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Nayasari Aissa
University of Indonesia, Indonesia, nayaaissa@gmail.com

Djoni Hartono
University of Indonesia, Indonesia, djoni.hartono@ui.ac.id

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THE IMPACT OF GEOTHERMAL ENERGY SECTOR DEVELOPMENT ON ELECTRICITY SECTOR IN INDONESIA ECONOMY

Nayasari Aissa[1]
Djoni Hartono[2]

Abstract

Energy is one of the most important inputs that supports Indonesia's economy. The government utilises coal and oil as the main sources for power plants energy mix. However, the utilization of fossil fuel energy has been proven to pose negative impacts on the environment such as, increasing carbon dioxide emission which leads to global warming. This study analyses investment policy on increasing electricity production of geothermal power plants as well as substitution of fossil energy to geothermal energy using Computable General Equilibrium (CGE) Model and Indonesia's data of Social Accounting Matrix 2008. The result shows that when investment on the substitution of energy from fossil to renewable energy takes place, economic growth will increase and carbon dioxide emission will reduce significantly.

Keywords: CGE, Electricity, CO2 Emission, Fossil Energy, Geothermal, Growth
JEL Classification: C68, O44, O21, Q4

1 Graduate from Master Degree Program Economics Science University of Indonesia (nayaaissa@gmail.com)
2 Lecturer at Department of Economics – University of Indonesia (djoni.hartono@ui.ac.id)

I. INTRODUCTION

Energy is one of the most important factors that supports economic growth of the country due to its role as a production input in various sectors (Stern, 2010). Energy consumption in every sector increases every year, including electricity sector. According to *The Handbook of Energy and Economic Statistics 2014*, Indonesia's electricity sector consumed energy as much as 14.3% of total energy supply. Growth of energy consumption of power plant increased 8% from 2010 to 2013.

The government, however, was confronted with two policies: 1) *least-cost policy* (choosing the cheapest energy); and 2) *environmental mitigation policy*. The least-cost policy was eventually chosen to reduce electricity production cost by using coal (Girianna, 2013). The government proposed not to use fuel oil anymore due to unstable price of crude oil on the global market. Nevertheless, the oil power plants are still widely used in almost all provinces in Indonesia. This certainly affects the government which has not been able to eliminate the contribution of fuel oil to the power generation energy mix.

Coal and oil have contributed significantly to Indonesia's electricity sector, but the use of those fossil energy sources also created costs to the environment. The government's energy policy in the past four decades has been proven to give negative impacts to the environment, namely on the increasing carbon dioxide (CO_2) emission. As Figure 1 shows, CO_2 emission on electricity sector increased significantly since 1971 and reached 149.62 million tons in 2010 (IEA, 2011).

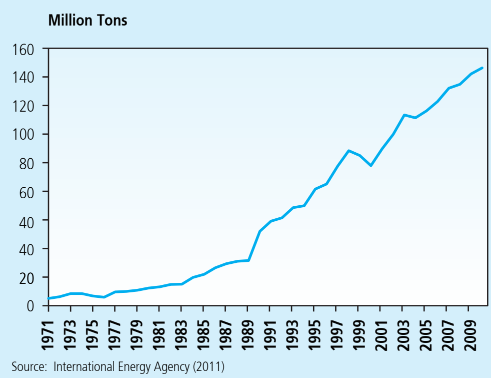


Figure 1. Emission of Carbon Dioxide that was Produced by Indonesia's Power Plants

Increasing CO_2 emissions from fossil energy, can be anticipated by replacing the fossils with the renewable ones, such as geothermal energy. Table 1 shows that geothermal energy produces fewer CO_2 emissions compared to fossil fuels.

Table 1. Carbon Dioxide Emission Produced by Coal, Fuel Oil, Natural Gas, and Geothermal Energy

No	Energy Type	Total producing of CO_2
1	Coal	1180 g/KWh
2	Fuel Oil	850 g/KWh
3	Natural Gas	530 g/KWh
4	Geothermal Energy*	12-380 g/KWh

Source: Hasan, et al., 2012; *Barbier, 2002

Geothermal energy already has a portion in the energy mix of power generation, yet its contribution was only amounted 2% in 2003. The government also needs to increase the portion of renewable energy in the energy mix. Based on Presidential Decree No.5 of National Energy Policy Year 2006, the contribution of geothermal on mix energy composition shall increase to 5% in 2025. Meanwhile, the State Electricity Company (*Perusahaan Listrik Negara* or abbreviated as PLN) has their own target to decrease the fuel oil's contribution to 1% of their energy mix in 2020 and will not develop fossil fuel power generation any further (RUPTL, 2013).

Hence, geothermal energy has potential for replacing fossil energy as fuel for power plants, and therefore the government should consider geothermal energy as the main concern. On the other hand, geothermal energy development in Indonesia is still facing some obstacles, such as the high cost of investment to build power plants and inexpensive selling price of geothermal energy due to being monopolized by PLN (Darma, et al., 2010, Mujiyanto and Tiess, 2013).

The government has already allocated subsidy amounted IDR 282.1 trillion in 2014 and it was broken down into two parts: oil subsidy (IDR 210.7 trillion) and electricity subsidy (IDR 71.4 trillion). It should, however, utilizes this subsidy allocation to develop renewable energy so Indonesia can consume a more environmentally-friendly energy source. Thus the government could initiate by providing investment to increase electricity production that will be produced by geothermal power plants using its oil subsidy.

This study analyses the role of energy policy in overcoming environmental problems that are induced by the use of fossil fuels. It observes the impact of investing in a geothermal power plant to increase output production and also, the impact of substituting fossil energy (coal and oil) for geothermal energy for the economy and environment.

II. THEORY

2.1. Theoritical Overview

This research uses Computable General Equilibrium (CGE) model that is functioned for analysing impact of policy. CGE model uses general equilibrium basic theory that was first developed by Leon Walras in 1874. The general equilibrium theory explains the interaction of inter-market that reached equilibrium in economy simultaneously, given a change in the market, then it will affect other market in the economy.

This study analyses the impact of a whole economy when electricity sector is given more investment and fossil fuels are substituted for geothermal energy. According to Walras (1874), when there was a change on one sector,it would thus affect another sector and also affect the whole economy. The economic condition could reach equilibrium condition, if amount n -market in economy and amount n-1 -market have already reached their equilibrium condition.

2.1.1. Economic Growth and Energy

Stern (2010) modified the Solow Growth Theory (1) to observe the impact of economic growth when there was a substitution between energy and capital,

$$Y(t) = F(K(t), A(t)L(t)), \tag{1}$$

Y(t) represents output, K(t) represents capital, A(t) represents technology and L(t) represents labour, whereas A (t) L (t) represents effective labour.

The result shows that substituting capital to energy will increase employment opportunities and rising of income, thus it will affect to the increase of economic growth. The production function is,

$$(Q_1, \dots, Q_m)' = f(A, X_1, \dots, X_n, E_1, \dots, E_p), \tag{2}$$

Q is output (factory goods and services); X is input (capital and labour); E is several energy inputs (coal and fuel oil); and A shows indicator of total factor productivity (TFP).

2.1.2. Economic Growth and Investment in Infrastructure

According to Mankiw (2007), investment is divided into three types: a) *business fixed investment* (BFI), the elimination of goods and services that was done by the company, such as buying machine; (b) *residential investment* (RI), the investment that was done by household through buying property; and c) *inventory investment* (II), the changing on production factor, such as input that was used by company in the production process.

An investment discussed in this study is the business fixed investment by investing in infrastructure, power generation for increasing output production. The main function of investing for investor is, to get recompensation of capital production factor.

Fedderke et al. (2008) argued that investment on infrastructure will give a positive impact on economic growth. The relationship between infrastructure and economic growth could be observed in two ways, directly or indirectly -related: 1) on directly related, infrastructure is observed as contributing sector to Gross Domestic Product (GDP) and as a production input to another sector, and 2) on indirectly related, when infrastructure was considered as complementary input on sector, thus it could increase productivity of other input factors.

2.2. Empirical Overview

There are numerous studies which explain the negative impact of the use of fossil energy on the environment. Aravena, et al. (2012) did a study on external cost that was caused by using fossil energy in a power plant. They suggested shifting to renewable energy to decrease carbon dioxide emission, and thus it would affect the external costs. Zou (2012) conducted a research to observe the negative impact of using fossil energy on power plant, thus there is a need to substitute fossil energy for hydroelectricity. Bravi and Basosi (2013), however, analysed that the used of renewable energy could in fact, increase CO_2 emission.

Krozer (2011), Kose (2007) and Moreno et al (2012) used econometric methods to observe the impact of substituting fossil fuel energy for renewable energy on power plant, thus it could reduce electricity cost and make electricity cost cheaper for consumers. Ortega et al (2013) did approximation on cost and profit while using renewable energy for power plant.

Lu, et al. (2009) discussed the impact of investing in energy sector for increasing economic growth in one of provinces in China. Rose (1995) also analysed the positive impact on economic growth using the dynamic linear programming to get results from substituting fossil energy for renewable energy. Halkso and Tzeremes (2013) obtained a rather different result, though, that, utilization of renewable energy as input for power plant in the long term will only give positive impact for developed countries, and not for developing country. Ohler and Fetters (2014) also revealed that utilization geothermal energy to produce electricity will give small impact on GDP growth.

There are studies with CGE model which come up with different results. Aydin (2010), for instance, developed a dynamic CGE model for Turkey, called TurGEM-D, by simulating the increasing quantity of hydroelectricity to substitute the role of fossil energy that Turkey currently does not have. The result is that investment in renewable energy influences the rising of economic growth and reduces CO_2 emission. Engida et al (2011) used static CGE model to show that investment in power plant gave positive results in economic growth. Dissou and Didic (2011) used recursive-dynamic CGE model to observe the impact of investing in infrastructure, including power plant, that give positive effect on economic growth. Borojo (2012) obtained a specific result by using recursive-dynamic CGE model that investing in power plant using foreign direct investment s increases economic growth.

There are several studies that used CGE model for modelling energy policy: 1) the impact of the energy pricing policy on the increase of electricity consumer price (Isdinarmiarti, 2011);

2) the impact of energy policy to replace the use of fossil fuels with other energy (natural gas, coal, and other renewable energy) (Sugiyono, 2009); and 3) the impact of energy price changes in output of industrial sector (Nikensari (2001). However, the research on investment policy on the geothermal sector and its substitution with a static CGE model is something new for economics science in Indonesian context.

The author sees that the use of fossil energy has given a negative impact on the Indonesia's air quality. Thus the government should begin to take action to start replacing fossil energy to renewable energy, namely geothermal energy, as an input source for the production of electricity generation.

III. METHODOLOGY AND DATA

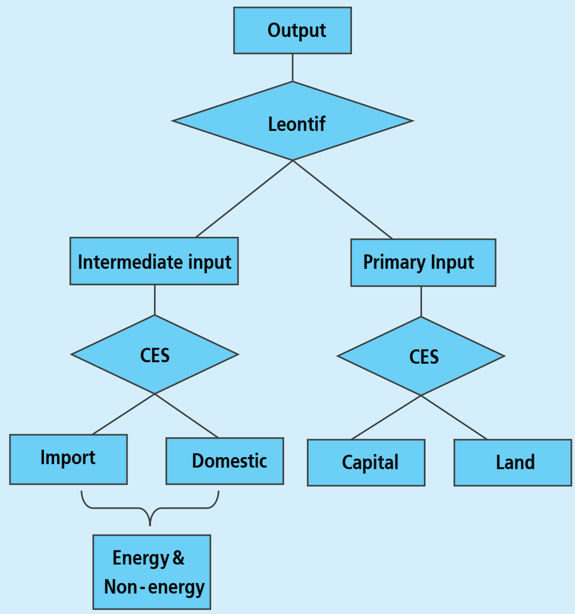
3.1. Computable General Equilibrium Model

Computable General Equilibrium (CGE) Model uses basic foundation General Equilibrium Theory as mentioned above. This model is functioned to analyse interactions between consumers, producers, and market equilibrium conditions in the economy. A market equilibrium condition is a market-clearing condition that is occurred when consumers can consume all of the output produced by producers (Lewis, 1991).

The CGE model used is the standard model for Indonesia (see Appendix 1). Similar models can be seen on the Inter-Regional Model System of Analysis for Indonesia in 5 Regions (IRSA-INDONESIA 5). The model developed by Resosudarmo et al. (2009) for regional analysis. This CGE Model assumed Indonesia as an open economy whose was a price taker that did not contribute impact for global price.

Figure 2 shows the standard model of CGE related to the linkage across blocks on the model. The diagram flow is described the followings:

- Capital and Land are aggregated using Constant Elasticity Substitution function to form the composite input;
- Composite input is combined with intermediate inputs (energy & non-energy) to produce domestic gross output, using the Leontief function;



Source: Resosudarmo, et al., 2009

Figure 2.
Model Structure of Open Economy CGE Model

This model has several equation systems which are divided into five blocks of equation. These blocks are: (1) *production block*,equations in this block reflect the structure of production activity and producers' behavior; (2) *consumption block*,equations in this block reflect the structure of household behavior and others institutions; (3) *export - import block* equations in this block describe the decision of country/region to invest in economy and demand of goods and services that was used on the new capital formation; (4) *market-clearing block*, equations in this block determine market-clearing conditions for labor, goods and services in economy, national payment balance is included into this block too.

3.2. Data

Social Accounting Matrix (SAM) 2008 is used as data for this research. The utilisation of this data source is particularly important due to SAM, as one of data collection systems, is an essential analytical tool that was developed to observe and analyse whether an economic policy can boost economic growth and create more equitable income distribution in a country. SAM is an economic balance of traditional double-entry which is shaped into matrix partition that recorded all economic transactions between agents, particularly between sectors within production blocks, sectors within institution blocks (including households), and sectors within production factor blocks in economy (Pyatt and Round, 1979; Sadoulet and de Janvry, 1995; Hartono and Resosudarmo, 1998).

Furthermore, SAM is a useful data collection system due to: (1) SAM summarizes all of economic transaction that was occurred in economy system for a certain period. Thus, SAM could provide a general overview of economic system in the region; and (2) SAM describes social-economic structure. Thus, SAM is reliable to provide poverty and income distribution issue in economy (Hartono and Resosudarmo, 1998).

SAM is also an important analysis tools, because: (1) It could show substantial impact of economic policy towards household income. Thus, it could discover impact of economic policy towards poverty and income distribution issue. (2) It is relatively simple. Thus, the application could be easily done in various countries (Hartono and Resosudarmo, 1998).

In this study, we modified Indonesian SAM that is published by Central Agency on Statistics of Indonesia in 2008. There are two main differences between published Indonesian SAM and our modified Indonesian SAM: (i) It modifies ten household groups into two groups of households (decile groups of urban and rural households); (ii) It disaggregates sectors and commodities, hence generating more detailed sectors related to the energy, namely geothermal, natural gas, coal, gasoline, kerosene, high speed diesel oil (HSDO) and diesel oil. There are fourty four sector that are used in this study.

To conduct disaggregation of Indonesia SAM 2008 (published by BPS), this study used several information and supporting data, such as Input-Output tables and statistics of energy. The information about the structure of output and input follow the assumptions contained in those data.

IV. RESULT AND ANALYSIS

4.2. Simulation Scenarios

Based on energy mix data of power plant in 2008, this research applies simulation scenarios. The main scenario is increasing the amount of investment for developing geothermal power generations and substituting a portion of fossil energy (coal and oil) for geothermal energy as an energy source for power plants, so that the electricity production will increase. There will be four scenarios which will be used for observing the impact of investing and substituting in geothermal sector for economic growth.

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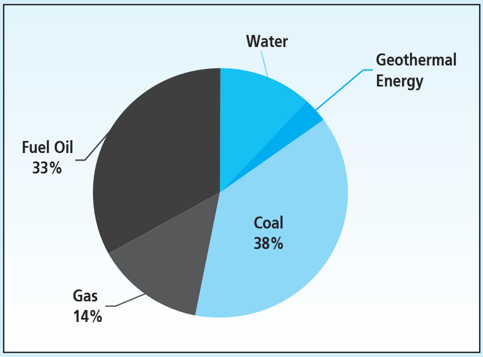

Source: Handbook of Energy and Economics Statistics Indonesia (2009)

Figure 3. Power Plants Energy Mix 2008

The amount of investment required by the PLN to increase the electricity production of geothermal power plant is 10%. In 2008, electricity produced by geothermal power plant was only 3390.66 GWh, with a production cost of IDR 746.61 per kWh, thus the total production cost in 2008 amounted IDR 2.5 trillion. The 2008 GDP in nominal terms itself is IDR 4,778 trillion. If we expect the electricity production with geothermal energy to increase by 10% (which the electricity output will increase amounted 339.066 gWh), the government require investment of around IDR 0.25 trillion for the geothermal energy power plant (10% of total cost production for 3390.66 GWh). The calculation is presented in Table 2 below.

Table 2.
Calculation of Electricity Production Cost per kWh (IDR)

Year	Electricity Output (gWh)	Production Cost per kWh (IDR)	Total Cost (IDR trillion)
2008	3390.66	746.61	2.5
Increasing 10% of 2008	339.066	746.61	0.25

Source: Statistik PLN 2008

The contribution of geothermal energy on power plant was only 3% of energy mix total in 2008. The biggest contribution of energy mix in 2008 was coal amounted 38% and followed by fuel oil, 33%. Based on energy mix data in 2008, the authors wish to observe what would occur if contribution of geothermal energy was increased and fossil energy was decreased.

This study uses four scenarios, denoted by SIM, to simulate investment policy and substitute energy with energy mix data for power plant in 2008. Those are:

1. SIM 1: invest to increase electricity production output of geothermal power plant by 10%.
2. SIM 2: invest to increase electricity production output of geothermal power plant by 10% and also substitute contribution of oil to geothermal energy by 10% as power plant energy source.
3. SIM 3: invest to increase electricity production output of geothermal power plant by 10% and also substitute contribution coal to geothermal energy by 10% as power plant energy source.
4. SIM 4: invest to increase electricity production output of geothermal power plant by 10% and also substitute oil and coal to geothermal energy by 5% for each fossil energy as power plant energy source.

4.2. Results and Analysis

The results of those simulation scenarios is analysed into two parts: (1) impact analysis of investment and substitution energy policy to Indonesia's economy; and (2) impact analysis of substitution energy policy to CO_2 emission level.

4.2.1. Impact Analysis of Policy to Indonesia's Economy

a) On Gross Domestic Product

This part analyses the impact of investment policy for geothermal power plants to increase electricity production output and substitute energy for Indonesia economic growth.

Table 3.
The Impact of Investment Policy for Geothermal Energy and Substitution Fossil Energy to Geothermal Energy for GDP

	SIM 1	SIM 2	SIM 3	SIM 4
GDP **Increase of GDP in 2008 (IDR trillion)**	0.236% 11.27608	0.013% 0.62114	0.013% 0.62114	0.013% 0.62114

Source: results of model calculations with software

From Table 3, we can see that Simulation 1 causes an increase on GDP by 0.236% whereas Simulation 2, 3, and 4 do not influence economic growth due to GDP increase of only 0.013%.

The authors use percentage of increasing GDP to calculate the nominal of increasing GDP. As an impact of investment on geothermal power plant, GDP increases more than IDR 11.27

trillion, meaning that investment in geothermal power plants amounted IDR 0.25 trillion will give profit as much as IDR 11.02 trillion for GDP in 2008. In the case of substitution of fossil energy for geothermal energy, nominal of GDP increases to IDR 0.37 trillion.

b) On Sectoral Output

SIM1 brings result that rail transport sector is the most affected by investment policy and substitution fossil energy to geothermal energy, the GDP increase is amounted 2.012%. The impacts are also happened in city-gas sector and non-subsidized energy sector with amount of increasing 1.894% and 0.781%, respectively. While, SIM 2, SIM 3, and SIM4 does not show significant impact for output sectoral, due to increasing portion geothermal energy in power plants energy mix of only 10%.

c) On Household Income

The household income that is mostly affected by increasing investment in a geothermal power plant, is the household within the category of urban-not poor, which increases by 0.528%. Meanwhile, the impacts on household income caused by substitution energy are felt by poor people in the village category, or increases by 0.020%. Poor households are defined as those with incomes below 20% (in decile 1 to decile 2)[1], while the non-poor households is the rest.

4.2.2. Analysis Impact of Policy for Carbon Dioxide Emission

This part explains the impact of investment and substitution policy on power plants towards total of CO_2 emission produced. Table 4 shows result of CO_2 emission caused by energy substitution.

Substitution energy from coal to geothermal as an energy source for power plants by 10% affects decreasing of carbon dioxide emission by 5.92%. Whereas, energy substitution from oil to geothermal only decreases carbon dioxide emission by 1.56%. Substitution between a combination of coal and oil for geothermal energy as an energy source for power plants, though, decreases carbon dioxide emission by 3.74%.

The figure from SIM 3 indicates that replacing coal to geothermal energy will give significant impact for the decrease of CO_2. It is due to the fact that coal is the biggest producer of CO_2 when was used as the source of power plants in comparison with fuel oil.

Table 4. The Impact of Geothermal Energy Investment Policy and Substitutions Fossil Energy for Geothermal Energy on Reducing Carbon Dioxide Emission

Amount of Carbon Dioxide Emission 2008 (million tons CO_2)	SIM 2	SIM 3	SIM 4
102	-1.56%	-5.92%	-3.74%

V. CONCLUSIONS

This study aims to explain the electricity sector's problems in Indonesia, especially environmental problem—increasing CO_2 emission—that was produced by fossil energy power plants. Using a CGE model, we develop model to analyse the impact of policy towards economic condition and the amount of CO_2 emission created, to support the development of geothermal energy as a source for power plants.

The simulation provides us several findings, *first*, the investment policy to increase geothermal power plant production increases GDP amounted IDR 11.02 trillion. The result is similar with Aydin (2010), Engida et al, (2011), Dissou and Didic (2011), and Borojo (2012) that investment in energy sector will give impact towards positive economic growth. Substitution from fossil energy to geothermal energy has insignificant effect, but still increases nominal of GDP amounted IDR 0.37 trillion.

Second finding from simulation is each sector increases when there is investment in geothermal power plants, the highest increase occurrs in transportation sector, which is the rail transport. *Third*, the household income affected the most by this investment policy is the household in urban-not poor category. Nonetheless, the substitution of fossil energy for geothermal energy does not affect significantly. *Lastly*, the substitutions energy from coal to geothermal energy affects more than that of oil to geothermal energy in the case of decreasing CO_2 emission.

Investment and substitution policy to increase electricity production that is produced by geothermal energy has proven to give positive impact for economic growth and output sectoral. Substitution from fossil energy to geothermal energy is also confirmed to decrease total CO_2 emission. This result could be the basis for the government to develop geothermal energy sector.

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Appendix 1. Basic Equations in CGE Model

Zero profit in sourcing

$$PQ\_S_c \cdot XD\_S_c = \sum_s PQ\_S_{cs} \cdot XD_{cs} \tag{1}$$

Price of foreign goods

$$PQ_{c,s=imp} = EXR \cdot PFIMP_c \tag{2}$$

Armington domestic-import composition

$$XD_{cs} = alparm_c^{-rhoarm_c} \cdot XD\_S_c \cdot delarm_{cs}^{1/(rhoarm_c+1)} \cdot \left(\frac{PQ_{cs}}{PQ\_S_c}\right)^{-1/(rhoarm_c+1)} \tag{3}$$

Aggregatting domestic-import composite (total demand)

$$XD\_S_c = \sum_i XINT_{ci} + \sum_h XHOU\_S_{ch} + XGOV\_S_c + XINV\_S_c \tag{4}$$

Intermediate demand

$$XINT\_S_{ci} = aint_{ci} \cdot XTOT_i \tag{5}$$

Household demad

$$PQ\_S_c \cdot XHOU\_S_{ch} = \beta_{ch} \cdot EH_h \tag{6}$$

Other institution's demand

$$PQ\_S_c \cdot XGOV\_S_c = bdgsrgov_c \cdot EGOV \tag{7}$$

Export demand to ROW

$$XEXP_c = alpexp_c \cdot \left[\frac{\left(PQ_{c=dom}/EXR\right)}{PEXP_c}\right]^{-expelas_c} \tag{8}$$

Demand for factors of production

$$XFAC_{fi} = alprim_i^{\left(-rhopirm_i/_{1+rhoprim_i}\right)} \cdot XPRIM_i \cdot delprim_{fi}^{\left(1/_{1+rhoprim_i}\right)} \cdot \left(\frac{WDIST_{fi} \cdot PFAC_f}{PPRIM_i}\right)^{\left(-1/_{1+rhoprim_i}\right)} \tag{9}$$

Price of value-added (factor composite)

$$PPRIM_i \cdot XPRIM_i = \left(\sum_f WDIST_{fi} \cdot PFAC_f\right) \cdot XFAC_{fi} \tag{10}$$

Demand for value-added (Leontief)

$$XPRIM_i = APRIM_i \cdot XTOT_i \tag{11}$$

Market clearing for factors

$$\sum_i XFAC_{fi} = XFACSUP_f \tag{12}$$

Total factor income

$$YFAC_f = \left(\sum_i WDIST_{fi} \cdot PFAC_f\right) \cdot XFAC_{fi} + EXR \cdot YFACRO_f \tag{13}$$

Zero profit in production

$$(1 - itx_i) \cdot PQ_{i=DOM} \cdot XTOT_i = PPRIM_i \cdot XPRIM_i + \sum_c PQ\_S_c \cdot XINT\_S_{ci} \tag{14}$$

Market clearing for commodities produced

$$XTOT_c = XD_{c=dom} + XEXP_c \tag{15}$$

Household income

$$YH_h = \sum_f sfachh_{hf} \cdot YFAC_f + strgovh_h \cdot YGOV + strroh_h \cdot EXR \cdot YRO + strenth_h \cdot YENT + \left(\sum_{hh} strhh_{hhh} \cdot (1 - savh_{hh}) \right) \cdot (1 - savh_{hh}) \cdot YH_h \tag{16}$$

Household disposable income for consumption

$$EH_h = \left(1 - \sum_{hh} strhh_{hhh} \right) - strhr_h - strhent_h \cdot (1 - savh_h) \cdot (1 - ytaxh_{hh}) \cdot YH_h \tag{17}$$

Household saving

$$SH_h = savh_h \cdot (1 - ytaxh_h) \cdot YH_h \tag{18}$$

Income of government

$$YGOV = \left(\sum_i itx_i \cdot PQ_{i=dom} \cdot XTOT_i \right) + strrgov \cdot EXR \cdot YRO + \left(\sum_f sfacgov_f \cdot YFAC_f \right) + \left(\sum_h ytaxh_h \cdot YH_h \right) + strgovgov \cdot YGOV + strentgov \cdot YENT \tag{19}$$

Expenditure of other's institution

$$EGOV = \left(1 - \sum_h strgovh_h \right) + strrgovr + strgovgov + strgovent \cdot YGOV \tag{20}$$

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Saving of other institutions

$$SGOV = savgov \cdot YGOV \tag{21}$$

Income of enterprises

$$\begin{aligned} YENT = {} & strroent \cdot EXR \cdot YRO + \left(\sum_f sfacent_f \cdot YFAC_f\right) + strgovent \cdot YGOV \\ & + \left(\sum_h strhent_h \cdot (1 - savh_h) \cdot (1 - ytaxh_h) \cdot YH_h\right) \end{aligned} \tag{22}$$

Expenditure of enterpirses

$$EENT = \left(\sum_h strhent_h\right) + (strentgov + savent + strentro) \cdot YENT \tag{23}$$

Saving of enterprises

$$SENT = savent \cdot YENT \tag{24}$$

Income of rest of the world (in ROW currency)

$$\begin{aligned} YRO = {} & \left(\frac{1}{EXR}\right) \cdot \left(\sum_f sfacro_f \cdot YFAC_f\right) + \left(\sum_c PFIMP_c \cdot XD_{c=IMP}\right) + strgovr \\ & \cdot \left(\frac{1}{EXR}\right) \cdot YGOV + strentro \cdot \left(\frac{1}{EXR}\right) \cdot YENT \\ & + \left(\sum_h strhr_h \cdot (1 - savh_h) \cdot (1 - ytaxh_h) \cdot \left(\frac{1}{EXR}\right) \cdot YH_h\right) \end{aligned} \tag{25}$$

Expenditure of rest of the world (in ROW currency)

$$\begin{aligned} ERO = {} & \left(\sum_c \left(\frac{1}{EXR}\right) \cdot PQ_{c=dom} \cdot XEXP_c\right) + strrgov + strroent + \left(\sum_h strroh_h\right) \\ & \cdot YRO + SRO + \left(\sum_f YFACRO_f\right) \end{aligned} \tag{26}$$

Aggregate saving

$$SAV = \left(\sum_{h} SH_h\right) + SGOV + EXR \cdot SRO + SENT \tag{27}$$

Aggregate investment

$$INV = \left(\sum_{c} PQ\_S_c \cdot XINV\_S_c\right) \tag{28}$$

Investment demand

$$PQ_{S_c} \cdot XINV_{S_c} = lambda_c \cdot SAV \tag{29}$$

Consumer's price index

$$CPI = \sum_{c} wgtcpi_c \cdot PQ\_S_c \tag{30}$$

Appendix 2. Equations for CO2 Emission in CGE Model

CO2 Emissions by industry

$$XCOI_{ei} = cci_{ei} \cdot shxcoi_{ei} \cdot XINT\_S_{ei} \tag{31}$$

CO2 Emissions by household

$$XCOH_{eh} = cch_{eh} \cdot shxcoh_{eh} \cdot XHOU\_S_{eh} \tag{32}$$

National CO2 emissions

$$XCO = \sum_{ei} XCOI_{ei} + \sum_{eh} XCOH_{eh} \tag{33}$$

Appendix 3 List of Parameters and Variables of the CGE Model

List of Parameters

$aint_{ci}$	aint(c,i)	Coefficients of intermediate input Leontief
$aprim_{i}$	aprim(i)	Coefficients of value added Leontief
$beta_{ch}$	beta(c,h)	Budget/ expenditure share household
$bdgsrgov_{c}$	bdgsrgov(c)	Budget share household government
$expelas_{c}$	expelas(c)	Elasticity of exports
$alpexp_{c}$	alpexp(c)	Shift parameter demand for export
itx_{i}	itx(i)	Rate of indirect tax
$delarm_{cs}$	delarm(c,s)	Share parameter CES Armington
$alparm_{c}$	alparm(c)	Shift parameter CES Armington
$rhoarm_{c}$	rhoarm(c)	Parameter CES Armington
$sigarm_{c}$	sigarm(c)	Elasticity of substition CES Armington
$alpprim_{i}$	alpprim(i)	Shift parameter value added CES
$rhoprim_{i}$	rhoprim(i)	Parameter of value-added CES
$sigprim_{i}$	sigprim(i)	Elasticity of substitution value-added
$delprim_{fi}$	delprim(f,i)	Share parameter value-added CES
$sfachh_{hf}$	sfachh(h,f)	Share of households factor income
$sfacent_{f}$	sfacent(f)	Share of corporate enterprises factor income
$sfacro_{f}$	sfacro(f)	Share of RoW (from abroad) factor income
$strgovh_{h}$	strgovh(h)	Share of government revenue transfered to households
strgovent	strgovent	Share of government revenue transfered to corporate enterprises
strgovro	strgovro	Share of government revenue transfered to abroad/ RoW
$strenth_{h}$	strenth(h)	Share of corporate enterprises revenue transfered to households
strentgov	strentgov	Share of corporate enterprises revenue transfered to government
strentro	strentro	Share of corporate enterprises revenue transfered to abroad/ RoW
$ytaxh_{h}$	ytaxh(h)	Rate of income tax for households
$strhh_{hhh}$	strhh(hh,h)	Share of households income transfered to other households
$savh_{h}$	savh(h)	Rate of households saving
savent	savent	Rate of corporate enterprises saving
$strroh_{h}$	strroh(h)	Share of RoW income transfered to households
strroent	strroent	Share of RoW income transfered to corporate enterprises
$strhr_{h}$	strhr(h)	Share of households income transfered to abroad/ RoW
$strhent_{h}$	strhent(h)	Share of households income transfered to corporate enterprises
strrgov	strrgov	Share of RoW income transfered to government
$sfacgov_{f}$	sfacgov(f)	Share of government factor income
strgovgov	strgovgov	Share of government revenue transfered to other government

strgovr	strgovr	Share of government revenue transfered to abroad/ RoW
savgov	savgov	Rate of government saving
$sfacro_f$	sfacro(f)	Share of factor income as part of abroad/ RoW
$lambda_c$	lambda(c)	Investment coefficient
$wgtcpi_c$	wgtcpi(c)	Weighted CPI (consumer price index)
$shxcoi_{ei}$	shxcoi(e,i)	share of co2 emitting energy consumption in industry
$shxcoh_{eh}$	shxcoh(e,h)	share of co2 emitting energy consumption in household
cci_{ei}	cci(e,i)	carbon content for industry
cch_{eh}	cch(e,h)	carbon content for household

List of Variables

PQ_{cs}	PQ(c,s)	Price of commodities, domestic and import
PQ_S_c	PQ_S(c)	Price of composite commodities, domestic and import
$PFIMP_c$	PFIMP(c)	Price of global import
$PFEXP_c$	PFEXP(c)	Price of global export
$PFAC_f$	PFAC(f)	Price of production factors
$PPRIM_i$	PPRIM(i)	Price of primary factors
CPI	CPI	Consumer price index
EXR	EXR	Exchange rate
XD_{cs}	XD(c,s)	Demand for commodity (domestic and import)
XD_S_c	XD_S(c)	Demand for composite commodity
$XINT\_S_{ci}$	XINT_S(c,i)	Demand for intermediate input by sector
$XHOU\_S_{ch}$	XHOU_S(c,h)	Household demand for commodity
$XGOV\_S_c$	XGOV_Sc	Government demand for commodity
$XOTH\_S_c$	XOTH_S(c)	Other institution demand for commodity
$XINV\_S_c$	XINV_S(c)	Composite investment goods
$XTOT_i$	XTOT(i)	Total output
$XEXP_c$	XEXP(c)	Demand for export
$XFAC_{fi}$	XFAC(f,i)	Demand for production factor
$XPRIM_i$	XPRIM(i)	Demand for primary factor
$XFACSUP_f$	XFACSUP(f)	Total supply of production factors
$YFAC_f$	YFAC(f)	Total income from production factor
$YFACRO_f$	YFACROf	Income received from abroad
$WDIST_{fi}$	WDISTf i	Price of production factor of labor by sectors
YH_h	YH(h)	Household income
YGOV	YGOV	Government revenue
YENT	YENT	Corporate enterprise/ company income
YRO	YRO	Transfer/ revenue from abroad

EHh	EH(h)	Household disposable income
EGOV	EGOV	Government expenditures/ consumption
EENT	EENT	Corporate enterprise expenditure
ERO	ERO	Expenditure from abroad
SGOV	SGOV	Government saving
SHh	SH(h)	Household saving
SRO	SRO	Saving from abroad
SENT	SENT	Corporate enterprise saving
SAV	SAV	Total saving
ANV	ANV	Total investment
$XCOI_{ei}$	XCOI(e,i)	CO2 Emissions by industry
$XCOH_{eh}$	XCOH(e,h)	CO2 Emissions by household
XCO	XCO	National CO2 emissions

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