THE IMPACT OF SOLAR ENERGY POLICY TO HOUSEHOLD AND INDUSTRY SECTOR IN THAILAND

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MASTER OF ECONOMICS

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A THESIS SUBMITTED TO CHIANG MAI UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ECONOMICS

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หัวข้อวิทยานิพนธ์ ผลกระทบของนโยบายปฏิรูปพลังงานแสงอาทิตย์ที่มีต่อภาคครัวเรือนและภาคอุตสาหกรรมในประเทศไทย

ผู้เขียน นายรัตน์ชัย เสถียรพัฒนากูล

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บทคัดย่อ

วิทยานิพนธ์ฉบับนี้มีวัตถุประสงค์หลักคือ ศึกษาผลกระทบของการทดแทนกันระหว่างพลังงานทางเลือกและพลังงานก๊าซธรรมชาติโดยใช้แบบจำลองดุลยภาพทั่วไป (CGE) ในการสร้างแบบจำลองนั้นเกิดจากรวมตารางปัจจัยการผลิตปี 2553 และข้อมูลรายได้ประชาชาติปี 2556 มาสร้างตารางเมตริกซ์บัญชีสังคม (SAM) เพื่อที่จะใช้เป็นฐานข้อมูลในแบบจำลอง GAMS ในส่วนของการฏิรูปอุตสาหกรรมไฟฟ้านั้นถูกสร้างขึ้นอยู่ภายใต้แบบจำลองทั้งห้าคือ การใช้พลังงานแสงอาทิตย์และพลังงานลมแทนพลังงานก๊าซธรรมชาติในการผลิตไฟฟ้า รวมถึงการส่งเสริมการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์ พลังงานลม และก๊าซธรรมชาติ ผลการวิเคราะห์จากตารางเมตริกซ์บัญชีสังคมแสดงให้เห็นว่าแบบจำลองที่ใช้พลังงานแสงอาทิตย์ทดแทนพลังงานก๊าซธรรมชาติสามารถส่งผลกระทบต่อระบบเศรษฐกิจได้มากกว่าการใช้พลังงานลม ทั้งในด้านผลิตภัณฑ์มวลรวมในประเทศ รายได้ครัวเรือนและผลผลิตในอุตสาหกรรมโดยเฉพาะภาคอุตสาหกรรมและภาคก่อสร้าง อย่างไรก็ตามแบบจำลองการส่งเสริมพลังงานแสงอาทิตย์ พลังงานลม และก๊าซธรรมชาติชี้ว่าผลกระทบโดยรวมต่อผลผลิตในอุตสาหกรรมสูงสุดอยู่ที่ภาคการก่อสร้าง ภาคชิ้นส่วนเครื่องจักรและภาคปิโตรเลียม ตามลำดับ นอกเหนือจากนี้ผลของแบบจำลอง CGE พบว่าผลกระทบในด้านอุตสาหกรรมนั้นมีทิศทางเดียวกับแบบจำลอง SAM ซึ่งแบบจำลองการใช้พลังงานแสงอาทิตย์ทดแทนนั้นส่งผลต่อผลผลิตภาคก่อสร้างเพิ่มขึ้น 3.39% และการใช้พลังงานลมทดแทนส่งผลให้ภาคชิ้นส่วนเครื่องจักรเพิ่มขึ้น 3.00% นอกจากนี้ผลทางด้านเศรษฐศาสตร์สวัสดิการ ยังแสดงให้เห็นว่าเกิดภาพเชิงบวกต่ออรรถประโยชน์ของแบบจำลองการใช้พลังงานแสงอาทิตย์ทดแทนมากกว่าการใช้พลังงานลมทดแทน ยิ่งไปกว่านั้นนโยบายกระตุ้นการลงทุนในพลังงานทดแทนทั้งจากผู้ผลิต และนักลงทุนในอุตสาหกรรมไฟฟ้าจากส่วนเพิ่มการรับซื้อไฟฟ้าที่มีเสถียรภาพ ในสัญญาระยะยาวถือว่าเป็นประโยชน์ต่อประเทศอย่างมาก

Thesis Title The Impact of Solar Energy Policy to Household and Industry Sector in Thailand

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ABSTRACT

This paper aims to investigate the economic impacts of the renewable energy replacement with the natural gas electricity by applying a Computable General Equilibrium (CGE) model. The method was conducted by conveying the database from input-output table by 2010 and national income account by 2013 in order to construct Social Accounting Matrix (SAM) to be a benchmark in General Algebraic Modeling System (GAMS). The electricity production reform was under five scenarios namely, replacing a natural gas reduction with solar and wind improvement, and improving solar, wind, and natural gas production. The SAM results show that the simulation of solar replacement is better-off than wind replacement as specified by the total GDP, household income, and the production output especially in construction and manufacturing sector. However, the simulation of solar and wind improvement can raise the production output in construction and machinery. Unlike, the simulation of gas improvement can increase mainly in petroleum, natural gas and mining sector. Additionally, The CGE results also support the similar direction in terms of sectoral impact as SAM. The solar replacement can significantly increase in construction by 3.39% and the wind can also increase in machinery by 3.00%. Furthermore, the economic welfare shows that a positive aspect in solar replacement is better-off than wind replacement. In addition, the policy implement is to convince a producer and investor in an electricity production by offering a payment stability for a long-term contract (Feed-in-Tariff).

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CHAPTER 1

Introduction

1.1 Rationale and Statement of Problem

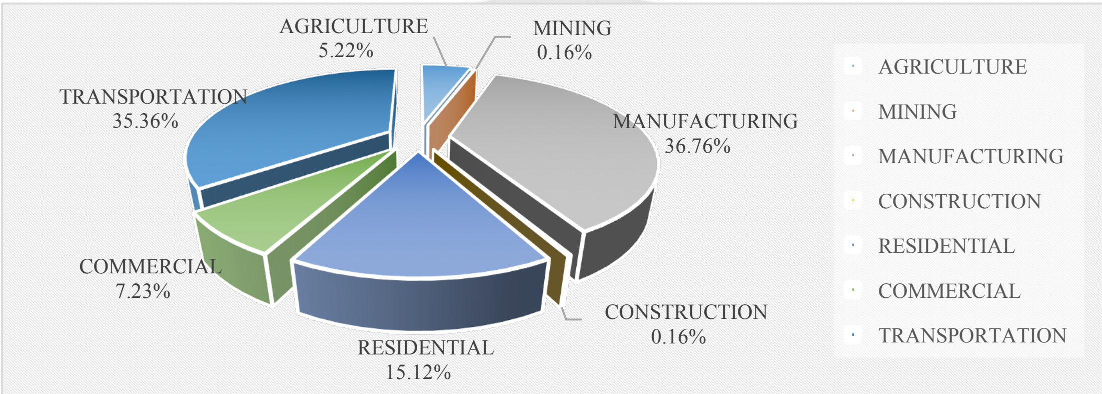
Southeast Asian countries have moderately changed an economy and developed several dimensions in the past decades. Asian Economy Community (AEC) was a significantly advanced union which was transformed from The Association of Southeast Asian Nations (ASEAN). Thailand has been a member of ASEAN since 1984. Nowadays, Thailand has 67 million of population and 232 billion dollars of GDP. As shown in Table 1.1, there was 3,451 US dollars of GDP per capita, with 1.76% of GDP growth. Thailand is considered as the developing country like Cambodia, Indonesia, Malaysia, Myanmar, Lao PDR, Philippine, and Vietnam. All in all, the neighbors of developing countries such as Lao PDR, Cambodia, Indonesia, and Vietnam have also simultaneously developed with the growth in GDP of 8.52%, 7.41%, 5.78%, and 5.42%, respectively in 2013 (World Bank, 2015).

Table 1.1: Thailand Overview of Economy and Energy Use.

Series Name	1980	1990	2000	2010	2014	Unit
GDP (constant 2005 US$)	41	88	137	210	232	Billion of US$
GDP per capita (constant 2005 US$)	882	1,572	2,206	3,164	3,451	US$
Agricultural Contribution to GDP	23	12	9	12	12	Percent of GDP
Industrial Contribution to GDP	28	37	42	45	42	Percent of GDP
Final Consumption Expenditure	77	66	69	67	67	Percent of GDP
Energy usage	22	41	72	117	173	10^3 ktoe

Source: World Bank 2015 and Department of Alternative Energy Development and Efficiency (DEDE, 2015)

However, Thailand has currently changed in its structural economy from agricultural to industrial country with potentials. Thai's economy has weightily based on the agricultural sector, which is accounted for 23% of its GDP, while the industrial contribution was 28% of GDP in 1980. Presently, manufacturing sector has rapidly grown to 42% of GDP but agricultural sector plays less role accounting for 12% of GDP as shown in Table 1.1. Due to Thailand's high value of consumption, with the final consumption expenditure accounted for 67.47% of GDP, an energy usage in 2013 resulted in 173,176 kiloton of oil equivalent (ktoe). Additionally, Indonesians consumed 209,008 ktoe in 2014, which was the highest energy usage among ASEAN that year (World Bank, 2015). In addition, Thailand has still imported energy, accounted for 80% of total final energy. This import is mostly included for crude oil and natural gas, accounted for 46% and 11% of total energy consumption, respectively (DEDE, 2015).

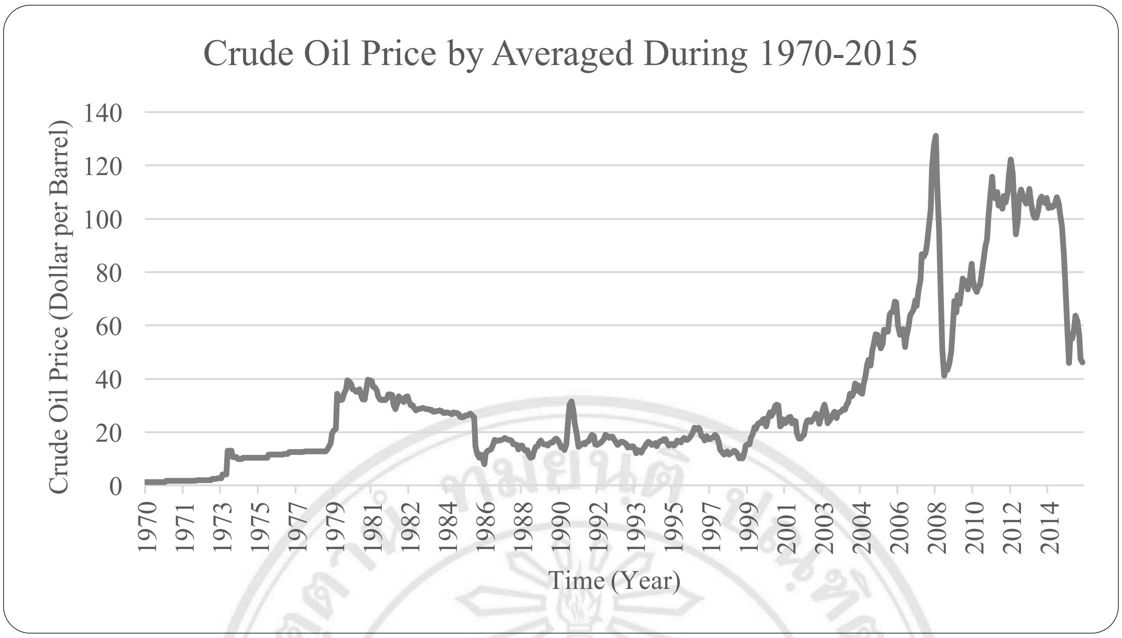


Source: Department of Alternative Energy Development and Efficiency (DEDE, 2015)

Figure 1.1: Total Energy Consumption by Sector in Thailand in 2014.

Table 1.1 indicates that Thai's economy use 67% of its GDP regarding to the final consumption in 2014. The total energy consumption can be separated into seven productions as presented in Figure 1.1. The manufacturing consumes 36.76% of total energy consumption especially used for petroleum products, an electricity, and renewable energy. The other of 35.36% of energy consumption was consumed by transportation, which was also used for petroleum products such as diesel fuel, jet fuel, and gasohol. Nevertheless, the resident uses 15.12% of total energy consumption while the rest of energy consumption is contributed for commercial, agricultural, mining, and construction sectors.

According to the total energy consumption by sectors, which obviously demonstrates that the manufacturing, transportation, and residential sectors have a large number of energy demands. Nonetheless, the cause of fluctuation in global oil-price also affects directly to the domestic energy stability and its imports. Figure 1.2, with the crude oil price since 1970, indicates that the oil price was quite stable for 1970-2004. Afterward, there was a strong shock on an economy in oil crises (2008-2009). Oil price unexpectedly leaped to the all-time high of $145 a barrel on 2008 (James D. Hamilton, 2009).



Source: Federal Reserve Economic Data, 2015

Figure 1.2: Crude Oil Price by averaged per month from 1970-2015.

In accordance with the above reasons, the growth of manufacturing, the high level of total energy consumption in each sector, and the oscillation of oil price could cause an uncertainty for Thailand's energy stability. Thai government has realized the energy related situation. They, therefore, proposed to disengage the limited fossil-fueled by the renewable energy such as bio-fuel, solar energy, wind energy, etc. Nevertheless, The Ministry of Energy of Thailand has announced the Renewable Energy Development Plan for fifteen years in 2008 (REDP: 2008-2022). The policy was intended to persuade more players to produce an electrical energy from natural resources and invest in renewable energy more than former periods by giving them promotions like adder in electricity (Table 2.1). However, there are mainly three categories of renewable energy usage in Thailand, which is for electricity, heat, and biofuel.

In addition, the Ministry of Energy also activated the Power Development Plan and the Alternative Energy Development Plan to control the energy security and alternative energy improvement. Nonetheless, the details of energy policies will be discussed in Chapter 2. Notwithstanding, there are still no price-effect indicators of the energy related research in Thailand for linking among economic sectors. Hence, this study aims to investigate the link of promoted renewable energy policies and economy impact, both in macro-level and micro-level.

1.2 Purpose

1.2.1 To investigate the economic impact of the solar and wind energy policy to household and industry institution.

1.2.2 To compare the economic impact of the solar energy and wind energy policy to natural gas energy policy.

1.3 Advantage of the Study

First, the model is constructed for analyzing the solar energy policy in Thailand. Therefore, it would be a beneficial model, for researchers or economists that totally involve with energy sectors, to apply under condition of energy structure in field work. Second, the results from the simulations were studied in the promotion measures of the energy policy, especially household and industry impacts. Thus, these results cound be advantages in wide-range for both macroeconomic and sectoral impacts. Third, this study also discussed about the suitable regions that can generate a great amount of electricity from solar energy. Then, the outcomes could be useful for the investors who would invest in renewable energy equipment for electricity production. Moreover, it would be an advantage to continue the analysis in various impacts such as environmental field, engineering field in sorts of green environment, technological development, respectively. All in all, this dissertation can be a supported literature for anyone who interested in energy policy reforms, including the Ministry of Energy officers such as policy makers and energy researchers.

1.4 Research Design, Unit of Analysis and Method

1.4.1 Unit of Analysis

The research is restricted to investigate the policy impact of solar energy and wind energy to household and industry sector, especially in electricity production in Thailand. The study refers to the ten-year of renewable energy policy from the Alternative Energy Development Plan (AEDP 2015) and Thailand Power Development Plan (PDP 2015). In terms of analysis, the study uses a Computable General Equilibrium approach (CGE) to capture the economic impact of renewable electricity replacement of solar and wind energy to the gas resource, based on 2014 energy statistics of Thailand. However, the study constructs the 2010 Social Accounting Matrix (SAM) by conducting 2010 Input-Output

Table (I-O Table) and 2013 National Income from National Economic and Social Development Board (NESDB). Afterward, the SAM model was used as a benchmark table in Computable General Equilibrium (CGE) through the General Algebraic Modeling System (GAMS). Additionally, the study needs to rearrange the economy production into 14 sectors in order to achieve our objectives.

CHAPTER 2

Theoretical Background and Literature Review

2.1 Economic Theory

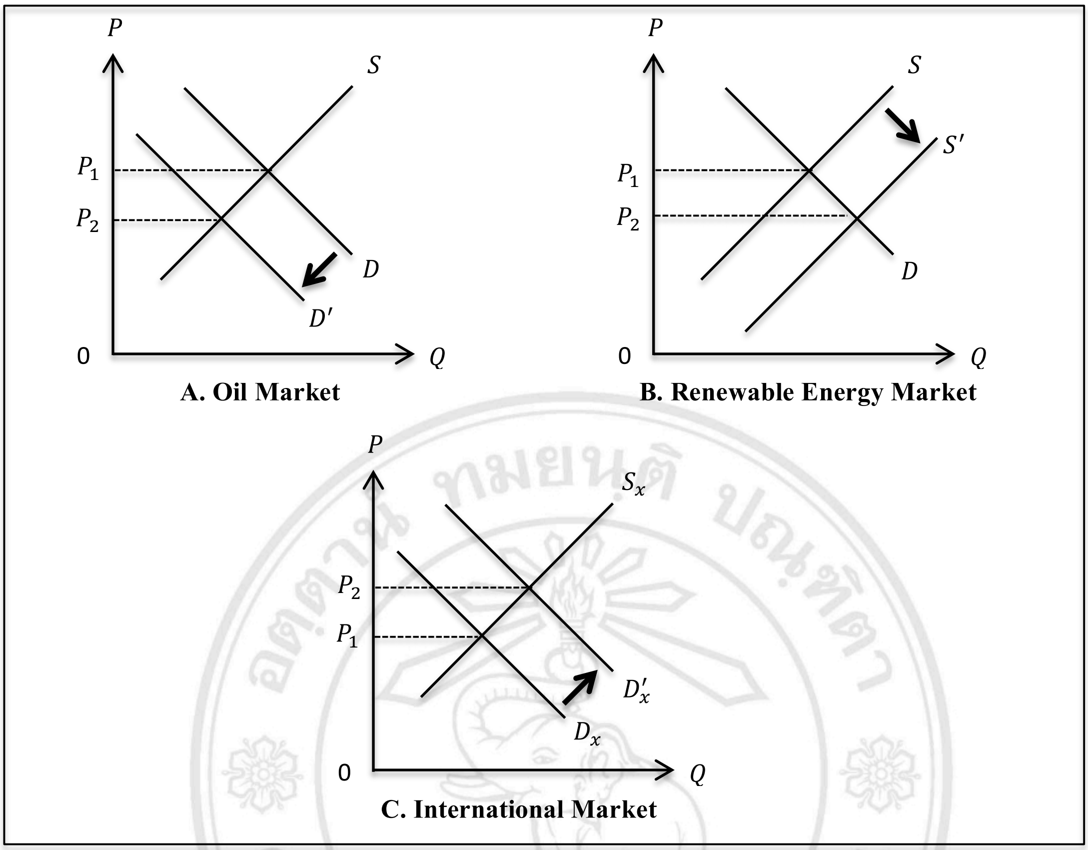
2.1.1 Sectoral Analysis

Social Accounting Matrix or SAM, which is the database of CGE model, reports the value of all transactions in the circular flow of national income and spending in an economy over specific period of time. In addition, SAM demonstrates the accounting reports by balancing between receipts or incoming and expenditure or outgoing of economy sector in terms of square matrix. SAM's column accounts show each agent's spending. Row accounts record each agent's sources of income. Hence, every cell in the SAM matrix describes a single transaction as being simultaneously an expenditure by an agent's column account and the receipt of income by an agent's row account. This procedure records the transaction and visually records how any single transaction links agents in the economy. For instance, the government row represents the government income. This income has only one element which is a government income from regional household in final demand. The government column shows its expenditure which contains demand for domestic good and service, with commodity sector, and sales tax with taxes row. The SAM balancing is when the sums of government income (receipts) and government expenditure (outlays) are equated (Burfisher, 2011).

2.1.2 General Equilibrium Theory

2.1.2.1 Stability of General Equilibrium

The general equilibrium defines that the quantities demanded equals to quantities supplied at the positive price. The price at $Q_d = Q_s$ is called equilibrium price. The equilibrium price is always stable if the demand curve meets the supply curve. Sometimes, an excess demand can drive price to decrease but sometimes an excess supply can drive price to increase. When the equilibrium makes unstable in equilibrium. The expression below can explain the stability of equilibrium well by multiple equilibria in graph.



Source: Own elaboration

Figure 2.1: The Impact of General Equilibrium among markets.

Following the general equilibrium definition, we suppose that the figure A represents the equilibrium of oil price in oil market. When the technology has been changed, the renewable energy become substitution energy instead of oil. At that time, the demand for oil will be decreased which also makes the new equilibrium in oil market and lower price (From P2 to P1). Nevertheless, the explanation in oil market is a partial equilibrium. In terms of general equilibrium, it also impacts other goods market. On the other side, the supply for renewable energy will be increased due to substitution effect of oil price as figure B (on the right), then the supply curve will shift to the right. It also changes the new equilibrium in goods market and influence to lower in price especially for renewable energy. For the international market, the equilibrium also changed following interacts among economy sectors. The demand for oil exports will be inclined and affect to the demand curve, shifting to the right. The new equilibrium and new higher price is found in this market as Figure 2.1.

2.1.2.2 Interdependence in the Economy

A Computable General Equilibrium model depicts the systems as a whole economy and the interaction among system. The equation system describes a consumers' demand or producers' supply followed the macroeconomic identities, including exogeneous, endogeneous variables, and also market clearing constraints. The economist determines the new value of endogeneous variables from the changes of exogeneous variables or "economic shock," which affect to the market equilibrium. The CGE includes demand for all goods and services in the economy.

One way to explain the interrelationships in a CGE model is to explain as a circular flow of income and spending in a national economy as shown in Figure 2.2. To start with, producers purchase inputs for their demand products and also hire factors of production (labor and capital) by return them with wages and rents. The factor of payment increases wage and capital income for the private households. Then, the households spend their income on goods and services, pay taxes to government, and saving. The government uses its tax revenue to buy goods and services, and investor use saving to buy capital investment goods for using in future production activities. The combined demand for goods and services from households, government, and investment constitutes final demand in the economy. Firms produce goods and services in response to this demand, which turn determines input demand, factor employment levels, household wages and rental income and so on, in a circular flow. The role of imports account in meeting of the domestic demand and the role of export demand is added as an additional source of demand for domestic goods. Lastly, the policy as taxes and subsidies as "price wedges" which increase or decrease the prices of goods between buyer and sellers or as transfer directly affect household's level of income and consequently their levels of consumption, savings, and taxes.

A Standard CGE model suppose that factors of production are in fixed supply. Nonetheless, there are both single country and multi-country CGE models for consideration. First, single-country model interprets only one country with export and import markets in reform. Second, multi-country CGE models compose two or more countries and illustrate in country's production, consumption, trade, taxes, tariffs, and so on. The multi-country models are linked to each other through trade and capital flow (Burfisher, 2011).

2.1.2.3 Walrasian System

Computable general equilibrium (CGE) models are based on a Walrasian representation of the economy and create a general equilibrium theory that combines behavioral assumptions regarding rational economic agents with the analysis of equilibrium conditions. They describe the resource allocation process in a market economy, as the result of interaction between demand and supply, generating equilibrium prices and an economy heading to a general equilibrium.

Leon Walras was an economist in 19th century and learnt the interconnectedness for all markets in economy, focusing on a set of existing prices in which the quantity of supply equal to demand in every markets at the same time. For the theory, he features that: (1) producers are profit-maximization who sell their goods in perfectly competitive market at zero economic profit; (2) consumers are utility-maximization who spend all of the income they receive from their production and sale of goods; and (3) prices adjust until demand for each commodity is equal to its supply. Walras's law demonstrates that the total value of excess supply must be equated by the total value of excess demand in the economy. One equation was redundant and has to be dropped out. As a consequence, his model has one more variable than the number of equations. Following to Walras', the solution was to fix one price in the model as a numeraire, which is the benchmark of value against for other price changes.

2.1.3 Compensating and Equivalent Variations

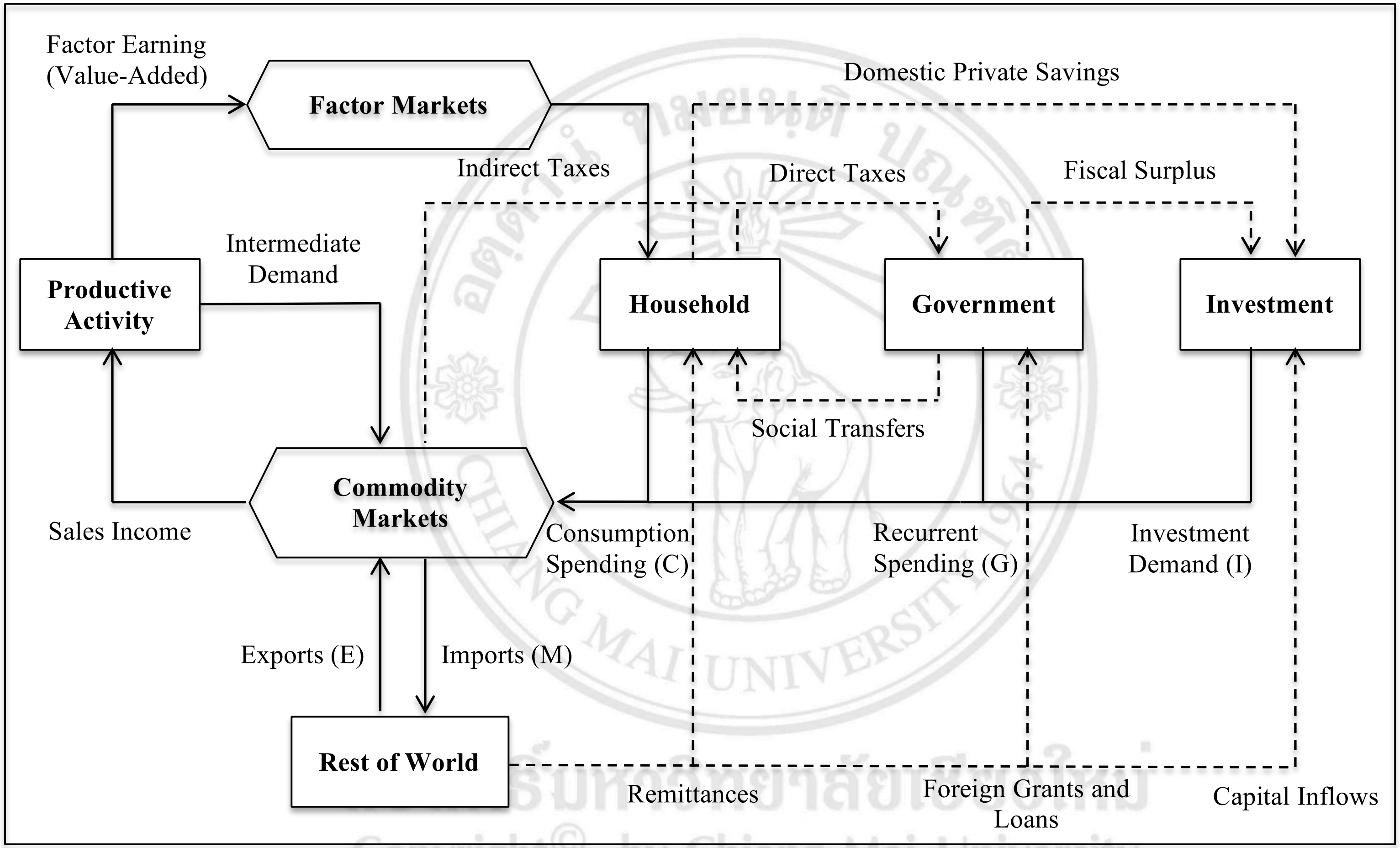
The compensating variation (CV) refers to the amount of money that the individual needs to reach initial utility after an economic change. In terms of welfare gain, compensating variation is the amount of money a person is willing to pay for the change. In terms of welfare loss, it is minus the amount of compensation a person needs for a change. The equivalent variation (EV) refers to the the amount of money (economic welfare) that the individual needs, if an economic change did not occur, to reach the same utility when an economic change. In this case, equivalent variation is the amount of money a person need to forego for the change. In addition, it is the amount of money a person is willing to pay to prevent change before it happens.

The difference between the compensating variation and equivalent variation can be explained by the followings; CV equal actual income subtract additional amount of money an individual need to reach initial utility after price change. However, EV is the income a person needs to achieve utility if price change, when there is no change in price. In other words, the only difference between CV and EV is the utility level at which the cost difference caused by the change in price. While CV is relevant to the level of original utility, EV is concerned with the level of final utility.

2.1.4 The Basic Structure of SAM

Social Accounting Matrices or SAM is a representation of the whole economy in terms of circular flow diagram as shown in Figure 2.3. There are real transfer and transaction, which captures between sectors and institutions. To Start with, productive activities purchase land, labor and capital from factor markets including intermediate inputs from commodities markets and also use these inputs to produce goods and services. Commodity markets like households (C), the government (G), Investors (I) and foreigners (E) could demand for goods and services from imports (M) as the suppliers. Each institution expense turns out as another institution income as followed the circular flow diagram. For instant, the household demands goods and services from commodity markets, then transfers amount of money to producers, after that producers use this money for their production process further. Moreover, international transfers, such as capital inflow and out flow, make sure that the circular flow is closed. On the other hand, all income and expenditure accounts are balanced with no leakages from economy system.

The basic structure of SAM is shown as Figure 2.2, which is demonstrated in specific accounting with quantity of incomes and expenditures in the circular flow diagram. A square matrix is illustrated for the lay out in each row and column that is called "an account". Each of boxes in the diagram is an account in SAM. Each matrix cell is a fund flows from a column account to a row account by convention. Every single row represents an income and every column represents the expenditure. One example of this is the circular flow diagram which shows the industry sectors spending sale taxes and import tariffs from commodities to the government as a fund flows. However, the important principle of SAM requires for an equal of total income and total expenditure. Therefore, an account row and a total column must be equated.



Source: Clemens Breisinger, Marcelle Thomas, and James Thurlow (IFPRI, 2010)

Figure 2.2: Circular Flows Diagram of the Economy.

Income Rows	Expenditure Columns: Activities C1	Commodities C2	Factors C3	Households C4	Government C5	Saving and Investment C6	Rest of World C7	Total
Activities R1		Domestic Supply						Activity Income
Commodities R2	Intermediate Demand			Consumption Spending (C)	Recurrent Spending (G)	Investment Demand (I)	Export Earning (E)	Total Demand
Factors R3	Value-Added							Total Factor Income
Households R4			Factor Payments to Households		Social Transfers			Total Household Income
Government R5		Sales Taxes and Import Tariffs		Direct Taxes				Government Income
Saving and Investment R6				Private Savings	Fiscal Surplus			Total Saving
Rest of World R7		Import Payments (M)						Foreign Exchange Outflow
Total	Gross Output	Total Supply	Total Factor Spending	Total Household Spending	Government Expenditure	Total Investment Spending	Foreign Exchange Inflow	

Source: Clemens Breisinger, Marcelle Thomas, and James Thurlow (IFPRI, 2010)

Figure 2.3: Basic Structure of Social Accounting Matrices (SAM).

Activity and Commodity:

One thing is quite different between Input-Output table and SAM. In IO table, it counts just as goods and services, but SAM separates to Activities and Commodities. Activities are the production process for goods and services, and Commodities are goods and services produced by activities as Figure 2.3. In case of an activity that produces more than one type of commodity or commodity is produced by more than one type of activity, that why SAM is separated for. For illustration, the electricity can be produced by main power generation or independent power plant. So, those accounts are measured prices by government regulations such as adder. Activities combine the production factors and intermediate inputs into produced goods and services. This is assigned in the activity column where activities pay factors as wages, rents, and profits for their production process. The payment account from activity to factor is called “value-added” and shows in the activity column and the factor row as C1-R3. In addition, the payment account from activities to commodities as intermediate demand in C1-R2. Then, adding intermediate demand and value-added together gives gross output. The production data from input-output table is conveyed into the activity column, factors, and also intermediate inputs.

Commodity accounts pay for indirect sales taxes and import tariffs as C2-R5 measured by market prices. Similarly, commodities are supplied domestically as C2-R1 and import as C2-R7. As previous mention, activities use intermediate inputs from commodities in production process as C1-R2. In commodity row shows the different entities of payments, which is consisted of household consumption spending as C4-R2, government consumption (recurrent expenditure) as C2-R2, investment demand as C6-R2, and export demand as C7-R2. SAM usually refers the commodity row and column accounts as a "Supply-Use Table" or total supply of commodities and other different types of uses. However, SAM basically assigns a quantity of various activities and commodities. Those numbers are constructed from the activity and commodity accounts that is normally founded in input-output table and national income account and published by country's statistical bureau.

Domestic Institutions:

The domestic institutions are separated into household and government. Again, SAM is quite different from input-output matrix because it divided the income and expenditure flows to activities and commodities, which is assigned information on different institutional accounts completely. Households are mostly the owners of production factors, so they could earn incomes by factors as C3-R4 and transfer payments such as social security and pension from government as C5-R4 including remittances from the rest of the world as C7-R4. Household must pay taxes directly to the government as C4-R5 and C4-R2 for commodities as well. Moreover, if household get incomes higher than expenditure, then they have saving and investment as C4-R6. On the other hand, the government obtains transfer payments for instance, foreign grants and development assistance from the rest of the world as C7-R5. Then, the government spends those kinds of taxes to pay for recurrent consumption spending as C5-R2 and social transfer to household as C5-R4. Finally, whether the total revenues and expenditures are going to be a surplus or deficit depends on whether revenues exceed expenditure or expenditure exceed revenues as C5-R6. The information accounts for household is normally drawn from national account and household surveys from country's statistic bureau, but for the government, it is published by a country's ministry of finance from public-sector budgets. Additionally, factor account could be usually disaggregated into labor and capital for some countries matrix.

Saving, Investment and the Foreign account:

Accordingly, the total saving and total investment spending must be equal following the account formation. So, the households have a private savings as C4-R6 and also fiscal surplus or public saving from the government as C5-R6. Besides, the total capital inflows from aboard or the current account balance as C7-R6 is assigned for the foreign accounts. In addition, the rest of world account both foreign exchange outflows from imported payment as C2-R7 and foreign inflows such as export from commodities in C7-R2, foreign remittance from household in C7-R4, foreign grant and loan from the government in C7-R5, and current account balance from saving and investment in C7-R6 must be equal as well. Lastly, that information is commonly drawn from the payment balance and published by central bank in each country.

Balance SAM:

This thesis uses various sources of the information to build SAM, for example the intermediate inputs comes from input-output table, factors and government budgets from national accounts, and balance of payments. While the SAM is fulfilled by all those data, the balancing of incomes and expenditure is always inconsistencies. For instance, the government expenditure in national accounts may not be similar with the government budget report. Therefore, the cross-entropy estimation is the general method for balancing SAM account between incomes and expenditure.

2.1.5 The Basic Structure of CGE

The computable general equilibrium (CGE) model is a mathematical system equation which explains a whole economy, and the interaction among its parts. The CGE model shares many features such as exogeneous and endogeneous variables, market-clearing constraints, and identity and behavioral equations. We introduce model closure, which is the design concerning which variable are exogeneous and which variable are endogeneous. The CGE model firstly starts with *Sets*, which are the domain on parameters, variables, and equations, that are subsequently defined.

Economic Properties of CGE Model

Modelers decide which variables are exogeneous and which are endogeneous. These decisions are called *"model closure"*. An example of a closure decision is the modeler's choice between (1) assuming that the economy's labor supply is exogeneous, and an endogeneous wage adjust until national labor supply and demand are equal, or (2) assuming that the economy world is that exogeneous labor supply and demand adjusts until national labor supply and demand are equal.

To demonstrate the important concept of model closure, assume that we interested in the effects of an increase in the demand for electricity, which causes the electricity industry's demand for worker to rise. If we suppose that the nation's total labor supply is exogeneous like fixed in an initial level, then the economy-wide will rise until the worker become full-employment in other industries. However, if the closure instead defines the economy-wide wages as exogeneous and fixed in an initial level, then the getting jobs in the electricity industry can cause full-employment. A change in dimension of a country's labor force changes the productive of capacity of its economy, and the gross domestic product (GDP) will be incline more in a CGE model, which is allowed unemployment reforms more than in a model which the closure fixes the national labor supply.

CGE model includes an exogeneous parameter, which is exogeneous variables in constant values. There are three types of exgeneous parameters: *tax and tariff rates*, *elasticity of demand* and supply, and the shift and share coefficients used in demand and supply equation. First, tax and tariff rates are essentially calculated by the CGE model data. A CGE model database reports the value of the imports in world prices and the amount of tariff revenue that is given to the government. The import tariff rate is calculated in terms of exogeneous parameter.

Import Tariff Rate = *Value of Tariff Revenue Value of Imports in World Price x 100*

Second, *elasticity parameter* is exogeneous parameter and also describe the response of demand and supply to changes in relative pieces and income. In addition, the magnitudes of model results are assumed directly from the elasticity size in the model. Third, supply elasticity parameters contain factor substitution elasticity, factor mobility elasticity, and export transformation elasticity. Factor substitution elasticity, σ_{VA}, describes the demand for factors of production such as labor (L) and capital (K). It illustrates that the flexibility of a production technology would changes in the quantity ratios of factors used in the production of output as relative prices change. Factor mobility elasticity explains the ease with which factor moves across industries in response to industry changing in wages or rents. Export transformation elasticity demonstrates industry's export supply, which is the technological ability of industry to reform in terms of product between the domestic and export markets.

Demand elasticity parameters compose *income elasticity of demand, own- and cross- price substitution elasticity, import substitution,* and *export demand elasticity*. *Income elasticity of demand* describes the effect of changes in income up demand for a commodity. *Own- and cross- price substitution elasticity* measures the response of consumer demand to changes in price of commodities. *Import substitution* relates to consumer demand for import, which described consumers' willingness to shift between imported (QM) and domestically produced varieties in their consumption of commodity i as the relative price of domestic (PD) to imported (PM) varieties changes. In terms of *Export demand elasticity*, single-country describes the rest of the world's demand for a country's exports as a function of its export price.

Shift parameters and *share parameters* are also exogeneous values in demand and supply function. This function describes the production technology of an industry.

$$QO = A(K^{\alpha}L^{1-\alpha})$$

Where QO is the output quantity. Parameter A represents for a shift parameter that describes the productivity of capital (K) and labor (L) in the production process. Parameter α is a share parameter, measuring the share of K in the total income received by labor and capital from their employment in the industry. In addition, labor's income share parameter is $1-\alpha$.

Model calibration calibrates the shift and share parameters in the production and utility functions in the CGE model. The solution is used as the benchmark equilibrium, compared with the result of model experiments. *The behavioral equations* explain the economic behavior of producer, consumers, and other agents based on microeconomic theory. *Identity equation* is defined as a constraint to confirm that the model solves for a market clearing in which quantities supply and demand are equal.

Macroclosure interprets the modeler's decision in two macroeconomic variables, which are saving and investment. They will be adjusted to be equal in CGE model. CGE model converts most of the initial or base prices into $1 or one unit of the currency in procedure by converting data into price and quantity data, which is called "*normalizing prices*". A CGE model reports prices for a single commodity in terms of producer prices, consumer prices, bilateral prices, and global prices.

However, CGE model explicates only relative prices. To demonstrate all prices in relative terms, the modeler chooses one price variable in the CGE model to remain fixed at its initial level. This price of model serves as a "*numeraire*", which is a benchmark of value for measuring with all other prices change. The numeraire and Walras' law are consistent in general equilibrium as mentioned in theoretical part (3.3.2 General Equilibrium).

Table 2.1: Prices in a Multi-country CGE Model.

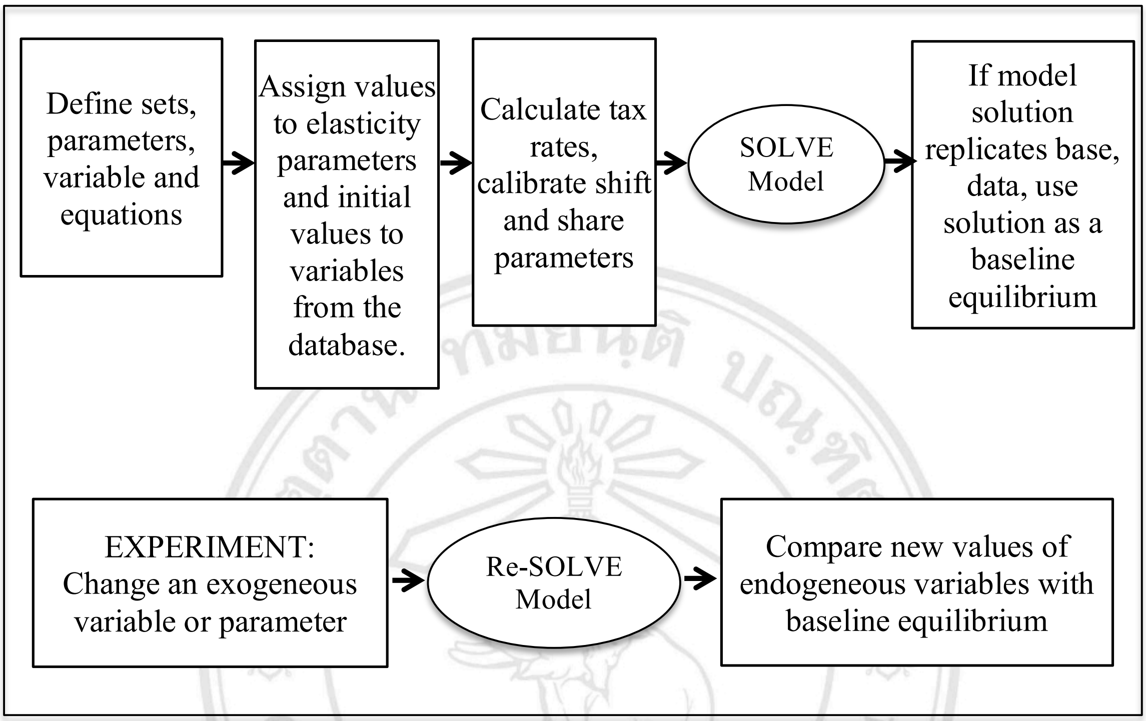
Type of Price	Sets	Definition
Producer piece (ps)	i,r	Cost of production, includes production tax or subsidy
Consumer price (pp)	i,r	Producer price plus sales tax (domestic variety) and bilateral *cif* import price import tariff and sales tax (import variety)
Bilateral import price (pcif)	i,r,s	Exporter's bilateral export price plus *cif* trade margins, excluding tariff
Bilateral export price (pfob)	i,r,s	Exporter's domestic producer price plus export tax
World import price (pim)	i,r	Trade-weighted sum of bilateral *cif* import price in country *r*
World export price (piw)	i,r	Trade-weighted sum of bilateral *cif* export price in country *r*
Global price (pxw)	i	Trade-weighted sum of all countries's bilateral export prices

Notes: i = set of commodities, r = the exporting country and s = the importing country

Source: Adopted from Burfisher, 2008

Basic Structure of CGE Model

A CGE model has the lengthy programing code, which is organized into small number of blocks to reach in the different tasks. Those tasks define each of the sets, exogeneous and endogeneous variables, and exogeneous parameters used in the model. Therefore, the modeler must define each of the elements in the model code before recognizing and using them. The figure below is shown to illustrate the step of model solution and the experiment from the change of exogeneous variable that causes new equilibrium value to all endogeneous variables.



Source: Adopted from Burfisher, 2011

Figure 2.4: Structure of a CGE Model and Experiment.

The Mathemetical of CGE:

1 The Social Accounting Matrix (SAM): The Algebra of Equilibrium

Following the circular flow is mentioned for the general equilibrium in Chapter 2.1 (General Equilibrium Theory). The boundary is considered under the hypothesis of closed free-market economy, which is comprised of *N* industries producing its product, and an anonymous number of households possessing an endowment of *F* in different kinds of primary factor together. Thus, we follow three assumptions to keep things simple about this economy (Sue Wing, 2004). Firstly, there are no tax or any subsidy distortions, or quantitative restrictions on the trade. Secondly, the households jointly behave as a single representative agent that earn income in exchange for renting the factors to the industries, and then households spend them to purchase the *N* commodities for their satisfaction in *D* types of demands. Thirdly, industry acts as a representative firm that employs inputs of the *F* primary factors and uses numbers of the *N* commodities as the intermediate inputs to produce a quantity *y* of its industry type of output.

To start with, in the mathematical part, the indices, $i = \{1, ..., N\}$ stand for the set of commodities, $j = \{1, ..., F\}$ for the set of primary factors, and $d = \{1, ..., D\}$ for the set of final demands. Afterward, the circular flow in the economy could entirely be identified by the three data matrices; $N \times N$ the input-output matrix of industries usage in commodities as intermediate inputs, signified by $\bar{\mathbf{X}}$, and $F \times N$ matrix of primary factor inputs to industries, denoted by $\bar{\mathbf{V}}$, and an $N \times D$ matrix of commodity uses by final demand activities, implied for $\bar{\mathbf{G}}$.

It is absolutely forthright approach to establish the elements of those three matrices may be prescribed to manifest the logic of the circular flow. First, the market clearance of commodity implies that the value of total output of industry i, which is value of the aggregate supply of the i^{th} commodity, $\bar{y}_i$, must equal to the sum of the j intermediate uses of that good, $\bar{x}_{ij}$, and the d final demands $\bar{g}_{id}$ which engage that

$$(1) \qquad \bar{y}_i = \sum_{j=1}^{N} \bar{x}_{ij} + \sum_{d=1}^{D} \bar{g}_{id} x$$

Likewise, the factor of market clearance indicates that the firms in the economy fully employ the representative agent's endowment of a factor, $\bar{V}_f$:

$$(2) \qquad \bar{V}_f = \sum_{i=1}^{N} \bar{v}_{fi}$$

The second equation shows that the value of gross output of j^{th} sector, $\bar{y}_j$, have to be equal to the summation of the benchmark values of inputs of the i intermediate goods $\bar{x}_{ij}$ and f primary factors $\bar{v}_{fi}$ which the industry employs in its own production:

$$(3) \qquad \bar{y}_j = \sum_{i=1}^{N} \bar{x}_{ij} + \sum_{i=1}^{F} \bar{v}_{fi}$$

The third equation is the representative agent's income, $\bar{m}$, which is the receipts from the rental of primary factors – none of which idle, and have to balance the total expenditure of the agent on satisfaction of commodity demands. These conditions indicate that income must to equate the sum of the elements of $\bar{V}$, which become equivalent with the sum of the elements of $\bar{G}$ following the equation (2).

$$(4) \qquad \bar{m} = \sum_{f=1}^{F} \bar{V}_f = \sum_{i=1}^{N} \sum_{d=1}^{D} \bar{g}_{id}$$

As the relationships in equation (1)-(4) imply that, the matrices $\bar{X}$, $\bar{V}$, and $\bar{G}$ should be arranged to demonstrate the logic of the circular flow.

2 The Computing General Equilibrium (CGE) model: The Algebra of Equilibrium with The Cobb-Douglas Economy

The previous mathematics framework of the SAM reflects the imposition of producer axiom and consumer maximization. To demonstrate this, we use the pedagogic device of a "Cobb-Douglas economy". The Cobb-Douglas can be explained in households as representative agents in terms of Cobb-Douglas preferences and also industry sectors as representative producers in terms of Cobb-Douglas production technologies.

2.1 Households

The household acts as a representative agent which maximize utility U by selecting the consumption level c of the N commodities in the economy, subject to their budget constraints, m, under the commodity price p. The household agent may demand goods and service to achieve their purposes of consumption – in the present example savings – which are assumed to be exogenous and constant. Thus, the problem of an agent is:

$$(5) \qquad \max_{c_i} U(c_1,...,c_N) \qquad \text{subject to}$$

$$m = \sum_{i=1}^{N} p_i(c_i + s_i)$$

The representative agent is supposed to has Cobb-Douglas preferences, so that the utility function is:

$$U = A_C c_1^{\alpha_1} c_2^{\alpha_2} ... c_N^{\alpha_N} = A_C \prod_{i=1}^{N} c_i^{\alpha_i} \quad ,$$

with $\alpha_1 + ... + \alpha_N = 1$. The equivalent mean that the representative agent maximizes the "profit" from the production of the "utility good" or U whose output is grown by consumption, and whose price p_U is the margin utility of aggregate consumption, which can be used as the numeraire price in the economy. So, equation (5) is equivalent to the problem:

$$(6) \quad \max_{c_i} p_U U - \sum_{i=1}^{N} p_i c_i$$

subject to the utility definition above, the resulting of this problem yields the representative agent's demand function for the consumption of the i^{th} commodity:

$$(7) \quad c_i = \alpha_i \frac{\left(m - \sum_{i=1}^{N} p_i s_i\right)}{p_i}$$

Re-arrange the yields $\alpha_i = \dfrac{c_i p_i}{\left(m - \sum_{i=1}^{N} p_i s_i\right)}$, which shows that the exponents of the utility function may be interpreted as the shares of each commodity in the total consumption value. However, other components of final demand such as saving or investment may be simply conducted directly as a demand functions, or the representative agent's utility function may be expanded to consolidate the representative agent's preferences for other types of expenditure.

2.2 Producers

The producer maximizes profit π by picking up levels of N intermediate inputs x and F primary factors v to produce output y, subject to the constraint of its technological production ϕ. The j^{th} producer's problem is thus:

$$(8) \quad \max_{x_{ij} v_{fj}} \pi_j = p_j y_j - \sum_{i=1}^{N} p_i x_{ij} - \sum_{f=1}^{F} w_f v_{fj} j^{th} \qquad \text{subject to}$$

$$y_j = \phi(\cdot)_j \left(x_{1j}, \ldots, x_{Nj}; v_{1j}, \ldots, v_{Fj}\right)$$

Allow the producer have Cobb-Douglas production technology, therefore its production function $\phi(\cdot)$ is a recipe to combine intermediate inputs and primary factors of the form

$$y_j = A_j\left(x_1^{\beta_1}x_2^{\beta_2}...x_N^{\beta_N}\right)\left(v_1^{\gamma_1}v_2^{\gamma_2}...v_F^{\gamma_N}\right) = A_j\prod_{i=1}^{N}x_{ij}^{\beta_{ij}}\prod_{f=1}^{F}v_{fj}^{\gamma_{fj}} \ ,$$

with $\beta_{1j}+...+\beta_{Nj}+\gamma_{1j}+...+\gamma_{Nj}=1$. The outcome by solving the problem in (8) yield producer *j*'s demands for the intermediate inputs of commodities:

$$(9) \quad x_{ij} = \beta_{ij}\frac{p_j y_j}{p_i} \ ,$$

and its demands for primary factor inputs:

$$(10) \quad v_{fj} = \gamma_{fj}\frac{p_j y_j}{p_f} \ ,$$

Re-arrange the equation (9) and (10) yield $\beta_{ij} = \dfrac{p_i x_{ij}}{p_j y_j}$ and $\gamma_{fj} = \dfrac{w_f v_{fj}}{p_j y_j}$, respectively. These equations are shown, similar to the demand for consumption goods above. And the exponents of the Cobb-Douglas production function illustrate the shares of their respective inputs to production in the output value.

2.3 General Equilibrium

As the equation (7), (9), and (10) are the building blocks from a CGE model which is constructed and used to solve for equilibrium by substituting these elements into general equilibrium conditions. Thus, the algebraically equation in this section must be re-formulated for the appropriately Cobb-Douglas economy.

Following the conditions for general equilibrium in the Cobb-Douglas economy, market clearance implies that the quantity of each commodity produced must equal the sum of the quantity of that commodity demanded by the *j* producers in the economy as an intermediate input to production while the representative agent as an input to consumption and saving activities. Thus, equation (1) expresses:

$$(11) \quad y_i = \sum_{j=1}^{N}x_{ij} + c_i + s_j$$

Moreover, the quantities of primary factor *f* used for all producers must sum to the representative agent's endowment of that factor, V_f.

The equation (2) expresses this condition that:

$$(12) \quad V_f = \sum_{j=1}^{N} v_{fj}$$

The equation between the output value generated by producer *j* and the value of the inputs of the *i* intermediate goods and *f* primary factors employed in production, which is implied of zero profit. Besides, this condition is easily subtracted by setting the right-hand side of equation (8) to zero and rearranging, which is the analogue of equation (3):

$$(13) \quad p_j y_j = \sum_{i=1}^{N} p_i x_{ij} - \sum_{f=1}^{F} w_f v_{fj} \text{ ,}$$

Income balance explains that the income of the representative agent must equal the value of producers' payments to her for the use of the primary factors that they owns and hire out, thus, as in equation (4):

$$(14) \quad m = \sum_{f=1}^{F} w_f V_f$$

The four equations can be expressed the core of a CGE model in easily specification. Then, placing (7) and (9) into equation (11), and (10) into equation (12) yields two excess demand vectors that determine the divergence Δ^C between demand and supply in the market for each commodity and the divergence Δ^F between demand and supply in the market for each primary factor. Furthermore, the absolute of the sets of different values are minimized to zero in general equilibrium. There are *N* such excess demand equations for the commodity market:

$$(15) \quad \Delta_i^C = \sum_{j=1}^{N} \beta_{ij} p_j y_j + \alpha_i \left(\sum_{f=1}^{F} w_f V_f - \sum_{j=1}^{N} p_j s_j \right) + p_i s_i - p_i y_i$$

and *F* equation standing for the factor market:

$$(16) \quad \Delta_f^F = \sum_{j=1}^{N} \gamma_{fj} \frac{p_j y_j}{w_f} - V_f$$

The absolute value of producers' profit is minimized to zero in general equilibrium as the zero profit condition. Thus, replacing equation (9) and (10) into the production function, and writing N pseudo-excess demand function that specify the per-unit excess profit (i.e. excess price over unit cost) Δ^{π} in each industry sector.

$$(17)\quad \Delta_j^{\pi} = p_j - A_j \prod_{i=1}^{N} \left(p_i / \beta_{ij} \right)^{\beta_{ij}} \prod_{f=1}^{F} \left(w_f / \gamma_{fj} \right)^{\gamma_{fj}}$$

Lastly, the income balance condition (14) can be re-written in terms of the excess of income over returns to the agent's endowment of primary factors, Δ^{m}:

$$(18)\quad \Delta^{m} = \sum_{f=1}^{F} w_f V_f - m$$

A General equilibrium is consequently the joint minimization of $\Delta^{C}, \Delta^{F}, \Delta^{\pi}, \Delta^{m}$.

3 The Computing General Equilibrium (CGE) model: The Formulation, Calibration and Solution

3.1 Model Formulation

There is such the way that a CGE model solves for an equilibrium. The model uses equation (15) – (18) to obtain a solution. However, the formulations express a system of *2N + F* equations in *2N + F* unknown: a *N*-vector of industry output- or "activity" levels $\mathbf{y} = [y_1, ..., y_N]$, an *N*-vector of commodity price $\mathbf{p} = [p_1, ..., p_N]$, an *F*-vector of primary factor prices $\mathbf{w} = [w_1, ..., w_N]$, and a scalar income level *m*. The problem of defining the vector of activity levels and prices that supports general equilibrium to consist of choosing values for these variables to solve the problem.

$$(19)\quad \xi(z) = 0,$$

For $z = [p, w, y, m]'$ stands for the vector of stacked price, level of activity and level of income, and $\xi(\cdot) = [\Delta^{C}, \Delta^{F}, \Delta^{\pi}, \Delta^{m}]'$ is the stacked system for pseudo-excess demand equations, which systematizes the whole production of pseudo-excess demand for economic correspondence.

The equation (19) expresses in complementarity existing between prices and excess demands, and between activity levels and profit. For the equilibrium in terms of economic definition, prices, level of activity, and income are all positive and finite $(0 \le z < \infty)$. While value of z approaches zero in the limit equation (15), (17), (18) all approach zero. And equation (16) tends to $-V_f$,implying that $\xi(0)=[0, -V, 0, 0]' \le 0$. If $z*$ represents for a vector of prices and activity and income levels on general equilibrium, it must be $0 \le z*$ and $\xi(z*) = 0$.

$$(20) \quad z \ge 0 \qquad \text{subject to} \quad \xi(z) \ge 0, \quad z'\xi(z) = 0,$$

which is the sum of the values of market demands equal to the sum of the values of market supplies following mathematical statement of Walras's Law.

3.2 Numerical Calibration Using the SAM

Consequently, the problem in equation (20) is still a non-linear along with the result that is no close-form analytical solution for z. That is a reason why the general equilibrium systems with realistic utility and productions must have calibrated on a SAM of the kind discussion in the section 3.3 (The Solution of a CGE Model in a Complementarity Format), conducting a numerical optimization problem that we can use optimization techniques for solution.

This numerical calibration is simply accomplished in the Cobb-Douglas economy. The underlying step in this consideration is to compare equation (1) - (4) with equation (11) - (14). To illustrate, the pairs (1) and (11), (2) and (12), (3) and (13), and (4) and (14) describe a striking symmetry. Specifically, the elements of each pair are equivalent as $\pi_j = 0$ (assume to zero profit), $p_i x_{ij} = \bar{x}_{ij}$ and $w_f v_{fj} = \bar{v}_{fj}$. Accordingly, a fundamental equivalence has drawn between the equations in a CGE model and the benchmark flows of value in a SAM by defining all prices in the benchmark year are equal to unity.

The observation is the foregoing crucial of the simplest calibration procedure by which a CGE model is "proper" to the benchmark equilibrium recorded in a SAM. Additionally, all prices are set as index numbers with a value of unity in the benchmark, and all those value flows into a SAM that are treated as benchmark quantities. The assumptions let the technical coefficients and elasticity parameters of the utility and production functions to be solved for directly. (3rd Mansur and Whalley, 1983)

(21) $\alpha_i = \bar{g}_{iC} / \bar{G}_C$,

(22) $A_C = \bar{G}_C \Big/ \left(\prod_{i=1}^{N} \bar{g}_{iC}^{\alpha_i} \right)$,

(23) $\beta_{ij} = \bar{x}_{ij} / \bar{y}_j$,

(24) $\gamma_{fj} = \bar{v}_{fj} / \bar{y}_j$,

(25) $A_j = \bar{y}_j \Big/ \left(\prod_{i=1}^{N} \bar{x}_{ij}^{\beta_{ij}} \prod_{f=1}^{F} \bar{v}_{fj}^{\gamma_{fj}} \right)$,

(26) $s_i = \bar{g}_{iS}$,

(27) $V_f = \bar{V}_f$, and

(28) $\bar{m} = \sum_{f=1}^{F} \bar{V}_f$

After solving the numerical problem in equation (20), then the quantities of the variables in the Cobb-Douglas economy will equal to the values of the corresponding flows in a SAM (i.e., $x_{ij} = \bar{x}_{ij}$, $v_{fj} = \bar{v}_{fj}$, and $c_i = \bar{g}_{iC}$), and duplicating the benchmark equilibrium.

3.3 The Solution of a CGE Model in a Complementarity Format

The procedure of calibration transforms (20) to a square system of numerical equations known as a *nonlinear complementarity problem* or *NCP* (3rd Ferris and Pang, 1997), by using algorithms for the solution. Previously, Mathiesen (1985) and Rutherford (1987) indicate the fundamental method, which is corresponding to a Newton-type steepest-descent optimization algorithm (3rd Kehoe 1991: 2068-2072). However, the algorithm repeatedly solves a sequence of *linear complementarity problems* or *LCPs* (3rd Cottle et al 1992), each of which is the first-order Taylor series expansion of the non-linear function ξ. Hence, the *LCP* determined in each iteration is one of finding:

(29) $z \geq 0$ subject to $q + Mz \geq 0$, $z'(q + Mz) = 0$,

where, the linear ξ around $z_{(k)}$, the state vector of price activity levels and income at iteration k, $q(z_{(k)}) = \nabla\xi(z_{(k)})z_{(k)} - \xi(z_{(k)})$ and $M(z_{(k)}) = \nabla\xi(z_{(k)})$. The initial point is $z_{(0)}$, and solution of the problem (21) at the k^{th} iteration $z^{*}_{(k)}$ collects the value of z following to:

$$(30) \quad z_{(k+1)} = \mu_{(k)} z^{*}_{(k)} + (1 - \mu_{(k)}) z_{(k)}$$

where the parameter $\mu_{(k)}$ expresses the forward step in z that the model can takes repeatedly. The convergence criterion contains equation (29) and (30) that is the numerical analogue of equation (19): $\left\|\xi(z_{(k)})\right\| < \varpi$, in which the scalar of ϖ is the maximize tolerance level of excess demands, profits, or income considered by the analysis to have converged for the equilibrium.

3.4 Existence and Uniqueness of Equilibrium in the Cobb-Douglas Economy

The previous explanation discusses how to finding an equilibrium, how to calibrated on real-world economic data for solution in a CGE model with a variety of price and quantity distortions. Nevertheless, the answer is both involved and elusive, following it hinges on three important underlying issues which span theoretical and empirical literatures on general: the existence, uniqueness, and stability of equilibrium (as section 3.3.1: stability of equilibrium).

4 The General Equilibrium Effects of Tax Distortions: Policy Analysis

To demonstrate the analysis of the distortion and phenomenon effect in taxation, we use the Cobb-Douglas economy to precede this section. In a CGE model, taxes are essentially specified in ad-valorem method, by which a tax given rate describes the fractional increase in the price level for the tax commodity. For instance, an ad-valorem tax at rate τ on the industry output j drives a wedge between the producer price of output p_j and the consumer price $(1+\tau)p_j$, generating revenue from y_j output units in amount of $\tau p_j y_j$. Anyways, the subsidy that drops the price down may be also incorporated, by specifying $\tau < 0$.

There are four types of market in the economy in which ad-valorem taxes or subsidies can be imposed: the market for input to production of intermediate goods and primary factors in each industry. The tax or subsidy rates, which is signified by τ_j^Y, τ_i^C, τ_{ij}^X, and τ_{fj}^V for each market in economy, respectively. The representative agent's problem turns out to be:

$$(6') \quad \max_{c_i} p_U U - \sum_{i=1}^{N} (1+\tau_i^C)(1+\tau_i^Y) p_i c_i$$

subject to the constraint of the Cobb-Douglas function, and the producer's problem is:

$$(8') \quad \max_{x_{ij}, v_{fj}} \pi_j = p_j y_j - \sum_{i=1}^{N} (1+\tau_{ij}^X)(1+\tau_i^Y) p_i x_{ij} - \sum_{f=1}^{F} (1+\tau_{fj}^V) w_f v_{fj}$$

subject to the constraint of the Cobb-Douglas function that also apply to the commodity and factor of demand function in equation (7), (9) and (10) as follows:

$$(7') \quad c_i = \alpha_i \frac{\left(m - \sum_{i=1}^{N} (1+\tau_i^Y) p_i s_i \right)}{(1+\tau_i^C)(1+\tau_i^Y) p_i},$$

$$(9') \quad x_{ij} = \beta_{ij} \frac{p_j y_j}{(1+\tau_{ij}^X)(1+\tau_i^Y) p_i}, \qquad \text{and}$$

$$(10') \quad v_{fj} = \gamma_{fj} \frac{p_j y_j}{(1+\tau_{fj}^V) w_f}$$

Nevertheless, each of the taxes (subsidy) outlined previously conducts a positive (negative) revenue stream, which is from an accounting in both increasing (decreasing) the income of any agents and negative (positive). The representative-agent models simulate the incident by treating the government as a passive existence that raise tax revenue and promptly returns it to the single household as a lump-sum supplement to the income from factor returns. The forward's income then becomes:

$$(14') \quad m = \sum_{f=1}^{F} w_f V_f + \underbrace{\sum_{j=1}^{N} \tau_j^Y p_j y_j}_{\substack{\text{Output} \\ \text{tax revenue}}} + \underbrace{\sum_{i=1}^{N} \tau_i^C p_i c_i}_{\substack{\text{Consumption} \\ \text{tax revenue}}} + \underbrace{\sum_{i=1}^{F} \sum_{j=1}^{N} \tau_{ij}^X p_i x_{ij}}_{\substack{\text{Intermediate input} \\ \text{tax revenue}}} + \underbrace{\sum_{f=1}^{F} \sum_{j=1}^{N} \tau_{fj}^V w_f v_{fj}}_{\substack{\text{Factor} \\ \text{tax revenue}}}$$

This equation expresses along with equation (7') and (9'), when replaced into (11), equation (10'), when replaced into (12), and equation (9') and (10'), when replaced into the production function, arrange the basis for a new excess demand correspondence that, when cast in the format of equation (20) may be examined to yield a new, tariff-ridden equilibrium. On the other hand, the welfare effect of a single tax or subsidy therefore depends on the interaction of factors: the tax level and the distribution of other taxes and subsidies across whole markets in the economy, the characteristic of the specific market that the tax is imposed, the linkages between this market and other markets in the economy, and the values of calibrated parameters A, α, β, and γ.

5 Taxes in a $2\times2\times1$ Cobb-Douglas Economy

This model is a Cobb-Douglas economy that is a single representative agent, two industries $(j=\{1,2\})$, each of which produces a single output $(i=\{1,2\})$, and two primary factors of production, labor L and capital $K(f=\{L,K\})$. These data indicate the benchmark equilibrium for a CGE model whose excess demand is consistent to equation (15) - (18), the calibrated parameters are according to equation (21) - (27). Due to the benchmark equilibrium, there are no any taxes. Hence, the values of τ_j^Y, τ_i^C, τ_{ij}^X, and τ_{fj}^V are primarily zero.

2.1.6 Theory and Structure of GAMS

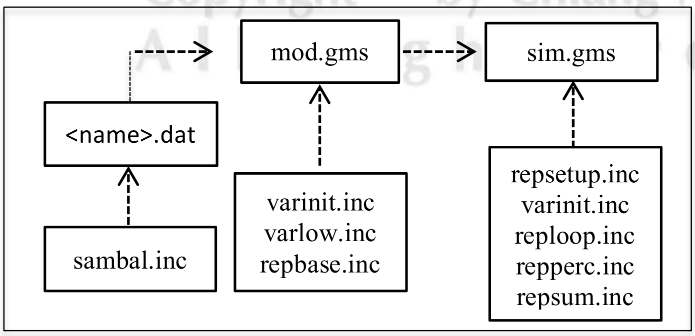
The General Algebraic Modeling System or GAMS is a computer modeling language, which contributes and facilitates for CGE model especially in a wider group of economists. The standard CGE model is written for application at the country level and has been implemented with an amount of country data sets but the minimal changes are needed to apply the model to a region within a country or to a producer, consumer and household agents. In addition, a number of features have designed to indicate the characteristics of developing countries. This specification has followed the neoclassical modeling tradition presented in Dervis et al (1982). It consolidates supplementary features developed in research projects conducted at IFPRI. These features include household consumption of non-marketed or home commodities, explicit treatment of transaction costs for commodities, which join into the market sphere, and a separation between production activities and commodities that allows any activity to produce.

The GAMS data provides sample databases, simulations, solution reports, and a social accounting matrix (SAM) aggregation program for the CGE model. In the GAMS code, the model is explicit linking to country data, including a standard SAM that follows the format requires and a set of elasticity for the standard CGE model. In terms of model code, a set of data is used to define model parameter values that ensures the base solution to the model exactly reproduce in SAM. On the other hand, the model is calibrated to the SAM. All in all, the CGE model and the accompanying GAMS code are composed to give analysts considerable flexibility in alternative treatments for macroeconomic balances and for factor markets. Due to flexibility, in sorts of model structure and the fact that model parameters are derived from an empirical database permit the analyst to capture specified country aspects of economy structure and function.

A social accounting matrix or SAM is a square matrix in which each account is represented for the payment by a row and a column, as mentioned in 3.4.1 (The Basic Structure of SAM). The underlying principle requires that total revenue equals total expenditure for each account in SAM. For one exception, it has all of the features required for implementation with the standard CGE model. This exception is that in the standard SAM, taxes must be paid to tax accounts, is aggregated by tax types each of which forwards its revenues, to the core government account. The tax types comprise direct taxes (domestic non-government institutions and factors), commodity sales taxes, import taxes, export taxes, activities tax, and value-added taxes. By the ways, any conventional SAM that contains such payments should be re-structured before being implemented with the standard CGE model. In terms of technical, the standard CGE model requires that the SAM have at least one household account; enterprise accounts are not important. The standard CGE model also accepts the SAM without explicit home consumption.

The GAMS has the specific modeling system. It is segmented into two main files, “*mod.gms*” and “*sim.gms*”. To start with sambal.inc, which is a simple program to balance the SAM if its account is imbalance including “*mod.gms*” and “*sim.gms*”. This segmented correspond to the two main steps in a regular CGE modeling project. First is “*mod.gms*”, which is identical set-up and calibrated to a country data sets that is read from include file “*<name>.dat*”. If the account imbalances in the SAM exceed a low cut-off point, a simple SAM balancing program as “*sambal.inc*” will be activated. Then, the file “*varinit.inc*” is also activated to initialize all variables at base levels. In the optional file as “varlow.inc”, which is the lower limits close to zero imposed for selected variables as performance solution. There are two models inside “*mod.gms*”, one for “mixed – complementarity programing or MCP” and one for “nonlinear programing or NLP” solvers. MCP model is identical to the model that discuss above but the NLP model is also including an objective function, which is an optimization problem and has no any influence on the solution because there is only a feasible solution that satisfies all constrains. After the model has been solved for the base, the program calls up the file as “*repbase.inc*” that generates a report on the solution.

In file “*sim.gms*”, which normally recalls the simulation from the file of “*mod.gms*”. For simulation steps, the solver has to choose the base levels of the model variables between alternative closures for macroeconomic constraint and factor markets by including the file of “*varinit.inc*”. The file of “*repsetup.inc*” defines the report parameters and definition of sets used in report. Next, the file of “repsum.inc” reports the highlight information of interest in a specific application. The modeling system can be shown in a variety of ways. First is carry out simulations with one of the existing data sets without any changes in the modeling structure or. The file of “*sim.gms*” summarizes the steps to carry out additional simulations. Second approach is taking the additional step of applying the model to their data set, and generating a properly formatted SAM. Before handing that way, the SAM should have the same format as GAMS such as a different treatment of taxes. A different formatted SAM is likely to be more time consuming and error-prone. The third approach is a combination of 1 and 2. The model could be change in the files “*mod.gms*” and “*<name>.dat*” as sets, parameters, variables, and equations) are modified and declared, and defined.



Source: IFPRI (2002)

Figure 2.5: The Structure of GAMS Model and Data Files.

2.2 Policy Review

2.2.1 Thailand's major energy regulatory framework

Thailand's main energy has been planned a long-term energy policy in the Power Development Plan (PDP, 2012-2030). This evidence is the initially planning regarding national electricity production. Additionally from the PDP, there are the Climate Change Master Plan (CCMP, 2012-2050), the Alternative Energy Development Plan (AEDP, 2012-2021) and the Energy Efficiency Plan (EEDP, 2011-2030). There planning are addressing the range of energy efficiency, renewable energy and also climate change. Both of AEDP and EEDP were prepared by the Ministry of Energy. By the way, ARDP is developed by the Department of Alternative Energy Development and Energy Effieciency (DEDE) and EEDP by the Energy Policy and Planning Office (EPPO). Recently, the NEPC declared to revise the PDP in the way that integrate AEDP and EEDP and therefore create a more inclusive approach for the consolidated energy planning.

2.2.2 Thailand Power Development Plan (PDP: 2015-2036)

This plan was revised in the second half of 2014 and was actived up to 2036. It has three mianly principles. At first, the security of power supply, transmission system and distribution system to the demand of electricity that supports conomy and social development plan is a guiding principle. The variety of fuels have to avoid relying too much on gas. Next, the electricity price to reflect the cost of energy more suitable and ensuring an efficient energy consumption is considered to slow down the construction of new power plant and to decline energy imports, thus as a rationale for the new PDP. Lastly, the PDP aim to reduce negative impacts on the environmental and communities especially carbon dioxide emission per unit of electricity production by promoting electricity production fron renewable energy and also promoting energy efficiency. The latest PDP (2015-2036) is assuming GDP growth average 3.94% that is insignificantly below the 4.41% that was used in the previous PDP from 2010. Nevertheless, it is depended on the assumption of increased energy efficiency and energy conservation campaigns. This plan added the capacity up to 57,400 MW in the end of 2036, thus the country's electricity capacity would be 70,410 MW in 21 years from now. Obviously, it also focuses on the cleaner fuel and natural gas reduction. The target mainly capacity should come from biomass or "clean coal", nuclear and importing power from neighbor countries. The policy maker aims to cut the share of natural gas to 30-40% from currently 64%. All in all, the proportion of renewable energy consumption will rise to 15-20% from currently 9%.

2.2.3 Alternative Energy Development Plan (AEDP 2015-2036)

The Alternative Energy Development Plan (AEDP) is now being modified that also effected to the target plan. The target of AEDP is to install capacity of alternative energy at 19,635 MW within 2036. From the currently is around 7,279 MW in 2014 following the Table 2 (The target plan of Renewable Energy Development Plan (REDP, 15 years) and Alternative Energy Development Plan (AEDP, 10 years) comparing to Thailand's energy comsumption in the current situation). Anyways, the AEDP has beeing keeped the ongoing plan. Firstly, the power generation fron waste, biomass, and biogas are more consideration. Secondly is the allocation of renewable energy generation capacity according to the demand and potential in regions and provinces. Thridly, the promotion of solar and wind power at a stage of "once the cost is competitive with the power generation from Liquefied Natural Gas (LNG). Fourthly, the competive bidding is going to be employed as a alternative process for the FIT application replacing of the "first-come first-serve" procedure. Lastly, the renewable energy comsumption would be increased from 8% to 20% of final energy consumption within 2036.

2.2.4 Renewable Energy Development Plan (REDP, 2008-2022)

The REDP was being ongoing plan that the National Energy Policy Council (NEPC) who approved a fifteen year of Renewable Energy Development Plan (REDP: 2008-2022) since January'2009 which is classified into three phases. The short-term is from 2008 to 2011, focusing on proven renewable energy technologies promotion and the high-potential renewable energy resources such as biofuels, power generation, and thermal energy from biomass and biogas with full financial support. The goal is to develop the RE at the amount of 10,961 ktoe or 15.6 percent of the total energy consumption (Table 2.1). Next, the mid-term is from 2012 to 2016, concentrated on the efforts to promote the renewable energy technology industry, to support the new renewable energy technology prototype development to make it economically sound, and to encourage new technologies in the biofuels production, the green city model development, and the strengthening of the local energy production. The goal is to develop the renewable energy at the amount of 15,579 ktoe or 19.1 percent of the total energy consumption (Table 2.2). The long-term is from 2017 to 2022, emphasized on the promotion of economically viable new renewable energy technology including the further implementation of the green city and local energy, and to promote Thailand as the ASEAN biofuels and renewable energy technology export hub. The goal is to develop the RE at the amount of 19,799 ktoe or 20.3 percent of the total energy consumption (Table 2.2). Anyways, those kinds of support both the latest AEDP and REDP including PDP 2015 are still maintain the ESCO fund that we will brief in the next paragraph including the conventional way of adder cost, which is supported to investor.

Thailand has a potential production in solar energy. Anyways, the cost of production still be high compared with generating an electricity from domestically fossil. Therefore, the measures intend to promote policy and persuade people for expanding an electricity production by solar energy. There are six flags in promoting measures to support this plan. To start with, Adder cost which is the Ministry of Energy given high-priority for renewable energy as Solar, Wind and Bio energy to induce greater investment by repurchasing the electricity from very small power producer (VSPP) in terms of Feed-in Tariff (FiT). In addition, a small power projects that could be installed within household or community, including the Solar PV Rooftop for residential units, community, office buildings, factories, and public buildings.

Table 2.2: Adder for Renewable Energy Power Production Sorted by Type and Capacity.

Fuel Type	Fuel Size	Adder (Baht/kWh)	Extra Adder (Baht/kWh)	Period Years
1.Biomass	Capacity ≤ 1 MW	0.5	1	20
	Capacity > 1 MW	0.3	1	20
2.Biogas	Capacity ≤ 1 MW	0.5	1	20
	Capacity > 1 MW	0.3	1	20
3.MSW	AD/Land Fill Gas	2.5	1	20
	Thermal Process	3.5	1	20
4.Wind Energy	Capacity ≤ 50 kW	4.5	1.5	20
	Capacity > 50 kW	3.5	1.5	20
5.Mini Hydro	Capacity 50 kW ≤ 200 kW	0.8	1	20
	Capacity < 50 kW	1.5	1	20
6.Solar PV	Thermal / Photovoltaic	8	1.5	20

Source: Department of Alternative Energy Development and Efficiency (DEDE, 2015)

Table 2.3: The Target Plan of Fifteen-year of REDP and Ten-year of AEDP with Thailand's Energy Comsumption in Currently.

Type of Energy	Unit	Current Situation				REDP 15-Year			AEDP 10-Year
		2012	2013	2014	Q1-2015	2008-2011	2012-2016	2017-2022	2012-2021
Electricity	ktoe	1,138	1,341	1,467	500	1,587	1,907	2,313	5,370
	MW	2,786	3,788	4,494	4,558	3,273	4,191	5,608	13,927
Solar Power	MW	377	823	1,299	1,303	55	95	500	3,000
Wind Energy	MW	112	223	224	225	115	375	800	1,800
Hydro Power	MW	102	109	142	142	165	281	324	324
Biomass	MW	1,960	2,321	2,452	2,487	1,610	3,220	3,700	4,800
Biogas	MW	193	265	312	327	46	90	120	3,600
Municipal Solid Waste	MW	43	47	66	75	0	130	160	400
Hydrogen	MW	n/a	n/a	n/a	n/a	0	0	4	3
Thermal	ktoe	4,886	5,279	5,775	2,091	4,150	5,582	7,433	9,801
Solar Thermal	ktoe	4	5	5	5	5	18	38	100
Biomass	ktoe	4,346	4,694	5,184	1,885	3,660	5,000	6,760	8,500
Biogas	ktoe	458	495	488	168	470	540	600	1,000
Municipal Solid Waste	ktoe	78	85	98	33	15	24	35	200
Biofuel	ktoe	1,270	1,612	1,783	567	1,755	2,831	3,986	9,467
	m lt/d	4	6	6	6	6	10	14	19
Ethanol	m lt/d	1	3	3	4	3	6	9	9
Biodiesel	m lt/d	3	3	3	3	3	4	5	7
Hydrogen	m lt/d	n/a	n/a	n/a	n/a	0	0	124	3
Compressed Bio-methan gas	t/d	n/a	n/a	n/a	n/a	0	0	0	1,200
Total Energy from Renewable Energy	ktoe	7,294	8,232	9,025	3,158	7,492	10,320	13,732	24,638
Total Energy Consumption	ktoe	73,316	75,214	75,804	26,401	70,300	81,500	97,300	99,838
Alternative Eenrgy Consumption Ratio	%	9.95%	10.94%	11.91%	11.96%	10.66%	12.66%	14.11%	25.00%

Source: World Bank Data and Department of Alternative Energy Development and Efficiency 2015

Second, circulating fund is a money support for financial institutions to stimulate a large number of investors. This fund carries much more 6,000 million baht including 6 concerned phases. Third is ESCO capital fund, holding financial support around 500 million baht. Energy Service Company (ESCO) which is the private company for taking care sustainable energy project especially for a new player of investment. This project contains Equity investment, ESCO venture capital, Carbon market, Equipment leasing, Credit Guarantee Equity and Technical Assistance. Fourth is Clean Develop Mechanism (CDM) that is the international negotiation in alternative energy to support developed green house effect reduction. Thailand can also repurchase a great number of units in green house effect reduction with developed country in United Nation Framework Convention on Climate Change (UNFCCC) following Kyoto protocol. Fifth, The Board of Investment (BOI), which provides investors by reducing import-tax particularly for imported machine or equipment involved with an electric production.

2.3 Literature reviews

Bundit Limmeechokchai and Pimporn Chaosuangroen (2006) investigate in the assessment of energy saving potential in the Thai residential sector particularly in long-range energy alternatives planning approach. They point into the patterned changes in energy consumption that can be described by two factors. First factor is the increase of natural based on population growth and the changes of demographic such as a household size, and the changes in age groups. Another factor is the incline of economic activity and development, for instance; the population of Thailand grew up with 1.16% of annual growth rate from 1990 to 2005. Consequently, they aim to construct an energy conversion and a technological structure in terms of a quantitative description. However, the methodology is separated to the base-case or business-as-usual (BAU) scenario and the energy efficiency case or alternative scenario for evaluate the potential of energy saving and the future trend of energy demand. Additionally, they use the Long-ranged Energy Alternative Planning (LEAP) model for an end-use driven scenario analysis with the technology and environmental database (TED). The LEAP model has been developed by the Stockholm Environment Institute Boston (SEI-B), which is appropriate for different tasks including energy consumption forecasting, environmental emission analysis, and energy scenario study. Finally, the result shows that the most efficiency improvement to save the energy consumption in household is cooking stoves such as charcoal, LPG, and wood stoves. The energy-saving account is indicated approximately on 29.41% of total energy consumption in the residential sector in 2020. Besides, the most efficiency improvement to reduce the electricity consumption in household is in electric cooling devices, which is also helpful for the reduction of carbon dioxide emission accounted 48.14% of the total amount of carbon dioxide emission from the residual sector.

Ian Sue Wing (2006) Computable General Equilibrium Models for the Analysis of Energy and Climate Policies Analyze the energy and climate policy reforms in the developing countries. In terms of policy analysis, they use CGE model to describe the impacts of abating fossil fuel CO2 emission in the U.S. They solved the model by establishing the relationship between the emission and the demand for the various fossil fuels, and projecting into the future baseline emission level. The result shows that the most vigorous CO2 abating occurs in mining and electricity generation while the largest quantities of emission are reduced by the fossil power and rest-of-world, with household consumption, transportation, coal mining, and petroleum accounting for most of the remaining cuts. Those reductions have negative impacts on revenue inclines by pre-existing taxes, specifically in energy sector.

Prapita Thanarak, Jürgen Schmid, Wattanapong Rakwichian, Mahasiri Chaowakul, Suchart Yammen (2006) study the economic evaluation of photovoltaic systems for rural electrification in Thailand. The journal aims to evaluate descriptively the economic impact of photovoltaic system in rural area. The study is separated in electricity production, the renewable energy development target plan, the national policy, and the future of photovoltaic for rural area. Therefore, the result is shown that there are two positive economic effects of rural electrification. First, the electricity can generate power of machines that make the labor such farmers and small-scale manufactures simply and more efficient. Second, the lighting that is the last-longer in the evening can extend longer opening of stores and increase sales for small shops in that village’s economy a small boost. In contrast, there is a negative economic impact on the community unless the community has adequate cash on pocket and thus cash flowing in as well as out. Moreover, the future of photovoltaic dissemination in Thailand in rural usage will largely be relied on the government’s policies. Thailand could emulate the experience of Philippines with the introduction of a “fee for service” system for electrification, operated by a private company with licensing by the government. It would allow the photovoltaic market expanded, while the government ensure to control licensing.

Chuanyi Lu, Xiliang Zhang, Jiankun He (2009) research in the impacts of energy investment on economic growth in the energy sectors of western areas of China on the local economy and carbon dioxide emission. The CGE model is a commonly use method for analysis, therefore a two-region ten sector CGE model was built and called "THCGE-MRS" or "MRS". In addition, the data for the MRS model is based on Shaanxi Province's 2002 input-output table, and the social accounting matrix (SAM) of Shaanxi. However, there are three scenarios in the quantitative analysis by an increase of investment to energy sectors at rate of 20%, 40%, and 60% according to the previous research, which is fixed assets investment in oil and gas sector in 1999-2004 is 13.30%-31.20%. (As cited in Hu J, Jiao B. Stimulating effect of oil and gas resources development on the regional economy in western China: a case study of Shaanxi Province. Resource Science 2007; 1: 2–8) Anyways, the macro-economic effects and sector effects are included in analysis method. As a consequence, the result indicates that the increase in the energy investment is helpful in extending the household income level and promoting the development of local economy including an employee expansion. In terms of calculating, as the energy sector investment increase at rate of 0-60%, the GDP grows 0-8.92%, production grows 0-9.08%, household consumption rises at 0-8.86%, investment grows 0-9.80%. In case of production, the largest rate is in oil and gas sector at 0-19.47% of growth, which consists coal, electricity, building industry, heavy industry and mineral industry. Similarly, the consumption for oil and gas sector inclines at 0-13.75%. Nevertheless, the lowest rate is the production in service sector at 6.36% of growth. Obviously, the development strategy takes higher economic accomplishment but inevitably higher emission of carbon dioxide as well. The environmental degradation becomes a major issue to concern for the future in western region. As a result, the development and application of low emission technologies should be considered as a measure of policy-making as early as possible.

N. Caldés; M. Varela; M. Santamaría; R. Sáez (2009) study the economic impact of solar thermal electricity deployment in Spain. They aim to estimate the socio-economic impacts of increasing the installed solar thermal energy power capacity in Spain by using an Input-Output (I-O) analysis, and also estimate the increase in the demand for good and services including in employment. To emphasize, they divided into two kinds of scenario, which is based on the two solar thermal power plants in operation with 50 and 17MW of installed capacity, and the compliance to the Spain Renewable Energy Plan (PER) 2005-2010 reaching 500MW by 2010. For individual impacts, the demand of goods and services in the economy world create 9,583.7 additional 1-year jobs from direct effect of 5,553.5 and indirect effect of 4,030.2 for parabolic trough plant, and also generate 5,491 additional 1-year jobs from 3,213 directly and 2,278 indirectly for solar tower power plant. Thus, the result can be expressed that the multiplier effect of the PER is 2.3 and the total employment reaches 108,992 equivalent full-time jobs of duration in one year. Futhermore, it can figure the Spanish unemployment in 4.5% as well.

Chayut Wana (2010) study in the impact of the oil price change on agricultural sectors of Thailand. The dissertation aims to study of the impacts by using the 1998 Social Accounting Matrix or SAM for analyzing under Price Analysis Model and also to conduct the field survey to interview farmer the impacts of oil price change on production cost, living cost, and perception on alternative sources of energies. In terms of methodology, they constructed SAM by disaggregating them into 64x64 SAM from the national Input-Output table database, balanced the SAM by RAS procedure, determined the set of exogeneous variables, and calculated for the SAM multiplier, and then analyzed the impacts of the SAM by Price Analysis Model. As a consequence, the most impact of increasing in oil price affect the price level is agricultural service sector and the second is fishery sector in 59.90% and 27.52%, respectively. Lastly, they also suggested the policy recommendations in both alternative energy promotion with the quality assurances and service station especially the natural gas station in long term.

J.M. Cansino; M.A. Cardenete; J.M. González-Limón; R. Román (2011) study the economic impact of solar thermal electricity technology deployment on Andausian productive activities by using a CGE approach. They aim to estimate the impact on productive activities from the deployment of solar thermal electricity and the compliance of "Plan Andaluz de Sostenibilidad Energética (PASENER) 2007-2013" requiring an installed capacity of 800MW by 2013 starting from 11MW in 2007, and comparing result with same bechmark. They separate the analysis of impact into two ways. First, the direct impacts that caused by the expansion of production in the other productive activities that demand for intermediate inputs of industry process from another branch of activities. Second, the induced impacts which happen in the productive structure by the relationship between consumption and intermediate demand. In addition, this kind of technology consists of a power plant with 50MW of installed capacity and central solar tower plant with 17MW of installed capacity. However, the data collection contains solar thermal plant data and Andalusian economic data from SAMAND, which is the SAM that constructed from Andalusian Input-Output Table dating from 2000 and implemented in 2008 by using a cross-entropy method including the overall information in the production and GDP. They mentioned to it as SAMAND08 (Caldés, Varela, Santamaría, & Sáez, 2009). Additionally, the calculation of the increased demand for investment costs of solar power plant is from solar field, tower, power block, land, storage, construction, engineering, and contingencies. Finally, the result is that the total increase in the economic activity according to a parabolic trough power plant amounts to 0.75%, which the largest increase are linked to activities of services contributed to sales, electricity and transport and communications, mining, iron and steel industry, and metal product. By the way, the other result from other scenaio of solar tower power plant amounts to 0.68%, which the largest increase are coverd to activities of sales, electricity, metal products, construction materials, and transport and communications. Neverthesis, the biggest weight of total production variation are and transport and communications that indicates the same result of scenarios. Moreover, the regional GDP variation and the net benefit of introducing the technologies are positive as well.

Suthin Wianwiwat and John Asafu-Adjaye (2012) study the renewable energy development in Thailand by applying a computable general equilibrium model based analysis. The objective of dissertation is to develop a computable general equilibrium or CGE model specifically in energy enhancement for Thailand and also simulate the bio-liquid fuel targets following the fifteen-year renewable energy development plan. This dissertation is applied with a modified version of the well-known Australian ORANI model, which is the comparative-static, multi-sectoral, multi-production, and single country model. This model is based on neo-classical assumption about agents' behavior, production, and consumption structures. Additional, the database came from the 2005 national Input-Output table produced by NESDB and a set of elasticity parameters mainly from GTAP 6. In order to assess the impacts of promoting bio-liquid fuels, they created Molasses-Ethanol, Cassava-Ethanol, and Biodiesel industries along with Gasohol-91, Gasohol-95, B2, and B5 by disaggregating from the petroleum refinery industry. Besides, to measure the subsidy of the biomass power plants, the electricity sector was disaggregated into four new industries such as Main Electricity, Hydro Power, Small Power Producer (SPP), and Very Small Power Producer (VSPP). This disaggregation technique could allow us to simulate energy policy and also energy shock precisely. Anyways, The analytical result shows that the bio-fuel promotion is a negative impact to real output and influence to a decline in aggregate employment for a short-run. By the ways, the long-run result indicates for a positive impact on real GDP through an increasing in aggregate investment, which is the affect from an increase in domestic saving, trade-balance improvement, and sectoral output increasing also. Obviously, the analysis of dissertation is described in terms of macroeconomic and sectoral impacts.

Zhang Da, Chai Qimin, Xiliang Zhang, He Jiankun, Yue Li, Dong Xiufen, Wu Shu (2012) study the economical assessment of large-scale photovoltaic power development in China. The study purpose to estimate the future of photovotaic installation in China. They use MESSAGE model, which is described the technology and technocal changes of a certain kind of energy with initial and annual cost at each period of time. They separate the three differect scenarios with constant declining rates of initial investment cost of photovotaic system every five year (90%, 85%, and 80%). As a result, the cost of photovotaic power will be competitive to conventional power in ten to fifteen years with inclining cost of coal-fired power. While the annual investment reaches 0.1% of GDP, the photovotaic power will be competitive before 2025. Moreover, the lumpsum subsidy and concess projects will be the main channels for the large-scale of investment in the future until the cost of photovotaic system turns out relatively steady. However, China should carefully reconsider the cost effectiveness of the subsidy policies since the aggressive subsidy policy is ineffective.

J.M. Cansino; M.A. Cardenete; J.M. González-Limón; R. Román (2014) determine in the economic influence of photovoltaic technology on electricity generation by computing CGE approach for Andalusian case. The dissertation purpose is to estimate the socio-economic impact of the "Energy Sustainability Plan of Andaluz" or PASENER by adding the photovoltaic electricity generation to the electricity grid in Andalusia and to assess the carbon-dioxide abatement associated with deployment. In terms of theory, the study base on general equilibrium. About the database, they use SAMAND (J.M. Cansino; M.A. Cardenete; J.M. González-Limón; R. Román, 2011) dated from 2000 for

Andalusian economic data, and 2008 euros publication for the cost of solar parks. Anyways, they start the methodology to gather construction cost, operation cost, and maintenance cost of solar parks, then take it into account for direct and indirect effect on the economic sectors, after that they simulate the model by using a CGE approach based on a SAM. Consequently, the result is shown that the employment index indicates the increasing of 215,148 one-year jobs in terms of macro-level, and the most impact after provoking an exogeneous shock into the model is sales services sector in 11.30% noteworthy. The result is also justified with its environmental benefits largely to the abatement of GHG emissions in 388,738 tons of carbon-dioxide of thermal plant from fuel and gas depending on the technological displaced pollution.

Projected Cost of Generating Electricity (2015) is the joint report by the International Energy Agency (IEA) and the Nuclear Energy Agency (NEA) on the costs of generating electricity in the series of study. This report indicates the results of work performance from 2014 to early 2015 to estimate the cost of generating for the mainly electricity generation from fossil fuel thermal, nuclear power, and a various of renewable energy generation, and also wind and solar power. The organization aims to expect the cost commission on their plants in 2020 by forward-looking study. They use LCOE calculations based on a levelised average lifetime cost approach, running with the discounted cash flow (DCF) method. The computation is combined the generic, country-specific, and technology-specific assumptions by the Expert Group on Projected Costs of Generating Electricity (EGC Expert Group). The analytical study is performed using three discount rates (3%, 7%, and 10%) based on data for 181 plants in 22 countries (including 3 non-OECD countries[1]). The analysis of LCOE range contains three baseload technologies (natural gas-fired CCGTs[2], coal, and nuclear), including the three categories of solar photovoltaic (residential, commercial, and ground-mounted) and the two categories of wind (onshore and offshore). The result shows that nuclear energy costs remain in line with the cost of baseload technologies, especially in decarbonisation markets. The result also describes that the cost of renewable technologies in solar photovoltaic have decreased significantly more five years in past, and those technologies are also no longer cost outlier. All in all, the cost drivers of the different generating

[1] Three non-OECD countries are Brazil, China, and South Africa.
[2] The abbreviation of CCGTs is Combined-Cycle Gas Turbines.

technologies remain both market-specific and technology-specific. Fundamentally, there is no any single technology that can be explained to be the cheapest price under all the circumstances. Anyways, the study of systems costs, market structure, policy environment, and resource endowment is clear than previous report and all continue to play an important role in definition the final levelised cost of any given investment.

Won-Sik Hwang and Leong-Dong Lee (2015) analysis the electricity market quantitatively changes by conducting a CGE model. The study aims to investigate the economic effects of privatization or liberalization in the electricity industry and also examine various counterfactual scenarios after Korean electricity industry reform through the integrated framework. To fulfill the quantitative analysis, the study conducts the developed approach, incorporating a top-down and bottom-up model based on general equilibrium that takes into account economic effect and technological constraints at the same time. In terms of methodology, first is to use the distinctive iterative process that are modified elaborately to investigate the economic effects from electricity market changes by provided the electricity price in the Bottom-up model and transferred to the Top-down model. The solution is more to converge between two models. Second, they also use the former study from the assessment of quantitative effects of Korea's electricity industry privatization and market changes. Then, they conduct the changes of price levels into the electricity market after privatization and investigate the market power of dominant companies including their ability to influence price through strategic behaviors in the privatized market. In conclusion, the simulation results indicate that the forward contracts can moderate the negative effects according to strategic behaviors abusing market powers. It implies that forward contracts not only reduce uncertainties for both buyers and sellers, but also make more competitive markets

CHAPTER 3

Methodology

3.1 Data Collection

The study uses micro-database from 2010 input-output table (NESDB), and the statistic of energy from 2014 EPPO (Ministry of Energy). However, the dimension of productive activities in input-output table is huge and the economic productive sector still have no transactions related to renewable energy. Those are not suitable for our analysis. However, the study has to elaborate the economy sectors that could be expressed for more realistic impact by aggregating the productive activity sectors into 14 sectors from the conventional input-output table classification of 26x26 sectors as shown in Table 3.1. To disaggregate the solar energy, the study separated the natural gas electricity from ‘Electricity and Water work’ (Sector number 18) as Table 3.1, and created a new name with ‘original electricity’. Moreover, the study also added a new electricity production of the solar and wind energy into the model.

Regarding a study in the impact of solar energy policy, the study conveys the disaggregated 2010 input-output table and database from 2013 national income account to construct a Thailand Social Accounting Matrix (SAM 2010). To balance the SAM 2010, the study uses RAS method to complete them. Then, the study could evaluate the impact through policy instument by conducting the SAM multiplier. Futhermore, the study would transfer the SAM 2010 to be a benchmark or base model in category of Computable General Equilibrium (CGE) through the instrument, namely the General Algebraic Modeling System (GAMS) for a high-level investigation. Additionally, the evaluation of SAM muliplier stands for sectoral analysis among economic sectors and the evaluation of GAMS stands for macro-impact analysis.

Table 3.1: Aggregation and Disaggregation Economy Sector.

No	Sector Name (58x58 sectors)	Aggregated sectors
1	Crops (001-017, 024)	Agriculture and Food Industry
2	Livestock (018-023)	Agriculture and Food Industry
3	Forestry (025-027)	Agriculture and Food Industry
4	Agriculture and Food Industry	Agriculture and Food Industry
5	Mining and Quarrying (030-041)	Mining, Iron and Steel
6	Food Manufacturing (042-061)	Agriculture and Food Industry
7	Beverages and Tobacco Products (062-066)	Agriculture and Food Industry
8	Textile Industry (067-074)	Manufacturing (Textile, Paper and Non-Metallic)
9	Paper Products and Printing (081-083)	Manufacturing (Textile, Paper and Non-Metallic)
10	Chemical Industries (084-092)	Rubber, Chemical and Petroleum Refineries
11	Petroleum Refineries (093-094)	Rubber, Chemical and Petroleum Refineries
12	Rubber and Plastic Products (095-098)	Rubber, Chemical and Petroleum Refineries
13	Non-metallic Products (099-104)	Manufacturing (Textile, Paper and Non-Metallic)
14	Basic Metal (105-107)	Mining, Iron and Steel
15	Fabricated Metal Products (108-111)	Mining, Iron and Steel
16	Machinery (112-128)	Machinery
17	Other Manufacturing (075-080, 129-134)	Other Manufacturing
18	Electricity and Water Works (135-137)	Original Electricity
		Gas generation and Gas supply
		Solar energy
		Wind energy
19	Construction (138-144)	Construction
20	Trade (145-146)	Commerce and Transportation
21	Restaurants and Hotels (147-148)	Service
22	Transportation and Communication (149-159)	Service
23	Banking and Insurance (160-162)	Service
24	Real Estate (163)	Service
25	Services (164-178)	Service
26	Unclassified (180)	Unclassified

Source: Adapted from Cansino, Cardenete, Gonzalez, & Pablo-Romero (2014)

To analyze the total investment and the operating costs of solar and wind electricity, the input-output table have been broken down as Table 3.2 and Table 3.3 by modification from the studies of Cansino, Cardenete, Gonzalez, & Pablo-Romero (2014). For further details, the investment cost contains photovoltaic module, inverter, measuring, and monitoring, basement structures, transformer and security. When there is no import from investment cost section, the total cost becomes the total domestic cost. Moreover, the variable “x” indicates the amount of investment cost in each item. Table 3.3 shows the transactions of each item, for example; the module, invertors, basement structure, transformer connected to the grid and the security alarm also demand materials from chemical sector. Furthermore, the variable “y” represents the share of demand for items.

Table 3.2: Breakdown of the Investment Cost to Acheive the Renewable Energy Policy Target.

Item	Total cost Investment	Total cost portion in imports	Total cost portion in domestic
	(Thousand Baht)	(Thousand Baht)	(Thousand Baht)
Photovoltaic module	x	-	x
Inverters, measuring and monitoring	x	-	x
Basement structures	x	-	x
Transformer and connection to the grid	x	-	x
Security and surveillance	x	-	x
Installation, engineer, filling and processing	x	-	x
Total	x	-	x

Source: Modified from Cansino, Cardenete, Gonzalez, & Pablo-Romero (2014)

Table 3.3: Assumed Percentage Distribution of the Domestic Investment Costs to the Economic Sectors.

Sector Number	Production Sector name	Photovoltaic modules	Investors, measuring and monitoring	Basement structures	Transformers and connect to the grid	Security, alarm, surveillance	Installation, engineer, filling and processing
5	Production and distribution electricity power	y	-	-	-	-	-
11	Chemical	y	y	y	y	y	-
12	Mining, Iron and Steel Industry	y	y	y	y	y	-
13	Metallic products	y	y	y	y	y	-
14	Manufacturing	y	y	-	y	y	y
15	Construction	y	y	y	y	y	y
16	Commerce and Transport	y	y	y	y	y	y
18	Sales services	-	-	-	-	-	y
19	Non-sales services	-	-	-	-	-	y
	Total (%)	100	100	100	100	100	100

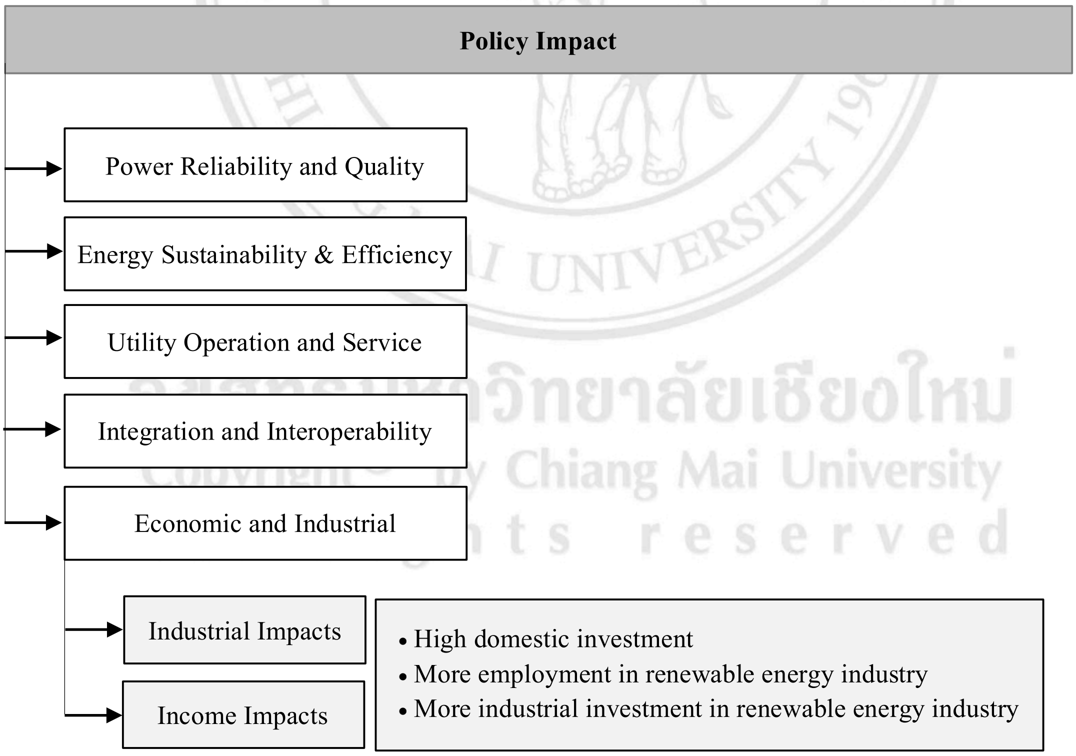
Source: Modified from Cansino, Cardenete, Gonzalez, & Pablo-Romero (2014)

3.2 Analytical Framework

The developing countries in ASEAN, like Thailand, employs the potential of industry to motivates the Thai's economy forward. However, the data of energy usage indicates that the manufacturing consumes a commercial energy for 19,131 ktoe or 32.18% of final total energy consumption, which is comprised of coal and its product (4,629 ktoe), petroleum and its products (8,685 ktoe), and the electricity (5,817 ktoe). Meanwhile, the transportation also consumes 26,801 ktoe or 30.95% of final total energy consumption in commercial energy which contributed toward road, air, rail, and water transportations in 2014 (Ministry of Energy, 2015). Evidently, more than 60% of total final energy consumption is contributed to energy and transportation sectors which can be shown how important energy is. Nevertheless, the demand for energy is increasing along with the growth of industries in economy. Subsequently, the fossil resource would no longer be sustainable for the future. Thus, continuing this without policy intervention for alternative energy, the energy resource will become a huge problem by doing nothing. Currently, there are several alternative energy policies in various dimensions of economy. One of them is to convince the citizen to switch from the fossil resource to sustainable energy, the demand for energy also switch from conventional energy to sustainable energy. As a consequence, the higher of the balance on demand and supply sides for energy can lead to the higher price in sustainable energy market. Nonetheless, the change of energy price influences on various dimensions such as energy consumption in manufacture and household sections. The linkage between the sustainable energy policy and economic sectors could be expressed under the general equilibrium, for example; the linkage in economy of the intervention policy in renewable energy policy is feed-in-tariff, it therefore can increase the household income from their own electricity production and reduce the total energy imports in industry for a natural gas in the border provinces in Thailand. Consequently, the amount of fossil usage will be leverage with sustainable energy usage and turns out to be a slightly higher in GDP.

3.3 Conceptual Framework

The conceptual framework of this study is shown in Figure 3.1. The energy policy impacts several areas in Thailand. There are mainly five strategic areas. Firstly, the power reliability and quality is indicator of the power system operation. Secondly, the energy sustainability and efficiency are mostly related to our study for replacing the limited fossil-fueled by the renewable energy such as bio-fuel, solar energy, wind energy, etc. The third is the utility operation and service to develop the innovation for better performance of power utility. Fourthly, the integration and interoperability is to improve the innovative equipment. Lastly, the economic and industrial competitiveness is essentially involved with this study, which is separated into direct effect and indirect effect. The direct effect appeared in both economic and industrial aspects such as higher domestic investment, higher employment and industrial investment in technologies. The indirect effect is the income that household and firm investing in renewable energy production.

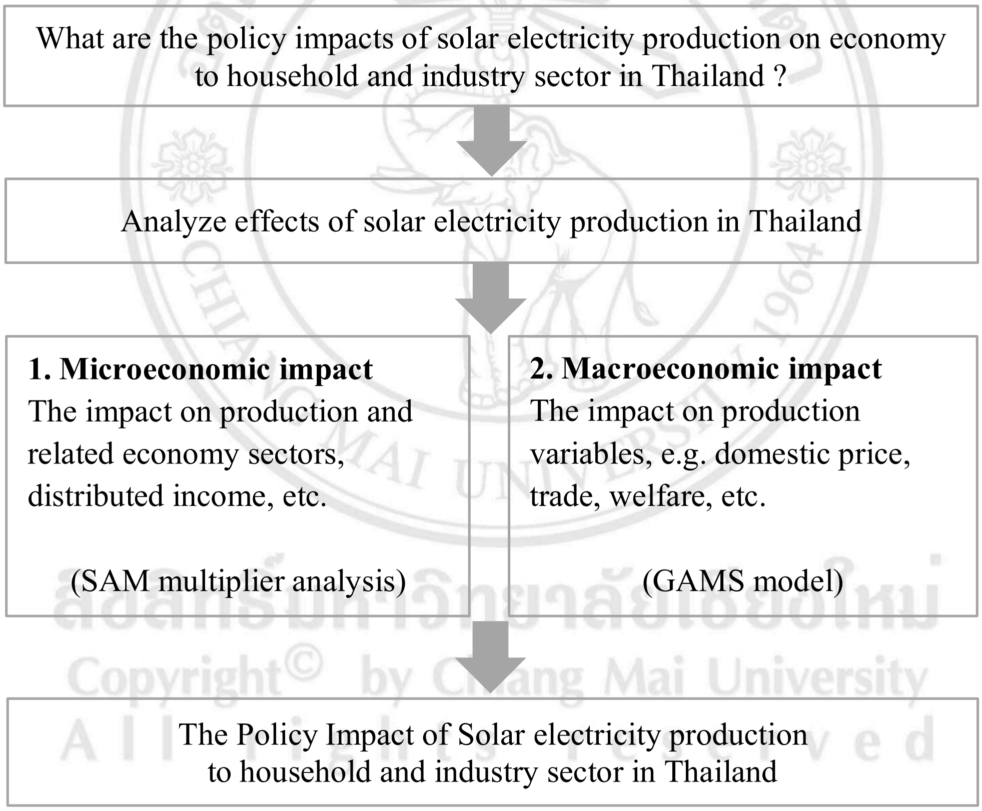


Source: Own elaboration

Figure 3.1: The Conceptual Framework.

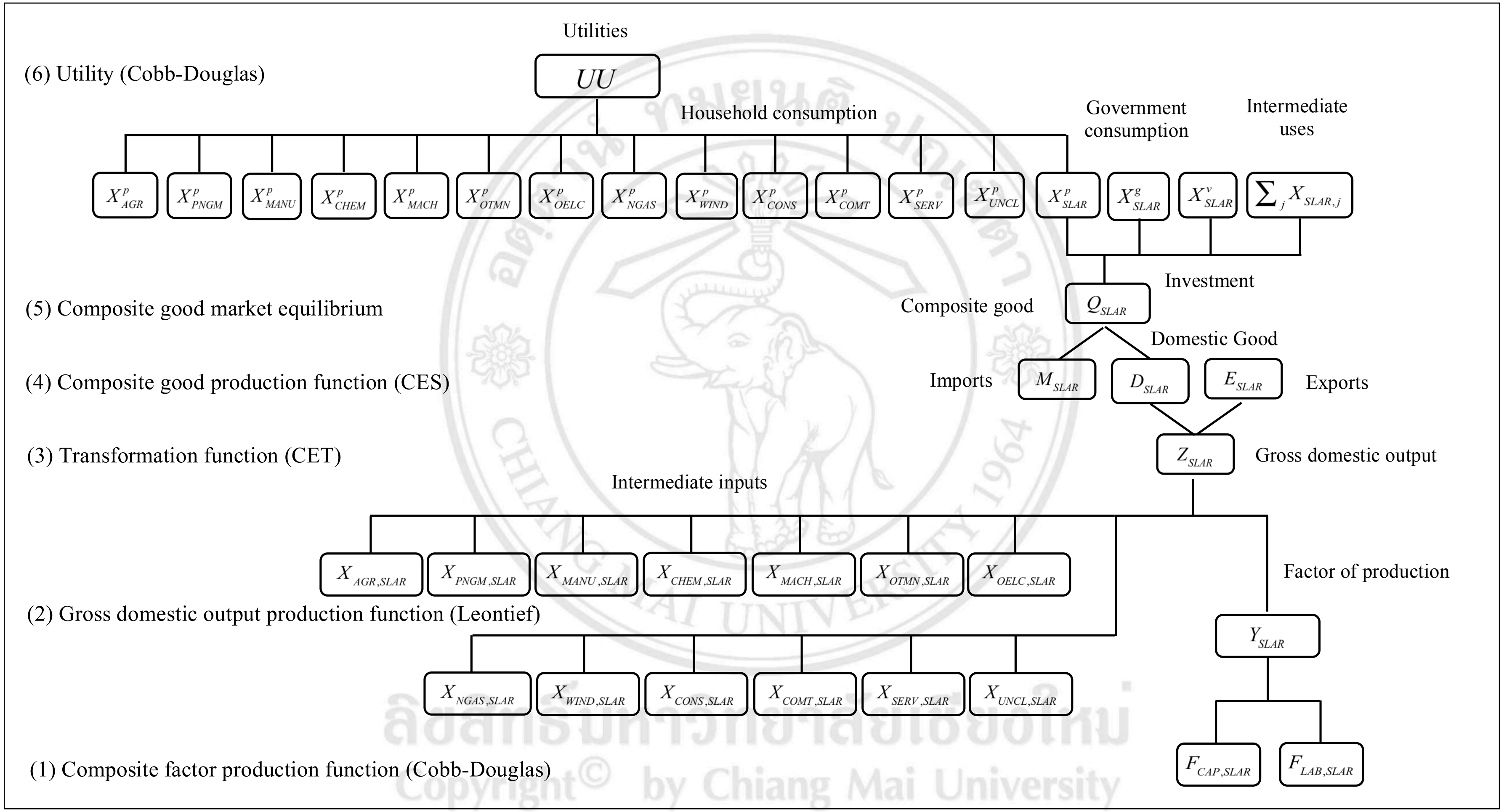
3.4 Research Methodology

The study focuses mainly on the impacts of solar energy and wind energy policy in microeconomic impact and macroeconomic impact. The micro-level is analyzed by a Thailand Social Accounting Matrix (SAM) and the SAM-based multiplier model for assessing the sectoral impact. The macro-level is analyzed by Computable General Equilibrium (CGE) in GAMS model. Referring to the Figure 3.2, the analysis of impact could be separated into two levels. In terms of microeconomics, the analysis covers the impact of solar electricity, wind electricity and natural gas electricity production and related economy sectors on production impact and distributed income. In terms of macroeconomics, the study can analyze the impact of product price, trade and welfare.



Source: Own elaboration

Figure 3.2: Research Method of the Impact of Solar Energy Policy to Household and Industry Sector.



Source: Adapted from Textbook of Computable General Equilibrium Modelling (Hosoe, 2011)

Figure 3.3: Model structure in standard economy

In Chapter 2, the study already proposed the general CGE model. The following part is the research model or "The Standard Hosoe CGE Model". We divided the content into six sections. The intermediate inputs are comprised in the model as section one, the government in section two, investment and saving in section three and international trade in section four. The market-clearing conditions is interpreted in section five. For the simultaneous equations are explained in section six. Additionally, the last section is about the computer program for solving the standard CGE model. We moved this part into the appendix.

3.5 Research Model

Before starting into model equations, the standard CGE model is drawn as Figure 3.3 from the transaction of the flows in an economy of goods and factors. The explanation of the goods and factors at each stage flow, which is combined for production or consumption. These flows are initially described the block from the bottom one to the top one in Figure 3.3. For illustration, the example uses the electricity and water works sector as Figure 3.3.

(1) The factor of production of capital $F_{CAP,SLAR}$ and labor $F_{LAB,SLAR}$ are aggregated into the composite factor Y_{SLAR} following the Cobb-Douglas composite factor production function.

(2) This composite factor Y_{SLAR} is integrated with the intermediate inputs of *agriculture and food industry* $X_{AGR,SLAR}$, *petroleum, natural gas and mining* $X_{PNGM,SLAR}$, *manufacturing* $X_{MANU,SLAR}$, *rubber, chemical and petroleum refineries* $X_{CHEM,SLAR}$, *machinery* $X_{MACH,SLAR}$, *other manufacturing* $X_{OTMN,SLAR}$, *original electricity* $X_{OELC,SLAR}$, *natural gas electricity* $X_{NGAS,SLAR}$, *wind electricity* $X_{WIND,SLAR}$, and *construction* $X_{CONS,SLAR}$, *commerce and transportation* $X_{COMT,SLAR}$, *service* $X_{SERV,SLAR}$ and *unclassified sector* $X_{UNCL,SLAR}$ to produce the gross domestic output Z_{SLAR} by conducting the gross domestic output production function.

(3) The gross domestic output Z_{SLAR} is changed to the exports E_{SLAR} and the domestic good D_{SLAR} conducting the gross domestic output transformation function.

(4) The domestic good D_{SLAR} is integrated with the imports M_{SLAR} to produce the composite good Q_{SLAR} with the composite good production function.

(5) The composite good Q_{SLAR} is separated among household consumption X^{p}_{SLAR}, government consumption X^{g}_{SLAR}, investment X^{v}_{SLAR} and intermediate uses by the agriculture, mining and quarrying, food industry, manufacturing, petroleum refineries, construction, electricity and water works, commerce and transportation, service, and unclassified sectors $\sum_j X_{SLAR,j}$.

(6) Household utility UU is originated by consumption X^{p}_{AGR}, X^{p}_{PNGM}, X^{p}_{MANU}, X^{p}_{CHEM}, X^{p}_{MACH}, X^{p}_{OTMN}, X^{p}_{OELC}, X^{p}_{NGAS}, X^{p}_{SLAR}, X^{p}_{WIND}, X^{p}_{CONS}, X^{p}_{COMT}, X^{p}_{SERV} and X^{p}_{UNCL} as the utility function indicates.

However, for the description of the composite factors, the composite goods and the functions are depicted as 3.5.1-3.5.6

3.5.1 Intermediate inputs

In the first stage, capital and labor are used as a composite factor (or value added) for the production. The production process of the composite factor can be considered as a factory behavior, which earns profit maximization by selecting output (or composite factor) level and inputs (capital and labor) use, depending on their relative prices subject to the technology. In the second stage, the factor of combination is integrated with the intermediates to deliver the gross domestic output, as indicated by the gross domestic output production function.

Moreover, for the technology in this two-stage production process, the model is assumed a Cobb-Douglas-type production function in the second stage. This two-stage production process are both homogeneous of degree one and characterized as constant-returns-to-scale. The Cobb-Douglas-type production function allows us to explain substitution between inputs, although the Leontief-type production function does not. As empirical CGE models are developed on basis of the input-output (I-O) tables, distinguishing dozens of sectors, the number of endogenous variables, especially for intermediate inputs, increase in accordance with the square of the number of sectors. In sort of consideration, the Leontief-type production function essentially reduces the complexity in the model and by way of the computational load.

The profit maximization problem for the j-th firm can be written as follow:

- For the first stage:

$$\underset{Y_j, F_{h,j}}{\text{maximize}}\ \pi_j^y = p_j^y Y_j - \sum_h p_h^f F_{h,j}$$

subject to

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad (1)$$

- For the second stage:

$$\underset{Z_j, Y_j X_{i,j}}{\text{maximize}}\ \pi_j^z = p_j^z Z_j - \left(p_j^y Y_j + \sum_i p_i^q X_{i,j} \right)$$

subject to

$$Z_j = \min \left(\begin{array}{l} \dfrac{X_{AGR,j}}{ax_{AGR,j}}, \dfrac{X_{PNGM,j}}{ax_{PNGM,j}}, \dfrac{X_{MANU,j}}{ax_{MANU,j}}, \dfrac{X_{CHEM,j}}{ax_{CHEM,j}}, \dfrac{X_{MACH,j}}{ax_{MACH,j}}, \dfrac{X_{OTMN,j}}{ax_{OTMN,j}}, \dfrac{X_{OELC,j}}{ax_{OELC,j}} \\ \dfrac{X_{NGAS,j}}{ax_{NGAS,j}}, \dfrac{X_{SLAR,j}}{ax_{SLAR,j}}, \dfrac{X_{WIND,j}}{ax_{WIND,j}}, \dfrac{X_{CONS,j}}{ax_{CONS,j}}, \dfrac{X_{COMT,j}}{ax_{COMT,j}}, \dfrac{X_{SERV,j}}{ax_{SERV,j}}, \dfrac{X_{UNCL,j}}{ax_{UNCL,j}}, \dfrac{Y_j}{ay_j} \end{array} \right) \quad (5')$$

Notation are:

π_j^y : the j-th firm profit producing composite factor in the first stage,

π_j^z : the j-th firm profit producing gross domestic output in the second stage,

Y_j : the first stage of composite factor, produced and used in the second stage,

$F_{h,j}$: the h-th factor used by the j-th firm in the first stage,

Z_j : the j-th firm's gross domestic output

$X_{i,j}$: intermediate input of the i-th good used by the j-th firm,

p_j^y : price of the j-th composite factor,

p_h^f : the h-th factor's price,

p_j^z : the j-th gross domestic output' price,

p_i^q : the i-th composite good' price,

$\beta_{h,j}$: share coefficient in the composite factor production function,

b_j : scaling coefficient of the composite factor production function,

$ax_{i,j}$: the input coefficient of the i-th intermediate input for a unit output of the j-th good,

ay_j : the input coefficient of the j-th composite good for a unit output of the j-th good,

The purpose value is the profit maximization of the firm in each stage of production. For the first-stage profit function, the right-hand side stands for the sales of the composite factor. Moreover, the second term stands for the input costs of capital and labor used for its production. The constraint (1) demonstrates the technology of the composite factor production interpreted by a Cobb-Douglas-type production function.

For the second-stage profit function, the right-hand side represents the sales of the gross domestic output, which comprises of ordinary sectors such as agriculture and manufacturing in this model; the second and third terms are the composite factor cost input and the intermediate inputs used in the second-stage production function for production of the gross domestic output with the composite factor and intermediate inputs.

To solve the two states of problem, we obtain;

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \qquad \forall j \tag{1}$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \qquad \forall h, j \tag{2}$$

$$X_{i,j} = ax_{i,j} Z_j \qquad \forall i, j \tag{3}$$

$$Y_j = ay_i Z_i \qquad \forall j \tag{4}$$

$$Z_j = \min\left(\begin{array}{l} \frac{X_{AGR,j}}{ax_{AGR,j}}, \frac{X_{PNGM,j}}{ax_{PNGM,j}}, \frac{X_{MANU,j}}{ax_{MANU,j}}, \frac{X_{CHEM,j}}{ax_{CHEM,j}}, \frac{X_{MACH,j}}{ax_{MACH,j}}, \frac{X_{OTMN,j}}{ax_{OTMN,j}}, \frac{X_{OELC,j}}{ax_{OELC,j}} \\ \frac{X_{NGAS,j}}{ax_{NGAS,j}}, \frac{X_{SLAR,j}}{ax_{SLAR,j}}, \frac{X_{WIND,j}}{ax_{WIND,j}}, \frac{X_{CONS,j}}{ax_{CONS,j}}, \frac{X_{COMT,j}}{ax_{COMT,j}}, \frac{X_{SERV,j}}{ax_{SERV,j}}, \frac{X_{UNCL,j}}{ax_{UNCL,j}}, \frac{Y_j}{ay_j} \end{array}\right) \forall j \quad (5')$$

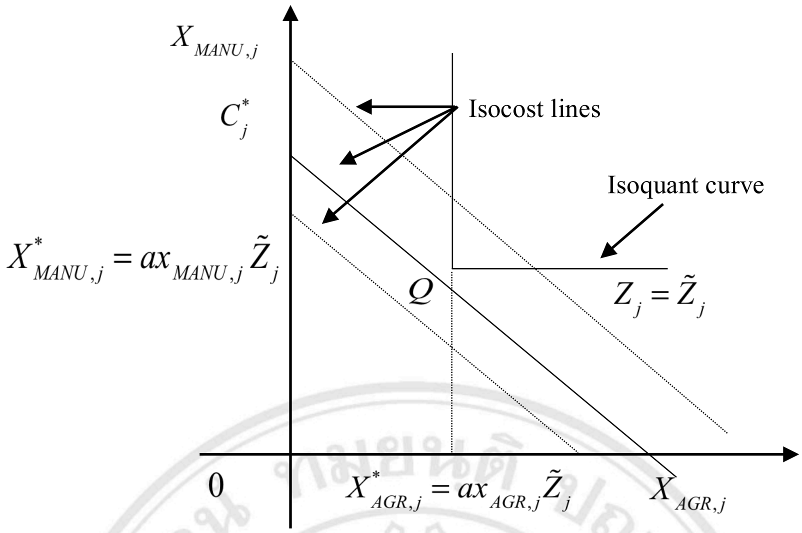
The production function ($5'$) generates the rectangular isoquants (iso-output curves) as indicated in Figure 3.4 as below. The kinks in the isoquants sometimes cause difficulty in numerical computations. Additionally, the model use cost-minimization problem instead of profit-maximization problem. In terms of mathematic, the firms is assumed to use only two kinds of intermediate input $i, j = (AGR, MANU)$. The j-th firm cost minimization problem is:

$$\underset{X_{i,j}}{\text{minimize}}\ C_j = \sum_i p_i^q X_{i,j} \tag{V.1}$$

subject to

$$\tilde{Z}_j = \min\left(\frac{X_{AGR,j}}{ax_{AGR,j}}, \frac{X_{MANU,j}}{ax_{MANU,j}}\right) \tag{V.2}$$

In this cost-minimization problem, the achieve amount of production $\tilde{Z}_j$ is exogenous. Then, the way to solve this problem can be graphically shown in Figure 3.4. Firstly, the isocost lines corresponding to the objective function (V.1) appear like downward-sloping lines as Figure 3.4. In addition, the isocost lines is drawn in the northeast represent higher costs than others in the southwest, which indicates the relative price of goods. Secondly, the isoquant curve corresponding to the output level $\tilde{Z}_j$ under the Leontief production technology (V.2), which is the right-angled curve.



Source: Textbook of Computable General Equilibrium Modelling (Hosoe, 2011)

Figure 3.4: Isoquant of Leontief-type production function and cost function.

Afterward, we replace ($5'$) with a zero-profit condition for solving the computational problem as below.

$$\pi_j^z = p_j^z Z_j - \left(p_j^y Y_j + \sum_i p_i^q X_{i,j} \right) = 0 \qquad \forall_j$$

Even though we included zero-profit condition in the model, it can be more convenient to transform it into a simpler expression of a unit cost function. Using (6.3) and (6.4), we can eliminate $X_{i,j}$ and Y_j to obtain:

$$p_j^z Z_j - \left(ay_j p_j^y Z_j + \sum_i ax_{i,j} p_i^q Z_j \right) = 0 \qquad \forall_j$$

and also eliminate Z_j, we get the unit cost function below:

$$p_j^z = ay_j p_j^y - \sum_i ax_{i,j} p_i^q \quad \forall_j \tag{5}$$

Lastly, replacing ($5'$) with (5), the model can be explained the firms' behavior with (1) - (5).

3.5.2 Government

The CGE model is mostly used for policy analysis, which can be used to explain the consequences of changes in government policy devices especially for tax rates. Accordingly, any realistic CGE model must contain a government in the model for interpreting a government behavior. However, the government is supposed to collect taxes and consume goods. The modeler noted that there is no such a perfect way of modelling these government activities from the viewpoint of micro-foundations, while the modelling of the household and the firms are also totally based on micro-foundations. Therefore, we need to develop our CGE model in the same purpose of our analysis with a government.

The modeler suppose that the government imposes a direct tax on household income at the tax rate τ^d, a production tax (or an indirect tax) on gross domestic output at the tax rate τ_j^z and an import tariff on imports at the rate τ_i^m. In the meantime, we assume that (1) the government spends whole revenues of tax on their consumption, and (2) the government consumes each good (i.e., agriculture or manufacturing sector) in fixed proportions out of total government expenditure. For example, the government spends 40% of its total revenues on the purchase of agricultural good and 60% on the purchase of manufactured good. Thus, the assumptions can be written as follows:

$$T^d = \tau^d \sum_h p_h^f FF_h \quad \forall_j \tag{6}$$

$$T_j^z = \tau_j^z p_j^z Z_j \quad \forall_j \tag{7}$$

$$T_i^m = \tau_i^m p_i^m M_i \quad \forall_j \tag{8}$$

$$X_i^g = \frac{\mu_i}{p_i^q}\left(T^d + \sum_j T_j^z + \sum_j T_j^m\right) \quad \forall_j \tag{9'}$$

where:

T^d : direct tax,

T_j^z : production tax on the j-th good,

T_i^m : import tariff on the i-th good,

τ^d : direct tax rate,

τ_j^z : production tax rate on the j-th good,

τ_i^m : import tariff rate on the i-th good,

FF_h : endowments of the h-th factor for the household,

Z_j : gross domestic output of the j-th firm,

M_i : imports of the i-th good,

X_i^g : government consumption of the i-th good,

p_j^z : price of the j-th gross domestic output,

p_h^f : price of the h-th factor,

p_i^m : price of the i-th imported good,

p_i^q : price of the i-th composite

μ_i : share of the i-th good in government expenditure ($0 \le \mu_i \le 1$, $\sum_i \mu_i = 1$)

Nevertheless, we assume that government expenditure is distributed among goods for consumption proportionately as equation ($9'$). We can simplify government behavior by setting government consumption at the initial equilibrium level X_i^{g0}:

$$X_i^g = X_i^{g0} \ \forall i$$

When the government make a negative consumption like selling its asset in historical databases such as Input-Output table. An application of the proportionate government expenditure behavior recommended above might not be suitable for such a negative consumption case. Then, we can alternatively develop a model that allows negative value for the consumption of some goods and assume positive proportional expenditure for others.

3.5.3 Investment and Savings

3.5.3.1 Introduction of investment and saving

The CGE model, which was developed, functions as a static model. In contrast, the investment and saving are dynamic factors which are obviously contradictory with the initial structure since it was a static model. Yet, the investment can not be denied as it majorly shares the final demand. Even though the investment could not be modeled in the solution, which is firmly compatible with an economic theory, it must be integrated someway. Then, to start with the role of the virtual investment agent, the funds that came from household, the government, and the external sector would be gathered by the investment agent, and then be paid for investment goods. The existing ideal supposes that a virtual agent attracts all the economic savings and then they would be spent for goods proportionately with a constant share λ_i, even though the government and household could actually decide how to invest and save. Hence, the investment could be expressed about its behavior by employing the investment demand function (10). Incidentally, there is the similarity of the government demand function for goods' assumption and the equation:

$$X_i^v = \frac{\lambda_i}{p_i^q}\left(S^p + S^g + \varepsilon S^f\right) \qquad \forall i \tag{10}$$

Notation are:

S^p : household savings,

S^g : government savings,

S^f : current account deficits in foreign currency terms (or equivalently foreign savings),

X_i^v : demand for the i-th investment good,

ε : foreign exchange rate (domestic currency / foreign currency),

p_i^q : price of the i-th composite good,

λ_i : expenditure share of the i-th good in total investment ($0 \le \lambda_i \le 1$, $\sum_i \lambda_i = 1$).

On the right-hand side of equation (10), those factors in parentheses equate with total savings containing saving of the household, the government and the external sector. It is worth mentioning that as the sum of the share parameter λ_i equate with unity, (10) indicates that, in economy, the total investment are always equivalent to its total saving. After that, as follows, we presume that both household and government are considered by constant average propensities for savings:

$$S^p = ss^p \sum_h p_h^f FF_h \tag{11}$$

$$S^g = ss^g \left(T^d + \sum_j T_j^z + \sum_j T_j^m \right) \tag{12}$$

where:

ss^p : average propensity for savings by the household,

ss^g : average propensity for savings by the government,

Furthermore the economy has other savings out of S^p and S^g, which is foreign savings S^f by assuming as an exogenous. Despite, it is assumable that these savings variables are whichever endogenous or exogenous varying on the viewpoint in the real economy. However, the investment is determined by (10) indicating to abandon commodities, which neither contributes to household utility nor to firm production.

In other word, the utility function is not reliant on the amount of investment X_i^v. Additionally, in this economy, the endowments of capital FF_{CAP} are predetermined and thus cannot be raised by the investment X_i^v in static model.

3.5.3.2 Modification of household and government behavior

Previously, regarding to the introduction of the government, we were required by investment and savings in the model to adapt the conventional model calculations explaining the behavior of household and government. The budget of household need some modification, assuming the same utility function. So, the amount of household savings and direct tax payments decreased the accessible funds for household consumption of goods X_i^p. So, the household's difficulty become as follows:

$$\underset{X_i^p}{\text{maximize}}\, UU = \prod_i X_i^{p^{\alpha_i}}$$

subject to

$$\sum_i p_i^q X_i^p = \sum_h p_h^f FF_h - S^p - T^d$$

where:

UU : utility

X_i^p : household consumption of the i-th good,

FF_h : endowment of the h-th factor for the household,

S^p : household savings,

T^d : direct tax,

p_i^q : the i-th composite good price,

p_h^f : the h-th factor price,

α_i : share parameter in the utility function ($0 \le \alpha_i \le 1$, $\sum_i \alpha_i = 1$).

The household demand function for the i-th good were gained by resolving this adapted household problem:

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f FF_h - S^p - T^d\right) \qquad \forall i \tag{13}$$

Combination of government savings in the same way resulted in modification of the government demand function for i-th good:

$$X_i^g = \frac{\mu_i}{p_i^q}\left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g\right) \qquad \forall i \tag{9}$$

3.5.4 International Trade

3.5.4.1 Small-country assumption and balance of payments

The standard CGE model extension feature is applying to closed-economy model to an open-economy model. We can, therefore, easily presume that the economy is so small so that there is no meaningful influence to the rest of world, even though with an ultimate action such as export dumping. The important assumption of the small country is that the export and import price demanded in foreign currency terms are exogenous, which is given for this economy.

Another key point is to separate into two types of price variables considering with international trade. First is price in sorts of the domestic currency and p_i^e and p_i^m. Second is in sorts of the foreign currency prices and p_i^{We} and p_i^{Wm}. They are linked with each other as below:

$$p_i^e = \varepsilon p_i^{We} \qquad \forall i \tag{14}$$

$$p_i^m = \varepsilon p_i^{Wm} \qquad \forall i \tag{15}$$

Moreover, there is an assumption that the economy confronts with the constraints of the balance of payments, that could be defined with export and import prices in foreign currency terms:

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \tag{16}$$

Notations are:

p_i^{We} : foreign currency export price (exogenous),

p_i^e : domestic currency export price,

ε : foreign exchange rate (domestic currency or foreign currency)

E_i : the i-th goods' exports,

p_i^{Wm} : foreign currency import price (exogenous),

p_i^m : domestic currency import price,

M_i : the i-th goods' imports,

S^f : foreign saving or equivalently foreign savings current account deficit; (exogenous)

As mentioned in Subdivision 3.5.3.1, the currency account deficit foreign currency terms S^f is an exogenous variable. On the other hand, by replacing p_i^{We} and p_i^{Wm} with p_i^e and p_i^m using (14) and (15), we could indicate the balance of payments constraint with regard to the domestic currency in the existing ideal.

3.5.4.2 Armington's assumption

The variances or likenesses of goods that produced or consumed in domestic and also those imported or exported need to be considered as the open economy model was reached. It is necessary, in this division, to supposed that there is *imperfect* substitution between them. The domestic bread and imported bread are presumed be similar but are slightly diverse.

Then, this model is supposed that all goods, that are exported, are perfectly substitutable with the related goods that are imported. So, there could not be the same goods in both exports and imports, concurrently. There is no reason importing 100 units of agriculture goods whilst there are 20 units exported and so the net imports is 80 units. Nevertheless, the real figures frequently report identical good for both exports and imports, that is called two-way trade. Obviously, there are conflict theory and custom. We, therefore, differentiate the exported goods with the imported goods even though both are classified as the one good. The elasticity of substitution parameter in constant elasticity of substitution (CES) functions could measure the variation of diversity or likeness among them. The elasticity of substitution would be small (i.e., inelastic) if the variation is notably diverse upon them, and conversely. In spite of that, substitution is more relevant between imports and domestic goods, and between exports and domestic goods, than between exports and imports. In CGE models, it is assumed that there are substitutions between the imports and domestic goods, and between exports and domestic goods in pairwise manner. Consequently, Armington's (1969) assumption concerns about imperfect substitution between imports and domestic goods.

3.5.4.3 Substitution between imports and domestic goods

The assumption of Armington denotes that none of the imported goods are consumed or used straightforwardly by households and firms but they consume or use in terms of as known ‘Armington composite good’, which includes imports and related domestic goods. In the Armington composite good forming procedure, assuming virtual firms to act aiming to maximize their profits by selecting an appropriate combination of imported and domestic goods can be used to explain the model. Then, the results of their profit-maximization goals appear in their input demands for imports and for domestic goods, and the output level by altering amount of imported and domestic goods, relying on the related prices. To demonstrate that, we assume that imported mango juice and domestic mango juice were mixed by firms to create bottle of mango juice under the label of the company in the supermarkets. A CES function (17) could frequently be used to demonstrate this production procedure.

Nevertheless, an expansion of declared Cobb-Douglas and Leontief functions is the production function. The CES function is classified by the parameter of elasticity of substitution, σ_i, which shows the percentage changes in the input factor ratio caused by a 1% change in relative input prices. This parameter defines graphically the curvature of isoquants. The gentler curvature or the more flexibly input share is altered (see isoquant of the CES function in Figure 3.5; nonetheless, it is worth mentioning that import tariff rate is neglected). The Leontief function is extreme case, where $\sigma_i = 0$.

Accordingly, the optimization condition for the i-th Armington-composite-good-producing firm is as follows:

$$\underset{Q_i, M_i, D_i}{\text{maximize}}\ \pi_i^q = p_i^q Q_i - \left[(1+\tau_i^m) p_i^m M_i + p_i^d D_i\right]$$

Subject to

$$Q_i = \gamma_i \left(\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i}\right)^{\frac{1}{\eta_i}} \tag{17}$$

Notations are:

π_i^q: the firm producing the i-th Armington composite good profit,

p_i^q : the i-th Armington composite good price,

p_i^m: the i-th imported good in terms of domestic price

p_i^d : the i-th imported good price in domestic currency,

Q_i: the i-th Armington composite goods,

M_i : the i-th imported goods,

D_i: the i-th domestic goods,

τ_i^m : imported tariff rate on the i-th goods,

γ_i : scaling coefficient in the Armington composite good production function

δm_i, δd_i: input share coefficient in the Armington composite good production function ($0 \le \delta m_i \le 1$, $0 \le \delta d_i \le 1$, $\delta m + \delta d_i = 1$)

η_i : parameter defined by the elasticity of substitution, $(\eta_i = (\sigma_i - 1)/\sigma_i, \eta_i \le 1)$,

σ_i : elasticity of substitution in the Armington composite good production function,

$$\left(\sigma_i = -\frac{d(M_i / D_i)}{M_i / D_i} \middle/ \frac{d(p_i^m / p_i^d)}{p_i^m / p_i^d}\right).$$

For an optimality of the above problem, the first-order conditions indicate the subsequent demand functions for imports and the domestic good:

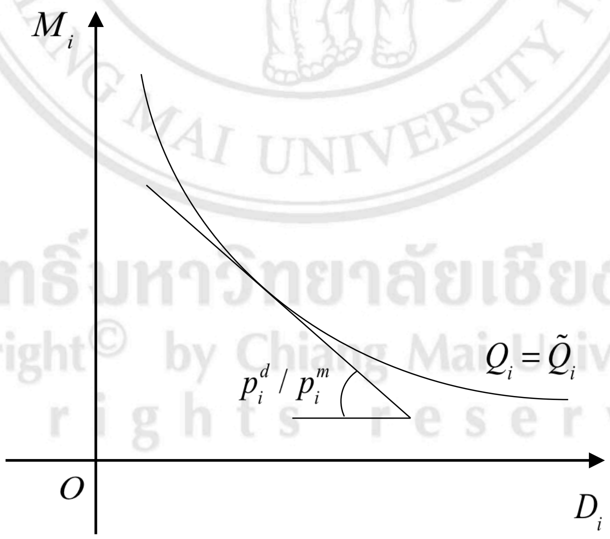
$$M_i = \left[\frac{\gamma_i^{\eta_i} \delta m_i p_i^q}{(1+\tau_i^m) p_i^m}\right]^{\frac{1}{1-\eta_i}} Q_i \qquad \forall i \tag{18}$$

$$Di = \left[\frac{\gamma_i^{\eta_i} \delta d_i p_i^q}{p_i^d}\right]^{\frac{1}{1-\eta_i}} Q_i \qquad \forall i \tag{19}$$

Furthermore, the Armington-composite-good-producing firm confronts tariff-inclusive import price $(1+\tau_i^m) p_i^m$ more than the tariff-exclusive import price p_i^m. Hence, the tariff rate τ_i^m is shown in the definition of its profit π_i^q. Consequently, $(1+\tau_i^m)p_i^m$ is also appeared in the derived import demand function (18).

3.5.4.4 Transformation between exports and domestic goods

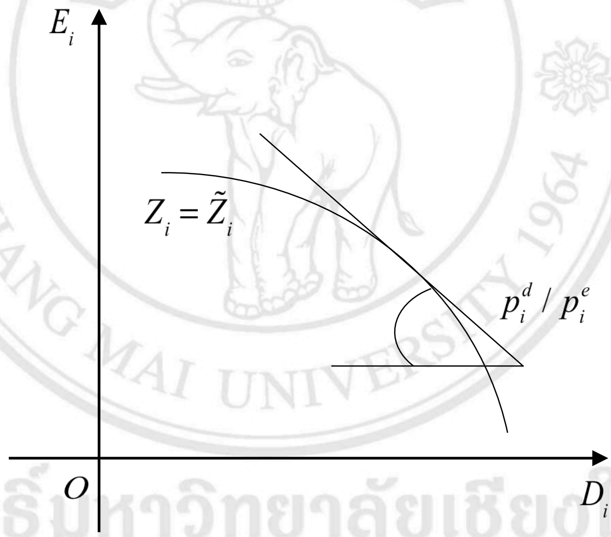
In terms of the exports and the domestic goods in supply side, the model is supposed that, by selling in international markets and also in domestic markets, the gross domestic output are transformed into goods by firms. In terms of transformation procedure, there is assumption of imperfect substitution (or imperfect transformation) between exports and the domestic good supply. To get a clarification of transformation between exports and domestic good, so for instant; electronic appliances are generally used all globally but those appliances are frequently categorized by country determining the preferences of targeted users. Those who delivered to Japan are probably aim to gain various functions in a tiny body, while those who exported to the international markets are rather simple in function of a bigger volume. Additionally, for instant; domestic sales for automobiles in Japan are usually furnished with luxurious preferences, whereas those who exported furnished with only necessary ones.



Source: Textbook of Computable General Equilibrium Modelling (Hosoe, 2011)

Figure 3.5: Isoquant of the CES function for the Armington composite good.

The model is assumed that for a firm (or the final process of a production in a firm), concerning with distribution of the gross domestic output to international markets and also to the domestic market, is considered about the supply ratio between these two markets and customizes its output to be appropriate for the aimed markets. This model is used to explain a transformation procedure with a constant elasticity of transformation (CET) function. The isoquants (or iso-input curves) for this transformation is shown in Figure 3.6, which is the mirror illustration of the isoquants (iso-output curves) of the CES function in Figure 3.5. The supply ratio change is contingent on the related price between exports and domestic goods. The larger of the elasticity of transformation ψ_i, is the gentler the isoquants curvature with a large elasticity of transformation, the export-domestic supply ratio tends to be more sensitive to a change in relative prices.



Source: Textbook of Computable General Equilibrium Modelling (Hosoe, 2011)

Figure 3.6: Isoquant of the CET function

The profit-maximization problem for the i-th firm transforming the gross domestic output into exports and domestic goods can be indicated as follows:

$$\underset{Z_i, E_i, D_i}{\text{maximize}}\ \pi_i = (p_i^e E_i + p_i^d D_i) - (1 + \tau_i^z) p_i^z Z_i$$

subject to

$$Z_i = \theta_i(\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i})^{\frac{1}{\phi_i}} \tag{20}$$

Notations are:

π_i : profit of the firm engaged in the i-th transformation,

p_i^e : price of the i-th export good in terms of domestic currency,

p_i^d : price of the i-th domestic good,

p_i^z : price of the i-th gross domestic output,

E_i : exports of the i-th good,

D_i : supply of the i-th domestic good,

Z_i : gross domestic output of the i-th good,

τ_i^z : production tax on the i-th gross domestic output,

θ_i : scaling coefficient of the i-th transformation,

ξe_i, ξd_i : share coefficients for the i-th good transformation,

($0 \le \xi e_i \le 1$, $0 \le \xi d_i \le 1$, $\xi e_i + \xi d_i = 1$),

ϕ_i : parameter defined by the elasticity of the transformation, ($\phi_i = (\psi_i + 1)/\psi_i$, $\psi_i \ge 1$)

ψ_i : elasticity of transformation of the i-th good transformation, $\left(\psi_i = \dfrac{d(E_i / D_i)}{E_i / D_i} \Big/ \dfrac{d(p_i^e / p_i^d)}{p_i^e / p_i^d}\right)$

To clarify this maximization problem, we get the subsequent supply function for exports and for domestic goods:

$$E_i = \left[\frac{\theta_i^{\phi_i} \xi e_i (1+\tau_i^z) p_i^z}{p_i^e} \right]^{\frac{1}{1-\phi_i}} Z_i \tag{21}$$

$$D_i = \left[\frac{\theta_i^{\phi_i} \xi d_i (1+\tau_i^z) p_i^z}{p_i^d} \right]^{\frac{1}{1-\phi_i}} Z_i \tag{22}$$

Due to the production tax, τ_i^z is levied on the gross domestic output Z_i, which is operated as the intermediate input in the transformation process, τ_i^z shows in the equation indicating the profit π_i and therefore in the numerators of the above two supply functions.

3.5.5 Market-clearing conditions

The model explanation above has been explained the economic behavior of agents, for instance; the household, the firm, the government, the investment and the external sector including a group of equations. The first method of the process in this model is to impose the market-clearing conditions, then demand meets supply in all market as follows:

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \qquad \forall i \tag{23}$$

$$\sum_j F_{h,j} = FF_h \qquad \forall j \tag{24}$$

In equation (23) demonstrates the Armington composite goods as the market-clearing condition. As previously discussed in Subsection 3.5.4.3, the composite good Q_i is used by the household, the government and the investment agent as well as for intermediate input. Thus, the model is applied the similar price p_i^q to all of them. Additionally, equation (24) is the factor of market-clearing condition. Nevertheless, the price p_i^q of household is not directly linked to the price p_i^z of firm in the market-clearing condition. The CES and ECT structures, which stand for substitution between exports and domestic goods respectively, and cause equality between the demand and supply of good by these agents but do not make a direct link between p_i^q and p_i^z. That is why, we do not impose price equalization constraint between p_i^q and p_i^z.

3.5.6 Model system

Following model discussion above, we have developed a system of simultaneous equations for the standard CGE model composing of (6.1) – (6.24).

- Domestic production:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \qquad \forall j \tag{1}$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \qquad \forall h, j \tag{2}$$

$$X_{i,j} = ax_{i,j} Z_j \qquad \forall i, j \tag{3}$$

$$Y_j = ay_i Z_i \qquad \forall j \tag{4}$$

$$p_j^z = ay_j p_j^y - \sum_i ax_{i,j} p_i^q \qquad \forall j \tag{5}$$

- Government:

$$T^d = \tau^d \sum_h p_h^f FF_h \tag{6}$$

$$T_j^z = \tau_j^z p_j^z Z_j \qquad \forall j \tag{7}$$

$$T_i^m = \tau_i^m p_i^m M_i \qquad \forall i \tag{8}$$

$$X_i^g = \frac{\mu_i}{p_i^q} \left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g \right) \quad \forall i \tag{9}$$

- Investment and savings:

$$X_i^v = \frac{\lambda_i}{p_i^q} \left(S^p + S^g + \varepsilon S^f \right) \qquad \forall i \tag{10}$$

$$S^p = ss^p \sum_h p_h^f FF_h \tag{11}$$

$$S^g = ss^g\left(T^d + \sum_j T_j^z + \sum_j T_j^m\right) \tag{12}$$

- Household:

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f FF_h - S^p - T^d\right) \qquad \forall i \tag{13}$$

- Export and import prices and the balance of payments constraint:

$$p_i^e = \varepsilon p_i^{We} \qquad \forall i \tag{14}$$

$$p_i^m = \varepsilon p_i^{Wm} \qquad \forall i \tag{15}$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \tag{16}$$

- Substitution between imports and domestic good (Armington composite):

$$Q_i = \gamma_i\left(\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i}\right)^{\frac{1}{\eta_i}} \qquad \forall i \tag{17}$$

$$M_i = \left[\frac{\gamma_i^{\eta_i}\delta m_i p_i^q}{(1+\tau_i^m)p_i^m}\right]^{\frac{1}{1-\eta_i}} Q_i \qquad \forall i \tag{18}$$

$$Di = \left[\frac{\gamma_i^{\eta_i}\delta d_i p_i^q}{p_i^d}\right]^{\frac{1}{1-\eta_i}} Q_i \qquad \forall i \tag{19}$$

- Transformation between exports and domestic goods:

$$Z_i = \theta_i(\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i})^{\frac{1}{\phi_i}} \qquad \forall i \tag{20}$$

$$E_i = \left[\frac{\theta_i^{\phi_i}\xi e_i(1+\tau_i^z)p_i^z}{p_i^e}\right]^{\frac{1}{1-\phi_i}} Z_i \qquad \forall i \tag{21}$$

$$D_i = \left[\frac{\theta_i^{\phi_i}\xi d_i(1+\tau_i^z)p_i^z}{p_i^d}\right]^{\frac{1}{1-\phi_i}} Z_i \qquad \forall i \tag{22}$$

- Market-clearing conditions:

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \qquad \forall i \tag{23}$$

$$\sum_j F_{h,j} = FF_h \qquad \forall i \tag{24}$$

The system of contemporary equations comprising of 24 sets of equations and the same number of endogenous variables

The endogenous variables in this model are:

$$Y_j,\ \ F_{h,j},\ \ X_{i,j},\ \ Z_j,\ \ X_i^p,\ \ X_i^g,\ \ X_i^v,\ \ E_i,\ \ M_i,\ \ Q_i,\ \ D_i,\ \ p_h^f,$$

$$p_j^y,\ \ p_j^z,\ \ p_i^q,\ \ p_i^e,\ \ p_i^m,\ \ p_i^d,\ \ \varepsilon,\ \ S^p,\ \ S^g,\ \ T^d,\ \ T_j^z \text{ and } T_i^m.$$

The exogenous are:

$$FF_h,\ \ S^f,\ \ p_i^{We},\ \ p_i^{Wm},\ \ \tau^d,\ \ \tau_j^z \text{ and } \tau_i^m.$$

According to Walras's law, we do not need to impose the market-clearing conditions on all *n* markets because the general equilibrium of this model economy holds with only then *n*-1 market clearing conditions. And one of those equations is redundant in this model. Hence, all the prices cannot be solved. Therefore, we have to select a numeraire and its price at a certain level, and express all the other price relative to the numeraire. Following the theory allows us to fix its price at an arbitrary level, thus we can fix it at unity for simplicity and for consistency with our calibration method, where all the prices are set at unity.

3.6 Research Simulation

The analysis performed five simulations of impact from the change of an exogenous variables affecting an endogenous variable. First is to replace the 40% of natural gas by solar electricity in electricity production. Second is to replace the 40% of natural gas by wind electricity in electricity production. The scenario of three-to-five is to stimulate all types of solar energy, wind energy and natural gas by 100,000 million baht, respectively. It might be interesting to examine the impact on economic productions, incomes, government revenue, imports, total saving, the changes of production price including the economic welfare.

To stimulate the policy simulation in terms of monetary unit, the scenarios aim to reduce 40% of total natural gas electricity production, which is equal to 93,831 million baht. Afterward, the amount of 93,831 million baht becomes 286.18% of solar improvement and also becomes 537.26% of wind improvement. In terms of calculation, the study uses the total supply in natural gas electricity or Sector 8, which is 234.579 million baht and multiplied by 0.40 as in the SAM table (Table A2). Furthermore, the scenario of three-to-five is to stimulate 100,000 million baht and the percentage of solar and wind electricity become 304.99% and 572.57% of improvement including 42.63% of gas improvement.

3.6.1 GAMS Simulation

In terms of policy simulation in GAMS model, the study aims to evaluate the impact from the replacement of natural gas by solar and wind energy in electricity production. Therefore, the policy simulation is activated into production supply. In the second stage, the composite factor is combined with intermediates to produce the gross domestic output, as indicated by the gross domestic output production function as Figure 3.3. The equation (3) is demonstrated as below.

$$X_{i,j} = ax_{i,j} Z_j \quad \forall i, j \qquad (3)$$

Z_j : gross domestic output of the j-th firm,

$X_{i,j}$: intermediate input of the i-th good used by the j-th firm,

$ax_{i,j}$: input requirement coefficient of the i-th intermediate input for a unit output of the j-th good,

In the technical terms, we use the dummy of "*afac*" to represent the shock parameter. Normally, the value of dummy is equal to 1 and it would make no change in production equation.

$$X_{i,j} = afac \times ax_{i,j} Z_j \qquad (3')$$

While the first scenario activates in the model, the dummy in gas supply would be changed into 0.60 caused by 0.40 of gas reduction. In the same time, the dummy of solar electricity supply would be change into 3.8616 caused by 2.8616 of solar improvement. The second scenario indicates the same value of gas reduction as the first scenario but the wind electricity would be changed into 6.3726 caused by 5.3726 of wind improvement. The value of dummy in the three-to-five scenario is 4.0499 in solar improvement, 6.7257 in wind improvement and 1.4263 in natural gas improvement. The simulation in GAMS code is as Table 3.4 and also in line 435 in Table A4 (GAMS code).

Table 3.4: The GAMS Simulation.

No.	Simulation Runs	The Value of Shock in GAMS Code		
		Natural Gas ******afac.fx* **(i,"S08")**	**Solar Energy** ******afac.fx* **(i,"S09")**	**Wind Energy** ******afac.fx* **(i,"S10")**
1	Reduction of Natural Gas and Improvement Solar Energy	0.6000	3.8616	-
2	Reduction of Natural Gas and Improvement Wind Energy	0.6000	-	6.3726
3	Improvement of Gas Energy by 100,000 Million THB	1.4263	-	-
3	Improvement of Solar Energy by 100,000 Million THB	-	4.0499	-
5	Improvement of Wind Energy by 100,000 Million THB	-	-	6.7257

Source: Own elaboration

** "fx" is the suffix standing for the bound constraint.*

CHAPTER 4

Empirical Results

4.1 Situation of Energy Sector

After Thailand's economy has stepped from agricultural into manufacturing industry. The Thai econony has gradually expanded in terms of GDP from 137 billion of US dollar to 232 billion of US dollar within fitteen years. Not only for GDP, but also the final consumption and energy use that had grown by 47.86 percent of ktoe in decades (Table 1.1). Additionally, the share of energy consumption in each economic sector shows a large number of usage, especially in manufaturing accounting for 36.7% of total energy consumption and transportation for 35.36% of total energy consumption.

One of the most important energy is an electricity. Thailand has a great amount of natural gas for the electricity production. Nowadays, Thailand's energy demands 67.42% of natural gas, 19.21% of lignite, 10.29% of hydropower, and a small share of renewable energy for producing an electricity in domestic consumption (EGAT, 2015). Accordingly, Thailand relies mostly on of natural gas, but the natural gas is limited-fossil resource or an energy scarcity. Therefore, the Ministry of Energy endeavors to improve energy security by reducing a natural gas usage and also enhance sustainable energy by pursuing the role of renewable energy especially in solar energy, wind energy, and also biomass for both electricity production and heat production. The Table 2.2 also shows the renewable energy consumption in Thailand that indicates 11.91% of alternative energy ratio in 2014. For instance, the changes in electricity's output supply and input demand could affect production, employment, and income distribution in those industrial sectors. On the other hand, the changes in other sectors could also create more production, employment, and income distribution in electricity sector. Therefore, this study attempts to analyze the impact between industrial sectors and household institutions from the renewable energy policy.

4.2 Data Analysis

In terms of data analysis, this section discusses the costs and other data concerned to solar energy, wind energy, and natural gas consumption in electricity sector related to the Thailand economy. To disaggregate those electricity generation sectors, the study assumes that *the original electricity and pipeline distribution sector* is divided into *solar electricity*, *wind electricity*, and *natural gas electricity*. Moreover, the study maintains *the original electricity and pipeline distribution sector* to standing for other types of electricity generation such as hydropower, biomass, and also traditional energy.

In the details of cost breakdown, the study aims to disaggregate the solar and wind electricity by using the cost of setting up in terms of equipment, machinery and construction but the problem is lacking of information in Thailand. However, there are several private companies in Thailand stock market that provides the information of cost but those account have no information for different types of energy. Thus, we could not classify them into that way the study needs.

In order to disaggregate the solar and wind electricity, the study found that U.S. Energy Information Administration (EIA) reported about capacity utilization. The capacity utilization rate is widely used for measuring the proportion of potential economic output. The capacity factor of solar electricity indicated that Thailand has a 11% of capacity factor, which is similar with Japan and South Korea by 12% of capacity factor. The capacity factor of wind electricity also showed that Thailand has 27% of capacity factor, which is similar with 22 percent of capacity factor in South Korea and 20 percent of capacity in Japan. All in all, the number of capacity factor could be described that Thailand has similar technology as Japan and South Korea in terms of solar electricity and wind electricity based on the capacity utilization rate. (EGAT, 2015)

4.2.1 Costs of Natural Gas in Electricity Production

One of the energy resources that is consumed in heating, cooking, and also electricity generation is natural gas. Not only for those utilities, but it also used as an alternatively fuel consumption for vehicles, chemical industry including plastic in manufacturing sector. Obviously, this kind of energy is beneficially in different advantages. That is what natural gas benefit for Thailand economy. And Thailand has a large gas resources mainly supplied by PTT which is gas procurement and distribution, then the gas is transported directly to a power producer namely Electricity Generating Authority of Thailand (EGAT).

Thailand provides 73.39 percent from domestic producers and others from imports in types of produced gas (DEDE, 2015). What the study interest is to use a natural gas in electricity generation, the information also shows that 58.21 percent of produced gas use in electricity generation (DEDE, 2015). The rest of produced gas is operated for gas distribution into industrial sector. Thus, the study refers that number for constructing a new natural gas electricity sector out of *the original electricity and pipeline distribution sector*. Therefore, the total cost of natural gas electricity is calculated to 234,579 million baht by conducting the value of produced gas and the share of electricity use. Although, the study added the new economy sector into the table, the total value of accounts is still the same as general IO table. Furthermore, the share of natural gas electricity demands is shown as Table 4.1.

Table 4.1: The Cost Breakdown of Natural Gas Electricity.

Economy Sector	Share of Demand (%)	Value (Million THB)
Natural Gas	92.61	173,077
Electricity	6.79	12,698
Service	0.56	51,045
Commerce	0.03	64
Service	0.01	7.74
Total	**100**	**103,709**

Source: Own elaboration

4.2.2 Costs of Solar Energy in Electricity Production

The renewable energy becomes a crucial source respected to newly technological improvement. And the solar energy is one of them. Basically, the solar energy is light of radiation and heat from the sun by using a range of technological equipment to produce an electricity and heat. The electricity generation in Thailand currently uses solar power around 25 percent of electricity generation calculated from total electricity of renewable energy but it indicates just only 3 percent of total electricity generation (DEDE, 2014).

In type of solar energy for electricity production, the study referred the information of capacity factor to compare cost of setting up with Japan technology. Table 4.2 indicates that the investment of solar in Japan country needs Photovoltaic module or PV module by 53.89 percent of total use and invertor, wiring transformer including electricity and site preparation as well.

Table 4.2: The Cost Breakdown of Solar Energy for Investment.

Equipment Name	Investment (2010 USD/Wp)	Share of total cost (%)	Economy Sector
PV module	1.87	53.89	Machinery
Invertor	0.25	7.20	Machinery
Wiring and Transformer	0.15	4.32	Construction
Electricity	0.1	2.88	Electricity
Site Preparation	0.2	5.76	Construction
Racking	0.4	11.53	Construction
Structure Installation	0.1	2.88	Construction
Business process	0.4	11.53	Service
Total	**3.47**	**100.00**	

Source: The installation cost is base on Ground-Mounted type in Europe, 2006

And the study also refers the alternative energy investment in Thailand which is 32,788 Million baht to be a total consumption of solar electricity in IO table (EGAT, 2010). Thus, we could build a solar electricity sector in consumption by using Table 4.2 to calculate the value of investment in each economy sector as Table 4.3.

Table 4.3: The Share Summation of Solar Energy Demand.

Economy Sector	Solar Energy Demand Share (%)	Value (Million THB)
Machinery	61.10	20,031.86
Electricity	2.88	944.90
Construction	24.50	8,031.64
Service	11.53	3,779.60
Total	**100.00**	**32,788**

Source: Own elaboration

4.2.3 Costs of Wind Energy in Electricity Production

One of the renewable energy which the study selects to compare with solar energy is wind energy. Wind power is the use of air flow through wind turbines and then mechanically to generate the power electricity. Thailand also has a potential wind energy in wind farms which is an area of consisting of several wind turbines and connected to the electricity transmission as well as the solar farm but different in mechanical source of energy.

The cost of wind investment is 17,465 million baht (EGAT, 2010). The study aims to construct a new account of electricity by using the information of that year in order to matching with 2010 input-output table. According to the information of capacity factors, we use the cost of a wind turbine installed in Japan to operate the new account of wind electricity generation in 2010 IO table as Table 4.4 and 4.5.

Table 4.4: The Cost Breakdown of Wind Energy for Investment.

Equipment Name	Investment (Euro 1,000/MW)	Share of total cost (%)	Economy Sector
Turbine	928	78.64	Machinery
Grid connection	109	9.24	Electricity
Foundation	80	6.78	Construction
Electricity	18	1.53	Electricity
Consultancy	15	1.27	Service
Financial costs	15	1.27	Service
Road construction	11	0.93	Construction
Control system	4	0.34	Construction
Total	**1180**	**100.00**	

Source: The Economics of Wind Energy by the European Wind Energy Association, March 2009

Table 4.5: The Share Summation of Wind Energy Demand.

Economy Sector	Wind energy demand share (%)	Value (Million THB)
Machinery	78.64	13,735.19
Electricity	10.76	1,879.71
Construction	8.05	1,406.08
Service	2.54	444.03
Total	**100.00**	**17,465**

Source: Own elaboration

4.3 SAM Simulation Result

In terms of analysis, the study uses a Social Accounting Matrix (SAM) of Thailand for evaluating the policy simulations. The analysis can generate the linkages both backward and forward linkages to describe the transaction between industrial sectors.

The layout of the proposed SAM is constructed from Thailand input-output table in 2010, including database from national income in 2013. After that we operate the RAS method for balancing this SAM for further analysis. There are 36 accounts in which contains 14 productive sectors for activities and other 14 for commodities, 2 factors of production, 2 types of households and one for firm and government, including saving-investment and rest of the world. The 14 productive sectors include *agriculture and food industry*, *petroleum, natural gas and mining, manufacturing, rubber, chemical and petroleum refinery, machinery, other manufacturing, original electricity and pipeline, natural gas electricity, solar electricity, wind electricity, construction, commerce and transportation, service* and *unclassified sector* as Table A7. Moreover, there are *labor* and *capital* in factors of production. The *agriculture household*, *non-agriculture household*, *firm* and *government* are included in institutions. Besides, *import* and *export* are important transaction and cooperate with *rest of world*. Lastly is *saving and investment* account. In addition, the Table A2-A6 show the distribution cost of disaggregation sector in natural gas electricity, solar energy and wind energy from original electricity sector.

4.3.1 Interpretation of 2010 SAM Multiplier

Table A2 shows the real transaction between 36 account as million baht and Table A8 indicates the multiplier matrix from 2010 SAM of Thailand. In multipliers, there are 33 endogenous accounts which consists of 14 productive activities, 14 commodities, 2 factors of production, 2 households and one firm. There are 3 types of exogenous account which is government, rest of world and saving and investment.

However, Table 4.3 can be described that an increase in demand of one unit of solar electricity induces an increase of production of 2.37 unit in whole economy, which increase 0.31 unit in machinery, 0.32 unit in service, 0.17 unit in agriculture and food industry, and 0.16 unit in commerce and transportation. Inversely, a decrease in demand of one unit of natural gas electricity gives a decrease 1.02 unit in a natural gas electricity itself, 0.69 unit in petroleum, natural gas, and mining, 0.27 unit in service, and 0.10 unit in original electricity and pipeline. The column 31, 32 and 33 also indicate the affect of income transfer to agriculture household, non-agriculture household. The SAM multiplier of non-agriculture household shows that the total impact to the whole economy at 1.49 units and 0.90 unit from agriculture household. In the production multiplier shows that the highest multiplier is 2.64 in construction sector, 2.53 in manufacturing and 2.46 in agricultural sector. The highest multiplier in electricity production is 2.53 in natural gas electricity, 2.48 in original electricity and 2.37 in solar electricity production.

4.3.2 Policy Simulation of 2010 SAM Multiplier

The Table 4.6 indicates the results of the fourteen-sector in Thailand economy model. There are five scenarios showing in each column. The interpretation is a one-unit increase in exogeneous demand leads to an increase in production output, GDP, and household income following the respective column part. The output multiplier amount to all linkage effects to estimate the overall increase in gross output in each sector. The GDP multiplier consolidate all labor and capital earnings created by the additional production in all sectors. Lastly, the income multipliers demonstrate the additional incomes created by agriculture and non-ahriculture households in each scenario. To emphasize the five simulations, we compare a replacement from 40 percent of natural gas electricity by solar electricity improvement and wind electricity improvement. A replacement of natural gas electricity by solar electricity causes to a lower GDP reduction compared to wind electricity. While a 40% of gas electricity reduction and become 286.18% of solar electricity improvement in terms of economic value. Table 4.6 shows that the solar replacement decreases GDP by 8,149 million baht. Meanwhile, the wind replacement decrease GDP by 13,081 million baht. For the three-to-five scenario is to improve by 100,000 million baht in solar electricity, wind electricity and natural gas electricity production. The result shows that the natural gas improvement can raise GDP by 67,503 million baht as scenario five in Table 4.6. The solar and wind improvement can also increase GDP by 58,770 million baht and 53,561 million baht as scenario three-to-four in Table 4.6.

Table 4.6: Multipliers Under the Five Electricity Policy Scenarios.

	Scenario 1 Decrease Natural Gas and Increase Solar Energy	**Scenario 2** Decrease Natural Gas and Increase Wind Energy
Activities-Agriculture and Food industry	-710.5	-2,714.9
Activity-Petroleum, Natural gas and Mining	-74,513.6	-74,586.5
Activity-Manufacturing	4,835.7	1,536.9
Activity-Rubber and Chemical	-1,721.9	-2,239.7
Activity-Machinery	42,618.2	54,350.0
Activity-Other Manufacturing	300.6	-25.7
Activity-Original Electricity	-3,837.8	2,762.0
Activity-Natural gas electricity	-539.1	236.8
Activity-Solar electricity	-19.4	-19.9
Activity-Wind electricity	-11.2	-9.8
Activity-Construction	18,500.1	6,073.9
Activity-Commerce and Transportation	5,523.5	4,922.6
Activity-Service	8,196.9	-3,678.2
Activity-Unclassified	94.2	29.5
Commodity-Agriculture and Food industry	-770.7	-2,945.2
Commodity-Petroleum, Natural gas and Mining	-95,564.9	-95,658.4
Commodity-Manufacturing	5,858.3	1,861.9
Commodity-Rubber and Chemical	-3,184.5	-4,142.1
Commodity-Machinery	68,670.2	87,573.6
Commodity-Other Manufacturing	439.7	-37.6
Commodity-Original Electricity	-4,609.8	3,317.7
Commodity-Natural gas electricity	-539.1	236.8
Commodity-Solar electricity	-19.4	-19.9
Commodity-Wind electricity	-11.2	-9.8
Commodity-Construction	23,031.1	7,561.5
Commodity-Commerce and Transportation	5,568.4	4,962.6
Commodity-Service	8,488.0	-3,808.9
Commodity-Unclassified	102.6	32.2
Factor-Labor	-2,552.0	-5,684.9
Factor-Capital	-5,642.1	-7,396.6
Agriculture Household	-1,765.9	-3,121.9
Non-Agriculture Household	-3,354.1	-5,929.6
Firm	-3,074.0	-4,030.0
Government	-3,508.3	-4,252.2
Rest of World	6,908.6	9,863.8
Saving/Investment	-1,634.4	-2,489.8
Total Output	*-1,284.2*	*-13,363.0*
Total Demand	*7,458.6*	*-1,075.6*
Total GDP	*-8,194.0*	*-13,081.5*
Total Income	*-5,120.0*	*-9,051.5*

Source: Own elaboration

Table 4.6: Multipliers Under the Five Electricity Policy Scenarios. (Continued)

	Scenario 3 Increase Solar Energy	**Scenario 4** Increase Wind Energy	**Scenario 5** Increase Natural Gas
Activities-Agriculture and Food industry	14,049.9	11,913.7	14,807.1
Activity-Petroleum, Natural gas and Mining	6,447.5	6,369.8	85,859.3
Activity-Manufacturing	8,305.1	4,789.5	3,151.6
Activity-Rubber and Chemical	6,991.1	6,439.3	8,826.2
Activity-Machinery	49,722.1	62,225.1	4,302.4
Activity-Other Manufacturing	2,094.9	1,747.1	1,774.5
Activity-Original Electricity	7,738.5	14,772.2	11,828.6
Activity-Natural gas electricity	1,440.2	2,267.1	2,014.7
Activity-Solar electricity	118.2	117.7	138.9
Activity-Wind electricity	64.3	65.8	76.2
Activity-Construction	19,953.2	6,710.1	237.0
Activity-Commerce and Transportation	19,115.2	18,474.8	13,228.6
Activity-Service	37,047.6	24,391.8	28,311.8
Activity-Unclassified	1,023.0	954.0	922.5
Commodity-Agriculture and Food industry	15,241.5	12,924.1	16,062.9
Commodity-Petroleum, Natural gas and Mining	8,269.0	8,169.4	110,115.9
Commodity-Manufacturing	10,061.4	5,802.3	3,818.0
Commodity-Rubber and Chemical	12,929.1	11,908.6	16,322.9
Commodity-Machinery	80,116.6	100,262.6	6,932.4
Commodity-Other Manufacturing	3,063.7	2,555.1	2,595.2
Commodity-Original Electricity	9,295.3	17,743.9	14,208.1
Commodity-Natural gas electricity	1,440.2	2,267.1	2,014.7
Commodity-Solar electricity	118.2	117.7	138.9
Commodity-Wind electricity	64.3	65.8	76.2
Commodity-Construction	24,840.1	8,353.5	295.0
Commodity-Commerce and Transportation	19,270.7	18,625.1	13,336.3
Commodity-Service	38,363.3	25,258.1	29,317.3
Commodity-Unclassified	1,113.5	1,038.4	1,004.1
Factor-Labor	24,451.8	21,113.0	27,171.5
Factor-Capital	34,318.6	32,448.7	40,331.5
Agriculture Household	13,820.9	12,375.8	15,702.9
Non-Agriculture Household	26,251.3	23,506.4	29,825.9
Firm	18,698.3	17,679.5	21,974.4
Government	13,607.2	12,814.5	17,346.2
Rest of World	61,305.4	64,454.8	53,942.6
Saving/Investment	11,266.5	10,354.9	13,008.4
Total Output	*174,110.8*	161,238.0	175,479.5
Total Demand	*224,187.0*	215,091.8	216,238.1
Total GDP	*58,770.4*	53,561.7	67,503.1
Total Income	*40,072.1*	35,882.2	45,528.7

Source: Own elaboration

The scenarios indicate that those electricity productions have large linkages for a few sectors because the SAM is constructed by author and there are not much specific linkages in details. The impact of electricity's multiplier indicates that the replacement of natural gas by solar energy leads the machinery to increase by 42,618 million baht and construction by 18,500 million baht but that negative effects lead the petroleum, natural gas and mining to decrease by 74,513 million baht, original electricity by 3,837 million baht and rubber and chemical by 1,721 million baht. The total output multiplier effect is -1,284, which means that the 40 percent by replaceing of natural gas by solar electricity causes to 1,284 million baht decrease in national output, similarlily as the total demand multiplier increased by 7,458 million baht. Therefore, this policy effects a large amount of negative and a positive following to decrease natural gas output itself and increase solar electricity affecting to all production output.

The result of the natural gas replacement by wind electricity indicates that the policy leads the machinery to increase by 54,350 million baht and construction by 6,073 million baht but the policy effects a negative impact to the petroleum, natural gas and mining output by 74,586 million baht, service by 3,678 million baht and agriculture and food industry by 2,714 million baht. Nevertheless, both scenarios of solar and wind replacement effect a negative to factor of production. Not only for factor production, but also for household income. The solar replacement declines the agriculture household by 1,765 million baht, non-agriculture household by 3,354 million baht and 3,074 million baht for firm. Meanwhile, the wind replacement also declines the agriculture household by 3,121 million baht, non-agriculture household by 5,929 million baht and firm by 4,030 million baht. The wind replacement affects to household income to decrease more than solar replacement. Hence, the policy of solar and wind replacement could effect a reduction in distribution income both agricultural household and non-agricultural household. The policy of solar and wind replacement has a high-value impact especially in machinery and construction because they are a large number of backward linkage in that production. Nevertheless, the natural gas reduction has a stronger linkage specifically in petroleum, natural gas and mining that is reasonable for a great number of negative.

The result of solar improvement, wind improvement and natural gas improvement by 100,000 million baht indicates a positive to all productions. The machinery output increases from solar improvement by 49,722 million baht and wind improvement by 62,225 million baht. The machinery demand is also increased much more the output both in solar and wind improvement. Moreover, the solar improvement effects to raises the production out in services by 37,047 million baht, commerce and transportation by 19,115 million baht and construction by 19,953 million baht. The wind improvement also effects to incline the service by 24,391 million baht, commerce and transportation by 18,474 million baht and original electricity by 14,772 million baht. In terms of natural gas improvement, the policy increases the petroleum, natural gas and mining 85,859 million baht, which is highest value of production output in improvement. The household income also gets a benefit from these policies. The agriculture household income increases 13,820 million baht and the non-agriculture income inclines 26,251 million baht. The wind and natural gas improvement can also effect the same direction by raising the incomes of household. The improvement of policies indicates the high GDP multiplier and high capital in factor of production as well, considering the high capital-intensity of solar, wind and gas enhancement. As a result, the policy of natural gas enhancement can create more impacts than solar and wind electricity improvement both production output and income distribution. However, the solar electricity and wind electricity effect to the machinery, commerce and transportation in the high value of improvement in order to a large number of linkages.

4.4 GAMS Simulation Result and Discussion

This part of analysis will be discussed among the five simulations that we already studied in the previous analysis by SAM multiplier. According to the Hosoe Standard CGE model in Chapter 3, the study operates the Hosoe GAMS model to simulate the renewable energy policy impacts following GAMS simulation as Table 3.4. In terms of the results, these are the microeconomic impacts, macroeconomic impacts and price effects including welfare to be the indicator of analysis. The discussion will be separated into sectoral impacts and macroeconomic impacts.

Table 4.7: The Scenario Results in GAMS.

Impacts	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Macroeconomic Impacts					
Household Consumption	0.00	0.00	0.00	0.00	0.00
Investment Consumption	-0.35	-0.08	0.01	0.00	0.01
Government Consumption	-0.08	-0.32	0.02	0.02	0.03
Microeconomic Impacts					
Sectoral Output					
Agriculture and Food industry	0.01	-0.02	0.02	0.01	0.00
Petroleum, Natural Gas and Mining	-8.73	-8.86	0.05	0.09	0.61
Manufacturing	0.74	0.32	0.15	0.07	0.00
Rubber, Chemical and Petroleum Refineries	-0.05	-0.10	0.03	0.03	0.01
Machinery	2.21	3.00	0.50	0.39	0.03
Other Manufacturing	0.20	0.09	0.04	0.03	0.01
Original Electricity	-0.39	0.03	0.12	0.56	0.61
Natural Gas Electricity	-0.18	-0.03	0.04	0.19	0.21
Solar Electricity	-0.07	-0.06	0.00	0.01	0.01
Wind Electricity	-0.08	-0.06	0.00	0.02	0.02
Construction	3.39	1.25	0.77	0.39	0.01
Commerce and Transportation	0.39	0.44	0.05	0.04	0.02
Service	-0.05	-0.10	0.06	0.01	0.01
Unclassified	0.08	0.09	0.01	0.01	0.00
Sectoral Price					
Agriculture and Food industry	0.04	0.06	0.02	0.01	0.00
Petroleum, Natural gas and Mining	0.03	0.06	0.02	0.01	0.00
Manufacturing	0.03	0.06	0.02	0.01	0.00
Rubber, Chemical and Petroleum Refineries	0.04	0.06	0.02	0.01	0.00
Machinery	0.04	0.06	0.02	0.01	0.00
Other Manufacturing	0.03	0.05	0.02	0.01	0.00
Original Electricity	0.03	0.05	0.02	0.01	0.00
Natural Gas Electricity	0.04	0.06	0.02	0.01	0.00
Solar Electricity	0.03	0.06	0.02	0.01	0.00
Wind Electricity	0.03	0.06	0.02	0.01	0.00
Construction	0.03	0.06	0.02	0.01	0.00
Commerce and Transportation	0.04	0.06	0.02	0.01	0.00
Service	0.03	0.05	0.02	0.01	0.00
Unclassified	0.04	0.06	0.02	0.01	0.00

Source: Own elaboration

Table 4.7: The Simulation Results GAMS (Continued).

Impacts	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Sectoral Export					
Agriculture and Food industry	0.03	-0.04	0.04	0.03	0.01
Petroleum, Natural gas and Mining	-8.72	-8.87	0.07	0.11	0.60
Manufacturing	0.76	0.32	0.16	0.09	0.01
Rubber, Chemical and Petroleum Refineries	-0.03	-0.11	0.04	0.04	0.01
Machinery	2.23	2.99	0.48	0.37	0.03
Other Manufacturing	0.23	0.09	0.06	0.05	0.02
Original Electricity	-0.37	0.02	0.14	0.57	0.61
Natural Gas Electricity	-0.16	-0.04	0.06	0.21	0.22
Solar Electricity	-0.05	-0.06	0.02	0.03	0.02
Wind Electricity	-0.05	-0.06	0.02	0.03	0.02
Construction	3.42	1.24	0.79	0.41	0.00
Commerce and Transportation	0.40	0.42	0.03	0.03	0.02
Service	-0.01	-0.09	0.07	0.02	0.01
Unclassified	0.10	0.08	0.01	0.01	0.01
Sectoral Import					
Agriculture and Food industry	-0.02	-0.01	0.01	0.01	0.01
Petroleum, Natural gas and Mining	-8.77	-8.85	0.03	0.07	0.62
Manufacturing	0.71	0.33	0.12	0.05	0.01
Rubber, Chemical and Petroleum Refineries	-0.10	-0.07	0.02	0.01	0.01
Machinery	2.12	3.07	0.59	0.47	0.01
Other Manufacturing	0.13	0.10	0.00	0.01	0.01
Original Electricity	-0.41	0.03	0.11	0.54	0.60
Natural Gas Electricity	-0.20	-0.02	0.02	0.18	0.20
Solar Electricity	-0.10	-0.05	0.02	0.00	0.01
Wind Electricity	-0.10	-0.05	0.02	0.00	0.01
Construction	3.37	1.25	0.76	0.38	0.01
Commerce and Transportation	0.37	0.46	0.07	0.06	0.01
Service	-0.08	-0.11	0.05	0.00	0.02
Unclassified	0.06	0.11	0.03	0.03	0.00

Source: Own elaboration

Table 4.7: The Simulation Results in GAMS (Continued).

Impacts	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Sectoral Capital Stock					
Agriculture and Food industry	-0.01	-0.05	0.03	0.02	0.00
Petroleum, Natural gas and Mining	-8.75	-8.88	0.06	0.10	0.61
Manufacturing	0.72	0.30	0.16	0.08	0.00
Rubber, Chemical and Petroleum Refineries	-0.07	-0.12	0.04	0.03	0.01
Machinery	2.19	2.98	0.50	0.39	0.03
Other Manufacturing	0.18	0.06	0.06	0.04	0.01
Original Electricity	-0.41	0.00	0.13	0.56	0.61
Natural Gas Electricity	-0.19	-0.05	0.05	0.20	0.21
Solar Electricity	-0.09	-0.09	0.01	0.02	0.01
Wind Electricity	-0.10	-0.09	0.01	0.03	0.02
Construction	3.38	1.22	0.78	0.40	0.01
Commerce and Transportation	0.38	0.42	0.04	0.04	0.02
Service	-0.07	-0.14	0.07	0.02	0.01
Unclassified	0.08	0.08	0.01	0.00	0.00
Sectoral Capital Rental					
Agriculture and Food industry	0.04	0.04	0.00	0.00	0.00
Petroleum, Natural gas and Mining	-8.70	-8.81	0.03	0.08	0.61
Manufacturing	0.77	0.38	0.13	0.06	0.00
Rubber, Chemical and Petroleum Refineries	-0.02	-0.04	0.01	0.01	0.00
Machinery	2.24	3.07	0.53	0.40	0.03
Other Manufacturing	0.23	0.14	0.02	0.02	0.01
Original Electricity	-0.36	0.08	0.10	0.54	0.61
Natural Gas Electricity	-0.14	0.03	0.02	0.18	0.21
Solar Electricity	-0.04	-0.01	0.02	0.00	0.01
Wind Electricity	-0.05	-0.01	0.02	0.01	0.02
Construction	3.43	1.30	0.75	0.38	0.01
Commerce and Transportation	0.43	0.50	0.07	0.06	0.02
Service	-0.02	-0.06	0.04	0.00	0.01
Unclassified	0.12	0.16	0.04	0.02	0.00
Welfare					
EV (Hicksian equivalent variations)	-78.34	-101.55	28.08	12.84	4.51

Source: Own elaboration

The first scenario stands for the replacement of natural gas reduction by solar electricity and the second scenario is the replacement of natural gas reduction by wind electricity. The macroecomic impact shows the institutions consumption in household, investment and government. The solar replacement declines the consumption both household consumption by -0.35% and govenrment consumption by -0.08%. Unlike, the wind replacement decrase the govenrment consumption by -0.32% and investment by -0.08%. Moreoever, the change of sectoral output is effected to the first and second scenario with a positive and negative direction in productions. The policy of solar replacement can increase the output of construction by 3.39% and machinery by 2.21% but the policy also effects differently the reduction output of petroleum, natural gas and mining by -8.73 percent and original electricity by -0.39%. Meanwhile, the wind replacement can lead a positive impact in machinery by 3.00%, commerce and transportation by 0.44% Unfortunately, it also declines the output of petroleum, natural gas and mining by -8.86 and rubber, chemical and petroleum refineries by -0.10%. Therefore, the solar replacement has an economic impacts than wind replacement as indicated in sectoral output.

In terms of sectoral price, the change in two policies is a slightly increased. The wind replacement can lead the sectoral price better than the solar replacement for all productions. Moreover, in the sectoral export and import, the directional change is the same as sectoral output. The solar replacement influences an export to increase the construction by 3.42% and the machinery by 2.23% but it affects an export to decrease the petroleum, natural gas and mining by -8.72% and orginal electricity by -0.37%. Although, the wind replacement affects an increase to the machinery by 2.99% and construction by 1.24%, it also affects a decrease to the petroleum, natural gas and mining by -8.87%. Therefore, the outcome of sectoral export and import demonstrate that the solar replacement is better-off than the wind replacement as higher positive impact in construction and lower negative impact in petroleum, natural gas and mining.

The result of sectoral capital rental show that the policy of solar replacement can raise the construction by 3.43% and machinery by 2.24%. Conversly, the wind replacement can increase the construction by 1.30% and machinery 3.07%. The wind and solar replacement also decline the petroleum, natural gas and mining in capital rental and capital stock. Hence, the machinery and construction get a benefit impact for the policy of solar replacement and wind replacement. Unlike, the petroleum, natural gas and mining get a negative direction in capital rental and capital stock. However, the Hicksian equivalent variations indiates the economic welfare between two policies. The solar replacement decreases the economic welfare by -78.34 EV and the wind replacement also decreases the welfare by -101.55. Therefore, the policy of natural gas reduction replacing by solar electricitiy is better-off than the wind replacement as specified by the economic welfare.

The scenario of three-to-five is to improve the solar electricity, wind electricity and natural gas electricity by 100,000 million baht. In terms of institution, the government has increase consumption a slightly positive in solar and wind policy by 0.02%, and natural gas policy by 0.03%. There is no change in household consumption for solar, wind and gas policy. The solar improvement can lead the construction increased by 0.77% and to machinery by 0.50%. The outcome of wind improvement can also incline the original electricity by 0.56% and to construction and machinery by 0.39%. Moreover, the gas improvement raises the petroleum, natural gas and mining, and the original electricity by 0.61%. In parts of the sectoral price, the solar improvement can create a 0.02% to all production, the wind policy creates a 0.01% to all production as well but the natural gas policy creates no change in their production price. In terms of export and import, the solar policy can increase the construction by 0.79% and machinery by 0.48%, the wind policy can increase the original electricity by 0.57% and machinery by 0.37%, and natural gas policy can increase the petroleum, natural gas and mining by 0.60%. The direction of sectoral export and import is inclined the similar changes. However, the result of capital rental and capital stock indicate that the construction and machinery of solar improvement has a best-off than wind policy and natural gas policy. Moreover, the outcome of capital rental and capital stock also show that the petroleum, natural gas, mining and original electricity has a better-off than solar improvement and wind improvement. Additionally, the economic welfare expresses that the solar improvement is the best-off as specified in welfare than the wind improvement and natural gas improvement.

CHAPTER 5

Conclusion

5.1 The Conclusion

The objective of this study is to evaluate the energy policy both in conventional energy and sustainable energy whether impacts to industry sectors and household or not. Since the Power Development Plan (PDP 2015) was assigned to improve more stability and security by reducing the conventional energy and the Alternative Energy Development Plan (AEDP) was also cover in the general promotion for the sustainable energy in the electricity field. Thus, the study objects to analysis the impact of policy in natural gas electricity reduction, solar electricity improvement and wind electricity improvement. The analysis contains five simulations in this study, which is the replacement of natural gas reduction by solar energy, the replacement of natural gas reduction by wind energy and the improvement of solar energy, wind energy and natural gas electricity. In terms of theory, the study applied the general equilibrium to mainly investigate the result. In methodology, we constructed social accounting matrix (SAM) by conveying a 2010 input-output table and 2014 national income database and also balancing the SAM by using RAS method. Hence, we use a SAM to be a benchmark table in GAMS model by applying the HOSOE standard model (HOSOE, 2004). As a consequent, the simulation result covers the sectoral impact from SAM multiplier analysis and macroeconomic impact from Computational General Equilibrium (CGE).

Consequently, the SAM multiplier demonstrates that the replacement of natural gas reduction by solar energy could impact directly in production output, production demand, including household income. The result indicates that the policy of solar replacement can cause the decrease in GDP but it was less than wind replacement. In production output, the petroleum, natural gas and mining get the high negative impacts in both solar replacement and wind replacement. However, the best-off production output in solar replacement policy is machinery and construction output. The best-off production output in wind replacement policy is also machinery and construction but it was slightly less than solar replacement. In terms of distribution income, it shows the households income is decreased. The household of solar replacement get a slightly better-off than household of wind replacement. In addition, the production output of construction, commerce and transportation of solar improvement get the best-off as specified in the group of improvement. The machinery of wind improvement gets the best-off and greater impacts than solar improvement. The natural gas has a large impact in petroleum, natural gas and food industry. The group of improvement scenarios can show that the large number of money injection is linking to the backward linkage in specific production. To summarize the SAM simulation, the solar replacement can create more production output, production demand and distribution income than wind replacement. The result indicates that we prefer to replace in solar electricity rather than wind electricity to natural gas electricity based on SAM simulation model.

As a results from GAMS analysis, the replacement of reduction by solar improvement and wind replacement could make the change to whole economy both positive and negative impacts as similar in SAM result. The effect of sectoral output in construction of solar replacement is much better-off then others. However, the wind replacement has a machinery that is better-off than others as specified in production output. The output of petroleum, natural gas and mining is the worst-off for both solar replacement and wind replacement policy. Additionally, the wind replacement policy can increase the sectoral price to all productions better-off than solar replacement. In terms of wages and capital, the solar replacement can affect the construction sector and machinery much better than other sectors. The wind replacement policy affects the machinery and construction much more than other sectors as well. The direction of scenario in three-to-five is similar to SAM result. Moreover, the wages of electricity group such as original electricity, natural gas electricity solar electricity and wind electricity fall down altogether in solar replacement but there is no much changes in wind replacement. The policy of solar improvement mostly raises the wages in construction. The policy of wind improvement and gas improvement also increase the wage mostly in original electricity sector as well. Lastly the economic welfare show that the wind replacement is worst-off than solar replacement and the solar improvement is better-off than the scenario group of improvement.

Finally, the GAMS and SAM results could point the same direction that the replacement of solar electricity can create more impacts in sector output, sector demand, distribution income and economic welfare than other scenarios. The replacement of natural gas reduction by solar policy also raise the wages in productions and a slightly product price. The study considers to invest solar energy rather than wind energy to replace the natural gas or the limited resource based on the study of economic model.

5.2 Policy Suggestion

Following the objective of study, we attempt to evaluate the energy policy between conventional energy and renewable energy. Consequently, the result also shows the microeconomic and macroeconomic impact to the economy while the study applied those simulations. Hence, there are several policy suggestions based on the result of the study. In Thailand, there is more likely a seasonal change in a year which effects directly to the electricity production from renewable energy such as solar electricity and wind electricity. Therefore, the suggestion is to give a direction and evaluation. For example, the spatial evaluation indicates that the northeast of Thailand which is a great area to plant the solar board or photovoltaic on it because that area has a high-intensity of radiation. It might be useful for those investor who would like to join the sustainable area.

In terms of distribution income, if the policy objective is to persuade household to invest in the renewable electricity production, the policy maker should consider a full support in several dimensions on it. The cost benefit is one of the most dimension that the household would like to know. Not only for the information of cost benefit, but also the technical knowledge. It could be better to understand whether they decide to invest or not. Nevertheless, the learning hub is one of the best solution for an education center to them.

The policy maker attempts to convince the producer or an electricity generation to change from natural gas usage to renewable energy. The feed-in-tariff is policy mechanism to persuade those investors to produce an electricity and they can get a payment by offering a long-term contract.

5.3 Future Work

In this research, we study the impact of the renewable energy and compare solar and wind energy in electricity field. It would be more interesting if the study could be extended by comparing among biomass, biogas, including hydropower in the model.

However, the biofuel is the one type of renewable energy that it has more linkages than solar and wind energy. To study the backward linkage of biofuel, the economic impact could have different linkages and more related production sectors especially in agriculture. Moreover, the policy impact in feed-in-tariff is not available in this model. The further study could include feed-in-tariff in the model for getting another transaction between household institutions and electricity generation sector. In addition, the study produced a SAM based on 2010 Input-Output table and 2014 national income database. It would be the newest version right now but the economy structure might be changed in the future. The further study could be inappropriate with this model. To precisely evaluation, it would be better to produce an up-to-date database in period of time.

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APPENDIX

Table A1: The Aggregation and Disaggregation of 2010 Input-Output Table Analysis.

No	26x26 Sector Name (180x180)	No	New Aggregated Sector Name (26x26)
1	Crops	1	Agriculture and Food Industry (001-004, 006-007)
2	Livestock	2	Petroleum, Natural gas and Mining (005, 014-015)
3	Forestry	3	Manufacturing (008-009, 013)
4	Fishery	4	Rubber, Chemical and Petroleum (010-012)
5	Mining and Quarrying	5	Machinery (016)
6	Food Manufacturing	6	Other Manufacturing (017)
7	Beverages and Tobacco Products	7	Original Electricity and Pipeline (018)
8	Textile Industry	8	Natural Gas Electricity (018)
9	Paper Products and Printing	9	Solar Electricity (018)
10	Chemical Industries	10	Wind Electricity (018)
11	Petroleum Refineries	11	Construction (019)
12	Rubber and Plastic Products	12	Commerce and Transportation (020)
13	Non-metallic Products	13	Service (021-025)
14	Basic Metal	14	Unclassified (026)
15	Fabricated Metal Products		
16	Machinery		
17	Other Manufacturing		
18	Electricity and Water Works		
19	Construction		
20	Trade		
21	Restaurants and Hotels		
22	Transportation and Communication		
23	Banking and Insurance		
24	Real Estate		
25	Services		
26	Unclassified		

Source: Own elaboration

Table A2: Social Accounting Matrix, Thailand 2010.

			Activities													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			AGRFI	PNGM	MANU	CHEM	MACH	OTMN	OELC	NELEC	SELEC	WELC	CONS	COMT	SERV	UNCL
Activities	1	AGRFI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	PNGM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	MANU	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	CHEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	MACH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	OTMN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	OELC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	NELEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	SELEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	WELC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	CONS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	COMT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	SERV	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	UNCL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commodities	15	AGRFI	1340163	242	12253	149582	111	24225	1592	0	0	0	4756	4457	292792	34507
	16	PNGM	22272	138253	56293	94824	137796	25385	57641	173077	0	0	83479	940	11726	12551
	17	MANU	20187	4364	270233	17530	47816	23283	1350	0	0	0	178534	18271	118210	18650
	18	CHEM	148400	79217	96938	284521	199411	49079	54940	0	0	0	25763	53041	543844	17897
	19	MACH	28930	21571	15058	17023	960417	12789	2903	0	11832	8113	20659	15254	229226	2087
	20	OTMN	4574	3882	12904	4641	26814	165822	831	0	0	0	16310	14762	35137	6600
	21	OELC	60898	26943	79163	76364	97419	21709	112677	12698	558	1110	7021	62897	192909	3043
	22	NELEC	0	0	0	0	0	0	93281	0	0	0	0	0	0	0
	23	SELEC	0	0	0	0	0	0	1127	0	0	0	0	0	0	0
	24	WELC	0	0	0	0	0	0	784	0	0	0	0	0	0	0
	25	CONS	2513	786	1753	1841	5534	1356	471	0	4744	831	890	1348	17723	229
	26	COMT	226496	33229	106842	136160	540564	132291	16151	1045	0	0	75777	17973	231145	16954
	27	SERV	175457	96906	100038	109274	201147	69887	62579	64	2232	262	112602	336733	904113	31546
	28	UNCL	13461	1188	9513	4759	11029	2737	2876	8	0	0	1166	28744	14828	1124
Factors	29	LAB	455319	118499	128734	145637	247786	119675	118664	9274	4942	2633	67580	496328	1583148	4873
	30	CAP	1144124	279328	266656	332654	650468	186751	211131	31267	7977	4249	130428	1788782	1648469	32096
Institutions	31	AGRH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	NAGRH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	FIRM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34	GOVT	199898	52490	21946	195714	133788	19614	9414	7147	502	267	10061	74197	138237	4181
Rest Of World	35	ROW	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saving/Investment	36	SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Column			*3842690*	*856896*	*1178324*	*1570523*	*3260101*	*854604*	*748412*	*234580*	*32788*	*17465*	*735026*	*2913728*	*5961506*	*186338*

Table A2: Social Accounting Matrix, Thailand 2010 (Continued).

			Commodities 15 AGRFI	16 PNGM	17 MANU	18 CHEM	19 MACH	20 OTMN	21 OELC	22 NELEC	23 SELEC	24 WELC	25 CONS	26 COMT	27 SERV	28 UNCL
Activities	1	AGRFI	3842690	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	PNGM	0	856896	0	0	0	0	0	0	0	0	0	0	0	0
	3	MANU	0	0	1178324	0	0	0	0	0	0	0	0	0	0	0
	4	CHEM	0	0	0	1570523	0	0	0	0	0	0	0	0	0	0
	5	MACH	0	0	0	0	3260101	0	0	0	0	0	0	0	0	0
	6	OTMN	0	0	0	0	0	854604	0	0	0	0	0	0	0	0
	7	OELC	0	0	0	0	0	0	748412	0	0	0	0	0	0	0
	8	NELEC	0	0	0	0	0	0	0	234580	0	0	0	0	0	0
	9	SELEC	0	0	0	0	0	0	0	0	32788	0	0	0	0	0
	10	WELC	0	0	0	0	0	0	0	0	0	17465	0	0	0	0
	11	CONS	0	0	0	0	0	0	0	0	0	0	735026	0	0	0
	12	COMT	0	0	0	0	0	0	0	0	0	0	0	2913728	0	0
	13	SERV	0	0	0	0	0	0	0	0	0	0	0	0	5961506	0
	14	UNCL	0	0	0	0	0	0	0	0	0	0	0	0	0	186338
Commodities	15	AGRFI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	16	PNGM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	17	MANU	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	18	CHEM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19	MACH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	OTMN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	OELC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	NELEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	SELEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	WELC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	CONS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	COMT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	27	SERV	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	UNCL	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Factors	29	LAB	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30	CAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Institutions	31	AGRH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	32	NAGRH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	33	FIRM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	34	GOVT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rest Of World	35	ROW	325907	242087	249182	1333947	1992863	395244	150557	0	0	0	180018	23702	211724	16483
Saving/Investment	36	SI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Column			*4168596*	*1098984*	*1427506*	*2904469*	*5252964*	*1249848*	*898969*	*234580*	*32788*	*17465*	*915044*	*2937429*	*6173230*	*202821*

Table A2: Social Accounting Matrix, Thailand 2010 (Continued).

			Factors			*Institutions*			*ROW*	*Capital*
			29	30	31	32	33	34	35	36
			LAB	CAP	AGRH	NAGRH	FIRM	GOVT	ROW	SI
Activities	1	AGRFI	0	0	0	0	0	0	0	0
	2	PNGM	0	0	0	0	0	0	0	0
	3	MANU	0	0	0	0	0	0	0	0
	4	CHEM	0	0	0	0	0	0	0	0
	5	MACH	0	0	0	0	0	0	0	0
	6	OTMN	0	0	0	0	0	0	0	0
	7	OELC	0	0	0	0	0	0	0	0
	8	NELEC	0	0	0	0	0	0	0	0
	9	SELEC	0	0	0	0	0	0	0	0
	10	WELC	0	0	0	0	0	0	0	0
	11	CONS	0	0	0	0	0	0	0	0
	12	COMT	0	0	0	0	0	0	0	0
	13	SERV	0	0	0	0	0	0	0	0
	14	UNCL	0	0	0	0	0	0	0	0
Commodities	15	AGRFI	0	0	414524	787344	0	18034	927416	156597
	16	PNGM	0	0	5191	9859	0	1238	330507	-62049
	17	MANU	0	0	77250	146728	0	34712	417271	33117
	18	CHEM	0	0	89520	170033	0	55286	1118292	-81713
	19	MACH	0	0	95568	181522	0	59623	2463062	1107329
	20	OTMN	0	0	72713	138110	0	20368	615491	110890
	21	OELC	0	0	27282	51819	0	19780	2375	42303
	22	NELEC	0	0	26852	51003	0	19469	2337	41637
	23	SELEC	0	0	6017	11428	0	4362	524	9330
	24	WELC	0	0	3170	6021	0	2298	276	4915
	25	CONS	0	0	2910	5528	0	9656	0	856931
	26	COMT	0	0	247650	470384	0	21851	428074	234844
	27	SERV	0	0	526191	999442	0	1599011	816603	29143
	28	UNCL	0	0	25055	47589	0	20865	17878	0
Factors	29	LAB	0	0	0	0	0	0	0	0
	30	CAP	0	0	0	0	0	0	0	0
Institutions	31	AGRH	1208217	1054047	0	0	0	0	0	0
	32	NAGRH	2294876	2002047	0	0	0	0	0	0
	33	FIRM	0	3658287	0	0	0	0	355347	0
	34	GOVT	0	0	288335	547662	530985	645439	2253	0
Rest Of World	35	ROW	0	0	18329	34813	2340685	0	0	0
Saving/Investment	36	SI	0	0	335706	637637	1141965	350134	17833	0
Total Column			*3503093*	*6714380*	*2262263*	*4296923*	*4013633*	*2882127*	*7515540*	*2483274*

Table A3: Social Accounting Matrix Multipliers, Thailand 2010.

			Activities													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
			AGRFI	PNGM	MANU	CHEM	MACH	OTMN	OELC	NELEC	SELEC	WELC	CONS	COMT	SERV	UNCL
Activities	1	AGRFI	1.66	0.19	0.21	0.30	0.17	0.24	0.20	0.15	0.17	0.16	0.21	0.20	0.29	0.44
	2	PNGM	0.03	1.17	0.09	0.09	0.07	0.06	0.20	0.69	0.05	0.05	0.14	0.03	0.04	0.10
	3	MANU	0.04	0.04	1.27	0.04	0.05	0.07	0.04	0.03	0.06	0.04	0.29	0.04	0.06	0.14
	4	CHEM	0.08	0.11	0.12	1.16	0.09	0.10	0.11	0.08	0.06	0.06	0.10	0.06	0.12	0.13
	5	MACH	0.04	0.06	0.05	0.04	1.26	0.05	0.04	0.04	0.31	0.38	0.06	0.04	0.07	0.05
	6	OTMN	0.02	0.02	0.03	0.02	0.03	1.17	0.02	0.02	0.02	0.02	0.04	0.02	0.03	0.05
	7	OELC	0.06	0.07	0.12	0.09	0.07	0.07	1.19	0.10	0.06	0.10	0.07	0.05	0.07	0.07
	8	NELEC	0.01	0.02	0.02	0.02	0.01	0.02	0.16	1.02	0.01	0.02	0.02	0.01	0.02	0.01
	9	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	10	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
	11	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.04	1.00	0.00	0.01	0.00
	12	COMT	0.20	0.16	0.24	0.20	0.31	0.30	0.15	0.13	0.16	0.16	0.26	1.13	0.19	0.24
	13	SERV	0.30	0.36	0.36	0.30	0.30	0.36	0.35	0.27	0.32	0.25	0.44	0.36	1.43	0.44
	14	UNCL	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	1.02
Commodities	15	AGRFI	0.71	0.20	0.23	0.32	0.18	0.26	0.22	0.17	0.19	0.17	0.22	0.22	0.32	0.48
	16	PNGM	0.04	0.22	0.12	0.11	0.09	0.08	0.25	0.88	0.06	0.06	0.18	0.03	0.05	0.12
	17	MANU	0.05	0.05	0.33	0.05	0.06	0.08	0.05	0.04	0.08	0.05	0.35	0.05	0.08	0.17
	18	CHEM	0.15	0.21	0.22	0.29	0.17	0.18	0.20	0.14	0.11	0.11	0.18	0.11	0.22	0.23
	19	MACH	0.07	0.09	0.08	0.06	0.41	0.08	0.07	0.06	0.50	0.62	0.10	0.06	0.11	0.08
	20	OTMN	0.03	0.03	0.04	0.03	0.04	0.25	0.03	0.03	0.03	0.03	0.06	0.04	0.04	0.07
	21	OELC	0.07	0.08	0.14	0.10	0.09	0.08	0.23	0.12	0.07	0.12	0.08	0.06	0.09	0.08
	22	NELEC	0.01	0.02	0.02	0.02	0.01	0.02	0.16	0.02	0.01	0.02	0.02	0.01	0.02	0.01
	23	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	24	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.01	0.00
	26	COMT	0.20	0.16	0.24	0.21	0.31	0.31	0.15	0.13	0.17	0.16	0.26	0.13	0.19	0.24
	27	SERV	0.31	0.37	0.37	0.31	0.32	0.37	0.36	0.27	0.33	0.26	0.46	0.37	0.45	0.46
	28	UNCL	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Factors	29	LAB	0.34	0.34	0.35	0.29	0.29	0.38	0.39	0.28	0.35	0.33	0.36	0.34	0.49	0.30
	30	CAP	0.56	0.51	0.51	0.45	0.48	0.49	0.51	0.45	0.44	0.43	0.49	0.69	0.45	0.52
Institutions	31	AGRH	0.21	0.20	0.20	0.17	0.18	0.21	0.21	0.17	0.19	0.18	0.20	0.23	0.24	0.19
	32	NAGRH	0.39	0.38	0.38	0.33	0.33	0.40	0.41	0.32	0.36	0.35	0.38	0.43	0.46	0.35
	33	FIRM	0.31	0.28	0.28	0.25	0.26	0.27	0.28	0.25	0.24	0.24	0.27	0.38	0.25	0.28
	34	GOVT	-0.05	-0.06	-0.02	-0.12	-0.04	-0.02	-0.01	-0.03	-0.02	-0.02	-0.01	-0.03	-0.02	-0.02
Rest Of World	35	ROW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saving/Investment	36	SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total production			*2.46*	*2.22*	*2.53*	*2.27*	*2.38*	*2.45*	*2.48*	*2.53*	*2.37*	*2.29*	*2.64*	*1.98*	*2.34*	*2.69*
Household income			*0.60*	*0.58*	*0.58*	*0.50*	*0.51*	*0.60*	*0.62*	*0.48*	*0.55*	*0.53*	*0.59*	*0.66*	*0.70*	*0.54*

Table A3: Social Accounting Matrix Multipliers, Thailand 2010 (Continued).

			Commodities													
			15	16	17	18	19	20	21	22	23	24	25	26	27	28
			AGRFI	PNGM	MANU	CHEM	MACH	OTMN	OELC	NELEC	SELEC	WELC	CONS	COMT	SERV	UNCL
Activities	1	AGRFI	1.53	0.15	0.17	0.16	0.10	0.16	0.17	0.15	0.17	0.16	0.17	0.20	0.28	0.40
	2	PNGM	0.03	0.91	0.07	0.05	0.05	0.04	0.16	0.69	0.05	0.05	0.11	0.03	0.03	0.09
	3	MANU	0.04	0.03	1.05	0.02	0.03	0.05	0.03	0.03	0.06	0.04	0.23	0.04	0.06	0.13
	4	CHEM	0.07	0.09	0.10	0.63	0.06	0.07	0.09	0.08	0.06	0.06	0.08	0.06	0.11	0.12
	5	MACH	0.04	0.04	0.04	0.02	0.78	0.03	0.04	0.04	0.31	0.38	0.05	0.04	0.07	0.04
	6	OTMN	0.02	0.02	0.02	0.01	0.02	0.80	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.04
	7	OELC	0.05	0.05	0.10	0.05	0.04	0.05	0.99	0.10	0.06	0.10	0.06	0.05	0.07	0.06
	8	NELEC	0.01	0.01	0.02	0.01	0.01	0.01	0.13	1.02	0.01	0.02	0.01	0.01	0.02	0.01
	9	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	10	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
	11	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.04	0.81	0.00	0.00	0.00
	12	COMT	0.18	0.13	0.19	0.11	0.19	0.21	0.13	0.13	0.16	0.16	0.21	1.12	0.18	0.22
	13	SERV	0.27	0.28	0.30	0.16	0.19	0.24	0.29	0.27	0.32	0.25	0.36	0.35	1.38	0.41
	14	UNCL	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.94
Commodities	15	AGRFI	1.66	0.16	0.19	0.18	0.11	0.18	0.18	0.17	0.19	0.17	0.18	0.22	0.30	0.44
	16	PNGM	0.04	1.17	0.10	0.06	0.06	0.05	0.21	0.88	0.06	0.06	0.15	0.03	0.04	0.11
	17	MANU	0.05	0.04	1.27	0.03	0.04	0.06	0.04	0.04	0.08	0.05	0.28	0.05	0.07	0.16
	18	CHEM	0.14	0.16	0.18	1.16	0.11	0.12	0.17	0.14	0.11	0.11	0.14	0.11	0.21	0.22
	19	MACH	0.06	0.07	0.06	0.03	1.26	0.05	0.06	0.06	0.50	0.62	0.08	0.06	0.11	0.07
	20	OTMN	0.03	0.03	0.04	0.02	0.02	1.17	0.03	0.03	0.03	0.03	0.05	0.04	0.04	0.06
	21	OELC	0.06	0.07	0.12	0.06	0.05	0.06	1.19	0.12	0.07	0.12	0.07	0.06	0.09	0.08
	22	NELEC	0.01	0.01	0.02	0.01	0.01	0.01	0.13	1.02	0.01	0.02	0.01	0.01	0.02	0.01
	23	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
	24	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
	25	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.05	1.00	0.00	0.01	0.00
	26	COMT	0.19	0.13	0.20	0.11	0.19	0.21	0.13	0.13	0.17	0.16	0.21	1.13	0.18	0.22
	27	SERV	0.28	0.29	0.31	0.17	0.20	0.25	0.30	0.27	0.33	0.26	0.37	0.37	1.43	0.42
	28	UNCL	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	1.02
Factors	29	LAB	0.32	0.27	0.29	0.16	0.18	0.26	0.32	0.28	0.35	0.33	0.29	0.34	0.48	0.27
	30	CAP	0.52	0.40	0.42	0.24	0.30	0.34	0.42	0.45	0.44	0.43	0.40	0.69	0.44	0.48
Institutions	31	AGRH	0.19	0.16	0.17	0.09	0.11	0.14	0.18	0.17	0.19	0.18	0.16	0.22	0.23	0.17
	32	NAGRH	0.36	0.29	0.31	0.18	0.21	0.27	0.34	0.32	0.36	0.35	0.31	0.43	0.44	0.32
	33	FIRM	0.28	0.22	0.23	0.13	0.16	0.18	0.23	0.25	0.24	0.24	0.22	0.37	0.24	0.26
	34	GOVT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rest Of World	35	ROW	-0.08	-0.22	-0.17	-0.46	-0.38	-0.32	-0.17	0.00	0.00	0.00	-0.20	-0.01	-0.03	-0.08
Saving/Investment	36	SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total production			*2.27*	*1.73*	*2.09*	*1.23*	*1.48*	*1.68*	*2.07*	*2.53*	*2.37*	*2.29*	*2.12*	*1.96*	*2.26*	*2.47*
Household income			*0.55*	*0.45*	*0.48*	*0.27*	*0.32*	*0.41*	*0.51*	*0.48*	*0.55*	*0.53*	*0.47*	*0.65*	*0.67*	*0.49*

Table A3: Social Accounting Matrix Multipliers, Thailand 2010 (Continued).

			Factors			*Institutions*			*ROW*	*Capital*
			29	30	31	32	33	34	35	36
			LAB	CAP	AGRH	NAGRH	FIRM	GOVT	ROW	SI
Activities	1	AGRFI	0.34	0.16	0.24	0.40	0.00	0.00	0.00	0.00
	2	PNGM	0.03	0.01	0.02	0.04	0.00	0.00	0.00	0.00
	3	MANU	0.06	0.03	0.04	0.07	0.00	0.00	0.00	0.00
	4	CHEM	0.07	0.03	0.05	0.08	0.00	0.00	0.00	0.00
	5	MACH	0.06	0.03	0.04	0.07	0.00	0.00	0.00	0.00
	6	OTMN	0.04	0.02	0.02	0.04	0.00	0.00	0.00	0.00
	7	OELC	0.05	0.02	0.03	0.05	0.00	0.00	0.00	0.00
	8	NELEC	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00
	9	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12	COMT	0.20	0.09	0.14	0.23	0.00	0.00	0.00	0.00
	13	SERV	0.39	0.18	0.28	0.46	0.00	0.00	0.00	0.00
	14	UNCL	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00
Commodities	15	AGRFI	0.37	0.17	0.26	0.43	0.00	-0.01	-0.12	-0.06
	16	PNGM	0.04	0.02	0.03	0.05	0.00	0.00	-0.04	0.02
	17	MANU	0.07	0.03	0.05	0.08	0.00	-0.01	-0.06	-0.01
	18	CHEM	0.13	0.06	0.09	0.15	0.00	-0.02	-0.15	0.03
	19	MACH	0.09	0.04	0.06	0.11	0.00	-0.02	-0.33	-0.45
	20	OTMN	0.05	0.02	0.04	0.06	0.00	-0.01	-0.08	-0.04
	21	OELC	0.06	0.03	0.04	0.07	0.00	-0.01	0.00	-0.02
	22	NELEC	0.02	0.01	0.01	0.02	0.00	-0.01	0.00	-0.02
	23	SELEC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	24	WELC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	CONS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.35
	26	COMT	0.20	0.09	0.14	0.23	0.00	-0.01	-0.06	-0.09
	27	SERV	0.41	0.19	0.29	0.47	0.00	-0.55	-0.11	-0.01
	28	UNCL	0.02	0.01	0.01	0.02	0.00	-0.01	0.00	0.00
Factors	29	LAB	1.22	0.10	0.15	0.25	0.00	0.00	0.00	0.00
	30	CAP	-0.01	1.00	-0.66	0.34	0.00	0.00	0.00	0.00
Institutions	31	AGRH	0.42	0.19	0.95	0.14	0.00	0.00	0.00	0.00
	32	NAGRH	0.80	0.36	-0.10	1.26	0.00	0.00	0.00	0.00
	33	FIRM	0.00	0.54	-0.36	0.18	1.00	0.00	-0.05	0.00
	34	GOVT	0.00	0.00	-0.13	0.00	-0.13	0.78	0.00	0.00
Rest Of World	35	ROW	0.00	0.00	-0.01	-0.13	-0.58	0.00	1.00	0.00
Saving/Investment	36	SI	0.00	0.00	-0.15	-0.01	-0.28	-0.12	0.00	1.00
Total production			*1.29*	*0.59*	*0.90*	*1.49*	*0.00*	*0.00*	*0.00*	*0.00*
Household income			*1.21*	*0.55*	*0.85*	*1.40*	*0.00*	*0.00*	*0.00*	*0.00*

Table A4: GAMS Code

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$Ontext
No description.

Hosoe, N, Gasawa, K, and Hashimoto, H
Handbook of Computible General Equilibrium Modeling
University of Tokyo Press, Tokyo, Japan, 2004
$Offtext

* Definition of sets for suffix --------------------------------------
Set    u     SAM entry     /S01, S02, S03, S04, S05, S06, S07, S08, S09, S10, S11, S12, S13, S14,
                            CAP, LAB, IDT, TRF, HOH, GOV, INV, EXT/
       i(u)    goods       /S01, S02, S03, S04, S05, S06, S07, S08, S09, S10, S11, S12, S13, S14/
       h(u)   factor       /CAP, LAB/;
Alias (u,v), (i,j), (h,k);
* -------------------------------------------------------------------
* Loading data -------------------------------------------------------
* Scaling from excel and Keep scientific value by X.XXXXXXE+YY

Table   SAM(u,v)       social accounting matrix
             S01              S02              S03              S04              S05
S01     1.262735E+06     2.187335E+02     1.115235E+04     1.343560E+05     9.222283E+01
S02     2.499939E+04     1.485800E+05     6.103815E+04     1.014618E+05     1.361749E+05
S03     2.113764E+04     4.375152E+03     2.733454E+05     1.749807E+04     4.408242E+04
S04     1.629058E+05     8.326119E+04     1.027968E+05     2.977418E+05     1.927302E+05
S05     4.471572E+04     3.192315E+04     2.248302E+04     2.508225E+04     1.306994E+06
S06     5.538167E+03     4.499967E+03     1.509314E+04     5.356428E+03     2.858410E+04
S07     6.029292E+04     2.554034E+04     7.571263E+04     7.207320E+04     8.491844E+04
S08     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
S09     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
S10     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
S11     9.214131E+03     2.759293E+03     6.211661E+03     6.434748E+03     1.786804E+04
S12     2.248727E+05     3.158728E+04     1.024712E+05     1.288686E+05     4.725203E+05
S13     1.386249E+05     7.330644E+04     7.635103E+04     8.230195E+04     1.399197E+05
S14     1.084329E+04     9.166728E+02     7.403040E+03     3.654630E+03     7.822169E+03
CAP     1.176261E+06     2.749582E+05     2.648277E+05     3.260205E+05     5.887794E+05
LAB     4.682998E+05     1.166935E+05     1.279035E+05     1.427917E+05     2.243786E+05
IDT     2.080503E+05     5.230658E+04     2.206472E+04     1.941800E+05     1.225951E+05
TRF     2.492029E+04     1.140527E+05     1.165124E+04     3.621260E+04     6.861076E+04
HOH     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
GOV     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
INV     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02     1.000000E-02
EXT     3.251857E+05     1.340046E+05     2.470007E+05     1.330435E+06     1.816894E+06
+
             S06              S07              S08              S09              S10
```

S01	2.152067E+04	1.481770E+03	1.000000E-02	1.000000E-02	1.000000E-02
S02	2.686461E+04	6.391240E+04	1.772822E+05	1.000000E-02	1.000000E-02
S03	2.298600E+04	1.396282E+03	1.000000E-02	1.000000E-02	1.000000E-02
S04	5.079616E+04	5.957692E+04	1.000000E-02	1.000000E-02	1.000000E-02
S05	1.863703E+04	4.431984E+03	1.000000E-02	1.157396E+04	9.032496E+03
S06	1.892992E+05	9.941130E+02	1.000000E-02	1.000000E-02	1.000000E-02
S07	2.026429E+04	1.102008E+05	1.147221E+04	3.496959E+02	7.917865E+02
S08	1.000000E-02	8.218554E+04	1.000000E-02	1.000000E-02	1.000000E-02
S09	1.000000E-02	9.266587E+02	1.000000E-02	1.000000E-02	1.000000E-02
S10	1.000000E-02	6.458842E+02	1.000000E-02	1.000000E-02	1.000000E-02
S11	4.689294E+03	1.706945E+03	1.000000E-02	1.101009E+04	2.193862E+03
S12	1.238339E+05	1.584059E+04	9.465934E+02	1.000000E-02	1.000000E-02
S13	5.205974E+04	4.884102E+04	4.617311E+01	1.116242E+03	1.492565E+02
S14	2.079084E+03	2.288706E+03	5.691312E+00	1.000000E-02	1.000000E-02
CAP	1.810199E+05	2.144229E+05	2.933431E+04	5.190405E+03	3.146789E+03
LAB	1.160504E+05	1.205631E+05	8.704770E+03	3.217089E+03	1.950426E+03
IDT	1.924673E+04	9.678337E+03	6.787881E+03	3.305206E+02	2.003850E+02
TRF	9.746844E+03	6.748701E+02	1.000000E-02	1.000000E-02	1.000000E-02
HOH	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
GOV	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
INV	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
EXT	3.907540E+05	1.591999E+05	1.000000E-02	1.000000E-02	1.000000E-02
+					
	S11	S12	S13	S14	CAP
S01	4.325504E+03	4.180640E+03	2.697700E+05	3.239122E+04	1.000000E-02
S02	9.043960E+04	1.050464E+03	1.287052E+04	1.403434E+04	1.000000E-02
S03	1.804403E+05	1.904720E+04	1.210393E+05	1.945533E+04	1.000000E-02
S04	2.729756E+04	5.796741E+04	5.837923E+05	1.957240E+04	1.000000E-02
S05	3.082089E+04	2.347374E+04	3.464663E+05	3.213424E+03	1.000000E-02
S06	1.906167E+04	1.779459E+04	4.160297E+04	7.960914E+03	1.000000E-02
S07	6.709618E+03	6.199564E+04	1.867647E+05	3.001194E+03	1.000000E-02
S08	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
S09	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
S10	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
S11	3.151310E+03	4.921572E+03	6.355705E+04	8.368110E+02	1.000000E-02
S12	7.261581E+04	1.776484E+04	2.244101E+05	1.676934E+04	1.000000E-02
S13	8.586876E+04	2.648638E+05	6.985110E+05	2.483028E+04	1.000000E-02
S14	9.067508E+02	2.305206E+04	1.168021E+04	9.016924E+02	1.000000E-02
CAP	1.294253E+05	1.830859E+06	1.657263E+06	3.287273E+04	1.000000E-02
LAB	6.708848E+04	5.082119E+05	1.592247E+06	4.993343E+03	1.000000E-02
IDT	1.010653E+04	7.688004E+04	1.406907E+05	4.335011E+03	1.000000E-02
TRF	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
HOH	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	6.714381E+06
GOV	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02
INV	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02	1.000000E-02

```
EXT   1.867863E+05   2.536602E+04   2.225660E+05   1.765279E+04   1.000000E-02
+
      LAB            IDT            TRF            HOH            GOV
S01   1.000000E-02   1.000000E-02   1.000000E-02   1.885873E+06   2.503543E+04
S02   1.000000E-02   1.000000E-02   1.000000E-02   2.867809E+04   2.087243E+03
S03   1.000000E-02   1.000000E-02   1.000000E-02   3.957257E+05   5.425999E+04
S04   1.000000E-02   1.000000E-02   1.000000E-02   4.829019E+05   9.100293E+04
S05   1.000000E-02   1.000000E-02   1.000000E-02   7.244318E+05   1.379109E+05
S06   1.000000E-02   1.000000E-02   1.000000E-02   4.303865E+05   3.678808E+04
S07   1.000000E-02   1.000000E-02   1.000000E-02   1.438426E+05   2.588230E+04
S08   1.000000E-02   1.000000E-02   1.000000E-02   1.172714E+05   2.594448E+04
S09   1.000000E-02   1.000000E-02   1.000000E-02   2.451814E+04   5.424259E+03
S10   1.000000E-02   1.000000E-02   1.000000E-02   1.294275E+04   2.863383E+03
S11   1.000000E-02   1.000000E-02   1.000000E-02   5.210931E+04   5.275638E+04
S12   1.000000E-02   1.000000E-02   1.000000E-02   1.187784E+06   3.197945E+04
S13   1.000000E-02   1.000000E-02   1.000000E-02   2.125297E+06   1.976429E+06
S14   1.000000E-02   1.000000E-02   1.000000E-02   9.433280E+04   2.793439E+04
CAP   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
LAB   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
IDT   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
TRF   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
HOH   3.503093E+06   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
GOV   1.000000E-02   8.674529E+05   2.658693E+05   1.640225E+06   1.000000E-02
INV   1.000000E-02   1.000000E-02   1.000000E-02   8.711535E+05   2.772496E+05
EXT   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02   1.000000E-02
+
      INV            EXT
S01   3.137229E+04   4.840919E+05
S02   1.000000E-02   2.095100E+05
S03   7.470517E+03   2.452470E+05
S04   1.000000E-02   6.921259E+05
S05   3.696240E+05   2.142149E+06
S06   2.890288E+04   4.179851E+05
S07   7.988100E+03   1.168289E+03
S08   8.007291E+03   1.171096E+03
S09   1.674098E+03   2.448430E+02
S10   8.837313E+02   1.292488E+02
S11   6.756239E+05   1.000000E-02
S12   4.959973E+04   2.355645E+05
S13   5.198332E+03   3.795158E+05
S14   1.000000E-02   8.999645E+03
CAP   1.000000E-02   1.000000E-02
LAB   1.000000E-02   1.000000E-02
IDT   1.000000E-02   1.000000E-02
TRF   1.000000E-02   1.000000E-02
```

```
HOH      1.000000E-02      1.000000E-02
GOV      1.000000E-02      1.000000E-02
INV      1.000000E-02      3.794182E+04
EXT      1.000000E-02      1.000000E-02
;

* Loading the initial values -----------------------------------------
Parameter     Y0(j)        composite factor
              F0(h,j)      the h-th factor input by the j-th firm
              X0(i,j)      intermediate input
              Z0(j)        output of the j-th good
              Xp0(i)       household consumption of the i-th good
              Xg0(i)       government consumption
              Xv0(i)       investment demand
              E0(i)        exports
              M0(i)        imports
              Q0(i)        Armington's composite good
              D0(i)        domestic good
              Sp0          private saving
              Sg0          government saving
              Td0          direct tax
              Tz0(j)       production tax
              Tm0(j)       import tariff

              FF(h)        factor endowment of the h-th factor
              Sf           foreign saving in US dollars
              pWe(i)       export price in US dollars
              pWm(i)       import price in US dollars
              tauz(i)      production tax rate
              taum(i)      import tariff rate
;

Td0    =SAM("GOV","HOH");
Tz0(j)  =SAM("IDT",j);
Tm0(j)  =SAM("TRF",J);

F0(h,j) =SAM(h,j);
Y0(j)   =sum(h, F0(h,j));
X0(i,j) =SAM(i,j);
Z0(j)   =Y0(j) +sum(i, X0(i,j));
M0(i)   =SAM("EXT",i);

tauz(j) =Tz0(j)/Z0(j);
taum(j) =Tm0(j)/M0(j);

```

```
Xp0(i)  =SAM(i,"HOH");
FF(h)   =SAM("HOH",h);

Xg0(i)  =SAM(i,"GOV");
Xv0(i)  =SAM(i,"INV");
E0(i)   =SAM(i,"EXT");
Q0(i)   =Xp0(i)+Xg0(i)+Xv0(i)+sum(j, X0(i,j));
D0(i)   =(1+tauz(i))*Z0(i)-E0(i);
Sp0     =SAM("INV","HOH");
Sg0     =SAM("INV","GOV");
Sf      =SAM("INV","EXT");

pWe(i)  =1;
pWm(i)  =1;

Display Y0,F0,X0,Z0,Xp0,Xg0,Xv0,E0,M0,Q0,D0,Sp0,Sg0,Td0,Tz0,Tm0,
        FF,Sf,tauz,taum;
* Calibration ---------------------------------------------------------
Parameter     sigma(i)      elasticity of substitution
              psi(i)        elasticity of transformation
              eta(i)        substitution elasticity parameter
              phi(i)        transformation elasticity parameter
;
sigma(i)=2;
psi(i)  =2;
eta(i)=(sigma(i)-1)/sigma(i);
phi(i)=(psi(i)+1)/psi(i);

Parameter     alpha(i)      share parameter in utility func.
              beta(h,j)     share parameter in production func.
              b(j)          scale parameter in production func.
              ax(i,j)       intermediate input requirement coeff.
              ay(j)         composite fact. input req. coeff.
              mu(i)         government consumption share
              lambda(i)     investment demand share
              deltam(i)     share par. in Armington func.
              deltad(i)     share par. in Armington func.
              gamma(i)      scale par. in Armington func.
              xid(i)        share par. in transformation func.
              xie(i)        share par. in transformation func.
              theta(i)      scale par. in transformation func.
              ssp           average propensity for private saving
              ssg           average propensity for gov. saving
              taud          direct tax rate
;
```

```
alpha(i)=Xp0(i)/sum(j, Xp0(j));
beta(h,j)=F0(h,j)/sum(k, F0(k,j));
b(j)    =Y0(j)/prod(h, F0(h,j)**beta(h,j));

ax(i,j) =X0(i,j)/Z0(j);
ay(j)   =Y0(j)/Z0(j);
mu(i)   =Xg0(i)/sum(j, Xg0(j));
lambda(i)=Xv0(i)/(Sp0+Sg0+Sf);

deltam(i)=(1+taum(i))*M0(i)**(1-eta(i))
          /((1+taum(i))*M0(i)**(1-eta(i)) +D0(i)**(1-eta(i)));
deltad(i)=D0(i)**(1-eta(i))
          /((1+taum(i))*M0(i)**(1-eta(i)) +D0(i)**(1-eta(i)));
gamma(i)=Q0(i)/(deltam(i)*M0(i)**eta(i)+deltad(i)*D0(i)**eta(i))
         **(1/eta(i));

xie(i)=E0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
xid(i)=D0(i)**(1-phi(i))/(E0(i)**(1-phi(i))+D0(i)**(1-phi(i)));
theta(i)=Z0(i)
         /(xie(i)*E0(i)**phi(i)+xid(i)*D0(i)**phi(i))**(1/phi(i));

ssp     =Sp0/sum(h, FF(h));
ssg     =Sg0/(Td0+sum(j, Tz0(j))+sum(j, Tm0(j)));
taud    =Td0/sum(h, FF(h));

Display alpha,beta,b,ax,ay,mu,lambda,deltam,deltad,gamma,xie,
        xid,theta,ssp,ssg,taud;
* --------------------------------------------------------------------


* Defining model system -----------------------------------------------
Variable     Y(j)        composite factor
             F(h,j)      the h-th factor input by the j-th firm
             X(i,j)      intermediate input
             Z(j)        output of the j-th good
             Xp(i)       household consumption of the i-th good
             Xg(i)       government consumption
             Xv(i)       investment demand
             E(i)        exports
             M(i)        imports
             Q(i)        Armington's composite good
             D(i)        domestic good

             pf(h)       the h-th factor price
             py(j)       composite factor price
             pz(j)       supply price of the i-th good
```

```
           pq(i)         Armington's composite good price
           pe(i)         export price in local currency
           pm(i)          import price in local currency
           pd(i)         the i-th domestic good price
           epsilon        exchange rate

           Sp            private saving
           Sg            government saving
           Td            direct tax
           Tz(j)         production tax
           Tm(i)          import tariff
           afac(i,j)     Factor of Shock
           afac0(i,j)     Factor of Shock
           UU             utility [fictitious]
;
Equation      eqpy(j)       composite factor agg. func.
           eqF(h,j)       factor demand function
           eqX(i,j)       intermediate demand function
           eqY(j)         composite factor demand function
           eqpzs(j)       unit cost function

           eqTd          direct tax revenue function
           eqTz(j)        production tax revenue function
           eqTm(i)         import tariff revenue function
           eqXg(i)        government demand function

           eqXv(i)        investment demand function
           eqSp          private saving function
           eqSg          government saving function

           eqXp(i)        household demand function

           eqpe(i)        world export price equation
           eqpm(i)         world import price equation
           eqepsilon       balance of payments

           eqpqs(i)       Armington function
           eqM(i)         import demand function
           eqD(i)         domestic good demand function

           eqpzd(i)        transformation function
           eqDs(i)        domestic good supply function
           eqE(i)         export supply function

           eqpqd(i)        market clearing cond. for comp. good
```

```
          eqpf(h)        factor market clearing condition

          obj            utility function [fictitious]
;
*[domestic production] ----
eqpy(j)..      Y(j)    =e= b(j)*prod(h, F(h,j)**beta(h,j));
eqF(h,j)..     F(h,j)  =e= beta(h,j)*py(j)*Y(j)/pf(h);
eqX(i,j)..     X(i,j)  =e= afac(i,j)*ax(i,j)*Z(j);
eqY(j)..       Y(j)    =e= ay(j)*Z(j);
eqpzs(j)..     pz(j)   =e= ay(j)*py(j) +sum(i, ax(i,j)*pq(i));

*[government behavior] ----
eqTd..         Td      =e= taud*sum(h, pf(h)*FF(h));
eqTz(j)..      Tz(j)   =e= tauz(j)*pz(j)*Z(j);
eqTm(i)..      Tm(i)   =e= taum(i)*pm(i)*M(i);
eqXg(i)..      Xg(i)   =e= mu(i)*(Td +sum(j, Tz(j)) +sum(j, Tm(j))
                           -Sg)/pq(i);
*[investment behavior] ----
eqXv(i)..      Xv(i)   =e= lambda(i)*(Sp +Sg +epsilon*Sf)/pq(i);

*[savings] ----------------
eqSp..         Sp      =e= ssp*sum(h, pf(h)*FF(h));
eqSg..         Sg      =e= ssg*(Td +sum(j, Tz(j))+sum(j, Tm(j)));

*[household consumption] --
eqXp(i)..      Xp(i)   =e= alpha(i)*(sum(h, pf(h)*FF(h)) -Sp -Td)
                           /pq(i);
*[international trade] ----
eqpe(i)..      pe(i)   =e= epsilon*pWe(i);
eqpm(i)..      pm(i)   =e= epsilon*pWm(i);
eqepsilon..    sum(i, pWe(i)*E(i)) +Sf
                       =e= sum(i, pWm(i)*M(i));

*[Armington function] -----
eqpqs(i)..     Q(i)    =e= gamma(i)*(deltam(i)*M(i)**eta(i)+deltad(i)
                           *D(i)**eta(i))**(1/eta(i));
eqM(i)..       M(i)    =e= (gamma(i)**eta(i)*deltam(i)*pq(i)
                           /((1+taum(i))*pm(i)))**(1/(1-eta(i)))*Q(i);
eqD(i)..       D(i)    =e= (gamma(i)**eta(i)*deltad(i)*pq(i)/pd(i))
                           **(1/(1-eta(i)))*Q(i);

*[transformation function] -----
eqpzd(i)..     Z(i)    =e= theta(i)*(xie(i)*E(i)**phi(i)+xid(i)
                           *D(i)**phi(i))**(1/phi(i));
eqE(i)..       E(i)    =e= (theta(i)**phi(i)*xie(i)*(1+tauz(i))*pz(i)
```

```
                     /pe(i))**(1/(1-phi(i)))*Z(i);
eqDs(i)..     D(i)    =e= (theta(i)**phi(i)*xid(i)*(1+tauz(i))*pz(i)
                     /pd(i))**(1/(1-phi(i)))*Z(i);

*[market clearing condition]
eqpqd(i)..    Q(i)    =e= Xp(i) +Xg(i) +Xv(i) +sum(j, X(i,j));
eqpf(h)..     sum(j, F(h,j)) =e= FF(h);

*[fictitious objective function]
obj..         UU      =e= prod(i, Xp(i)**alpha(i));
* ---------------------------------------------------------------------

* Initializing variables ----------------------------------------------
Y.l(j)  =Y0(j);
F.l(h,j)=F0(h,j);
X.l(i,j)=X0(i,j);
Z.l(j)  =Z0(j);
Xp.l(i) =Xp0(i);
Xg.l(i) =Xg0(i);
Xv.l(i) =Xv0(i);
E.l(i)  =E0(i);
M.l(i)  =M0(i);
Q.l(i)  =Q0(i);
D.l(i)  =D0(i);
pf.l(h) =1;
py.l(j) =1;
pz.l(j) =1;
pq.l(i) =1;
pe.l(i) =1;
pm.l(i) =1;
pd.l(i) =1;
epsilon.l=1;
Sp.l    =Sp0;
Sg.l    =Sg0;
Td.l    =Td0;
Tz.l(j) =Tz0(j);
Tm.l(i) =Tm0(i);
afac0.l(i,j) =1;
afac.fx(i,j)=afac0.l(i,j);
* ---------------------------------------------------------------------
* Setting lower bounds to avoid division by zero ----------------------
Y.lo(j) =0.000001;
F.lo(h,j)=0.000001;
X.lo(i,j)=0.000001;
Z.lo(j) =0.0000001;
```

```
Xp.lo(i)=0.0000001;
Xg.lo(i)=0.0000001;
Xv.lo(i)=0.0000001;
E.lo(i) =0.0000001;
M.lo(i) =0.0000001;
Q.lo(i) =0.0000001;
D.lo(i) =0.0000001;
pf.lo(h)=0.0000001;
py.lo(j)=0.0000001;
pz.lo(j)=0.0000001;
pq.lo(i)=0.0000001;
pe.lo(i)=0.0000001;
pm.lo(i)=0.0000001;
pd.lo(i)=0.0000001;
epsilon.lo=0.0000001;
Sp.lo   =0.0000001;
Sg.lo   =0.0000001;
Td.lo   =0.0000001;
Tz.lo(j)=0.0000;
Tm.lo(i)=0.0000;
afac.fx(i,j) =1;
* ----------------------------------------------------------------------
* numeraire ---
pf.fx("LAB")=1;
* ----------------------------------------------------------------------
* Defining and solving the model ---------------------------------------
Model stdcge /all/;
Solve stdcge maximizing UU using nlp;

* ----------------------------------------------------------------------
* Simulation Runs: Reduction of Natural Gas and Improvement Solar Energy
* afac.fx(i,"S08")=0.6000;
* afac.fx(i,"S09")=3.8616;
* Simulation Runs: Reduction of Natural Gas and Improvement Wind Energy
* afac.fx(i,"S08")=0.6000;
* afac.fx(i,"S10")=6.3726;

* Simulation Runs: Improvement of Natural Gas Electricity Production by 100,000 Million Baht
* afac.fx(i,"S08")=1.4263;
* Simulation Runs: Improvement of Solar Electricity Production by 100,000 Million Baht
* afac.fx(i,"S09")=4.0499;
* Simulation Runs: Improvement of Wind Electricity Poduction
* afac.fx(i,"S10")=6.7257;

Solve stdcge maximizing UU using nlp;
```

```
* -------------------------------------------------------------------
* -------------------------------------------------------------------
* List8.1: Display of changes ------------------------------------------
Parameter
dY(j),dF(h,j),dX(i,j),dZ(j),dXp(i),dXg(i),dXv(i),
dE(i),dM(i),dQ(i),dD(i),dpf(h),dpy(j),dpz(i),dpq(i),
dpe(i),dpm(i),dpd(i),depsilon,dTd,dTz(i),dTm(i),dSp,dSg;
;
dY(j)  =(Y.l(j)  /Y0(j)  -1)*100;
dF(h,j)=(F.l(h,j)/F0(h,j)-1)*100;
dX(i,j)=(X.l(i,j)/X0(i,j)-1)*100;
dZ(j)  =(Z.l(j)  /Z0(j)  -1)*100;
dXp(i) =(Xp.l(i) /Xp0(i) -1)*100;
dXg(i) =(Xg.l(i) /Xg0(i) -1)*100;
dXv(i) =(Xv.l(i) /Xv0(i) -1)*100;
dE(i)  =(E.l(i)  /E0(i)  -1)*100;
dM(i)  =(M.l(i)  /M0(i)  -1)*100;
dQ(i)  =(Q.l(i)  /Q0(i)  -1)*100;
dD(i)  =(D.l(i)  /D0(i)  -1)*100;
dpf(h) =(pf.l(h) /1 -1)*100;
dpy(j) =(py.l(j) /1 -1)*100;
dpz(j) =(pz.l(j) /1 -1)*100;
dpq(i) =(pq.l(i) /1 -1)*100;
dpe(i) =(pe.l(i) /1 -1)*100;
dpm(i) =(pm.l(i) /1 -1)*100;
dpd(i) =(pd.l(i) /1 -1)*100;
depsilon=(epsilon.l/1 -1)*100;
dTd    =(Td.l    /Td0    -1)*100;
dTz(j) =(Tz.l(j) /Tz0(j) -1)*100;
dTm(i) =(Tm.l(i) /Tm0(i) -1)*100;
dSp    =(Sp.l    /Sp0    -1)*100;
dSg    =(Sg.l    /Sg0    -1)*100;

Display
dY,dF,dX,dZ,dXp,dXg,dXv,dE,dM,dQ,dD,dpf,dpy,dpz,
dpq,dpe,dpm,dpd,depsilon,dTd,dTz,dTm,dSp,dSg;

* Welfare measure: Hicksian equivalent variations ---------------------
Parameter      UU0           utility level in the Base Run Eq.
               ep0           expenditure func. in the Base Run Eq.
               ep1           expenditure func. in the C-f Eq.
               EV            Hicksian equivalent variations
;
UU0     =prod(i, Xp0(i)**alpha(i));
ep0     =UU0 /prod(i, (alpha(i)/1)**alpha(i));
```

```
ep1     =UU.l/prod(i, (alpha(i)/1)**alpha(i));
EV      =ep1-ep0;

Display EV;

* end of model -------------------------------------------------------
* ---------------------------------------------------------------------
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CURRICULUM VITAE

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