CHAPTER 3
METHODOLOGY

3.1 Model Setup

This study is based on the Standard CGE model developed by PEP research network [19]. It is a recursive model which means that each period is determined as static equilibrium. It is represented by equations and their assumptions as follows.

3.1.1 Production

Similar to CGE models, a perfectly competitive environment is assumed so that the representative firm maximizes profits subject to its production technology. The nested structure of production is represented in Figure 2.1. At the first level, the output of each sector j combines value-added and intermediate consumption in the Leontief function as Equations 1 and 2. The Leontief function states that there is no substitution between these two aggregate inputs.

$$VA_{j,t} = v_j XST_{j,t} \quad (1)$$

$$CI_{j,t} = io_j XST_{j,t} \quad (2)$$

where

$CI_{j,t}$: Total intermediate consumption of industry j

$VA_{j,t}$: Value-added of industry j

$XST_{j,t}$: Total aggregate output of industry j

io_j : Coefficient (Leontief-intermediate consumption)

v_j : Coefficient (Leontief-value added)

At the second level, each value-added of the firm selects combinations between composite labor and composite capital following a constant elasticity of substitution (CES). In this study, there is only one type of labor and one capital.

$$VA_{j,t} = B_j^{VA}[\beta_j^{VA} LDC_{j,t}^{-\rho_j^{VA}} + (1-\beta_j^{VA}) KDC_{j,t}^{-\rho_j^{VA}}]^{-\frac{1}{-\rho_j^{VA}}} \quad (3)$$

where

$KDC_{j,t}$: Industry *j* demand for composite capital

$LDC_{j,t}$: Industry *j* demand for composite labor

B_j^{VA} : Scale parameter (CES – value added)

β_j^{VA} : Share parameter (CES – value added)

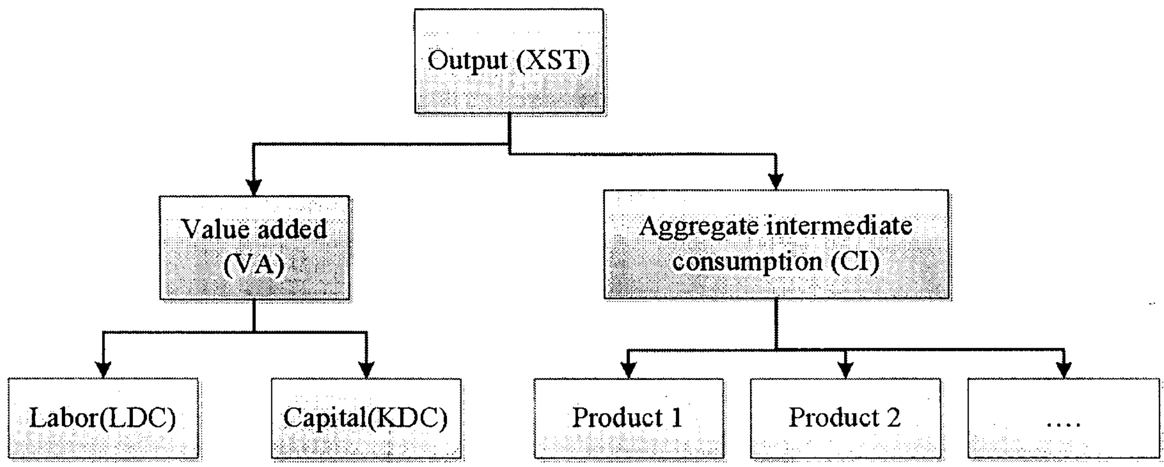

Figure 3.1 Nested structure of production

ρ_j^{VA} : Elasticity parameter (CES – value added) : -1< ρ_j^{VA}<∞

Demand for labor relative to capital describes behavior by the CES production function following Equation 4.

$$LDC_{j,t} = [\frac{B_j^{VA}}{(1-B_j^{VA})}\frac{RC_{j,t}}{WC_{j,t}}]^{\sigma_j^{VA}} KDC_{j,t} \qquad (4)$$

where

$RC_{j,t}$: Rental rate of industry *j* composite capital

$WC_{j,t}$: Wage rate of industry *j* composite labor

σ_j^{VA} : Elasticity of transformation (CES-value added) : 0 < σ_j^{VA} < ∞

At the bottom level on the value-added block, the demands for various categories of labor are combined following a constant elasticity of substitution (CES) technology (Equation 5) which represents the imperfect substitutability between different types of labor. The business selects labor to minimize labor cost given the relative wage rates. The representative firm requires labor of each type derived from the first-order condition of cost minimization subject to CES technology (Equation 6). Similarly, in composite capital, CES technology is used for selection of combination of the different categories of capital. In capital, it is also assumed there is different types of capital (Equation 7) (land, building and equipment and etc.). The demand for each type of capital results are determined by Equation 8.

$$LDC_{j,t} = B_j^{LD} \, [\textstyle\sum_l \beta_{l,j}^{LD} \, LD_{l,j,t}^{-\rho_j^{LD}}]^{-\frac{1}{\rho_j^{LD}}} \qquad (5)$$

$$LD_{l,j,t} = [\frac{\beta_{l,j}^{LD} WC_{j,t}}{WTI_{l,j,t}}]^{\sigma_j^{LD}} (B_j^{LD})^{\sigma_j^{LD}-1} LDC_{j,t} \qquad (6)$$

$$KDC_{j,t} = B_j^{KD} \left[\sum_k \beta_{k,j}^{KD} KD_{k,j,t}^{-\rho_j^{KD}}\right]^{-\frac{1}{\rho_j^{KD}}} \qquad (7)$$

$$KD_{k,j,t} = \left[\frac{\beta_{k,j}^{KD} WC_{j,t}}{RTI_{k,j,t}}\right]^{\sigma_j^{KD}} (B_j^{KD})^{\sigma_j^{KD}-1} KDC_{j,t} \qquad (8)$$

where

$KD_{k,j,t}$: Demand for type *k* capital by industry *j*

$LD_{l,j,t}$: Demand for type *l* labor by industry *j*

$RTI_{k,j,t}$: Rental rate paid by industry *j* for type *k* capital, including capital taxes

$WTI_{l,j,t}$: Wage rate paid by industry *j* for type *l* labor, including payroll taxes

B_j^{KD} : Scale parameter (CES – composite capital)

B_j^{LD} : Scale parameter (CES – composite labor)

$\beta_{k,j}^{KD}$: Share parameter (CES – composite capital)

$\beta_{l,j}^{LD}$: Share parameter (CES – composite labor)

ρ_j^{KD} : Elasticity parameter (CES – composite capital): $-1 < \rho_j^{KD} < \infty$

ρ_j^{LD} : Elasticity parameter (CES – composite labor): $-1 < \rho_j^{LD} < \infty$

σ_j^{KD} : Elasticity of substitution (CES – composite capital): $0 < \sigma_j^{KD} < \infty$

σ_j^{LD} : Elasticity of substitution (CES – composite labor): $0 < \sigma_j^{LD} < \infty$

Lastly, the intermediate consumption side at the second level of the production is the combination of several goods and services by the Leontief production function, for which there is no substitution between types of goods and services. It is represented in equation 9.

$$DI_{i,j,t} = aij_{i,j} CI_{j,t} \qquad (9)$$

where

$DI_{i,j,t}$: Intermediate consumption of commodity *i* by industry *j*

$aij_{i,j}$: Input-output coefficient

3.1.2 Income and savings

3.1.2.1 Households

Households receive their income form three sources: labor income, capital income and transfers received from other agents.

$$YH_{h,t} = YHL_{h,t} + YHK_{h,t} + YHTR_{h,t} \qquad (10)$$

where

$YH_{h,t}$: Total income of type *h* households

$YHK_{h,t}$: Capital income of type *h* households

$YHL_{h,t}$: Labor income of type *h* households

$YHTR_{h,t}$: Transfer income of type *h* households

The distribution of income between types of households is applied by the fixed share of the earnings of each type of labor (Equation 11). Similarly capital income is distributed between agents, including households, in fixed proportions. Lastly, transfer income is the sum of all transfers received by each type of household.

$$YHL_{h,t} = \sum_l \lambda_{h,l}^{WL} [W_{l,t} \sum_j LD_{l,j,t}] \quad (11)$$

$$YHK_{h,t} = \sum_k \lambda_{h,k}^{RK} [\sum_j R_{k,j,t} KD_{k,j,t}] \quad (12)$$

$$YHTR_{h,t} = \sum_{ag} TR_{h,ag,t} \quad (13)$$

where

$R_{k,j,t}$: Rental rate of type *k* capital in industry *j*

$TR_{h,ag,t}$: Transfers from agent *ag* to type *h* households

$W_{l,t}$: Wage rate of type *l* labor

$\lambda_{h,k}^{RK}$: Share of type *k* capital income received by agent *ag*

$\lambda_{h,l}^{WL}$: Share of type *l* labor income received by type *h* households

Household disposable income is calculated from total income of type of household subtracted by direct taxes and household transfers to government income that government mostly contributes to social programs. It is represented in equation 14. After savings and transfers to other agents, disposal income is considered as consumption budget to spend on goods and services in equation 15.

A Linear equation can be used to describe the saving behavior of households, which is different from that normally used where savings are a fixed proportion of income. Since savings of household in the model some can be negative while the others can be positive. Linear equation 16 categorizes net saving into two terms. The first term represents for the minimum necessity of expense for households, which it could be positive or negative values. If it is negative, then it implies income of those poorest income group's earning is inadequate to expense. In this case, this first term becomes negative. For those household of which their earning income are greater than the minimum necessary expenditure. An average rate of surplus of income form expense is adopted as the marginal propensity to save for this group.

$$YDH_{h,t} = YH_{h,t} - TDH_{h,t} + TR_{gvt,h,t} \quad (14)$$

$$CTH_{h,t} = YDH_{h,t} - SH_{h,t} + \sum_{agng} TR_{agng,h,t} \quad (15)$$

$$SH_{h,t} = PIXCON_t^{\eta} sh0_{h,t} + sh1_{h,t} YDH_{h,t} \quad (16)$$

where

$CTH_{h,t}$: Consumption budget of type *h* households

$PIXCON_t^{\eta}$: Consumer price index

$SH_{h,t}$: Savings of type *h* households

$TDH_{h,t}$: Income taxes of type *h* households

$YDH_{h,t}$: Disposable income of type *h* households

η : Price elasticity of indexed transfers and parameters

$sh0_{h,t}$: Intercept (type *h* household savings)

$sh1_{h,t}$: Slope (type *h* household savings)

$Agng$: Index of non-government agents

3.1.2.2 Businesses

Business income comes from its share of capital income and transfer from other agents as shown in Equations 17 – 19.

$$YF_{f,t} = YFK_{f,t} - YFTR_{f,t} \quad (17)$$

$$YFK_{f,t} = \sum_k \lambda_{r,k}^{RK} [\sum_j R_{k,j,t} KD_{k,j,t}] \quad (18)$$

$$YFTR_{f,t} = \sum_{ag} TR_{f,ag,t} \quad (19)$$

where

$YF_{f,t}$: Total income of type *f* businesses

$YFK_{f,t}$: Capital income of type *f* businesses

$YFTR_{f,t}$: Transfer income of type *f* businesses

The disposable income of each type of business is determined from the deduction of business income taxes from total income (Equation 20). Likewise, subtracting transfers to other agents from disposable income is a form of business saving (Equation 21).

$$YDF_{f,t} = YF_{f,t} - TDF_{f,t} \quad (20)$$

$$SF_{f,t} = YDF_{f,t} - \sum_{ag} TR_{ag,f,t} \quad (21)$$

where

$SF_{f,t}$: Savings of type *f* businesses

$TDF_{f,t}$: Income taxes of type *f* businesses

$YDF_{f,t}$: Disposable income of type *f* businesses

3.1.2.3 Government

Government income consists of household taxes, business income taxes, taxes on products and on imports, and other production taxes. Generally, taxes on products and imports are comprised of indirect taxes on consumption and taxes and duties on imports, whereas other taxes on production consist of payroll taxes, taxes on capital and taxes on production. In addition, government receives income from other agents. Government revenue is represented in Equations 22 to 34.

$$YG_t = YGK_t + TDHT_t + TDFT_t + TPRODN_t + TPRCTS_t + YGTR_t \quad (22)$$

$$YGK_t = \sum_k \lambda^{RK}_{gvt,k} [\sum_j R_{k,j,t} KD_{k,j,t}] \quad (23)$$

$$TDHT_t = \sum_h TDH_{h,t} \quad (24)$$

$$TDFT_t = \sum_f TDF_{f,t} \quad (25)$$

$$TPRODN_t = TIWT_t + TIKT_t + TIPT_t \quad (26)$$

$$TIWT_t = \sum_{l,j} TIW_{l,j,t} \quad (27)$$

$$TIKT_t = \sum_{k,j} TIK_{k,j,t} \quad (28)$$

$$TIPT_t = \sum_j TIP_{j,t} \quad (29)$$

$$TPRCTS_t = TICT_t + TIMT_t + TIXT_t \quad (30)$$

$$TICT_t = \sum_i TIC_{i,t} \quad (31)$$

$$TIMT_t = \sum_i TIM_{i,t} \quad (32)$$

$$TIXT_t = \sum_i TIX_{i,t} \quad (33)$$

$$YGTR_t = \sum_{agng} TR_{gvt,agng,t} \quad (34)$$

where

$TDFT_t$: Total government revenue from business income taxes

$TDHT_t$: Total government revenue from household income taxes

$TIC_{i,t}$: Government revenue from indirect taxes on product *i*

$TICT_t$: Total government receipts of indirect taxes on commodities

$TIK_{k,j,t}$: Government revenue from taxes on type *k* capital used by industry *j*

$TIKT_t$: Total government revenue from from taxes on capital

$TIM_{i,t}$: Government revenue from import duties on product *i*

$TIMT_t$: Total government revenue from import duties

$TIP_{j,t}$: Government revenue from taxes on industry *j* production (excluding taxes directly related to the use of capital and labor)

$TIPT_t$: Total government revenue from production taxes (excluding taxes directly related to the use of capital and labor

$TIW_{l,j,t}$: Government revenue from payroll taxes on type *l* labor in industry *j*

$TIWT_t$: Total government revenue from payroll taxes

$TIX_{i,t}$: Government revenue from export taxes on product *i*

$TPRCTS_t$: Total government revenue from export taxes on product and imports

$TPRODN_t$: Total government revenue from other taxes on production

YG_t : Total government income

YGK_t : Government capital income

$YGTR_t$: Government transfer income

Income taxes are represented as a linear function of total income which is similar to household savings: for households (Equation 35) or for business (Equation 36). This marginal rate of taxation does differ from the average rate. This formulation allows for simulating fiscal changes. The income tax intercepts and marginal rate of taxation are time indexes which grow each period at the same rate n_t. It is easy to simulate scenarios in which fiscal policy changes through time.

$$TDH_{h,t} = PIXCON_t^{\eta} ttdh0_{h,t} + ttdh1_{h,t} YH_{h,t} \quad (35)$$

$$TDF_{h,t} = PIXCON_t^{\eta} ttdf0_{f,t} + ttdf1_{f,t} YFK_{f,t} \quad (36)$$

where

$ttdf0_{f,t}$: Intercept (income taxes of type *f* businesses)

$ttdf1_{f,t}$: Marginal income tax rate of type *f* businesses

$ttdh0_{h,t}$: Intercept (income taxes of type *h* households)

$ttdh1_{h,t}$: Marginal income tax rate of type *h* households

This Model is designed to make it easy to simulate scenarios by identifying tax rates in each industry and also in each labor and capital. Tax rates apply to the corresponding transactions in Equations 37 to 38 and a tax also applies to the total value of production output (Equation 39).

$$TIW_{l,j,t} = ttiw_{l,j,t} W_{l,t} LD_{l,j,t} \quad (37)$$

$$TIK_{k,j,t} = ttik_{k,j,t} R_{k,j,t} KD_{k,j,t} \quad (38)$$

$$TIP_{j,t} = ttip_{j,t} PP_{j,t} XST_{j,t} \quad (39)$$

where

$PP_{j,t}$: Industry *j* unit cost, including taxes directly related to use of capital and labor, but excluding other taxes on production

$ttik_{k,j,t}$: Tax rate on type k capital used in industry

$ttip_{j,t}$: Tax rate on the production of industry j

$ttiw_{l,j,t}$: Tax rate on type l worker compensation in industry j

Three types of taxes are implemented on products. These taxes apply on the sale values including margin which are the trade and transport margins. Equation 40 depicts how taxes are levied. Import and export tax collection is shown in Equations 41and 42 respectively.

$$TIC_{m,t} = ttic_{m,t}[(PL_{m,t} + \sum_i PC_{i,t} tmrg_{i,m})\, DD_{m,t} + ((1 + ttim_{m,t})PWM_{m,t}e_t + \sum_i PC_{i,t} tmrg_{i,m})\, IM_{m,t}] \qquad (40)$$

$$TIM_{i,t} = ttim_{i,t} PWM_{i,t} e_t IM_{i,t} \qquad (41)$$

$$TIX_{i,t} = ttix_{i,t}(PE_{i,t} + \sum_{ij} PC_{ij,t} tmrg_{ij,i}^{X})\, EXD_{i,t} \qquad (42)$$

where

$DD_{m,t}$: Domestic demand for commodity i produced locally

e_t : Exchange rate: price of foreign currency in terms of local currency

$EXD_{i,t}$: Quantity of product i exported

$IM_{i,t}$: Quantity of product i imported

$PC_{i,t}$: Purchaser price of composite commodity i (including all taxes and margins)

$PE_{i,t}$: Price received for exported commodity i (excluding export taxes)

$PL_{m,t}$: Price of local product i (excluding all taxes on products)

$PWM_{m,t}$: World price of imported product i (expressed in foreign currency)

$ttic_{m,t}$: Tax rate on commodity i

$ttim_{m,t}$: Rate of taxes and duties on imports of commodity i

$ttix_{i,t}$: Export tax rate on exported commodity i

$tmrg_{i,m}$: Rate of margin i applied to commodity ij

$tmrg_{ij,i}^{X}$: Rate of margin ij applied to export i

The government budget is government's expenditure on goods and services and transfer money to other agents. The budget surplus or deficit is described by the difference between its revenues and its expenditures.

$$SG_t = YG_t - \sum_{agng} TR_{agng,gvt,t} - G_t \qquad (43)$$

where

SG_t : Government savings

G_t : Current government expenditures on goods and services

3.1.2.4 Rest of the world

The rest of the world is the sum of payment for the value of imports, part of the income from capital and transfers from domestic agents (Equation 44). Subtracting spending of rest of the world from foreign receipts is the amount of rest-of-the-world saving (Equation 45), which are equal in absolute values to current account balance (Equation 46).

$$YROW_t = e_t PWM_{i,t} IM_{i,t} + \sum_k \lambda_{row,k}^{RK} [\sum_j R_{k,j,t} KD_{k,j,t}] + \sum_{agd} TR_{row,agd,t} \quad (44)$$

$$SROW_t = YROW_t - \sum_i PE_{i,t}^{FOB} EXD_{i,t} - \sum_{agd} TR_{agd,row,t} \quad (45)$$

$$SROW_t = -CAB_t \quad (46)$$

where

CAB_t : Current account balance

$PE_{i,t}^{FOB}$: FOB price of exported product i (in the national currency)

$SROW_t$: Rest-of-the-world savings

$YROW_t$: Rest-of-the-world income

3.1.2.5 Transfers

In the CGE model, transfer is not clear since these are payments without any real agent and there is no specification of economic behavior. For inadequate information of this nature, transfer is treated in the most neutral way which could not impact on economic agents' behavior. Therefore household transfers to non-government agents and business are proportional to the disposable income of households and firms respectively. All initial value of transfers adopt form SAM values and they grow in each period according to the same rate of pop_t.

$$TR_{agng,h,t} = \lambda_{agng,h}^{TR} YDH_{h,t} \quad (47)$$

$$TR_{gvt,h,t} = PIXCON_t^{\eta} tr0_{h,t} + tr1_{h,t} YH_{h,t} \quad (48)$$

$$TR_{ag,f,t} = \lambda_{ag,f}^{TR} YDF_{f,t} \quad (49)$$

$$TR_{agng,gvt,t} = PIXCON_t^{\eta} TR_{agng,gvt}^{O} pop_t \quad (50)$$

$$TR_{agd,row,t} = PIXCON_t^{\eta} TR_{agd,row}^{O} pop_t \quad (51)$$

where

$\lambda_{agng,h}^{TR}$: Share parameter (transfer functions)

$tr0_{h,t}$: Intercept (transfers by type h households to government)

$tr1_{h,t}$: Marginal rate of transfers by type h households to government

pop_t : Population index

3.1.3 Demand

Demand for goods and service comes from household consumption demand, investment demand, public aspirations and demand on transport or trade margins. Stone-Geary utility function describes household behavior or demand. This utility function characteristic is the minimum level of consumption of each commodity, as it is a linear equation. However most of CGE assumes Cobb-Douglas utility functions which do not explicitly describe income-elasticity for all goods. Its function offers a degree of flexibility carrying out possible substitution when relative price of product change. Equation 52 represents household demand for each product determined by utility maximization within the budget constraint.

$$PC_{i,t}C_{i,h,t} = PC_{i,t}C_{i,h,t}^{MIN} + \gamma_{i,h}^{LES}(CTH_{h,t} - \sum_{ij} PC_{ij,t}C_{ij,h,t}^{MIN}) \quad (52)$$

where

$C_{i,h,t}$: Consumption of commodity i by type h households

$C_{i,h,t}^{MIN}$: Minimum consumption of commodity i by type h households

$\gamma_{i,h}^{LES}$: Marginal share of commodity i in type h household consumption budget

The investment demand is assumed to be equal to a gross fixed capital formation (GFCF), which it equals to the total saving of the country minus a change in the value of inventory. This change in stock may be positive or negative. In Equation 53, if the values of GFCF is negative, it is hard to achieve a solution in a CGE model. To avoid this difficulty, the Equation 53 is then separated into two term. The first IT_t represents for the total investment expenditure in year t and is always positive, while the second term of $VSTK_{i,t}$ is inventory change of commodity i during the year, could be either positive or negative. The total investment expenditure is determined by the saving-investment equilibrium constraint in Equation 89 which is summation of household, government, firm and rest of the world saving. GFCF comprises of private and public investment. The quantity demanded of each commodity i for investment is the sum of the quantity demanded for private and public investment, which is shown in Equation56. The distribution of private and public investment in each commodity is allocated with a fixed share (Equations 54 and 55). The share of commodity i for private and public investment purpose is determined form SAM 2010 in the model as database in calibration model.

Likewise, the government produces a current expenditure budget selecting the quantity demanded of each commodity by using fixed shares, as shown in Equation 57.

$$GFCF_t = IT_t - \sum_i PC_{i,t} VSTK_{i,t} \quad (53)$$

$$PC_{i,t} INV_{i,t}^{PRI} = \gamma_i^{INVPRI} IT_t^{PRI} \quad (54)$$

$$PC_{i,t} INV_{i,t}^{PUB} = \gamma_i^{INVPUB} IT_t^{PUB} \quad (55)$$

$$INV_{i,t} = INV_{i,t}^{PRI} + INV_{i,t}^{PUB} \quad (56)$$

$$PC_{i,t} CG_{i,t} = \gamma_i^{GVT} G_t \quad (57)$$

where

$GFCF_t$: Gross fixed capital formation

$INV_{i,t}$: Final demand of commodity *i* for investment purposes

$INV_{i,t}^{PRI}$: Final demand of commodity *i* for private investment purposes

$INV_{i,t}^{PUB}$: Final demand of commodity *i* for public investment purposes

IT_t : Total investment expenditures

$VSTK_{i,t}$: Inventory change of commodity *i*

$CG_{i,t}$: Public consumption of commodity *i* (volume)

γ_i^{GVT} : Share of commodity *i* in total current public expenditures on goods and services

γ_i^{INVPRI} : Share of commodity *i* in total private investment expenditure

γ_i^{INVPUB} : Share of commodity *i* in total public investment expenditure

Moreover, goods and services are used as inputs for production processes, which calls on intermediate demand. Equation 58 explains the sum of industry demand.

$$DIT_{i,t} = \sum_j DI_{i,j,t} \quad (58)$$

where

$DIT_{i,t}$: Total intermediate demand for commodity *i*

Lastly, transport, retail and wholesale trade are services that mobilize commodities and make them available for the market. The value of domestic production and import include margin rate to determine the quantities of these margin service required to distribute commodities to buyers.

$$MRGN_{i,t} = \sum_{ij} tmr_{i,ij} DD_{ij,t} + \sum_{ij} tmrg_{i,ij} IM_{ij,t} + \sum_{ij} tmrg_{i,ij}^X DD_{ij,t} \quad (59)$$

where

$MRGN_{i,t}$: Demand for commodity *i* as a trade or transport margin

3.1.4 Producer supplies of product and international trade

This section describes the supply of export and the demand for imports. Domestic buyer behavior and domestic producer's supply behavior explicitly explain the trade relations with the rest of the world. The domestic producer's supply behavior consists of two aspects: technology to translate output into product and how the supply of each product is directed to markets. Generally in the CGE model, the small-country rule is adopted in which the world price of traded goods is exogenous.

Production explains how industries combine inputs to produce total aggregate output, subject to technological constraints. Generally industries have more than one product which made input-output in the rectangular format. In producers' aspect, they must produce the proportion of products that can meet the profit maximization but there is a limitation on transformables. This is represented by constant elasticity transformation (CET) which states how easily the product mix can be adjusted in response to price changes.

$$XST_{j,t} = B_j^{XT}[\sum_i \beta_{j,i}^{XT} XS_{j,i,t}^{\rho_j^{XT}}]^{\frac{1}{\rho_j^{XT}}} \qquad (60)$$

where

$XS_{j,i,t}$: Industry j production of commodity i

B_j^{XT} : Scale parameter (CET – total output)

$\beta_{j,i}^{XT}$: Share parameter (CET – total output)

ρ_j^{XT} : Elasticity parameter (CET – total output) : $1< \rho_j^{XT} <\infty$

Each type of product supply function is derived from the first order condition of revenue maximizing as shown in equation 61.

$$XS_{j,i,t} = \frac{XST_{j,t}}{(B_j^{XT})^{1+\sigma_j^{XT}}}[\frac{P_{j,i,t}}{B_{j,i}^{XT} PT_{j,t}}]^{\sigma_j^{XT}} \qquad (61)$$

where

$P_{j,i,t}$: Basic price of industry j's production of commodity i

σ_j^{XT} : Elasticity of transformation (CET – total output) : $0< \sigma_j^{XT} <\infty$

The market selection, whether domestic or export, of producers' behavior based on goal of maximizing the firm's total revenue. It is assumed that the product in one market is different from another market which is describing through the constant elasticity of transformation (CET). It represents how readily production can be redirected from one market to another.

$$XS_{j,i,t} = B_{j,i}^{X}[\beta_{j,i}^{X}EX_{j,i,t}^{\rho_{j,i}^{X}} + (1-\beta_{j,i}^{X})DS_{j,i,t}^{\rho_{j,x}^{X}}]^{\frac{1}{\rho_{j,i}^{X}}} \quad (62)$$

where

$DS_{j,i,t}$: Supply of commodity *i* by sector *j* to the domestic market

$EX_{j,i,t}$: Quantity of product *i* exported by sector *j*

$B_{j,i}^{X}$: Scale parameter (CET – exports and local sales)

$\beta_{j,i}^{X}$: Share parameter (CET – exports and local sales)

$\rho_{j,x}^{X}$: Elasticity parameter (CET – exports and local sales) : $1< \rho_{j,i}^{X} <\infty$

Likewise, the first-order condition is applied subject to the CET function in Equation 62, from which is obtained the ratio of the supply function responding to price, as shown in Equation 63.

$$EX_{j,i,t} = [\frac{1-\beta_{j,i}^{X}}{\beta_{j,i}^{X}}\frac{PE_{i,t}}{PL_{i,t}}]^{\sigma_{j,i}^{X}}DS_{j,i,t} \quad (63)$$

where

$\sigma_{j,i}^{X}$: Elasticity of transformation (CET – exports and local sales): $0< \sigma_{j,i}^{X} <\infty$

In conclusion, the producer behavior is controlled by the CET function, which includes product to supply and in which market to distribute goods and services.

In this model, the producers can increase sales to the world market only by offering a price $PE_{i,t}^{FOB}$ that is advantageous relative to the world price $PWX_{i,t}$. The share can be increased depending on the degree of substitutability of the product. Equation 64 shows that it could simulate an exogenous in world demand through change in the variableEXD_{t}^{O}, which assumes a growth each period at the same rate as population index pop_t.

$$EXD_{i,t} = EXD_{t}^{O}pop_{t}[\frac{e_{t}PWX_{i,t}}{PE_{i,t}^{FOB}}]^{\sigma_{i}^{XD}} \quad (64)$$

where

$EXD_{i,t}$: World demand for exports of product *i*

$PWX_{i,t}$: World price of exported product *i* (expressed in foreign currency)

σ_{i}^{XD} : Price-elasticity of the world demand for exports of product *i*

Consumer behavior is similar to producer behavior, in which it is assumed that local products are imperfect substitutes for imports. Then, the composite goods which combine local and import goods is on the domestic marker. This imperfect substitutability between goods from two origins is described by the constant elasticity of substitution (CES) function (Equation 65).

$$Q_{i,t} = B_i^M[\beta_i^M IM_{i,t}^{-\rho_i^M} + (1-\beta_i^M)DD_{i,t}^{-\rho_j^M}]^{\frac{-1}{\rho_i^M}} \quad (65)$$

where

$Q_{i,t}$: Quantity demanded of composite commodity i

B_i^M : Scale parameter (CES – composite commodity)

β_i^M : Share parameter (CES – composite commodity)

ρ_j^M : Elasticity parameter (CES – composite commodity): $1< \rho_j^M <\infty$

Similarly, in seller, the buyer minimizes expenses subject to CES aggregation function (Equation 65). Demand of buyer proved form the first-order condition is represented in Equation 66.

$$IM_{i,t} = [\frac{B_i^M}{(1-B_i^M)}\frac{PD_{i,t}}{PM_{i,t}}]^{\sigma_i^M} DD_{i,t} \quad (66)$$

where

$PD_{i,t}$: Price of local product i sold on the domestic market (including all taxes and margins)

$PM_{i,t}$: Price of imported product i (including all taxes and margins)

σ_i^M : Elasticity of substitution (CES – composite commodity) $0< \sigma_i^M <\infty$

3.1.5 Prices

3.1.5.1 Production

Prices and price indexes of this model depend on functional forms and assumptions already mentioned in the previous section. The weighted sum of the price of components in aggregations is the price of aggregates. According to Leontief proportion, the weight does not change in response to price changes. In the other function, component proportions, component price weight changes in response to relative price changes based on elasticity of substitution or transformation. Equation 67 is an example of weight sum of the prices of values added and aggregate intermediate consumption.

$$PP_{j,t} = \frac{PVA_{j,t}VA_{j,t}+PCI_{j,t}CI_{j,t}}{XST_{j,t}} \quad (67)$$

In Equation 67, the weights are $VA_{j,t}/XST_{j,t}$ and $CI_{j,t}/XST_{j,t}$. Likewise, the prices of other aggregates is applied this principle such as price of aggregate intermediate consumption, price of values added and also price of composite labor and capital, which are explained in Equations 69 to 73.

According to model, various types of taxes are implemented so it is essential to identify the relationship between price before taxes and price including taxes. Taxes on production are added into basic price of unit cost. The same is applied to wage and rental of capital following equation 72 and 74.

$$PT_{j,t} = (1 + ttip_{j,t})PP_{j,t} \quad (68)$$

$$PCI_{j,t} = \frac{\sum_i PC_{i,t} DI_{i,j,t}}{CI_{j,t}} \quad (69)$$

$$PVA_{j,t} = \frac{WC_{j,t} LDC_{j,t} + RC_{j,t} KDC_{j,t}}{VA_{j,t}} \quad (70)$$

$$WC_{j,t} = \frac{\sum_l WTI_{l,j,t} LD_{l,j,t}}{LDC_{j,t}} \quad (71)$$

$$WTI_{l,j,t} = W_{l,t}(1 + ttiw_{l,j,t}) \quad (72)$$

$$RC_{j,t} = \frac{\sum_k RTI_{k,j,t} KD_{k,j,t}}{KDC_{j,t}} \quad (73)$$

$$RTI_{k,j,t} = R_{k,j,t}(1 + ttik_{k,j,t}) \quad (74)$$

where

$PT_{j,t}$: Basic price of industry *j*'s output

$PVA_{j,t}$: Price of industry *j* value added (including taxes on production directly related to the use of capital and labor)

$PCI_{j,t}$: Intermediate consumption price index of industry *j*

In this model, capital is assumed to be specific in each industry and it is fixed at the beginning of the period according to the accumulation rule of Equation 97.

3.1.5.2 International trade

The price aggregation principle is applied to exporting industries that have a possibility of selling their output on the international or the domestic market. Equation 75 describes the quantity of product sold on that market and the proportion that is assigned by weight to each market. The weight varies in response to relative price changes that depends on the elasticity of transformation in the CET. Margins and export taxes are added to create the FOB price which is different from the one received by the producer (Equation 77). The basic price is obtained by using price aggregation principle as shown in Equation 76.

$$PT_{j,t} = \frac{\sum_i P_{j,i,t} XS_{j,i,t}}{XST_{j,t}} \quad (75)$$

$$P_{j,i,t} = \frac{PE_{i,t} EX_{j,i,t} + PL_{i,t} DS_{j,i,t}}{CS_{j,i,t}} \quad (76)$$

$$PE_{i,t}^{FOB} = [PE_{i,t} + \textstyle\sum_{ij} PC_{ij,t} tmrg_{ij,i}^{X}]\,(1 + ttix_{i,t}) \quad (77)$$

As mentioned earlier, the domestic market consists of domestic and imported products. With market competition, the price of composite is the weighted sum of the price paid for domestically product and imported goods. Domestic product price in the domestic market are the sum of the prices received by the producer, margin and indirect taxes, as shown in Equation 78. Likewise imported product price in the domestic market is the sum of the world price translated into local currency plus taxes and import duties, margin and indirect tax as Equation 80.

$$PD_{i,t} = (1 + ttic_{i,t})[PL_{i,t} + \sum_{ij} PC_{ij,t} tmrg_{ij,i}] \quad (78)$$

$$PM_{i,t} = (1 + ttic_{i,t})[(1 + ttim_{i,t})e_t PWM_{i,t} + \sum_{ij} PC_{ij,t} tmrg_{ij,i}] \quad (79)$$

$$PC_{i,t} = \frac{PM_{i,t} IM_{j,i,t} + PD_{i,t} DD_{i,t}}{Q_{i,t}} \quad (80)$$

3.1.5.3 Price Indexes

There are five indexes in this model: the GDP deflator (Equation 81), the consumer price index (Equation 82), the private investment price index (Equation 83), the public investment price index (Equation 84) and the public current expenditure (Equation 85). The types of indexes are the Fisher index, Laspeyres index, and exact price indexes with Cobb-Douglas functions, which create the commodity demand for investment purposes and for public consumption.

$$PIXGDP_t = \sqrt{\frac{\sum_j PVA_{j,t} VA_j^O}{\sum_j PVA_{j,t}^O VA_j^O} \frac{\sum_j PVA_{j,t} VA_j}{\sum_j PVA_{j,t}^O VA_j}} \quad (81)$$

$$PIXCON_t = \frac{\sum_i PCA_{i,t} \sum_h C_{i,h}^O}{\sum_{ij} PVA_{ij}^O \sum_h C_{ij,h}^O} \quad (82)$$

$$PIXINV_t^{PRI} = \prod_i [\frac{PC_{i,t}}{PC_i^O}]^{\gamma_i^{INVPRI}} \quad (83)$$

$$PIXINV_t^{PUB} = \prod_i [\frac{PC_{i,t}}{PC_i^O}]^{\gamma_i^{INVPUB}} \quad (84)$$

$$PIXGVT_t = \prod_i [\frac{PC_{i,t}}{PC_i^O}]^{\gamma_i^{GVT}} \quad (85)$$

where

$PIXGDP_t$: GDP deflator

$PIXINV_t^{PRI}$: Private investment price index

$PIXINV_t^{PUB}$: Public investment price index

$PIXGVT_t$: Public expenditures price index

3.1.6 Equilibrium

Supply and demand equilibrium must be identified in the goods and service markets or the factor market. The equilibrium between the supply and demand of each commodity on the market is described by Equation 86. Equations 87 and 88 show total demand for each factor and total supply in period. The summation of savings from all agents in the economy must be equal to total investment as shown in equation 89. Changes in inventories and public investment expenditures are quasi-exogenous in Equation 90. The sum of all commodity consumption by local industry must be equal to domestic demand for domestic product Equation 91. Lastly, supply to the rest of the world market of each good must be matched by demand (Equation 92).

$$Q_{i,t} = \sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + VSTK_{i,t} + DIT_{i,t} + MRGN_{i,t} \quad (86)$$

$$\sum_j LD_{l,j,t} = LS_{l,t} \quad (87)$$

$$\sum_j KD_{k,j,t} = KS_{k,t} \quad (88)$$

$$IT_t = \sum_h SH_{h,t} + \sum_f SF_{f,t} + SG_t + SROW_t \quad (89)$$

$$IT_t^{PRI} = IT_t - IT_t^{PUB} - \sum_i PC_{i,t} VSTK_{i,t} \quad (90)$$

$$\sum_j DS_{j,i,t} = DD_{i,t} \quad (91)$$

$$\sum_j EX_{j,i,t} = EXD_{i,t} \quad (92)$$

where

$LS_{l,t}$: Supply of type l labor

$KS_{k,t}$: Supply of type k capital

3.1.7 Gross domestic product

GDP at basic price is equal to total values of value-added or factor used in each industry plus taxes on production other than taxes on labor and capital, since it is included in factor costs as shown in Equation 93. GDP at market price from demand perspective consists of net expenditure of household, current public expenditures on good and services, investment expenditure, plus net export in Equation 96. On the other hand, GDP from income perspective consist of total income from labor and capital, plus taxes on product and imports, plus other taxes on production (Equation 95). GDP at market price is summation of GDP at basic price plus the amount of taxes on products and import, as shown in Equation 94.

$$GDP_t^{BP} = \sum_j PVA_{j,t} VA_{j,t} + TIPT_t \quad (93)$$

$$GDP_t^{MP} = GDP_t^{BP} + TPRCTS_t \quad (94)$$

$$GDP_t^{IB} = \sum_{l,j} W_{l,t} LD_{l,j,t} + \sum_{k,j} R_{k,j,t} KD_{k,j,t} + TPRODN_t + TPRCTS_t \quad (95)$$

$$GDP_t^{FD} = \sum_i PC_{i,t} \left[\sum_h C_{i,h,t} + CG_{i,t} + INV_{i,t} + VSTK_{i,t}\right] + \sum_i PE_{i,t}^{FOB} EXD_{i,t} - \sum_i e_t PWM_{i,t} IM_{i,t} \quad (96)$$

where

GDP_t^{BP} : GDP at basic prices

GDP_t^{FD} : GDP at purchasers' prices from the perspective of final demand

GDP_t^{IB} : GDP at market prices (income-based)

GDP_t^{MP} : GDP at market prices

3.1.8 Dynamic equation

Dynamic assignment represents the relation of one period to the next. There are two categories in the model. First is set of statement update variables which are growing at a constant rate per period. The second are further equations controlling the accumulation of capital as shown in Equations 97 to 103.

In dynamic models, it is important to consider population growth over time. This model represents population growth through population index pop_t and growth each period at rate n_t. The value of pop_t at the first period is equal to 1 and $pop_t = pop_{t-1} (1 + n_t - 1)$ at the next period of study.

As the previous equation statements, the population index is applied to several constants in model, interception of household saving (Equation 16), interception of income taxes for household and firm (Equations 35 and 36), interception of the household transfers to government (Equation 48), transfer from government (Equation 50) and form the rest of the world (Equation 51).

Likewise, the variables grow at the population growth rate n_t which consists of labor supply, the current account balance, minimum consumption of commodities in the LES demand equation, government current expenditures, public investment by category and by public sector industry and change in inventories.

$$LS_{l,t} = LS_l^O \, pop_t$$

$$CAB_t = CAB^O \, pop_t$$

$$C_{i,h,t}^{MIN} = C_{i,h}^{MIN\_O} \, pop_t$$

$$G_t = G^O pop_t$$

$$IND_{k,pub.t} = IND_{k,pub}^O \, pop_t$$

$$VSTK_{i,t} = VSTK_{i,t}^O \, pop_t$$

where

$IND_{k,pub.t}$: Volume of new type *k* capital investment to public sector *pub*

The explanation for assuming the same growth rate in constant and exogenous variables is to make the model simulate a balanced growth path. As in economic theory, when all quantities grow at a constant rate in balanced growth path, relative price remains constant. This is useful for test model consistency.

$$KD_{k,j,t+1} = KD_{k,j,t}(1 - \delta_{k,j}) + IND_{k,j,t} \quad (97)$$

where

$IND_{k,j,t}$:Volume of new type *k* capital investment to sector *j* (whether public or private)

$\delta_{k,j}$: Depreciation rate of capital *k* used in industry *j*

According to equation 97, the capital in industry j in period t+1 is equal to the stock of the preceding period, minus depreciation, plus the volume of new capital investment in the preceding period. The amount of public investment expenditure is calculated by Equation 98.

$$IT_t^{PUB} = PK_t^{PUB} \sum_{k,pub} IND_{k,pub,t} \quad (98)$$

where

PK_t^{PUB} : Price of new public capital

Likewise, the volume of new private investment follows Equation 99.

$$IT_t^{PRI} = PK_t^{PRI} \sum_{k,bus} IND_{k,bus,t} \quad (99)$$

where

PK_t^{PRI} : Price of new private capital

$IND_{k,bus,t}$: Volume of new type *k* capital investment to private business sector *bus*

The prices of new private and public capital is determined by Equations 100 and 101, which follow on from Investment Demand Functions 54 and 55. The allocation of new private capital form private investment between categories and industries is proportional to the existing stock of capital and the proportion varies according to the ratio of the rental rate.

$$PK_t^{PRI} = \frac{1}{A^{K\_PRI}} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPRI}}\right]^{\gamma_i^{INVPRI}} \quad (100)$$

$$PK_t^{PUB} = \frac{1}{A^{K\_PUB}} \prod_i \left[\frac{PC_{i,t}}{\gamma_i^{INVPUB}}\right]^{\gamma_i^{INVPUB}} \quad (101)$$

$$INT_{k,bus,t} = \emptyset_{k,bus}[\frac{R_{k,bus,t}}{U_{k,bus,t}}]^{\sigma_{k,bus}^{INV}} KD_{k,bus,t} \qquad (102)$$

$$U_{k,bus,t} = PK_t^{PRI}(\delta_{k,bus} + IR_t) \text{ และ } U_{k,pub,t} = PK_t^{PUB}(\delta_{k,pub} + IR_t) \qquad (103)$$

where

A^{K_PRI} : Scale parameter (price of new private capital)

A^{K_PUB} : Scale parameter (price of new public capital)

IR_t : Interest rate

$U_{k,j,t}$: User cost of type k capital in industry j

$\emptyset_{k,j}$: Scale parameter (allocation of investment to industries)

$\sigma_{k,bus}^{INV}$: Elasticity of private investment demand relative to Tobin's q

3.2 Social Accounting Matrix as Database Input

In order to input our SAM into this model, it must be modified it into their SAM format according to the following guideline.

- The user must prepare the SAM as an EXCEL file.
- The SAM is categorized into five groups: factor of production, institutions, commodities, industries and accumulation.
- Like the other the SAM, each account must have one column and one row. According to the model, the user must use the same title as shown in the first two rows in the model's SAM format.

The model's SAM format is shown in Figures 3.2 and 3.3.

		L	L	K	K	AG	AG	AG	AG	AG	AG	AG	AG	AG	AG	AG	AG	AG	AG
		USK	SK	CAP	LAND	HRP	HUP	HRR	HUR	FIRM	GVT	TD	TM	TI	USK	SK	CAP	LAND	ROW
L	USK																		
L	SK																		
K	CAP																		
K	LAND																		
AG	HRP	5915	5078	526	1132														
AG	HUP	7300	4697	1054							139								
AG	HRR	872	1242	526	3602														
AG	HUR	1210	1010	6221	100					1900									
AG	FIRM			4741	488			10			10								
AG	GVT					40	100		122	81		2308	2500	4375	1843	137	46		
AG	TD					44	428	146	390	1300									
AG	TM																		
AG	TI																		
AG	USK																		
AG	SK																		
AG	CAP																		
AG	LAND																		
AG	ROW			42	911				10	370	30								
J	AGR																		
J	IND																		
J	SER																		
J	ADM																		
I	AGR					6338	4496	2441	1755										
I	FOOD					2504	3050	950	2400										
I	OTHIND					1090	1601	1003	3043										
I	SER					2635	3515	1620	2426										
I	ADM										8255								
X	AGR																		7576
X	FOOD																		241
X	OTHIND																		1200
X	SER																		2653
OTH	INV							72	295	1598	1231								5425
OTH	VSTK																		
OTH	TOT	15297	12027	13110	6233	12651	13190	6242	10441	5249	9665	2308	2500	4375	1843	137	46		17095

Figure 3.2 A fictitious SAM format in the model (left panel) [20]

		J	J	J	J	I	I	I	I	I	X	X	X	X	OTH	OTH	OTH
		AGR	IND	SER	ADM	AGR	FOOD	OTHIND	SER	ADM	AGR	FOOD	OTHIND	SER	INV	VSTK	TOT
L	USK	10002	2289		3006												15297
L	SK	910		10147	970												12027
K	CAP	2086	7015	4009													13110
K	LAND	6133	100														6233
AG	HRP																12651
AG	HUP																13190
AG	HRR																6242
AG	HUR																10441
AG	FIRM																5249
AG	GVT	-1693	-293								99						9665
AG	TD																2308
AG	TM					500	200	1800									2500
AG	TI					684	1400	1554	737								4375
AG	USK	1500	343														1843
AG	SK	137															137
AG	CAP	46															46
AG	LAND																
AG	ROW					2613	1458	9970	1691								17095
J	AGR					17834	250		210		7417						25711
J	IND					400	15698		20			241	1180				17539
J	SER						150		18532					2653			21335
J	ADM									8255							8255
I	AGR	2715	1402	1327	93										2164	-600	22131
I	FOOD	825	770	1600											6857	200	19156
I	OTHIND	1102	2930	455	2100												13324
I	SER	1948	2983	3797	2086	100					60		20				21190
I	ADM																8255
X	AGR																7576
X	FOOD																241
X	OTHIND																1200
X	SER																2653
OTH	INV																8621
OTH	VSTK														-400		-400
OTH	TOT	25711	17539	21335	8255	22131	19156	13324	21190	8255	7576	241	1200	2653	8621	-400	

Figure 3.3 A fictitious SAM format in the model (right panel) [20]

3.2.2 Activity and Commodities in SAM

There are 40 activities and 49 commodities in the SAM used for this model. All sectors and commodities are shown in Table 3.1.

Table 3.1 Activity and commodities in the model and SAM

Sector Number	Activity	Good Number	Commodities
1.	Paddy	1.	Paddy
2.	Corn	2.	Corn
3.	Cassava	3.	Cassava
4.	Cane	4.	Cane
5.	Oil Palm	5.	Oil Palm
6.	Livestock	6.	Livestock
7.	Charcoal	7.	Charcoal
8.	Fisheries	8.	Fishery
9.	Other agricultural	9.	Other agricultural goods
10.	Mining	10.	Mineral
11.	Crude oil and natural gas	11.	Crude oil
12.	Coal and Lignite	12.	Natural gas
13.	Food	13.	Coal and Lignite
14.	Palm oil	14.	Food
15.	Rice	15.	Palm oil
16.	Starch	16.	Rice
17.	Maize	17.	Starch
18.	Sugar	18.	Maize
19.	Textile	19.	Sugar
20.	Wood	20.	Molas
21.	Paper	21.	Textile
22.	Ethanol	22.	Wood
23.	Chemical	23.	Paper
24.	Refinery	24.	Ethanol
25.	Rubber	25.	Chemical product
26.	Non-metal	26.	Gasoline
27.	Metal Manufacturing	27.	Jet fuel

28.	Iron	28.	LPG
29.	Motor	29.	Diesel
30.	Machine	30.	Fuel oil
31.	Other manufacturing	31.	Other refinery product
32.	Electricity	32.	Gasohol
33.	Construction	33.	Biodiesel
34.	Trade	34.	Rubber
35.	Road transport	35.	Non-metal
36.	Rail transport	36.	Metal
37.	Water transport	37.	Iron
38.	Air transport	38.	Motors
39.	Other transport	39.	Machines
40.	Services	40.	Other manufacturing good
		41.	Electricity
		42.	Property
		43.	Trade
		44.	Road transport
		45.	Rail transport
		46.	Water transport
		47.	Air transport
		48.	Other transport
		49.	Service

3.2.3 Database

The core database for input to the model is an unofficial Social Accounting Matrix (SAM) 2010 developed by Chulalongkorn University's economic team, which was developed from official IO tables 2005 [21] . It was used in the study of the impact of macroeconomic factors of Thailand's underlying emission control [22].

3.2.4 Dynamic Assumption

In order to make the model replicate the economy in the future, several parameters are set based on historical data of Thailand. The average macroeconomic data of Thailand in the past is shown in Table 3.2.

From the existing study of forecasting parameter for Thailand's economic by National Institute of Development and Administration [23], it is used time series to estimate government expenditure and investment for year 2010 to 2025. The result is shown in Tables 3.3 and 3.4.

Table 3.2 Macroeconomic data of Thailand [source NESDB]

Year	GDP Growth (%)	Labor Growth (%)	Capital Growth (%)
Average 2002-2006	5.69	0.71	1.66
Average 1982-2010	6.00	0.60	4.60
2010	4.75	0.49	2.11

Table 3.3 Estimated government expenditure and investment [23]

Year	Government expenditure growth (%)	Government investment growth (%)
2013	3.91	0.84
2014	4.17	2.28
2015	4.33	2.90
2016	4.44	3.16
2017	4.52	3.28
2018	4.57	3.32
2019	4.60	3.34
2020	4.62	3.35

According to the historical data, the GDP of Thailand has been mainly driven by export and government consumption accounting for 95% of GDP. Its study is predicted export ratio in the future as shown in Table 3.4. Finally, the model is set exogenous parameter, government expenditure growth, total investment, export growth and population growth. It is shown in Table 3.5.

As a result of those parameters, the model can forecast trends for the economy which is similar to Thailand's average economic growth in the years 2000 – 2012. The Real Gross Domestic Product growth is about 4.3% yearly and the inflation growth rate accounts for 2.2%. Furthermore, the elasticity of government income per GDP growth is close to real value equally to one. A result of GDP generated by model is shown in figure 3.3.

Table 3.4 Result of forecasting long-term economic performance of Thailand [23]

Year	2010 – 2017	2017 – 2019	2020 – 2024
GDP growth (%)	4.45	4.23	4.12
Ratio of GOV consumption per GDP	13.13%	13.55%	14.31%
Ratio of export per GDP	81.27%	86.73%	91.94%

Table 3.5 Value of exogenous parameters in the dynamic model [this study]

Exogenous parameters	Value in percentage
Population growth	0.5
Government expenditure	5
Total investment	10
Export growth	5

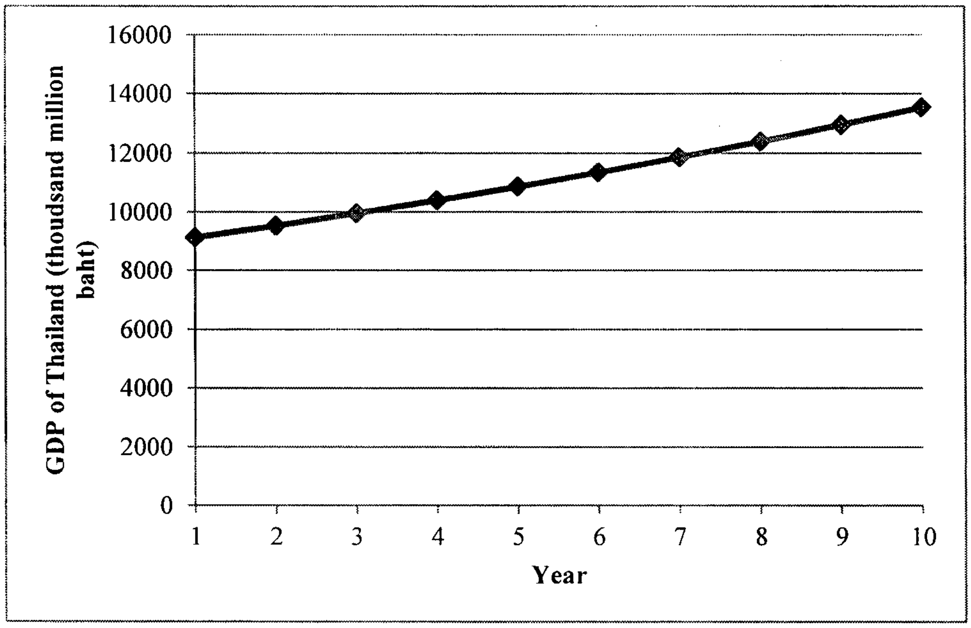

Figure 3.4 Base case's GDP generated by the model [this study]

3.2.5 Electricity system

The proportion of primary energy sources used for electricity generation was based on the year 2010 proportion and assumed to be constant for the entire period of this study. The proportion of energy sources generating electricity is shown in Table 1.1 in Chapter 1.

3.2.6 Carbon Tax Scenarios

In this study, there are four scenarios in order to deliberate the impacts of carbon tax policy on the only electricity generation sector on Thailand economic in the long-term and the short-term.

Firstly, the base case scenario does not implement carbon tax on electricity generation, which is used as a reference case for scenario comparison. The other scenarios has been implemented in various carbon tax price based on historic carbon price tax data in European market between Oct, 2009 and Sep, 2013 as shown in appendix A. It is varying from 17.75 EUD/ton to 2.88 EUD/ton during 2009-2013 and equivalent to 714.26 Baht/ton to 115.90 Baht/ton (at the average exchange rate 1 EUD = 40.24 Baht in year 2012) [24]. The other three scenarios are implied by the lowest tax rate (LT) 150 baht/ton CO_2, the average tax rate (AT) 450 baht/ ton CO_2 and the highest tax rate (HT) 750 baht/ton CO_2, which are shown in Table 3.6.

3.2.7 CO_2 emissions from electricity generation

CO_2 emissions in the model were calculated based on existing technology in year 2010 by using emission data, which is categorized by technology and fuel. The average CO_2 emissions from power generation for each technology is shown in Table 3.7 Multiplying emission data by electricity output according to the generation technology gives the total CO_2 emissions in 2010. The average emission factor applied in the model is determined by dividing the total CO_2 emission by the total value of electricity activity in the base year data.

In this model, the CO_2 emissions are determined from the output of the electricity generation sector multiplied by the average emission factor, calculated as described previously.

Table 3.6 CO_2 price in each scenario

Scenario	(baht/tonCO_2)		
BAU	**LT**	**AT**	**HT**
0	150	450	750

Table 3.7 The average CO_2 emissions of power generation in each technology [25]

Technology	CO_2 emission factor (kg/MWh)
	CO_2
Thermal : Lignite	972.5258
Thermal : Natural gas + Fuel oil	587.0509
Thermal : Fuel oil	727.5238
Cogeneration : Natural gas	454.4100
Gas turbine : Natural gas	731.6774
Gas Turbine : Diesel	N/A
Engine	737.6723
Average CO_2 emissions by fossil fuel technology	663.2272
Average CO_2 emissions by all technology	587.4783