	Trade Elasticities = 2.5
GDP at factor costs	0.39	-0.01	-0.30
GDP at market prices from income side	0.48	0.60	4.07
GDP at market prices from expenditure side	0.91	0.29	0.01
Total private consumption	1.51	1.30	3.90
Total investment	-2.70	-2.27	-2.01
Total real government consumption	0.59	2.54	22.45
Total export	0.03	-0.30	-1.64
Total import	0.76	-0.47	-5.44
Net export	-7.23	1.34	36.23
Net indirect tax (total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	26.82	15.01	15.28
Total payment to all workers (WAGEBILL)	-0.41	-0.05	-5.97
Total payment to capital (CAPBILL)	1.27	0.04	5.95

7.4.3. Simulation 3: Imposing a Carbon Tax without Compensation

In simulation 3, we examine the impact of implementing the carbon tax (Rp. 100,000/ ton CO_2e) on carbon-based fuels within the condition if the additional revenue raised from carbon tax is not returned to the economy or not used for compensation. In other words, the tax revenue is kept as government saving to run a budget surplus. All taxes and subsidies as well as government expenditures on goods remain unchanged. This scenario aims to investigate the impact of carbon tax on Indonesia’s economy when there is no revenue-neutralizing mechanism.

7.4.3.1. Impacts on Macroeconomic and CO_2 Emission Account

Table 7.13 presents the macroeconomic implications of introducing the carbon tax without any compensation to the economy. The results show that the introduction of a carbon tax leads to a huge increase in net government saving (budget surplus) by 43%. Compared to scenarios of a carbon tax with revenue recycling schemes (simulation 1 and simulation 2), the economy is more adversely affected: all GDPs contract –GDP at factor costs (-0.31%), GDP at market price from income side by -0.83%, GDP at market price from expenditure side by -0.87%. The reduction of GDP at factor costs is related to a decline of its components of both total capital bills (-0.33%) and wage bills (-0.29%). The contraction of the GDP at market price from expenditure side is slightly higher than that of the GDP at factor costs due to a large decline in the net indirect tax (-28.54%). In other words, the equilibrium output tends to shift downward which in turn reduces the net indirect tax revenues. In terms of trade, both export and import indicate a strong contraction, which are -4.14% and -4.68%. The reason for this is clear: since the increased domestic price of energy products due to imposing the carbon tax is not compensated through a revenue-recycling scheme, the production costs rise. As a result, the contraction in aggregate demand is more pronounced in simulation 3 than that of simulation 1 and simulation 2.

Table 7.13: Simulation 3: Impact on National Income Account

Variables	**BASE**	**SHOCKED**	**% CHANGE**
	(Billions Rupiah)		
GDP at factor costs	5,139,651.22	5,123,988.28	-0.31
GDP at market prices from income side	5,472,898.80	5,427,691.66	-0.83
GDP at market prices from expenditure side	5,243,713.58	5,198,349.81	-0.87
Total private consumption	3,318,104.75	3,353,772.77	1.08
Total investment	1,508,830.58	1,451,343.49	-3.81
Total real government consumption	294,566.35	302,490.95	2.69
Total export	1,531,028.46	1,467,599.42	-4.14
Total import	1,391,532.58	1,326,438.36	-4.68
Net export	139,495.88	141,161.06	1.19
Net indirect tax (total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	104,062.37	74,361.53	-28.54
Total payment to all workers (WAGEBILL)	2,692,617.74	2,684,914.07	-0.29
Total payment to capital (CAPBILL)	2,447,033.48	2,439,074.22	-0.33
Budget Surplus	229,473.13	321,262.38	40
Emissions	**(Billions Ton CO_2)**		
CO_2 emissions from Households	4.54	3.97	-12.53
CO_2 emissions from Industries	61.26	60.65	-0.99
CO_2 emissions from Government	0.55	0.55	-
TOTAL CO_2	66.35	65.17	-1.77

In terms of emissions, the results show that total emissions generated from households strongly decrease (-12.53%); but total emissions generated from firm slightly drop (-0.99%). Overall, the national carbon emissions drop by 1.77%, a pronounced drop than in simulation 1 and simulation 2.

7.4.3.2. Impacts on Output and Energy Composite

Table 7.14 presents the impacts of simulation 3 on industries' output and the required industries' input of energy composite as well as the industries' energy intensities. The price changes of energy composite across industries are substantially larger than in simulation 1 and simulation 2 especially in the energy-intensive (utilities) sectors, i.e. conventional generation plant (90.62%) and land transportation sector (24.16%). The increasing price of the energy composite immediately leads to a sharp decline in their input volumes, by 100% in conventional electricity generation and followed land transport by 26.21%, since their production heavily relies on fossil fuel inputs. However, the results also reveal that some energy-intensive sectors increase their energy composite input, which in turn it induces a higher energy intensity.

For non-energy intensive industries, the changes of energy aggregate input prominently vary, although they are not necessarily in line with the changes of their output production. From Table 7.14, it can be seen that implementing a carbon tax without a revenue-recycling scheme could initiate large structural changes across non-energy industries. In other words, simulation 3 leads to a greater uncertainty about the magnitude of energy consumption pattern across non-energy industries. We suspect that the changes might be related to a substantial shift of inputs combination between industries such that the production costs are minimized. For example, four non-energy sectors have a large reduction in energy composite input, namely air, sea, and communication transportation (-9.81%); city gas utilities (-15.37%); forestry and hunting (-29.51%); and hotel (-83.78%). In contrast, six sectors have a sharp increase in energy composite input, namely food, drink, and tobacco (13.34%); other mining and excavations (13.09%); real estate, and private services (21.75%); and supporting services for transportation and warehouse (45.31%). Furthermore, in terms of output, conventional power plant hurts the most (-63.07%); however, the small or zero emissions-based generation indicate the largest improvement by 935.41% (hydro) and 81.21% (geothermal).

In terms of energy intensity, the changes vary across industries. Conventional power plant and hotel indicate the largest decline of energy intensity by -100%. This means that the industries require approximately half the energy input to produce a unit of output. In contrast, some sectors indicate a sharp increase in energy intensity, i.e. chemical, trade, paper products, food and drink products, supporting services for transportation, and paper products.

Table 7.14: Simulation 3: Impact on Energy Composite, Output, and Energy Intensity (% Change)

Industry	**Energy Composite**		**Output**		**Energy Intensity** $\boldsymbol{ENCOM}/\boldsymbol{QA}$
	Quantity ($ENCOM$)	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Energy and Energy-Intensive Industry					
Coal Mining	-8.38	4.81	-1.89	0.02	-6.68
Natural Gas Mining	-1.47	10.65	-2.63	0.08	-0.08
Oil Mining	-0.11	11.33	-1.24	0.00	0.00
Conventional Power Plant (Aggregated Fossil Fuels Generation)	-100.00	90.62	-63.07	23.68	-100.00
Refineries	-1.84	7.16	-2.47	2.88	-3.96
Chemical	51.41	-47.31	-7.83	11.02	36.45
Metal Ores Mining	-0.40	-1.41	-11.76	8.87	-8.15
Land Transportation	-26.21	24.16	-1.98	2.10	-27.37
Construction	15.69	-16.14	-1.52	-0.11	16.63
Paper, Printing, Transport Equipment, and Products from Metal	44.34	-44.66	-2.17	1.53	42.43
Trade	63.43	-63.19	-0.07	1.23	60.53
Spinning, Textile, Garment, and Leather Industries	6.62	-8.92	7.45	-15.87	26.78
Non-Energy Intensive Industry					
Agriculture Food Crops	-0.96	-0.88	0.42	-2.36	1.43
Air, Sea, and Communication Transportation	-9.81	8.25	10.59	-12.79	2.38
Bank and Assurance	-1.39	-0.54	-23.03	31.26	-23.82
Cattle and the Products	-1.06	-0.82	1.55	-4.15	3.23
City Gas	-15.37	10.24	-5.19	-2.20	-12.36
Real Estate, and Private Services	0.41	-1.45	0.29	-1.02	1.03
Fishery	-3.46	1.83	0.95	-2.24	2.30
Food, Drink, and Tobacco	13.34	-14.59	0.17	-2.21	20.85
Forestry and Hunting	-29.51	10.43	-40.83	60.14	-68.78
Geothermal Mining	-1.85	11.00	-1.60	0.02	-1.86
Government and Defence, Education, Health, Film, and Other Social Services	3.66	-4.23	-1.78	2.47	3.33
Hotel	-83.78	5.99	12.22	-100.02	-100.00
Hydro Generation	na	na	935.41	-0.08	0.08
Individual Services, Households, and Other Service	3.25	-3.87	-3.20	5.04	14.24
Agriculture for Other Crops	-3.74	1.20	-4.56	3.24	-3.13
Other Mining and Excavations	13.09	-9.57	3.38	-0.48	20.57

Table 7.14 (continued)

Industry	Energy Composite		Output		Energy Intensity $ENCOM/QA$
	Quantity ($ENCOM$)	Price (P_ENCOM)	Quantity (QA)	Price (P_QA)	
Geothermal Generation	na	na	81.21	-1.87	1.91
Restaurant	-1.32	-0.64	0.48	-0.81	0.82
Supporting Services for Transportation and Warehouse	45.31	-21.41	34.83	-29.19	111.84
Train Transportation	-4.69	1.59	-11.55	16.86	-14.43
Electricity Transmission and Distribution	-1.99	0.02	-0.12	-0.04	0.03
Clean Water	3.77	-2.03	-1.13	1.19	2.55
Wood and the Products	4.49	-5.88	-4.29	3.77	15.64

7.4.3.3. Impacts on Employed Factors and Factor-Fuels

Table 7.15 presents the changes in production factors (volume) as well as volumes and prices of the capital-energy composite and the value added-energy composite. As previously discussed, the size of the output changes across industries are related to their nested production structure. From Table 7.15 it can be seen that imposing a carbon tax on fossil fuel products without revenue-recycling (simulation 3) results in large structural changes for some industries. Based on the model, at the fourth stage, the labour composite is combined with the capital-energy composite to obtain the value added-energy composite. The results reveal that for all energy sectors – i.e. coal mining, natural gas mining, oil mining, and conventional generation inputs shift from the capital-energy aggregate to labour. The conventional generation sector indicates the largest shift, where its quantity of capital-energy composite declines by 133.27% and price of capital-energy composite increases by 49.07% while the number of employments sharply increase reaching 1,536.46%. In contrast, most energy-intensive sectors indicate a contraction in employment but an increase in the capital-energy composite.

Orlov (2012) argued that the magnitude of reduction of capital-energy composite depends on the ratio of capital cost relative to energy input costs. When energy costs are higher than the capital costs, the capital-energy aggregate declines more. For example, the largest decline in capital-energy composite is obtained in conventional generation plants, since this industry heavily relies on fossil-fuels combustion; on the contrary, there is only a slight decrease of capital-energy composite in the oil sector since they depend more on capital (machineries) to exploit the crude oil resources beneath the soil.

In the next stage of the production structure (the fourth stage), the capital-energy composite is combined with the labour composite using a Cobb-Douglas function to obtain the value added-energy composite. Table 7.15 shows that the pattern of changes of value added-energy composite varies across industries. The contraction of value added-energy composite is more pronounced in energy and energy-intensive sectors than in non-energy industries. For example, the conventional generation sector has the largest reduction (-23.67%), while the forestry sector has the largest increase (60.14%).

Table 7.15: Simulation 3: Impact on Employed Factors and Factor-Fuels (% Change)

Industry	cost ratio of capital/labor	Capital	Labor	Capital-Energy Composite		Value Added-Energy Composite	
				Volume	Price	Volume	Price
Energy and Energy-Intensive Industry							
Coal Mining	3.72	-9.00	42.87	-9.00	0.51	0.01	-8.36
Natural Gas Mining	12.77	-2.97	53.67	-2.97	2.06	0.07	-1.00
Oil Mining	8.81	-0.74	5.86	-0.74	1.12	0.00	0.37
Conventional Power Plant (Aggregated Fossil Fuels Generation)	51.73	34.53	1536.46	-133.27	49.07	-23.67	65.49
Refineries	4.55	-2.36	32.68	-2.60	1.19	2.88	-4.44
Chemical	1.03	-0.63	-29.84	29.59	-29.57	10.99	-12.92
Metal Ores Mining	5.41	-0.29	-36.67	-0.19	-0.58	8.87	-14.66
Land Transportation	0.21	-0.73	71.63	-20.90	20.08	2.10	-3.26
Construction	1.13	0.76	-7.18	4.53	-4.11	-0.13	0.55
Paper, Printing, Transport Equipment, and Products from Metal	1.41	-0.43	-7.35	7.03	-7.72	1.53	-2.44
Trade	0.13	2.23	-6.88	32.47	-30.80	1.23	0.66
Spinning, Textile, Garment, and Leather Industries	1.37	-1.18	-38.87	0.04	-1.38	-15.87	15.60
Non-Energy Intensive Industry							
Agriculture Food Crops	0.06	0.12	-2.50	0.20	-1.13	-2.36	1.45
Air, Sea, and Communication Transportation	1.72	-0.32	-34.04	-2.92	2.26	-12.81	12.85
Bank and Assurance	2.29	-0.68	110.33	-0.74	-0.27	31.25	-31.60
Cattle and the Products	0.42	-0.45	-5.67	-0.47	-0.47	-4.17	3.26
City Gas	3.19	-8.84	71.59	-12.21	4.04	-2.23	-6.05
Real Estate, and Private Services	3.35	0.37	-5.81	0.38	-0.52	-1.04	0.90
Fishery	1.71	-0.31	-11.85	-0.59	-0.13	-2.24	1.55
Food, Drink, and Tobacco	1.38	-0.14	-6.41	0.49	-0.95	-2.21	1.77

Table 7.15 (continued)

Industry	cost ratio of capital/labor	Capital	Labor	Capital-Energy Composite		Value Added-Energy Composite	
				Volume	Price	Volume	Price
Forestry and Hunting	1.62	-18.01	257.37	-18.60	0.18	60.14	-60.61
Geothermal Mining	12.03	-2.27	35.48	-2.26	1.85	0.01	-0.52
Government and Defence, Education, Health, Film, and Other Social Services	0.16	0.65	2.67	1.35	-1.00	2.47	-2.22
Hotel	1.53	-76.49	-280.29	-76.61	-0.14	-100.02	19.89
Hydro Generation	32.71	20.70	-100.00				
Individual Services, Households, and Other Service	0.65	1.73	7.42	1.82	-0.29	5.04	-3.60
Agriculture for Other Crops	0.21	-1.23	4.28	-2.91	1.76	3.24	-4.88
Other Mining and Excavations	0.35	5.12	-3.51	6.84	-1.87	-0.48	5.00
Geothermal Generation	24.10	189.07	487.04				
Restaurant	0.11	0.15	-1.04	1.39	-1.58	-0.81	-0.11
Supporting Services for Transportation and Warehouse	0.30	19.87	-49.78	25.54	-5.90	-29.19	56.07
Train Transportation	0.28	-3.58	151.11	-32.86	28.17	16.86	-18.78
Electricity Transmission and Distribution	2.84	-0.36	12.11	-0.87	0.37		
Clean Water	0.19	4.17	-0.66	6.36	-3.68	1.21	1.55
Wood and the Products	1.01	-0.14	6.89	0.41	-0.88	3.80	-4.86

7.4.3.4. Impacts on Commodities

Based on the SAM dataset, the commodities are separated into three groups: energy commodities, energy-intensive commodities, and non-energy commodities. Table 7.16 summarizes the impact of simulation 3 on commodity prices and volumes.

On the supply side, the producer prices of energy and energy-intensive commodities decline by more than in simulation 1 and simulation 2. These declines are induced by a sharp decrease in their final domestic consumption. On the other hand, the producer price of a non-energy commodity tends to increase because of the increase in their domestic consumption. By looking at these results, it can be concluded that the introduction of carbon tax without revenue recycling can initiate a large shift of domestic consumption patterns from energy commodities towards non-energy commodities.

On the demand side, since the carbon tax is imposed on consumer prices of fossil fuels according to their level of emissions, it immediately increases the consumer prices of fuel products, namely coal (288.03%), natural gas (79.59%), crude oil (113.02%), bioethanol (125.43%), biodiesel (7.41%), kerosene (154.12%), LNG (127.63%), non-subsidized gasoline (438.82%), non-subsidized LPG (168.10%), subsidized biogas (140.16%), subsidized diesel (148.44%), subsidized gasoline (141.79%), and subsidized LPG (65.83%). However, for energy-intensive commodities, most consumer prices fall because consumers switch from fuels with a higher carbon content (higher emission factor) to less polluting (lower emission factor). For non-energy commodities, some consumer prices rise and some drop.

In terms of trade, since Indonesia is a small and open economy that does not influence the world price of trade, the changes of domestic prices of exports (P_i^E) and imports (P_i^M) are fully determined by the endogenous exchange rate. The results found that simulation 3 leads to an appreciation of the domestic currency. Thus, as shown in Table 7.16, the domestic price of exported and imported goods and services falls in line with the appreciated exchange rate (-2.01%). In terms of trade volumes, the impacts of simulation 3 vary substantially across commodities. In sum, the implementation of a carbon tax without compensation returned to the economy would lead to uncertainty in trade volume patterns, although the energy consumption clearly falls.

Table 7.16: Simulation 3: Impact on Commodity Prices and Volumes (% Change)

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Energy and Energy-Intensive Sector								
Coal Mining	-1.89	288.03	-2.01	0.02	1.81	-2.28	-4.77	-2.96
Natural Gas Mining	-2.63	79.59	-2.01	0.07	3.66	-0.17	-1.74	-1.71
Oil Mining	-1.24	113.02	-2.01	0.09	0.57	0.38	2.20	-0.12
Bioethanol	-2.48	125.43	-2.01	-121.97	n.a	-122.69	257.56	-1.83
Biodiesel	-2.32	7.41	-2.01	2.89	5.15	1.47	-14.70	-1.84
Kerosene	0.00	154.12	-2.01	0.00	n.a	-100.00	0.47	-1.67
LNG	-1.27	127.63	-2.01	2.88	3.50	-100.00	-75.59	-441.35
Non-Subsidized Gasoline	-3.74	438.82	-2.01	2.55	n.a	2.54	-0.77	-1.16
Non-Subsidized LPG	-11.56	168.10	-2.01	10.18	n.a	10.16	-8.54	-1.79
Other Oil Products	5.32	69.59	-2.01	-17.56	-28.73	-12.52	-7.25	-0.87
Subsidized Biodiesel	-17.85	125.85	-2.01	23.41	n.a	23.26	-4.85	-0.81
Subsidized Biogas	14.91	140.16	-2.01	-20.51	n.a	-20.73	5.20	-0.79
Subsidized Diesel	-4.29	148.44	-2.01	3.12	n.a	3.12	-1.30	-1.17
Subsidized Gasoline	-4.80	141.79	-2.01	3.46	n.a	3.46	-0.62	-0.99
Subsidized LPG	-5.76	65.83	-2.01	4.92	n.a	4.92	-2.47	-0.75
Electricity	-0.13	-0.13	-2.01	-0.03	n.a	-0.02	n.a	-0.03
Chemical	-7.83	-7.21	-2.01	11.02	22.86	8.36	-6.15	4.55
Metal Ores Mining	-11.74	-10.06	-2.01	8.87	11.40	10.26	-39.53	4.70
Land Transportation	-1.98	-1.99	-2.01	2.10	3.74	2.07	2.06	2.08
Construction	-1.52	-1.52	-2.01	-0.11	n.a	-0.12	n.a	-0.11
Trade	-0.07	-0.07	-2.01	1.23	n.a	1.23	n.a	1.23
Supporting Services for Transportation and Warehouse	34.83	29.99	-2.01	-29.35	-93.88	-21.92	60.85	-5.31

Table 7.16 (continued)

Commodity	Producer Price	Consumer Price	Export and Import Price	Domestic Production	Export	Domestic Demand	Import	Domestic Consumption
Spinning, Textile, Garment, and Leather Industries	7.45	10.62	-2.01	-15.88	-30.60	-7.75	20.06	-5.24
Non-Energy Intensive Sector								
Agriculture Food Crops	0.43	0.26	-2.01	-2.36	-5.18	-2.35	2.51	-2.02
Air, Sea, and Communication Transportation	10.59	9.81	-2.01	-12.79	-33.33	-8.92	20.73	-3.50
Bank and Assurance	-23.03	-11.10	-2.01	31.28	77.71	30.62	-100.00	5.81
Cattle and the Products	1.55	1.50	-2.01	-4.15	-9.36	-4.14	2.91	-4.03
City Gas	-5.19	-6.78	-2.01	-1.76	n.a	-1.74	n.a	-0.07
Real Estate, and Private Services	0.28	0.00	-2.01	-1.03	-3.63	-0.86	3.89	-0.14
Fishery	0.95	0.98	-2.01	-2.25	-5.05	-2.19	0.35	-2.19
Food, Drink, and Tobacco	0.17	0.58	-2.01	-2.21	-4.47	-1.62	-0.96	-1.84
Forestry and Hunting	-40.83	-13.76	-2.01	60.19	98.72	59.59	-100.00	-28.97
Geothermal Mining	-1.60	-1.63	-2.01	-1.84	n.a	-1.88	n.a	-1.87
Government and Defense, Education, Health, Film, and Other Social Services	-1.79	-1.81	-2.01	2.47	3.75	2.44	2.95	2.46
Hotel	12.22	16.64	-2.01	-100.04	-130.86	-50.43	25.14	-12.57
Individual Services, Households, and Other Service	-3.20	0.94	-2.01	5.04	9.60	0.70	6.77	0.92
Agriculture for Other Crops	-4.56	-4.73	-2.01	3.20	9.91	2.49	-3.55	2.12
Other Mining and Excavations	3.38	3.10	-2.01	-0.06	-17.81	0.12	11.24	0.84
Paper, Printing, Transport Equipment, and Products from Metal	-2.17	-2.26	-2.01	1.53	3.76	1.12	0.36	0.90
Restaurant	0.48	0.48	-2.01	-0.87	-4.30	-0.68	4.49	-0.49
Train Transportation	-11.57	-13.71	-2.01	15.24	37.22	9.47	-17.78	8.10
Clean Water	-1.13	-1.13	-2.01	1.20	n.a	1.21	n.a	1.20
Wood and the Products	-4.29	-4.75	-2.01	3.80	6.80	3.41	-3.21	3.30

7.4.3.5. Impacts on Income Distribution and Welfare

In rural areas, the welfare of lower-income groups – i.e. rural households with unclear occupations and rural households who employed as agricultural labours with low income – declines by -0.438% and -0.364%, respectively; whilst the welfare on higher income groups – i.e. rural households who employed in non-agricultural with high income and rural households who employed as agricultural employer – declines only by -0.162% and -0.148%, respectively. Similarly, in urban areas, the welfare of lower-income groups – i.e. urban households with unclear occupations and urban households with low income – declines by -0.183 and -0.159; whilst the welfare on richest urban households (urban households with high income) shows a strong improvement by 9.490%.

We argue that although the households' spending on energy goods strongly increased as income rises, the changes in the distributional income are also determined by factor returns and the pattern of household spending on non-energy goods. As previously discussed, the introduction of carbon tax on energy fossil commodities without revenue-recycling initiates a large shifting of domestic consumption pattern from energy commodity towards non-energy commodity types. In turn, it increases the prices of non-energy commodities which negatively affects the poorer household consumption more than the richest.

Regarding income distribution, the result shows that inequality (measured by the Theil-L index) increases from 0.136 to 0.140. We argue that this increase in inequality is due to the regressive nature of simulation 3 where the welfare loss by poorer households increases the inequality gap among households.

In sum, the implementation of a carbon tax without compensation tends to be regressive – the welfare losses on lower income households are more deteriorating than higher income households in both rural and urban areas. In other words, the poorer groups carry a greater burden of the carbon tax.

Table 7.17: Simulation 3: Impact on Income Distribution and Welfare

Household's Group	Initial Total Budget	Budget on Energy Consumption	WELFARE		Inequality	
			VALUE	%CHANGE	BASE	SHOCKED
	Billion Rp					
Rural households' - unclear occupations	158015.28	3528.11	-22451.694	-0.438		
Rural households' - agricultural labors with low income	162021.42	1662.63	-18650.571	-0.364		
Rural households' – non-agricultural labors with low income	385336.98	7871.47	-6571.953	-0.128		
Rural households' – non-agricultural with high income	450508.35	6962.91	-8320.558	-0.162		
Rural Households' - Agricultural Employers	642327.17	8864.30	-7601.123	-0.148		
Urban households' - unclear occupations	213768.06	4859.06	-9394.397	-0.183		
Urban households' - low income	633498.92	7775.67	-8171.281	-0.159		
Urban households' - high income	672628.57	11447.65	486269.25	9.490		
Total				12.20	0.136	0.140

7.4.3.6. Sensitivity Analysis

As previously mentioned, since the parameters used in the model are ‘borrowed’ from literature, thus, it is necessary to check the robustness of the simulation results with respect to parameters uncertainty (Yusuf, 2008). This is done by implementing a sensitivity analysis of trade parameters and examining the changes of endogenous variables. We choose to vary the import elasticity (CES trade parameters) by a 25% decrease and increase (between 1.5 and 2.5) and then check the reliability of results. Table 7.18 presents the sensitivity analysis results of simulation 3 on macroeconomic accounts.

Similar to simulation 1 and simulation 2, the sensitivity analysis of simulation 3 shows that the changes of trade elasticity of substitution would affect the results of macroeconomic accounts due to a change in trade accounts (export and import as well as the net export). The higher elasticity of trade lowers exports and imports but improves the net exports (export reduction is less pronounced than import). As shown in Table 7.18, by increasing the trade elasticity from 1.5 to 2.5, exports strongly decrease from -0.52% to -7.18% and imports from 1.53% to -12.23%. These changes influence the size of changes of composite commodities demand, which in turn, will affect the total factor costs – as trade elasticity increases, total wage bills fall but total capital bills improve.

Table 7.18: Sensitivity Analysis of Simulation 3 on National Income Accounts (% Change)

Variables	Trade Elasticities = 1.5	Trade Elasticities = 2.0	Trade Elasticities = 2.5
	%CHANGE		
GDP at factor costs	-1.21	-0.31	-0.21
GDP at market prices from income side	-0.02	-0.83	-2.62
GDP at market prices from expenditure side	-0.03	-0.87	1.27
Total private consumption	0.88	1.08	-7.30
Total investment	-4.60	-3.81	-3.88
Total real government consumption	1.55	2.69	9.85
Total export	-0.52	-4.14	-7.18
Total import	1.53	-4.68	-12.23
Net export	-20.89	1.19	43.17
Net indirect tax (total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	58.13	-28.54	74.53
Total payment to all workers (WAGEBILL)	0.25	-0.29	-2.86
Total payment to capital (CAPBILL)	-2.82	-0.33	2.69

7.4.4. Introducing the FIT scheme Under Different Financing Options

In this section, we examine the implications of introducing the Feed-in Tariff (FIT) scheme (or subsidy to renewable production) under two different financing scenarios:

i. Simulation 4: The FIT is financed by electricity consumers through the endogenous electricity tax rate ($vatrate(electc)$); and

ii. Simulation 5: The FIT is financed through the carbon tax adjustment.

As previously explained, the FIT scheme guarantees a fixed price for purchases of renewable generation from the producer within a long-term contract (Mendoca *et al.*, 2010; Bohringer *et al.*, 2012). The price cap is usually set higher than either the average unit cost rate of electricity supplied into the grid connectors or the average unit cost of the most expensive fuel generators, i.e. natural gas-fired generators (Mendoca, *et al.*, 2010; and Bohringer *et al.*, 2012).

According to the current FIT schemes in the Minister of Energy and Mineral Resources Regulation No. 04/2012, the price of each type of renewable sources is fixed Rp. 656/kWh – Rp. 1,722.5/kWh depending on the types of renewables, level of generated voltage, and geographic location. Since the CGE model we used a single country model, following Bohringer *et al.* (2012), we use the mid-point between these price caps (Rp. 1,189.25/kWh).

According to PLN (2011b), the average unit cost of electricity generation was year 2011 is Rp. 1,051.14/kWh. The FITs therefore translate into approximately a 15% subsidy rate for purchasing renewable generation technologies.

7.4.4.1. Impacts on Macroeconomic and CO_2 Emission Account

Table 7.19 presents the macroeconomic impacts of the two FIT scenarios: (1) implementing the FIT financed by an increase in electricity tax rates; and (2) implementing the FIT financed by an increase in carbon tax. Overall, the results show that the effects of both FIT scenarios on macroeconomic accounts are negligible. The GDP at factor costs remains unchanged, while, the GDP at market prices (income side and expenditure side) indicate a slight decline by -0.003% due to a contraction in the net indirect tax – by the introduction of subsidy on renewable sources.

We suspect that these negligible impacts are due to the low shares of renewables (geothermal and hydro) generation load in total electricity mix. Based on the SAM dataset in year 2008, the initial share is only about 5% for geothermal and 11% for hydro. In other words, the Indonesian electricity supply is still dominated by fossil fuels (conventional) based generation, which account for about 85% of the electricity mix. Therefore, the implementation of the current FIT regulation – about subsidies of 15% on hydro and geothermal production – would not necessarily affect the national income account.

Compared to simulation 4, financing FIT through carbon taxation (simulation 5) leads to a larger contraction in GDP at market prices. This is because the differentiated carbon tax on polluted fuels immediately increases their commodity prices as well as the energy-associated products, which leads to a downward shift in their output, private consumption, and investment. In turn, the total government receipts from output taxes declines more than in simulation 4. Net indirect tax drops by -1.118%. As a result, GDP at market prices declines more by -0.022%. On the other hand, under simulation 4, the increase in electricity tax rates only leads to a higher price of electricity commodity, which results in a less contraction to the national output and net indirect tax.

In terms of carbon emissions, the FIT schemes do not effectively reduce the national emissions. As shown in table 7.19, the percentage decline of total CO_2 emissions is only tiny, from -0.001% to -0.004%. Therefore, it can be concluded that the proposed FIT schemes are insufficient to achieve the ambitious target of lowering the national emissions from energy utilization by about 1%.

Table 7.19: FIT Impacts on National Income account (% Change)

Variables	Simulation 4	Simulation 5
GDP at factor costs	0.000	0.000
GDP at market prices from income side	-0.003	-0.022
GDP at market prices from expenditure side	-0.003	-0.022
Total private consumption	0.000	-0.001
Total investment	0.000	-0.001
Total real government consumption	0.002	0.000
Total export	-0.001	0.000
Total import	-0.001	0.000
Net export	0.000	0.002
Net indirect tax (the total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	-0.162	-1.118
Total payment to all workers (WAGEBILL)	0.000	0.000
Total payment to capital (CAPBILL)	0.000	0.000
Emissions		
CO_2 emissions from Households	-0.003	-0.005
CO_2 emissions from Industries	-0.005	0.000
CO_2 emissions from Government		
TOTAL CO_2	-0.004	-0.001

7.4.4.2. Impacts on the Generation Technology

Table 7.20 presents the effects of the two FIT schemes on the electricity production from fossil fuels (conventional) and renewable sources (hydro and geothermal). Overall, the results suggest that the magnitude change of each electricity generation is very small. Nonetheless, compared to simulation 4, the generation technological changes resulted from simulation 5 are slightly more pronounced: conventional output slightly reduces by -0.007%, while hydro output slightly increases by 0.004%. This is because the FIT's financing option through carbon taxation would increase the prices of fossil fuels, which in turn, leads to more decline in conventional output load (or an increase price in conventional output load price). As a result, the output load of renewable generation technologies (hydro and geothermal) tends to slightly increase (or slightly decline in renewable output price) more than simulation 5. It can be concluded that the FIT scenarios do not achieve the main goal of promoting clean energy production.

Table 7.20: FIT Impacts on National Income account (% Change)

Generation Technology	Output Load		Output Price	
	Simulation 4	Simulation 5	Simulation 4	Simulation 5
Conventional (fossil fuels composite)	-0.000	-0.007	-0.321	1.173
Hydro	0.000	0.004	-0.321	-0.934
Geothermal	0.000	0.000	-0.321	-3.306

7.4.4.3. Impacts on Output and Energy Composite

Table 7.21 summarises the impacts of the two FIT schemes on output and on the energy composite. The results found that not all scenarios affect the sectoral outputs. This is due to the small shares of renewables generation (hydro and geothermal) in total electricity supply; thus, the implementation of a 15% subsidy to these renewable productions would have negligible impacts on sectoral output. However, in terms of the energy composite input used by industries, the FIT scenarios differ considerably. Compared to simulation 4, the FIT's financing scheme through carbon taxation on fossil fuels leads to a larger contraction in energy composite demand, particularly among energy-intensive sectors such as metal mining, land transportation, construction, paper products, trade, and textiles. This is because carbon taxation raises the price of carbon-based fuels.

Table 7.21: FIT Impacts on Output and Energy Composite (% Change)

Industry	Energy Composite				Output			
	Volumes		Prices		Volumes		Prices	
	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5
Energy and Energy-Intensive Industry								
Coal Mining	0.001	0.008	-0.002	0.001	0.000	0.000	-0.001	0.000
Natural Gas Mining	-0.009	-0.021	0.010	0.000	0.000	0.000	0.060	-0.002
Oil Mining	0.014	0.000	0.000	0.001	0.000	0.000	-0.001	0.000
Refineries	-0.018	0.000	0.054	-0.001	-0.012	0.001	0.003	-0.001
Chemical	0.012	0.025	-0.019	-0.024	0.001	0.010	0.000	-0.006
Metal Ores Mining	-1.960	-74.889	2.004	10.556	-0.035	0.019	0.033	-0.016
Land Transportation	-0.002	-1.625	0.000	1.612	0.000	0.008	0.000	-0.004
Construction	0.000	-1.830	0.000	1.694	0.000	0.000	0.000	-0.001
Paper, Printing, Transport Equipment, and Products from Metal	0.066	-0.148	-0.073	0.150	0.000	0.000	0.000	-0.001
Trade	0.037	-0.022	-0.042	0.021	0.000	0.002	0.000	0.000
Spinning, Textile, Garment, and Leather Industries	0.199	-0.017	-0.197	0.017	0.021	-0.006	-0.007	0.003

Table 7.21 (continued)

Industry	Energy Composite				Output			
	Volumes		Prices		Volumes		Prices	
	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5
Non-Energy Intensive Industry								
Agriculture Food Crops	28.969	68.509	-22.395	-65.604	0.000	0.004	-0.003	-0.003
Air, Sea, and Communication Transportation	0.051	-0.402	-0.051	0.402	0.010	-0.050	-0.007	0.038
Bank and Assurance	0.210	10.461	-0.208	-11.224	0.000	0.012	0.001	-0.007
Cattle and the Products	-4.516	3.620	4.761	-3.606	-0.015	0.001	0.019	-0.001
City Gas	-0.646	-0.001	1.410	0.000	0.013	0.000	0.560	0.000
Real Estate, and Private Services	0.111	-1.584	-0.111	-5.809	0.000	0.000	0.001	0.001
Fishery	0.773	-11.527	-0.797	12.586	0.026	0.001	-0.037	0.000
Food, Drink, and Tobacco	-0.090	-8.491	0.092	8.859	-0.002	0.003	0.000	-0.002
Forestry and Hunting	-0.048	50.752	0.051	-37.531	0.000	0.001	0.003	-0.001
Government and Defense, Education, Health, Film, and Other Social Services	-0.045	-5.237	0.046	5.287	-0.001	0.003	0.001	-0.002
Hotel	0.638	-0.808	-0.634	-31.808	0.006	0.004	-0.001	-0.004
Individual Services, Households, and Other Service	-0.395	0.196	0.406	-0.196	-0.004	0.003	0.007	-0.002
Agriculture for Other Crops	-0.280	1.321	0.290	-1.358	-0.004	0.004	0.009	0.000
Other Mining and Excavations	0.027	0.391	-0.028	-0.415	0.000	0.001	-0.001	0.000
Restaurant	-3.841	0.483	4.012	-0.519	-0.015	0.000	0.016	-0.001
Supporting Services for Transportation and Warehouse	0.342	1.138	-0.348	-1.151	0.013	-0.035	-0.012	0.026
Train Transportation	0.416	-8.620	-0.470	-3.437	0.229	-0.006	-0.171	0.004
Electricity Transmission and Distribution	0.000	-0.274	0.000	0.338	0.000	0.000	0.009	0.048
Clean Water	-0.520	0.520	0.618	-0.515	-0.044	0.047	0.087	-0.024
Wood and the Products	0.036	-0.444	-0.037	0.446	0.001	0.001	-0.001	0.000

7.4.4.4. Impacts on Commodities

Table 7.21 summarises the impacts of the two FIT schemes on commodity types (volumes and prices). The results reveal that the implications of the two scenarios (simulation 4 and simulation 5) on domestic commodities tend to be very small (and even negligible for some commodity types). Nevertheless, compared to simulation 4, the financing scenario through carbon taxation leads to a higher contraction in the domestic consumption of energy products due to their lower domestic demand. For example, in simulation 5, domestic consumption falls for bioethanol (-0.018%), biodiesel (-0.018%), non-subsidised gasoline (-0.007%), subsidised biodiesel (-0.005%), subsidised biogas (-0.004%), subsidised diesel (-0.007%), and other oil products (-0.012%). On the other hand, in simulation 4, the changes of domestic consumption for these energy products are negligibly small (less than 0.000%).

The reason for these negligible patterns is because in simulation 4 the subsidy on renewables is financed by the electricity consumers through an increased price of electricity. Hence, from Table 7.21, it can be seen that the consumer price of electricity commodity slightly increases (by only 0.010%) due to the low subsidy rates for renewable generations (hydro and geothermal plant). As a result, the effects of simulation 4 on energy domestic commodities are smaller than of simulation 5.

Table 7.22: FIT Impacts on Commodities (% Change)

Commodity	Producer Price		Consumer Price		Domestic Production		Domestic Demand		Domestic Consumption	
	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5
Energy and Energy-Intensive Sector										
Coal	-0.001	0.000	-0.002	0.000	0.000	0.000	0.001	-0.004	0.002	-0.006
Natural Gas	0.060	-0.002	0.064	-0.002	0.000	0.000	0.000	0.010	0.000	0.011
Crude Oil	-0.001	0.000	-0.001	0.000	0.000	0.000	-0.001	-0.002	-0.001	-0.004
Bioethanol	-0.008	-0.001	-0.005	-0.003	-0.004	-0.012	-0.004	-0.012	0.000	-0.018
Biodiesel	-0.002	0.001	-0.004	0.003	0.001	-0.012	0.004	-0.017	0.000	-0.018
Kerosene	0.000	0.000	-0.003	0.002	-0.086	1.459	-0.086	1.459	-0.007	0.000
LNG	0.000	0.000	0.000	0.144	0.001	-0.012	-0.329	0.033	-0.059	-0.013
Non-Subsidized Gasoline	0.005	-0.001	0.003	-0.001	0.001	-0.012	0.001	-0.012	0.000	-0.007
Non-Subsidized LPG	0.009	-0.005	0.006	-0.003	0.001	-0.012	0.001	-0.012	-0.002	-0.006
Other Oil Products	0.000	0.000	0.000	0.000	0.001	-0.012	0.000	-0.012	0.000	-0.012
Subsidized Biodiesel	0.004	-0.001	0.001	0.000	0.001	-0.012	0.001	-0.012	0.000	-0.005
Subsidized Biogas	0.006	0.000	0.002	0.000	0.000	-0.012	-0.001	-0.012	0.000	-0.004
Subsidized Diesel	0.005	-0.001	0.003	-0.001	0.001	-0.012	0.001	-0.012	0.000	-0.007
Subsidized Gasoline	0.007	-0.002	0.003	-0.001	0.001	-0.012	0.001	-0.012	-0.001	-0.004
Subsidized LPG	0.008	-0.005	0.004	-0.003	0.001	-0.012	0.001	-0.012	-0.004	-0.005
Electricity	-0.166	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chemical	0.000	-0.006	0.000	-0.006	0.010	0.001	0.007	0.000	0.003	0.000
Metal Ores Mining	0.033	-0.016	0.039	-0.019	0.019	-0.035	0.010	-0.015	0.006	-0.007
Land Transportation	0.000	-0.004	0.000	-0.004	0.008	0.000	0.008	0.000	0.007	0.000
Construction	0.000	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000
Trade	0.000	0.000	0.000	0.000	0.002	0.000	0.002	0.000	0.002	0.000
Supporting Services for Transportation and Warehouse	-0.012	0.026	-0.011	0.023	-0.035	0.013	-0.029	0.010	-0.017	0.005
Spinning, Textile, Garment, and Leather Industries	-0.007	0.003	-0.010	0.004	-0.006	0.021	-0.003	0.014	-0.002	0.012

Table 7.22 (continued)

Commodity	Producer Price		Consumer Price		Domestic Production		Domestic Demand		Domestic Consumption	
	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5	Sim 4	Sim 5
Non-Energy Intensive Sector										
Agriculture Food Crops	-0.003	-0.003	-0.003	-0.003	0.000	0.004	0.000	0.004	0.000	0.003
Air, Sea, and Communication Transportation	-0.007	0.038	-0.007	0.036	0.010	-0.050	0.007	-0.036	0.004	-0.019
Bank and Assurance	0.001	-0.007	0.001	-0.007	0.000	0.012	0.000	0.011	0.000	0.011
Cattle and the Products	0.019	-0.001	0.019	-0.001	-0.015	0.001	-0.015	0.001	-0.015	0.001
City Gas	0.560	0.000	0.560	0.000	0.013	0.000	0.013	0.000	0.013	0.000
Real Estate, and Private Services	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fishery	-0.037	0.000	-0.037	0.000	0.026	0.001	0.025	0.001	0.025	0.001
Food, Drink, and Tobacco	0.000	-0.002	0.000	-0.002	-0.002	0.003	-0.002	0.002	-0.002	0.002
Forestry and Hunting	0.003	-0.001	0.003	0.000	0.000	0.001	0.000	0.001	0.000	0.000
Geothermal Mining	3.237	-0.023	3.237	-0.023	0.000	0.000	0.000	0.000	0.000	0.000
Government and Defense, Education, Health, Film, and Other Social Services	0.001	-0.002	0.001	-0.002	-0.001	0.003	-0.001	0.003	-0.001	0.003
Hotel	-0.001	-0.004	-0.001	-0.005	0.006	0.004	0.003	-0.007	0.001	-0.016
Individual Services, Households, and Other Service	0.007	-0.002	0.007	-0.002	-0.004	0.003	-0.004	0.003	-0.003	0.003
Agriculture for Other Crops	0.009	0.000	0.009	0.000	-0.004	0.004	-0.002	0.004	0.000	0.004
Other Mining and Excavations	-0.001	0.000	-0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.001
Paper, Printing, Transport Equipment, and Products from Metal	0.000	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	-0.001
Restaurant	0.016	-0.001	0.016	-0.001	-0.015	0.000	-0.014	0.000	-0.013	0.000
Train Transportation	-0.171	0.004	-0.206	0.005	0.229	-0.006	0.137	-0.004	0.115	-0.003
Clean Water	0.087	-0.024	0.087	0.023	-0.044	0.047	-0.044	0.047	-0.044	0.001
Wood and the Products	-0.001	0.000	-0.001	0.000	0.001	0.001	0.000	0.002	0.000	0.002

7.4.4.5. Impacts on Income Distribution and Welfare

Table 7.23 shows that none of the FIT schemes (simulation 4 and simulation 5) affects the households' welfare in rural and urban areas.

Compared to simulation 4, financing the FIT's support by carbon taxation would slightly change the households' welfare. The impacts tend to be slightly progressive in rural and urban areas – i.e. rural households who work as agricultural employers (-001%); rural households who worked in non-agricultural fields with high income (-0.001%); urban households with low income (-0.002%). This is because the richer households spend a larger share of their budget on fuels than poorer households; thus, the higher income households would pay a higher share of their budget on carbon tax. On the other hand, in simulation 4, household welfare remains unchanged for all income groups (changes of less than 0.0005%). Regarding income distribution – measured as Theil-L index – the results show that in all scenarios, the inequality remains unchanged by 0.136 due to the negligible changes in household welfare.

Table 7.23: FIT Impacts on Income Distribution and Welfare

Households' Group	Initial Total Budget	Budget Shares on Energy Consumption	Welfare				Inequality		
			VALUE		%CHANGE		BASE	SHOCKED	
			Sim 4	Sim 5	Sim 4	Sim 5		Sim 4	Sim 5
	Billion Rp								
Rural households' - unclear occupations	158015.28	3528.11	-0.067	-18.757	0.000	0.000			
Rural households' - agricultural labors with low income	162021.42	1662.63	1.080	-21.543	0.000	0.000			
Rural households' – non-agricultural labors with low income	385336.98	7871.47	-0.396	-40.086	0.000	-0.001			
Rural households' – non-agricultural with high income	450508.35	6962.91	2.507	-63.037	0.000	-0.001			
Rural Households' - Agricultural Employers	642327.17	8864.3	3.615	-31.302	0.000	-0.001			
Urban households' - unclear occupations	213768.06	4859.06	-0.048	333.309	0.000	0.006			
Urban households' - low income	633498.92	7775.67	-2.354	-127.207	0.000	-0.002			
Urban households' - high income	672628.57	11447.65	7.449	-11.733	0.000	0.000			
Total	3318104.75	52983.586			0.000	0.001	0.136	0.136	0.136

7.4.4.6. Sensitivity Analysis

Since the parameters used in this model are obtained from other literature, it is necessary to check the robustness of the simulation results with respect to parameter uncertainty. We implement a sensitivity analysis of trade parameters and examine the changes in macroeconomic variables. We vary the import elasticity (CES trade parameters) by a 25% decrease and increase (between 1.5 and 2.5) and then check the reliability of results. Table 7.24 shows the sensitivity analysis of the two FIT scenarios (simulation 4 and simulation 5) on macroeconomic accounts.

The results found that, under high and low elasticity, all FIT scenarios generate a consistent pattern across all macroeconomic variables, although several variables show small changes. The robustness of results within a CGE model framework is usually confirmed in two conditions: (i) a small variation in the results of post shock and (ii) consistent signs (increase or decrease). Therefore, based on sensitivity results given in Table 7.24, the results can be considered robust and consistent.

Table 7.24: Sensitivity Analysis of the FIT Schemes on National Income Accounts (% Change)

Variables	Simulation 4			Simulation 5		
	Trade elasticity = 1.5	Trade elasticity = 2	Trade elasticity = 2.5	Trade elasticity = 1.5	Trade elasticity = 2	Trade elasticity = 2.5
GDP at factor costs	0.000	0.000	0.000	0.000	0.000	0.000
GDP at market prices from income side	-0.004	-0.003	-0.002	-0.000	-0.022	-0.000
GDP at market prices from expenditure side	-0.004	-0.003	-0.002	-0.000	-0.022	-0.000
Total private consumption	0.000	0.000	0.000	-0.000	-0.001	-0.000
Total investment	0.000	0.000	0.000	-0.000	-0.001	-0.000
Total net government consumption	0.000	0.002	0.001	0.000	0.000	0.000
Total export	0.000	-0.001	-0.001	0.000	0.000	0.000
Total import	0.000	-0.001	-0.001	0.000	0.000	0.000
Net export	0.000	0.000	0.000	0.000	0.002	0.000
Net indirect tax (the total of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	-0.185	-0.162	-0.112	-0.016	-1.118	0.000
Total payment to all workers (WAGEBILL)	0.000	0.000	0.000	0.000	0.000	0.000
Total payment to capital (CAPBILL)	0.000	0.000	0.000	0.000	0.000	0.000

7.5. Conclusions

In this chapter, by employing the extended CGE-energy model developed in Chapter 6, we investigate the economy-wide impacts of introducing two specific environmental (energy) policies: (1) implementing carbon tax on fossil fuels; and (2) promoting the production of renewable electricity through the feed-in tariff (FIT) scheme. In the case of a carbon tax, we assume that the Indonesia's government levies a tax of Rp. 100,000/ton CO_2e with three possible revenue-recycling mechanisms. In the first simulation, we allow the revenue neutralizing scheme by which the revenue raised from a carbon tax is neutralized through a reduction in the income (labour) tax rate across activities. In the second simulation, we allow the government to adjust their spending on goods proportionally in response to the revenue raised from a carbon tax. The third simulation assumes endogenous government saving, without any revenue recycling, to allow a budget surplus. In latter case of a feed-in tariff scheme, we assume that the government sets a 15% subsidy rate to renewable generation (hydro and geothermal), with two possible financing schemes. In the fourth simulation, we assume that the FIT is distributed equally among the electricity consumers through a higher electricity tax rate. Finally, the fifth simulation assumes the FIT is financed by a carbon tax on fossil fuels.

Aside from their achievement in reducing the national greenhouse gas emissions, the results also reveal that all scenarios of carbon taxation would affect the economy's performance differently in their magnitude of changes. Imposing carbon tax on fossil fuels immediately increases their consumer prices. In turn, these changes make the economy (such as sectoral outputs, aggregate demand, as well as household welfare) contract. Nonetheless, these adverse effects can properly be addressed through the selected compensation (revenue-recycling) scenarios. Of all scenarios, compensating the carbon tax by a reduction in labour (income) tax is likely the most beneficial scheme, of which a double dividend is gained. The increased price of fuels is offset through household income improvement via labour income reduction. Hence, it would initiate a higher domestic demand due to improvement in their disposable income, which in turn, increases the aggregate output. The impacts on household welfare are negligible (neutral) in both rural and urban area; and inequality remains unchanged. In the scenario of revenue-recycling through higher public spending, the the model predicts that the GDP at factor costs slightly falls but the GDP at market prices improves. The downward effects of a carbon tax are offset by the expansion of public expenditure on commodities that shifts up aggregate demand. The impacts on household welfare tend to be progressive: the welfare losses for higher income groups, especially urban households, are larger than for lower income groups; thus, the inequality gap between households is slightly reduced. In contrast, the uncompensated scenario – where the additional revenue raised from a carbon tax is kept as government saving to run budget surplus – generates the most disadvantages on economy's performance. All GDPs contract, since the increased domestic price of energy products due to carbon tax is not compensated through a revenue-recycling scheme. In terms of sectoral outputs, the production costs are relatively more expensive than in the compensating scenarios, which results in a higher drop in aggregate demand. The impacts on household welfare tend to be regressive: the welfare losses for poor households are larger than for higher income households in rural and urban area.

Furthermore, in the FIT scenarios, the results found that their impacts on Indonesia's economy are negligible, i.e. all GDPs, sectoral outputs, and households' welfare remain unchanged. This is due to the fact that the initial renewable shares on total electricity production are small (about 5% from geothermal generation and 11% for hydro generation). In other words, the Indonesian electricity supply is still dominated by fossil fuels (conventional) based generation covering about 85% of the electricity mix. Therefore, the implementation of the current FIT regulation – about 15% subsidies to hydro and geothermal production – would not necessarily affect the national income account. Specifically, in the electricity sector, the FIT schemes are unable to improve the share of clean energy production in Indonesia’s electricity mix. However, by comparing the two financing methods, it is revealed that financing FITs through a carbon tax leads to a larger contraction in GDP at market prices. This is because the increased price of carbon-based fuels leads to a fall in output production, private consumption, and investment. In turn, the total government receipts from output taxes decline more. In terms of carbon accounting, the results reveal that the FIT schemes do not effectively reduce the national emissions. Compared to carbon taxes, the proposed FIT schemes are insufficient to achieve the ambitious target of lowering the national emissions from energy utilization by about 1%.

Chapter 8
General Conclusions

8.1. Introduction

This thesis has analyzed the implications of fiscal expansion (or contraction) as well as implementing the carbon tax and feed-in tariff on Indonesia's main macroeconomic indicators and their effects on different institutions and sectors in the economy, within the context of a static computable general equilibrium model.

In the first research, three scenarios were carried out in order to analyze the effects of expanding the exogenous public spending using a standard CGE model that is calibrated to the official Social Accounting Matrix (SAM) for Indonesia in the year 2008. These scenarios were related to the sources of financing to cover the additional public expenditure on goods and services: (1) to allow borrowing (budget deficit adjustment); (2) to allow a reduction of subsidies across activities; and (3) to allow an increase of output tax rates.

In the second research, five scenarios were conducted to investigate the effects of introducing the carbon tax and a feed-in tariff using a hybrid CGE model that is calibrated to the hypothetical Energy-SAM for Indonesia in the year 2008. The hybrid CGE model was the extended version of the standard CGE model in which we incorporated the energy factors combinations and electricity technological explicitness. The scenarios were principally related to the mechanism of compensating (recycling) the carbon tax revenue or financing the feed-in tariff incentives. To compensate the carbon tax, three scenarios were carried out: (1) a reduction of income (labor) tax rates; (2) an increase of public expenditures on commodities; (3) government saving adjustment to run a budget surplus. To finance the feed-in tariff incentives, two scenarios were carried out: (4) an increase of electricity tax rate; and (5) allowing the carbon tax to adjust.

The thesis was presented through eight chapters. The introductory chapter explained the research problems and specified the objectives of the study. Chapter 1 reviewed the overview of Indonesian economy. Chapter 2 presented the principles and schematic frameworks of the Social Accounting Matrix dataset including the preliminary modification of the official SAM for Indonesia in year 2008. Chapter 3 discussed the construction of the standard CGE model including the closure choices. Chapter 4 discussed the background and results of fiscal policy scenarios. Chapter 5 presented the background as well as the steps of constructing the Indonesian Energy-SAM. Chapter 6 explained the construction of the hybrid CGE model for specific energy analysis. Chapter 7 discussed the results of implementing the carbon tax (or feed-in tariff) scenarios. Finally, Chapter 8 presented the general conclusions of the thesis.

This chapter is organized as follows. Section 8.2 presents the summary of research results. Section 8.3 describes the limitations of the study. Finally, Section 8.4 discusses suggestions for further research.

8.2. Summary of research results

In the first research study, we employ the standard CGE model developed in Chapter 3 to examine the impact of implementing specific fiscal policies on Indonesia's main macroeconomic indicators and to their consequences by examining how different institutions and sectors in the economy are affected a result. The results show that an increase in public expenditure shifts up the equilibrium output. Simulation 1 generates the strongest impact due to the static nature of the model that does not consider the deficit payment in the future. The financing scheme of lowering subsidy rates to activities given in simulation 2 resulted in a smaller improvement of Indonesia's GDP. This is because a subsidy cut directly increases the cost of production which in turn reduces national income. We also found that fiscal expansion with higher output tax revenue under simulation 3 gives the largest contraction in national income; the sectors were pressurized by higher taxes which creates deindustrialization, low employment, and thus reduces equilibrium national income and output.

In the second research study, we employ the extended CGE energy model developed in Chapter 6 to investigate the economy-wide impacts of introducing two specific environmental (energy) policies: (1) implementing a carbon tax on fossil fuels; and (2) promoting the production of renewable electricity through the feed-in tariff (FIT) scheme. In the case of a carbon tax, we allow the government of Indonesia to collect a carbon tax of Rp. 100,000/ton CO_2e by three possible revenue-recycling mechanisms. In the first simulation, we allow the revenue neutralizing scheme by which the revenue raised from carbon tax is recycled through a reduction in income (labor) tax rate across activities. In the second simulation, we allow the government to adjust their spending on goods proportionally in response to the revenue raised from carbon tax. The third simulation assumes endogenous government saving, without any revenue recycling, to allow a budget surplus. While in case of feed-in tariff scheme, we assume that the government sets a 15% subsidy rate to renewable generation (hydro and geothermal) with two possible financing schemes. In the fourth scenario, we assume that the FIT is distributed equally among the electricity consumers through higher electricity tax rate. Finally, the fifth simulation assumes that the FIT is financed by a carbon tax on fossil fuels.

Aside from their achievement in reducing the national greenhouse gas emissions, the results reveal that all scenarios of carbon taxation would affect the economy's performance differently in their magnitude. Imposing a carbon tax on fossil fuels immediately increases their consumer prices. In turn, these changes would lead to economy's contraction such as sectoral outputs, aggregate demand, as well as households' welfare. Nonetheless, these adverse effects can properly be addressed through the selected compensation (revenue-recycling) scenarios. Compensating the carbon tax by a reduction in labor (income) tax would likely be the most benefited scheme, of which a double dividend is gained. The increased price of fuels is offset through household income improvement via labor income reduction. Hence, it would initiate a higher domestic demand due to improvement in their disposable income, which in turn, increases the aggregate outputs. The impacts on household welfare are negligible in both rural and urban areas; and inequality remains unchanged. In the scenario of revenue-recycling through public spending improvement, the results found that the GDP at factor costs slightly falls but the GDP at market prices improves. The downward effects of carbon tax are offset by the expansion of public expenditures on commodities that would shift up the aggregate demand. The impacts on households' welfare tend to be progressive because the welfare losses on higher income groups, especially urban households, are worse-off than those of lower income groups; thus, the inequality gap among households is slightly reduced. In contrast, the uncompensated scenario – where the additional revenue raised from carbon tax is kept as government saving to run budget surplus – generates the most disadvantages on economy's performance. All GDPs contract since the increased domestic price of energy products due to carbon tax are not compensated through a revenue-recycling scheme. In terms of sectoral outputs, the production costs are more expensive than in the compensated scenarios, which results in a steeper drop in aggregate demand. The impacts on household welfare tend to be regressive, in which the welfare losses on poor households are more deteriorating than higher income households in both rural and urban areas.

Furthermore, the FIT scenarios have negligible impacts on Indonesia's economy: GDP, sectoral outputs, and household welfare remain unchanged. This is due to the fact that the initial renewable shares on total electricity production are small (5% from geothermal generation and 11% for hydro). In other words, the Indonesian electricity supply is still dominated by fossil fuels (conventional) based generation covering about 85% shares in the electricity mix. Therefore, the implementation of the current FIT regulation – about 15% subsidies on hydro and geothermal production – would not affect the national income account. Specifically, in the electricity sector, the FIT schemes are unable to improve the clean energy production shares in Indonesia's electricity mix at a large scale. Comparing the two financing methods, financing through a carbon taxat leads to more contraction in GDP at market prices. This is because the increased price of carbon-based fuels leads to a fall in output, private consumption, and investment. In turn, the total government receipts from output taxes decline more. In terms of carbon accounting, the results reveal that the FIT schemes do not effectively reduce the national emissions. Compared to a carbon tax, the proposed FIT schemes are insufficient to achieve the ambitious target of lowering the national emissions from energy utilization by about 1%.

8.3. Research Limitations

Overall, the studies are constrained by some limitations related to the model features as well as the SAM dataset to calibrate the model. In both research studies, the analysis is within the context of a comparative static-single country CGE model. Therefore, the analysis does not capture the changes of household income and expenditure and technological changes that would affect investment-saving over time. The parameters of substitution elasticity used in the model are taken from another literature. In other words, the parameter is not econometrically estimated. Although the robustness of the simulation results was tested using sensitivity analysis, the chosen parameter value may be sensitive at the micro level, i.e. the magnitude of some industrial outputs, commodities, and household income distribution.

Another limitation is the source of dataset to calibrate the CGE model. The analysis is based on the Indonesian SAM dataset which represents the global economy in the year 2008. To our findings, this SAM dataset is the most recent source published officially by the Indonesian statistic agency. The official Indonesian SAM dataset is usually updated every five years; we expect that the official SAM dataset in year 2013 should had been issued. However, the latest version of the SAM is still that for 2008. Although it is possible to update the SAM manually, the efforts would be very sophisticated since the processes of the SAM updating cover all of the economy's transaction in details which include the SAM balancing method to square the matrices. In turn, the updated SAM will probably lead to huge discrepancies of transactions compared to reality.

In the second research contribution, the limitations are as follows. Although the analysis is based on the extended hybrid CGE model – that allows for factor-fuels and inter-fuels substitution, introduces the satellite features of carbon emission and its taxation module as well incorporates the electricity technological explicitness, the mechanisms of the supply-demand framework are based on a market with perfect competition. In other words, the producers are price takers (zero profit condition). Nonetheless, the energy markets are often imperfect, such as natural monopolistic or oligopolistic market. This can affect the outcome of implementing a carbon tax (or feed-in tariff) (Orlov, 2012). In term of sectoral outputs, numerous literatures argued that the implementation of a carbon tax on energy-intensive industries would significantly reduce their competitiveness in the domestic and international markets. Apart from the regressive nature of carbon tax on households' welfare, these concerns have been another important issue in political debates. Therefore, a carbon tax free to energy-intensive industries are sometimes implemented (OECD, 1995 and 2006; Fullerton *et al*., 2008).

The hybrid model used in this analysis is also based on a single country. It would be more ideal if a multi-regional based CGE model is used, since regional disparities play an important role to examine the impacts of environmental taxes on household welfare and inequality (Hasnain, 2010). To establish a multi-regional based hybrid CGE model, a multi-regional SAM dataset is thus required. Furthermore, the carbon tax analysis provided in this study focuses only on CO_2 emissions generated from fossil fuels combustion. Therefore, the impacts of carbon taxes on other greenhouse gas emissions types – i.e. methane (CH_4), nitrogen oxides (NO_2), sulphur oxides (SO_2) and other particulates – generated from deforestation and land-use change activities are not captured in the model. Following Allan *et al.* (2008), we do not take into account the pollutants from non-CO2 emissions due to the complexity of identifications that are strongly related to combustion conditions and technology specificity.

Most of the above model limitations are related to the data limitation. As mentioned earlier, the hybrid model used in the second research is calibrated to the hypothetical Energy-SAM dataset in the year 2008. This SAM dataset is the extended version of the official Indonesian SAM in year 2008 in which we disaggregated the energy sectors and the natural resources factor. To our knowledge, there is no such available information to specify, in details, the transaction flows of each of energy type according to that of SAM framework. Therefore, to establish the squared Energy-SAM dataset, we roughly adopt the shares approximation using the most available information of energy statistics. This approach might lead to discrepancy of results especially in the trade (export-import) analysis.

8.4. Suggestions for further research

Due to above limitations, we consider some recommendations for further research to our study as follows:

1. Updating the official Indonesian SAM to the most recent period is useful to examine the impacts on Indonesia’s economy at recent year. The construction of a multi-regional SAM dataset would also help to assess the effects of inter-regional disparities and transaction flows especially on households’ welfare and inequality. In addition, estimating the elasticity parameters econometrically can make the simulation results more realistric.
2. To enlarge the model from a single country CGE model into a multi-regional CGE model would be ideal to assess the regional disparities in Indonesia. A recursive dynamic version of a CGE model through technological changes would be a better tool to predict the dynamic welfare effects in the long run especially in the case of implementing the carbon tax (and feed-in tariffs). This is because the implementation of carbon tax (or feed-in tariffs) could induce the acceleration of energy efficiency, less carbon-intensive technologies, and

research innovation in the long run (Orlov, 2012). Implementing imperfect market competition, especially in energy markets, would generate more realistic results.

3. Finally, enriching the types of carbon emissions apart from CO_2 such as CH_4, NO_2, SO_2, CO, and other particulates as well as emitters from deforestation and land use change will specify the results of introducing the carbon taxes in detail. Reilly *et al.* (2004) argued that the curbing of non CO_2 GHG emissions is less costly than CO_2 emissions. Therefore, targeting a carbon tax towards these emissions could be considered.

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