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The Impact of Capital Intensive Farming in Thailand: A Computable General Equilibrium Approach

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Abstract

The aim of this study is to explore whether efforts to encourage producers to use agricultural machinery and equipment will significantly improve agricultural productivity, income distribution amongst social groups, as well as macroeconomic performance in Thailand. A 2000 Social Accounting Matrix (SAM) of Thailand was constructed as a data set, and then a 20 production-sector Computable General Equilibrium (CGE) model was developed for the Thai economy. The CGE model is employed to simulate the impact of capital-intensive farming on the Thai economy under two different scenarios: technological change and free trade. Four simulations were conducted. Simulation 1 increased the share parameter of capital in the agricultural sector by 5%. Simulation 2 shows a 5% increase in agricultural capital stock. A removal in import tariffs for agricultural machinery sector forms the basis for Simulation 3. The last simulation (Simulation 4) is the combination of the above three simulations.

The results for each simulation are divided into four effects: input, output, income and macroeconomic effects. The results of the first two simulations produced opposite outcomes in terms of the four effects. Simulation 2 accelerated the capital intensification of all agricultural sectors, whereas Simulation 1 led to more capital intensity in some agricultural sectors. The effects of the input reallocation had a simultaneous impact on output in every sector. Simulation 1 led to a fall of almost all outputs in the agricultural sectors, whereas there was an increase in agricultural output in Simulation 2. In terms of domestic income effects, as a result of the decline of the average price of factors in Simulation 1, there was a decrease in factor incomes belonging to households and enterprises. Consequently, government revenue decreased by 0.7%. In contrast, Simulation 2 resulted in an increase in all incomes above. Finally, regarding macroeconomic variables, Simulation 1 had a negative impact on private consumption, government consumption, investment, imports and exports, resulting in Gross Domestic Product (GDP) decreasing by 0.8%. On the other hand, Simulation 2 had a positive impact on those same variables, affecting a 0.4% rise of GDP. The effects of Simulation 3 were very small in everything compared with the first two simulations. The effect of Simulation 4 was mostly dominated by Simulations 1 and 2; the negative results of Simulation 1 were compensated by the positive effects of Simulation 2.

Key words: Capital intensive farming, CGE, general equilibrium, SAM, Thailand

1. Introduction

Although the share of labour in the Thai agriculture sector has been decreasing since 1960 because of the outflow of workers to non-agricultural sectors, the agricultural sector is still quantitatively important to the economy because nearly 40 percent of overall employment was still engaged in this sector. The downward trend of the labour supply available in agriculture sector resulted in farming patterns being divided into two categories; “casual farmers” and “progressive farmers” (Siamwalla, 1996). The first category is old and conservative while the second one is more progressive and uses modern technology.

In economic production functions, total output can be increased if the inputs such as labour or machinery are increased. Moreover, technological change and improvements in the process for producing goods and services can shift production functions upward (Samuelson and Nordhaus, 1995). However, changes in inputs and/or technological change in a sector may affect reallocation of factors as intermediate inputs of other sectors. (Hayami and Ruttan, 1985)

Therefore, this study aims to investigate the impact of capital intensive farming on the Thai economy under two different policy concepts; the technological change concept by Jackson (1998) and the free trade concept. Four policy simulation exercises are conducted. The first two simulations relate to the technological change concept by increasing the share parameter of agricultural input capital together with percentages decrease in the share parameter of agricultural labour, and the increase in capital stock in agricultural sector respectively. The third simulation is a removal in import tariffs for the agricultural machinery sector. The last simulation is the combination of the above three simulations. The primary analytical tool is a Computable General Equilibrium (CGE) model which has 20 production sectors.

This paper is organised as follows. Section 2 describes the structure of the CGE model. The structure of the Social Accounting Matrix (SAM) and the calibration of the CGE model are presented in Section 3. The empirical results of the simulation are presented in Section 4. Section 5 concludes the research findings and presents the important policy implications.

2. The Structure of the Thai CGE Model

2.1 General Features of the Thai CGE Model

Generally, a basic single-country CGE model is a set of simultaneous equations that describe the flow of economic interaction among agents; producers, households, firms, governments and the rest of the world (Hanson, Golan, Vogel, & Olmsted, 2002). This standard model is based on a Social Accounting Matrix or SAM data base which represents the flow of resources among agents in an economy (Provide Project, 2003).

The circular flow of income in a basic SAM and CGE model is shown in Figure 1. Producers purchase intermediate commodity goods and pay value-added (rent for capital and wages for labour) to factor markets in the factor markets which belong to household in order to produce commodity goods. On the other hand, a producer receives payments from selling commodity goods to domestic markets. Robinson (2003) defines the commodity account as a department store which buys products from domestic producers and international markets. Their receipts are from selling the products to other economic agents i.e. households and government and from exporting goods to the world market.

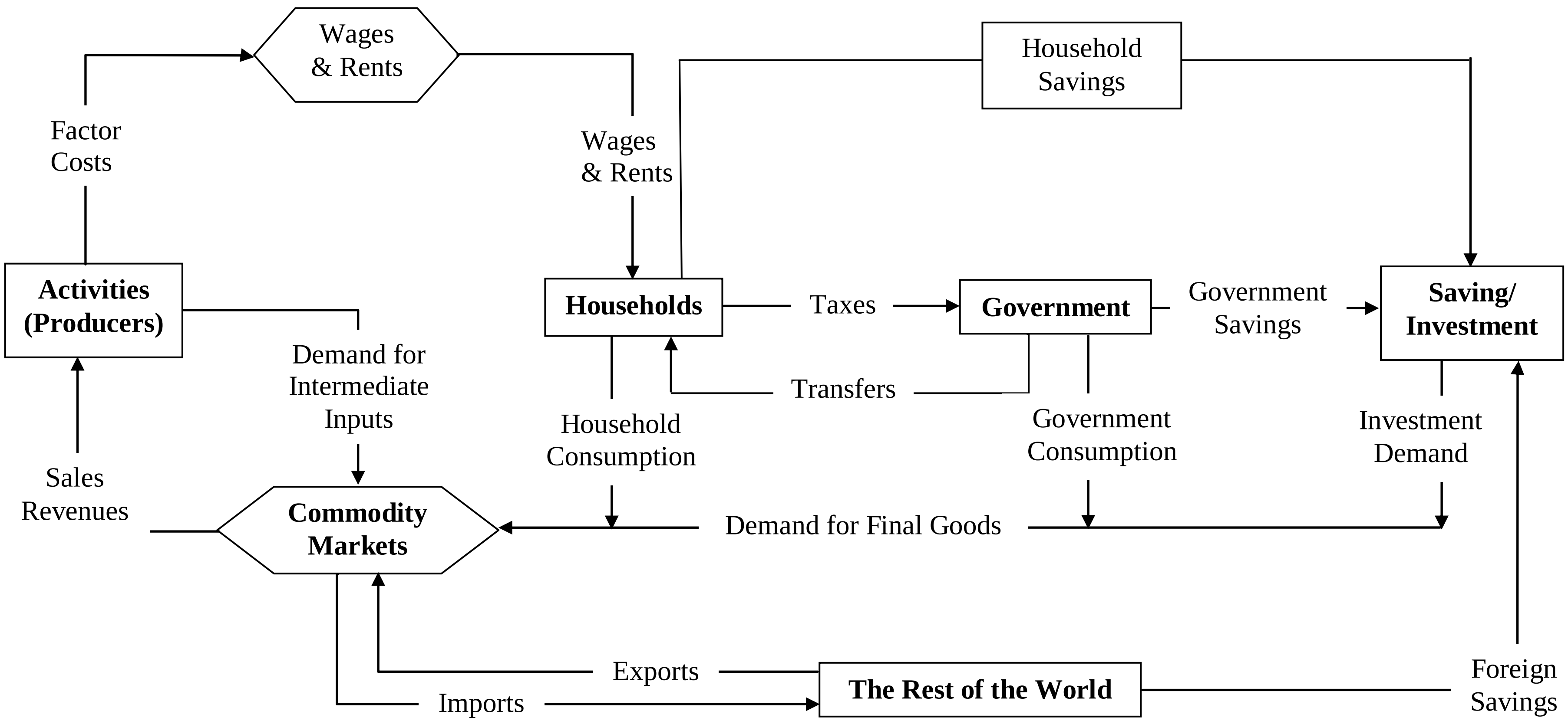
Households' payments are consumption (buying commodities), direct taxes (paying to government) and household savings (investment in capital account). In terms of government expenditure, there are a few outlay transactions: government consumption, saving and transfers to households.

The transactions in the capital account involve investment and saving. The sources of fund for investment are from institution savings (households, firms and government) and the rest of the world.

The outflow transaction from the local economy to the rest of the world comprises buying goods or services (imports). On the other hand, the rest of the world receipts payments from local commodities as well.

Our Thai CGE model has been developed from the CGE model of Lofgren (2003). The model depicts a small open economy with 20 production sectors (see Appendix A). Each sector has two inputs; capital and labour. There are three types of institutions (household, enterprise and government). The model is calibrated using data from the 2000 micro Social Accounting Matrix (SAM), which is constructed using the latest Input-Output table of Thailand year 2000, National Income Account and capital stock of Thailand from Office of National Economic and Social Development Board (NESDB), and the labour force survey from the National Statistical Office. The model is coded and run in General Algebraic Modelling System (GAMS) software following guidelines developed in Lofgren (2003) and Lofgren, Harris, & Robinson (2002). In the discussion below, endogenous variables are in uppercase Latin letters, whereas exogenous variables and parameters are, respectively, in lowercase Latin and Greek letters. The definitions of all indices, endogenous and exogenous variables and the parameters in the model are given in the Appendix B.

Figure 1: The circular flow of income in the basic CGE model



Source: Modified from Thomas & Bautista (1999) and Ganuza, Morley, Pineiro, Robinson, & Vos (2005)

2.2 Equations

In developing the equations shown in this section we extend those given in Lofgren et al (2002), Lofgren (2003) and Thaiprasert (2006).

The model has been divided into 4 blocks; price block, production and commodity block, institution block and system constraint block. Each block contains equations relating to their functions.

2.2.1 Price Block

The price system of the model is defined in the price block which consists of equations (1) to (6). Each price links to other prices and other model variables. As the economy of Thailand is small relative to the world market, the import and export commodity price equations can be written as equations (1) and (2).

$$PM_c = (1 + tm_c) \cdot EXR \cdot pwm_c, \qquad c \in CM \qquad (1)$$

$$PE_c = (1 + te_c) \cdot EXR \cdot pwe_c, \qquad c \in CE \qquad (2)$$

The absorption for each commodity is the total domestic spending on the commodity at domestic prices ($PQ_c \cdot QQ_c$). It can be expressed as the spending on domestic outputs ($PD_c \cdot QD_c$) plus imports ($PM_c \cdot QM_c$) including an upward adjustment for sale tax as shown in equation (3). Therefore, the composite price (PQ_c) could be derived by dividing equation (3) by composite supply (QQ_c) (see discussion of QQ_c on equation (11).

$$PQ_c \cdot QQ_c = \left[PD_c \cdot QD_c + \left(PM_c \cdot QM_c\right)_{|c \in CM}\right] \cdot (1 + tq_c), \; c \in C \qquad (3)$$

Domestic output valued at the producer price ($PX_c \cdot QX_c$) is the value of domestic sales ($PD_c \cdot QD_c$) plus the export value ($PE_c \cdot QE_c$). It can be expressed as equation (4). Again, the producer price (PX_c) could be derived when dividing equation (4) by domestic output (QX_c).

$$PX_c \cdot QX_c = \left[PD_c \cdot QD_c + \left(PE_c \cdot QE_c\right)_{|c \in CE}\right], \; c \in C \qquad (4)$$

The last two price equations are activity price (PA_a) and value-added price (PVA_a). Equation (5) describes activity price which is the sum of producer price times yields whereas equation (6), value-added price, is the activity price minus value added tax and input cost per activity unit.

$$PA_a = \sum_{c \in C} PX_c \theta_{ac}, \qquad a \in A \qquad (5)$$

$$PVA_a = PA_a \cdot (1 - tia_a) - \sum_{c \in C} PQ_c \cdot ica_{ca}, \qquad a \in A \qquad (6)$$

2.2.2 Production and Commodity Block

Following standard practice, we assumed that each producer maximize profits subject to its production function, which is using Cobb-Douglas production technology with two inputs (capital and labour). Therefore, the activity production function can be expressed as equation (7).

$$QA_a = ad_a \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad , \qquad a \in A \tag{7}$$

Assuming perfect competition and profit maximization, the demand for factor inputs can be derived as in equation (8). The factor markets clear when the model solves for average factor prices (WF_f). The parameters ($WFDIST_{fa}$) are equal to one when there is no distortion in the factor markets.

$$WF_f \cdot WFDIST_{fa} = \frac{\alpha_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \quad , \qquad f \in F \text{ and } a \in A \tag{8}$$

Equation (9) is the demand for intermediate inputs which is fixed. It is the function of activity level. Equation (10), another kind of function of activity level, is the output function

$$QINT_{ca} = ica_{ca} \cdot QA_a \tag{9}$$

$$QX_c = \sum_{a \in A} \theta_{ac} QA_a - ag_a \quad , \qquad c \in C \tag{10}$$

According to the Armington assumption, the composite commodities are produced by using domestic commodities (QD_c) from domestic markets and from imported markets (QM_c) for these commodities. As the original idea of the Armington assumption was based on the Constant Elasticity of Substitution function (CES), the composite supply (Armington) function can be written as equation (11).

$$QQ_c = aq_c \left[\delta_c^q \cdot QM_c^{-\rho_c^q} + (1 - \delta_c^q) \cdot QD_c^{-\rho_c^q} \right]^{-1/\rho_c^q} , \qquad c \in CM \tag{11}$$

The optimal mixture between imports (QM_c) and domestic output (QD_c) in equation (11) is described in Equation (12). It is the import-domestic demand ratio for commodity C.

$$\frac{QM_c}{QD_c} = \left[\left(\frac{PD_c}{PM_c} \right) \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right]^{\frac{1}{1+\rho_c^q}} , \qquad c \in CM \tag{12}$$

Similarly to the composite commodity, the domestic output has the choices between selling its commodity on the domestic market or on foreign market as exports (QE_c) which is captured by equation (13). We use Constant Elasticity of Transformation function (CET) because its property is as same as CES function except for only the elasticity. Therefore, the domestic output (QX_c) is written as the output transformation (CET) which is shown as equation (13).

$$QX_c = at_c \cdot \left[\delta_c^t \cdot QE_c^{\rho_c^t} + \left(1 - \delta_c^t\right) \cdot QD_c^{\rho_c^t} \right]^{\frac{1}{\rho_c^t}} , \qquad c \in CE \tag{13}$$

In the same way as equation (12), the optimal mixture between exports (QE_c) and domestic sale (QD_c) in equation (13) is described in Equation (14) which is the export-domestic demand ratio for commodity C.

$$\frac{QE_c}{QD_c} = \left[\left(\frac{PE_c}{PD_c} \right) \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right]^{\frac{1}{\rho_c^t - 1}} , \qquad c \in CE \tag{14}$$

2.2.3 Institution Block

In the institution block, there are nine equation types; factor income, institution incomes, household income, household consumption demand, enterprise income, enterprise expenditure, investment demand, government revenue and expenditure.

Equation 15 defines income of factor f (YF_f), capital and labour, as equal to the sum of average factor prices (WF_f) multiplied by quantity demanded of factor f (QF_{fa}) with distortion wage ($WFDIST_{fa}$). This factor income in equation (15) is then split into households and enterprises in fixed shares ($shryid_{id,f}$) as shown in equation (16). Labour income belongs to households whereas capital income must be subtracted the payment of tax on capital before flowing to households and enterprises.

$$YF_f = \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa}, \qquad f \in F \tag{15}$$

$$YFID_{id,f} = shryid_{id,f} \cdot \left[\left(1 - tcap_f \right) \cdot YF_f \right], \qquad id \in ID, f \in F \tag{16}$$

Household income YH_h is derived from three sources: factors (capital and labour), transfers from government and remittances from abroad as described in equation (17). In contrast, household expenditure comprises direct income taxes (paid to government) and direct payments to enterprises as interest or insurance. Income remaining after the above expenditure is household savings, which are used to calculate the household saving rate or Marginal Propensity to Save (MPS) for the household. The remaining households' payments are consumption (buying commodities). It is assumed that households maximise a Cobb-Douglas utility function subject to budget constraints. The result of the first-order conditions is then derived for household consumption demand QH_{ch} as shown in equation (18).

$$YH_h = \sum_{f \in F} YFID_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row}, \qquad h \in H \tag{17}$$

$$QH_{ch} = \frac{\beta_{ch} \cdot \left(1 - mps_h\right) \cdot \left(1 - ty_h\right) \cdot \left(1 - \mathrm{int}_{ent,h}\right) \cdot YH_h}{PQ_c}, \quad c \in C, h \in H \tag{18}$$

Equations (19) and (20) define enterprise income and expenditure respectively. The sources of its income ($YENT_{ent}$) are rent, interest payment from household, transfers from government and transfers from the rest of the world (equation 19), whereas a firm distributes its income by paying to households and transferring to abroad. Income after expenditure of the firm is enterprise savings (equation 20).

$$YENT_{ent} = \sum_{f \in F} YFID_{ent,f} + \left(\sum_{h \in H} \mathrm{int}_{ent,h} \cdot YH_h \right) + tr_{ent,gov} + EXR \cdot tr_{ent,row}, \; ent \in ENT \tag{19}$$

$$YENT_{ent} - \left(tent_{ent} \cdot YENT_{ent} \right) - EXR \cdot tr_{row,ent} = ENTSAV_{ent}, \qquad ent \in ENT \tag{20}$$

Equation (21) defines quantity demand for investment. It multiplies base-year investment demand ($qinvbar_c$) by an investment adjustment factor ($IADJ$).

$$QINV_c = qinvbar_c \cdot IADJ \tag{21}$$

In terms of the government sector, its income and expenditure are shown in equations (22) and (23) respectively. Government revenue is direct taxes from factors, direct income tax from domestic institutions (households and enterprises), sale tax, value added tax, import tariffs, export taxes and transfers from the rest of the world (equation 22). On the other hand, government expenditure is from government consumption of commodity goods and transfers to households, firms and the rest of the world account (equation23). Government income after expenditure is government saving.

$$\begin{aligned} YG = & \left(\sum_{f \in F} tcap \cdot YF_f \right) + \left(\sum_{h \in H} ty_h \cdot YH_h \right) + \left(\sum_{ent \in ENT} tent_{ent} \cdot YENT_{ent} \right) \\ & + \sum_{c \in C} tic_c \cdot \left(PD_c \cdot QD_c + \left(PM_c \cdot QM_c \right)_{|c \in CE} \right) \\ & + \left[\sum_{a \in A} tia_a \cdot \left(PA_a \cdot QA_a \right) \right] + \left(\sum_{c \in CM} tm_c \cdot EXR \cdot pwm_c \cdot QM_c \right) \\ & + \left(\sum_{c \in CE} te_c \cdot EXR \cdot pwe_c \cdot QE_c \right) + EXR \cdot tr_{gov,row} \end{aligned} \tag{22}$$

$$EG = \left(\sum_{c \in C} PQ_c \cdot qg_c \right) + \sum tr_{h,gov} + \sum tr_{rnt,gov} + \sum EXR \cdot tr_{row,gov} \tag{23}$$

2.2.4 System Constraint Block

Equations in this block define the system constraints that must be satisfied by the model. Clearance in the commodity and factor markets is obtained via flexible prices, while current account balance is cleared by floating foreign exchange rates. The model satisfies Walras' Law. Hence, the macro constraint satisfies the identity in equation (27), indicating that saving equals investment.

The equilibrium in the factor market is defined in equation (24) which is the equality in total quantity demanded and supplied of the two factors (capital and labour). In the model, it is assumed that the supplies of factors are exogenous and given. The factor market is cleared by the average factor prices (WF_f).

$$\sum_{a \in A} QF_{fa} = QFS_f, \qquad f \in F \tag{24}$$

The condition in equation (25) is the equality in composite commodity supply and demand. The composite commodity supply (QQ_c) is from the Armington function as described in equation (11) whereas the composite commodity demand (the right hand side of equation 25) is the sum of domestic demand for commodity by activity, household, government and investment demand. This market is cleared by the composite commodity price (PQ_c).

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c, \qquad c \in C \tag{25}$$

Regarding the current account balance (expressed in foreign currency), the country's earnings equal its spending of foreign exchange which is represented by equation

(26). The earning side is from export revenue, transfers from aboard and foreign savings. The spending side comes from import spending, transfers to the rest of the world and foreign investment. We assumed that foreign saving is fixed and the current account balance is cleared by the foreign exchange rate.

$$\sum_{c \in CE} pwe_c \cdot QE_c + \sum_{i \in I} tr_{i,row} + FSAV = \sum_{c \in CM} pwm_c \cdot QM_c + \sum_{i \in I} tr_{row,i} + finv \tag{26}$$

Another macro constraint is the saving-investment balance as shown in equation (27). Total saving is the sum of savings from households, enterprise, government and the rest of the world. In contrast, total investment is the sum of the value of investment. The $WALRAS$ variable is introduced in this equation in order to check whether the saving-investment balance holds or not. If the model works, the value of $WALRAS$ will be zero.

$$\begin{aligned} &\sum_{h \in H} mps_h \cdot (1 - ty_h) \cdot (1 - \text{int}_{\text{int},h}) \cdot YH_h + (YG - EG) \\ &+ \left[\sum_{ent \in ENT} YENT_{ent} - (tent_{ent} \cdot YENT_{ent}) - EXR \cdot tr_{row,ent} \right] + EXR \cdot FSAV \\ &= \sum_{c \in C} PQ_c \cdot QINV_c + EXR \cdot finv + WALRAS \end{aligned} \tag{27}$$

The last equation in the system constraint block involves price normalization (equation 28). The consumer price index is defined as a weighted sum of composite commodity prices. The weights, commodities weight in the consumer price index, are the ratio of demand for each commodity to total demand. The consumer price index (cpi) in equation (28) is fixed. Hence, in a simulation, when a simulated price is changing, it can be directly given a value viz-a`-vis the cpi.

$$\sum_{c \in C} PQ_c \cdot cwts_c = cpi \tag{28}$$

2.3 Equilibrium Condition and Macro Closure

There are three main equilibrium conditions: the market equilibrium (equation 25), current account balance (equation 26) and saving-investment balance (equation 27). Since our model incorporates "neoclassical closure" based on Walrasian models, it is assumed that at equilibrium there is full employment in the economy and all investment is determined by saving, in other words it is the saving driven model (Thissen, 1998). As the model must satisfy Walras' law, a slack variable ($WALRAS$) is introduced in equation (27). The number of endogenous variables is equal to the number of equations. The $WALRAS$ variable should return a zero value at equilibrium when the model is fully closed and all markets are cleared.

3. Data, Software and Model Calibration

Database for this model is Social Accounting Matrix or SAM which is "a comprehensive, economy-wide data framework" (Lofgren et al, 2002; pp3). SAM presents economic transactions (flow of income) in a form of square matrix (see Table 1) representing the flow of resources among agents in an economy as explained in section 2.1 and Figure 1. The most important property of a SAM is that it is “based on a fundamental principle of economics: for every income and receipt there is a corresponding expenditure or outlay. This principle underlies the double-entry accounting procedure that “makes up the macroeconomics accounts of any countries” (Reinert and Roland-Host 1997; pp. 95).

We constructed a SAM as a database for our CGE model by using information in the year 2000 of National Income Accounts, Input-Output table, Capital Stock of Thailand from Office of National Economic and Social Development Board (NESDB), and the Labour Force Survey from Office of National Statistics. The actual construction of the 2000 SAM proceeded in three steps as follows. Firstly, an aggregate macro 2000 SAM of Thailand was constructed to provide and control the totals. Secondly, the activity and commodity categories in the macro SAM are disaggregated into the 2000 micro SAM with 20 sectors with eight agricultural sectors to serve for policy simulations in the CGE model. Lastly, the Cross Entropy technique is used to balance the 2000 micro SAM. The balanced 2000 micro SAM is then used as benchmark data for the CGE model.

However, as the cell entries in a macro SAM come from various sources, the total sum in each column and row may not be equal at the start. To resolve this problem, we used the General Algebraic Modelling System (GAMS) software to estimate the 2000 micro SAM by using “cross entropy method” (Robison, Cattaneo and Said 2000).

Most parameters in the model are calibrated from the 2000 micro SAM of Thailand. In calibration, it is assumed that all initial prices at equilibrium in the model are equal to one (1). Therefore, the demand and supply of goods are obtained as the base year solution of the model that must be equal to the initial equilibrium as captured by SAM. After obtaining the base year values for variables in the model, parameters are derived from equations in the model. For example in equation (7) there are three parameters, which are production function efficiency parameter (ad_a) and two production function share parameters for factor f in activity a (α_{fa} and $1-\alpha_{fa}$). With the first order conditions for profit maximization, the demand for factor inputs is derived as equation (8) which can solve for share parameter (α_{fa} and $1-\alpha_{fa}$).

However, the limited availability of time series data on elasticity estimation in Thailand, estimates of the elasticity of substitution between domestic goods and imports for commodity *C*, the Armington elasticity (σ_c^q), are taken from Warr and Lapiz (1994). For a similar reason, the elasticity of transformation between domestic sales and exports for commodity *C* (σ_t^q) are taken from Warr and Lapiz (1994) and Wattanakuljarus and Coxhead, I. (2006). Both elasticities are presented in Appendix C.

The following necessary informational inputs have now been developed: elasticity coefficients, numbers of employed workers and the value of net capital stock of Thailand year 2000 in each sector (Appendix D), and the values of other required variables and parameters have been obtained from the 2000 micro SAM of Thailand. Finally the CGE model is ready to be calibrated and simulated by GAMS using all above information. Since the value of the initial prices of commodities and factors are unities, the base year solution of running the CGE model duplicates the initial values as captured by SAM. The GAMS codes of the CGE model are based on, and extended, those given in Lofgren et al.(2002) and Lofgren (2003). Detailed data and GAMS codes are available upon request.

Table 1: The Basic SAM structure used in the CGE model

		Expenditure								
		Activities (1)	**Commodities (2)**	**Factors (3)**	**Households (4)**	**Enterprises (5)**	**Government (6)**	**Saving-Investment (7)**	**Rest of World (8)**	**Total**
Receipts	**Activities (1)**		Marketed outputs				Export subsidies			**Activity income**
	Commodity (2)	Intermediate Inputs			Households consumption		Government consumption	Investment	Exports	**Domestic demand**
	Factors (3)	Value-added								**Factor income**
	Household (4)			Factor income to households		Transfer to households	Transfer to household		Transfers to household from ROW	**Household income**
	Enterprises (5)			Factor income to enterprises	Transfer to enterprises		Transfer to enterprises		Transfers to enterprises from ROW	**Firm income**
	Government (6)	Producer taxes, Value-added taxes	Sales taxes, tariffs, export taxes	Factor income to government	Transfer to government, direct taxes	Transfer to government, enterprise taxes			Transfers to government from ROW	**Government income**
	Saving-Investment (7)				Household savings	Enterprise savings	Government saving		Foreign savings	**Total saving**
	Rest of the World (ROW) (8)		Imports	Factor income to ROW		Current transfer abroad	Government transfer to ROW			**Foreign exchange outflow**
	Total	**Activity expenditure**	**Supply expenditures**	**Factor expenditures**	**Households expenditures**	**Enterprise expenditures**	**Government expenditure**	**Total investment**	**Foreign exchange inflow**	

Source: Based on Lofgren et al. (2002)

4. Policy Simulation Design and Results

4.1 Simulation Design

The empirical objective of this study is to examine the impact of capital intensive farming in Thailand. In order to measure this impact, by increasing the share parameter of agricultural capital input with a decrease in the share parameter of agricultural labour, this study has applied the non-neutral technological change concept from Jackson (1998) as follows.

Before going into the technological change forms, it is necessary to understand the terms of the definition of "*technical change*" and "*technological change*" because both terms are used in research involving invention and innovations. Jackson (1998) defines technical change as "any change in knowledge about production: about methods of production, about products or about inputs to making products and it results in both invention and innovations" Jackson (1998; pp. 14). However, the author states that technological change is the process innovation which involves "a physical alteration (plant, equipment or intermediate products) as a central feature. He also points out that capital-saving (or using) and labour-saving (or using) are the parts of non-neutral technological change (Jackson, 1998; pp. 15).

Non-neutral technological change was first introduced by W.E.G. Salter. The original definition of non-neutral technological change was "the labour or capital-saving biases of technical advance are measured by the relative change in capital per labour unit when relative factor prices are constant" (Salter, 1966; pp. 31-32). Jackson (1998) followed Salter's definition in the production functions as follows:

$$Q = ZL^{a}K^{b} \tag{29}$$

Where
Q = quantity output per period
Z = adjustment factor
L = Quantity of input of labour
K = the acquisition cost at constant price of the fixed capital stock
a = the partial elasticity of Q with respect to L (when K is constant) or production function share parameter for factor L in activity a (or α_L in the model).
b = the partial elasticity of Q with respect to K (when L is constant) or production function share parameter for factor K in activity a (or α_K in the model).
$a + b = 1$
Equation (29) can be expressed in K as a function of Q and L:

$$K = \left(Q/Z \right)^{\frac{1}{b}} L^{\frac{-a}{b}} \tag{30}$$

If we take derivative of equation (30) with respect to L, $\frac{dK}{dL}$:

$$\frac{dK}{dL} = -\left(a/b\right)\left(Q/Z\right)^{\frac{1}{b}} L^{\left(\frac{-a}{b}-1\right)} = \left(a/b\right)\left(Q/Z\right)^{\frac{1}{b}} L^{-\left(\frac{1}{b}\right)} \tag{31}$$

The condition for cost minimization is given as follows:

$$\frac{dK}{dL} = -\frac{p_L}{P_K} \tag{32}$$

Where:
P_L = wage rate per labour-hour
P_K = price of a unit of capital

Therefore, equation (31) is equal to equation (32):

$$-\left(a/b\right)\left(Q/Z\right)^{\frac{1}{b}} L^{-\left(\frac{1}{b}\right)} = -\left(\frac{P_L}{P_K}\right) \quad (33)$$

Solving equation (33) for the minimum cost quantity of input of labour *(L*)* gives:

$$L^* = \left[\frac{\left(a/b\right)}{\left(p_L/p_K\right)}\right]^b \left(\frac{Q}{Z}\right) \quad (34)$$

Similarly, the value of the minimum cost quantity of capital input *(K^*)* can be derived as:

$$K^* = \left[\frac{\left(a/b\right)}{\left(p_L/p_K\right)}\right]^{-a} \left(\frac{Q}{Z}\right) \quad (35)$$

Dividing equation (35) by (34), yields the minimum cost of the capital-labour ratio $\left(K/L\right)^*$ as:

$$\left(K/L\right)^* = \left[\frac{p_L/p_K}{a/b}\right] \quad (36)$$

Jackson (1998) called a non-neutral technological change as "capital-using" or "labour saving" if the ratio of exponent (a/b) falls and then the capital-labour ratio at minimum cost $\left(K/L\right)^*$ increases, meaning that capital is substituted for labour. In contrast, he defined a non-neutral technological change as "capital-saving" or "labour using" if the ratio of exponents (a/b) rises and then the capital-labour ratio at minimum cost $\left(K/L\right)^*$ decreases, indicating that labour is substituted for capital (see Table 2).

Table 2: A synopsis of possibilities of non-neutral technical change

The ratio of exponents (a/b)	The capital-labour ratio at minimum cost $\left(K/L\right)^*$	Non-neutrality is referred to as:
Falls	Increases	Capital-using/ Labour-saving
Rises	Decreases	Labour-using/ Capital-saving

Source: Based on Jackson (1998)

In this study, four simulations are conducted to achieve the research objectives. The first simulation is to decrease the ratio of exponents a/b following Jackson's concept, in order to answer the question: What are the impacts of capital-using in the Thai agricultural sector? In this experiment, we assumed that the production function share parameters for factor K (b in the Jackson's concept or α_K in the model) in Thai agricultural sectors (Sectors 1 – 8) are increased by 5 percent. The increase in b brings about a decrease in a or (α_L in the model) because the constant returns to scale in the production function assumed that $a+b=1$ (or $\alpha_L+\alpha_K$ = 1 in the model). In the end, the ratio of exponents a/b has fallen.

Another of Jackson's concepts, leading to our second simulation, deals with the impact of capital intensive farming when the capital-labour ratio at minimum cost $\left(K/L\right)^*$ increases in agricultural sectors. In this experiment, we shock the model by increasing net capital stock (K) in agricultural sectors (Sectors 1 – 8) by 5 percent. When the capital stock (K) is increased, this affects the capital-labour ratio $\left(K/L\right)^*$, causing it to increase as well.

The third simulation deals with an import tariff. According to free trade theory, a country can import more goods or services when there is no tariff barrier. Therefore, the Agricultural Machinery sector (Sector 16) is disaggregated especially for this simulation. The reason is that historically there have been increasing in the import of high quality equipment of agricultural machinery in Thailand. Therefore, if there is no import tariff on sector 16, it is expected that Thailand would import more agricultural machinery. The consequence of the increase in these imports might be expected to affect other economic variables in the model Salvatore (2005) and Kreinin (1998). This simulation is intended to provide quantitative measurements of these effects.

The last simulation is the combination of Simulations 1, 2 and 3 in order to test the *total* impact of capital intensive farming if Thailand implemented *all* the above simulations' actions combined (see Table 3).

The simulations are determined by the closure rules. For all simulations, we assume that investment is savings driven, input capital is activity-specific and fully utilized, labour is mobile and fully employed and the exchange rate is flexible.

Table 3: A synopsis of possibilities of non-neutral technical change

Simulation	Description
Simulation 1	Production function share parameter for input capital (α_K) in agricultural sectors (ACT01 – ACT08) increased by 5%
Simulation 2	Capital stock in agricultural sectors (ACT01 – 08) increased by 5%
Simulation 3	The removal of import tariff on Sector 16 (COM 16)
Simulation 4	The combination of Simulations 1, 2 and 3

4.2 Simulation Results

This section reports and discusses the results of CGE simulations as "capital-using" in agricultural sector of Thailand compared with the base year. The impact of all policy experiments are divided into four analyses: input factor effects, sectoral output effects, income effects and finally macro economic effects.

4.2.1 Input Factor Effects

Before discussing the detail of simulation results, it is best to summarise the basic role of the production share parameter for the factors. According to Chung (1994), in a Cobb-Douglas production function $y = f(x_1,...,x_n) = A\prod_{i=1}^{n} x_i^{a_i}$, "each parameter ($a_i$) directly indicates the share of output paid to the respective input". In addition, Chung points out that "if the value of parameter a_i is greater than the value of parameters a_j, that mean the output (y) share of input i is greater than the share of input j". Moreover, he explains that if there are only two inputs (let x_i and x_j be capital (K) and labour (L) respectively), then "if the capital-labour ratio (K/L) of output y_1 is greater than that of output y_2 for the given wage-rental ratio, output y_1 is called the capital-intensive good whereas output y_2 is called the labour-intensive good.

Considering the base year value of the production function share parameter (α_{fa}) of factor input obtained from the model (see Table 4), it can be seen that the output of every sector paid to capital is greater than to labour (α_{fa} of capital is greater than α_{fa} of labour in each sector). In other words, the share of capital input is greater than the share of labour input in each sector in the Thai economy. The increase in α_{fa} of capital by approximately 5 percent (Simulation 1) resulted in the decrease in α_{fa} of labour in all agricultural sectors (Sectors 1 to 8) by approximately 8 – 21%. That means output of agricultural sectors paid to capital input is more than in the base year. Meanwhile, the production function share parameter remained the same in Simulations 2 and 3 (Assumed). However, the result of Simulation 4 regarding α_{fa} was the same as for Simulation 1 (see Table 4).

Table 4: Percentage change from base year of the policy simulations of share parameter of factor input (α_{fa}) in the production functions

Sector	α_{fa} (Base year)		SIM 1 (%Δ)		SIM 2 (%Δ)		SIM 3 (%Δ)		SIM 4 (%Δ)	
	Lab1/	Cap2/	Lab1/	Cap2/	Lab1/	Cap2/	Lab1/	Cap2/	Lab1/	Cap2/
1. Paddy and Maize	0.381	0.619	-7.87	4.85	-	-	-	-	-7.87	4.85
2. Cassava, Beans and Nuts	0.353	0.647	-9.07	4.95	-	-	-	-	-9.07	4.95
3. Vegetables, Sugarcane and Fruits	0.248	0.752	-15.32	5.05	-	-	-	-	-15.32	5.05
4. Rubber and Latex	0.217	0.783	-17.97	4.98	-	-	-	-	-17.97	4.98
5. Other Crops	0.228	0.772	-17.11	5.05	-	-	-	-	-17.11	5.05
6. Livestock	0.194	0.806	-21.13	5.09	-	-	-	-	-21.13	5.09
7. Forestry	0.367	0.633	-8.72	5.06	-	-	-	-	-8.72	5.06
8. Fishery	0.266	0.734	-13.53	4.90	-	-	-	-	-13.53	4.90
9. Mining and Quarrying	0.349	0.651	-	-	-	-	-	-	-	-
10. Food Manufacturing	0.343	0.657	-	-	-	-	-	-	-	-
11. Textile Industry	0.428	0.572	-	-	-	-	-	-	-	-
12. Paper Industries and Printing	0.182	0.818	-	-	-	-	-	-	-	-
13. Rubber Chemical and Petroleum Industries	0.341	0.659	-	-	-	-	-	-	-	-
14. Non Metallic Products	0.342	0.658	-	-	-	-	-	-	-	-
15. Metal Product and Machinery	0.37	0.63	-	-	-	-	-	-	-	-
16. Agricultural Machinery	0.536	0.464	-	-	-	-	-	-	-	-
17. Other Manufacturing	0.381	0.619	-	-	-	-	-	-	-	-
18. Electricity, Water Work and Public Utilities	0.532	0.468	-	-	-	-	-	-	-	-
19. Construction and Trade	0.214	0.786	-	-	-	-	-	-	-	-
20. Service Transportation and Communication	0.604	0.396	-	-	-	-	-	-	-	-

Source: Model Simulations 1 – 4

Note: 1/ Labour input

2/ Capital input

The effect of policy simulations in terms of quantities demanded of each factor is shown in Table 5. Simulation 1 led to a decrease in demand for labour in four agricultural sectors (Sectors 3, 4, 6 and 7) and some non agricultural sectors (Sectors 9, 10, 13, 16 and 20). The previous excess demand for labour in these sectors moved to other sectors in the economy. Simulation 2, on the other hand, resulted in either a rise or a drop of labour demand in agricultural sectors. For example, there was a drop in demand for labour in Sectors 1, 2 and 5 whereas the demand for labour in other agricultural sectors increased. While the free trade in agricultural machinery, Simulation 3, resulted in an increase in the demand for labour in almost all agricultural sectors (Sectors 1 – 8), there was a decrease in this demand in non-agricultural sectors except Agricultural Machinery sector. The results of Simulation 4 in terms of demand for labour are a mix of those three simulations. Labour demand in Simulation 4's results increased or decreased in the same direction of changes as Simulation 1 (see Table 5).

Table 5: Percentage change from base year of policy simulations on demand for input factors (QF)

Sector	SIM 1 (%Δ)		SIM 2 (%Δ)		SIM 3 (%Δ)		SIM 4 (%Δ)	
	Lab[1/]	Cap[2/]	Lab[1/]	Cap[2/]	Lab[1/]	Cap[2/]	Lab[1/]	Cap[2/]
1. Paddy and Maize	1.51	-	-1.83	5.00	0.05	-	0.25	5.00
2. Cassava, Beans and Nuts	10.1	-	-5.27	5.00	0.12	-	6.24	5.00
3. Vegetables, Sugarcane and Fruits	-2.42	-	1.14	5.00	0.11	-	-0.94	5.00
4. Rubber and Latex	-8.87	-	4.61	5.00	0.04	-	-4.62	5.00
5. Other Crops	5.66	-	-2.22	5.00	0.30	-	3.57	5.00
6. Livestock	-7.58	-	4.18	5.00	-0.04	-	-3.82	5.00
7. Forestry	-6.09	-	1.91	5.00	0.22	-	-3.83	5.00
8. Fishery	0.90	-	2.76	5.00	0.10	-	3.63	5.00
9. Mining and Quarrying	-2.39	-	1.28	-	-0.03	-	-1.19	-
10. Food Manufacturing	-1.73	-	0.62	-	0.02	-	-0.97	-
11. Textile Industry	2.91	-	-0.98	-	-0.06	-	1.74	-
12. Paper Industries and Printing	1.44	-	-0.53	-	-0.04	-	0.77	-
13. Rubber Chemical and Petroleum Industries	-2.07	-	0.88	-	-0.01	-	-1.24	-
14. Non Metallic Products	0.55	-	0.30	-	-0.14	-	0.29	-
15. Metal Product and Machinery	0.80	-	-0.22	-	-0.10	-	0.32	-
16. Agricultural Machinery	-	-	10.0	-	2.11	-	-	-
17. Other Manufacturing	0.46	-	-0.10	-	-0.05	-	0.20	-
18. Electricity, Water Work and Public Utilities	3.38	-	-1.12	-	-0.17	-	1.69	-
19. Construction and Trade	1.07	-	-0.34	-	-0.06	-	0.51	-
20. Service Transportation and Communication	-0.11	-	0.15	-	-0.05	-	-0.14	-

Source: Model Simulations 1 – 4

Note: Base year values of QF is in Appendix D

If we consider the capital-labour ratio (K/L) in each sector in the base year (Table 6), it is found that most K/L ratios in the non-agricultural sectors (Sectors 9 – 20) are greater than in the agricultural sectors (Sectors 1 – 8). This means that non-agricultural sectors are the capital-intensive sectors compared to agricultural sectors which are labour-intensive sectors. The result of Simulation 1 had an effect on the increase and decrease in the ratios in some agricultural sectors. Meanwhile Simulation 2 affected the increase in the K/L ratio in all agricultural sectors (Sectors 1 – 8). In Simulation 3, the capital-labour ratio (K/L) in most agricultural sectors decreased but this ratio increased in the non-agricultural sector as a consequence of either an increase or decrease in the demand for labour. Meanwhile, the direction of changes in K/L ratios in Simulation 4 results is similar to Simulation 2 in the agricultural sectors but it is possible that this direction of changes in K/L ratios is similar to Simulation 1's results in non-agricultural sectors (See Table 6).

Table 6: Percentage change from the base year of policy simulation on the capital-labour ratio (K/L)

Sector	Base year[1/]	SIM 1	SIM 2	SIM 3	SIM 4
1. Paddy and Maize	0.049	-1.49	6.95	-0.05	4.74
2. Cassava, Beans and Nuts	0.056	-9.19	10.84	-0.12	-1.17
3. Vegetables, Sugarcane and Fruits	0.092	2.48	3.82	-0.11	5.99
4. Rubber and Latex	0.110	9.73	0.37	-0.04	10.08
5. Other Crops	0.103	-5.36	7.39	-0.30	1.38
6. Livestock	0.126	8.21	0.79	0.04	9.18
7. Forestry	0.053	6.48	3.03	-0.22	9.18
8. Fishery	0.410	-0.90	2.17	-0.10	1.32
9. Mining and Quarrying	3.341	2.45	-1.27	0.03	1.21
10. Food Manufacturing	0.634	1.76	-0.61	-0.02	0.98
11. Textile Industry	0.443	-2.82	0.99	0.06	-1.71
12. Paper Industries and Printing	1.497	-1.42	0.53	0.04	-0.76
13. Rubber Chemical and Petroleum Industries	0.631	2.11	-0.87	0.01	1.26
14. Non Metallic Products	0.642	-0.54	-0.30	0.14	-0.29
15. Metal Product and Machinery	0.549	-0.80	0.22	0.10	-0.32
16. Agricultural Machinery	0.289	25.90	-9.12	-2.06	16.02
17. Other Manufacturing	0.541	-0.46	0.10	0.05	-0.20
18. Electricity, Water Work and Public Utilities	12.335	-3.27	1.13	0.17	-1.67
19. Construction and Trade	0.290	-1.06	0.34	0.06	-0.50
20. Service Transportation and Communication	1.302	0.11	-0.15	0.05	0.14

Source: Model Simulations 1 – 4,
Note: [1/] 100 million baht per 100 persons

4.2.2 Sectoral Output Effects

As a consequence of labour demand reallocation in Simulation 1, there was a decrease in almost all output, i.e. the level of activity a (QA), quantity of domestic output (QX), quantity of export (QE), output sold domestically (QD), composite commodity (QQ) and some quantity of import (QM) in almost all sectors especially in agricultural sectors (Table 7). The reasons behind this decrease is that the reduction in QA simultaneously led to a decrease in domestic output (QX), exports (QE), imports (QD) and composite supply (QQ) in the agricultural sectors. A fall in agricultural domestic output was compensated by a rise of some agricultural imports.

The result of Simulation 2 confirms the production function theory, in that output can be increased if an input is increased. It can be seen from Table 7 that when extra capital input was injected into agricultural sectors (Sectors 1 – 8), the level of activity a (QA) in Sectors 1 – 8 (which was using Cobb-Douglas production function) were increased. Consequently, QX, QE, QD, QQ were increased. This is because the positive changes in QA in agricultural sectors simultaneously affected the reallocation of factors as intermediate inputs of other sectors as a result.

The Simulation 3 resulted in more imports of Agricultural Machinery (QM) in Sector 16 because its import price (PM) was decreased. This decrease in (PM) led to the decline of other prices (PD, PX, PQ and PA) in its sector. Therefore, QD, QX and QQ in the Agricultural Machinery sector increased by 0.31, 0.29 and 0.24%, respectively. The greatest output increase in the non-agricultural sector was QA in the Agricultural Machinery sector, which increased by 1.12% (see Table 7). The only output to decrease was QE, which decreased by 0.31 % because there was a rise in PE. Other output changes in agricultural sectors as well as non-agricultural sectors were caused by an increase or a decrease in demand for those sectors respectively.

The sectoral output effects of Simulation 4 (which combines Simulations 1 – 3) are similar to Simulation 1, in that there was a decline in almost all outputs in both the agricultural and non-agricultural sectors (see Table 7). As discussed, Simulation 1 led to a decrease in almost all outputs in the agricultural sectors and some outputs in the non-agricultural sectors. On the other hand, Simulations 2 and 3 produced more output in the agricultural sectors and some outputs in the non-agricultural sectors. The effects of Simulations 2 and 3 on outputs were not strong enough to turn the outputs in the model into positive changes. Therefore, it can be concluded that the output effects of Simulation 4 are dominated by Simulation 1 rather than Simulations 2 or 3.

Table 7: Percentage changes from base year of the policy simulations on activity (*QA*), quantity of domestic output (*QX*), quantity of export (*QE*), output c sold domestically (*QD*), quantity of import (*QM*) and composite commodity (*QQ*)

Sector	Simulation 1 (%Δ)						Simulation 2 (%Δ)					
	QA	*QX*	*QE*	*QD*	*QM*	*QQ*	*QA*	*QX*	*QE*	*QD*	*QM*	*QQ*
1. Paddy and Maize	-8.41	-3.30	-8.46	-2.65	4.14	-2.60	2.34	1.28	3.51	0.98	-1.71	0.96
2. Cassava, Beans and Nuts	-6.06	-4.48	-6.42	-3.87	1.45	-2.57	1.25	1.62	2.45	1.36	-0.79	0.83
3. Vegetables, Sugarcane and Fruits	-9.05	-2.53	-2.76	-2.51	1.66	-2.35	4.03	1.12	1.22	1.11	-0.58	1.05
4. Rubber and Latex	-9.79	-0.98	-3.42	-0.71	2.38	-0.71	4.92	0.45	1.55	0.30	-0.99	0.30
5. Other Crops	-7.45	-1.48	-0.09	-1.69	-12.13	-3.91	3.31	0.66	0.18	0.73	4.64	1.49
6. Livestock	-9.10	-1.40	-1.51	-1.39	-0.41	-1.37	4.84	0.69	0.75	0.68	0.22	0.67
7. Forestry	-10.80	-2.40	-2.57	-2.36	-1.57	-2.13	3.86	0.95	1.02	0.94	0.63	0.84
8. Fishery	-3.02	-0.65	6.67	-0.75	-0.65	-0.75	4.40	0.42	7.80	0.32	0.81	0.32
9. Mining and Quarrying	-0.84	-0.18	0.07	-0.20	-0.50	-0.28	0.45	0.12	0.03	0.13	0.24	0.16
10. Food Manufacturing	-0.60	-3.84	-4.03	-3.74	1.15	-2.73	0.21	1.85	1.92	1.80	-0.15	1.39
11. Textile Industry	1.23	0.54	0.57	0.53	-0.10	0.40	-0.42	-0.14	-0.16	-0.14	0.14	-0.08
12. Paper Industries and Printing	0.26	0.02	0.01	0.02	0.11	0.04	-0.10	0.01	0.01	0.01	0.02	0.01
13. Rubber Chemical and Petroleum Industries	-0.71	-0.96	-0.89	-0.98	-1.66	-1.18	0.30	0.50	0.48	0.51	0.82	0.61
14. Non Metallic Products	0.19	-0.07	-0.04	-0.10	-0.43	-0.17	0.10	0.10	0.09	0.12	0.29	0.15
15. Metal Product and Machinery	0.30	0.24	0.26	0.22	-0.18	-0.01	-0.08	-0.06	-0.07	-0.05	0.15	0.06
16. Agricultural Machinery	-11.61	-3.04	-3.16	-3.03	-9.35	-5.97	5.26	1.42	0.03	1.46	4.39	2.77
17. Other Manufacturing	0.17	-0.21	-0.21	-0.21	-0.21	-0.21	-0.04	0.11	0.11	0.12	0.17	0.14
18. Electricity, Water Work and Public Utilities	1.78	0.32	0.24	0.32	0.26	0.32	-0.60	-0.04	-0.11	-0.03	-0.04	-0.03
19. Construction and Trade	0.23	0.07	0.12	0.07	-0.04	0.07	-0.07	0.04	-0.09	0.04	0.09	0.04
20. Service Transportation and Communication	-0.07	-0.53	-0.55	-0.52	-0.32	-0.50	0.09	0.32	0.33	0.31	0.17	0.30

Table 7: Percentage changes from base year of the policy simulations on activity (QA), quantity of domestic output (QX), quantity of export (QE), output c sold domestically (QD), quantity of import (QM) and composite commodity (QQ) (Cont.)

Sector	Simulation 3 (%Δ)						Simulation 4 (%Δ)					
	QA	*QX*	*QE*	*QD*	*QM*	*QQ*	*QA*	*QX*	*QE*	*QD*	*QM*	*QQ*
1. Paddy and Maize	0.02	0.02	0.07	0.01	-0.04	0.01	-5.88	-2.02	-5.00	-1.63	2.20	-1.60
2. Cassava, Beans and Nuts	0.04	0.04	0.07	0.03	-0.03	0.02	-4.00	-2.66	-3.76	-2.31	0.67	-1.57
3. Vegetables, Sugarcane and Fruits	0.03	0.02	0.03	0.02	-0.04	0.02	-5.17	-1.45	-1.58	-1.44	0.95	-1.35
4. Rubber and Latex	0.01	-	0.06	-	-	-	-5.33	-0.58	-1.88	-0.43	1.19	-0.42
5. Other Crops	0.07	0.03	0.03	0.03	-	0.02	-4.08	-0.89	-	-1.02	-7.85	-2.44
6. Livestock	-0.01	-	0.01	-	-	-	-4.69	-0.71	-0.77	-0.71	-0.25	-0.70
7. Forestry	0.08	0.01	0.01	0.01	-	-	-7.13	-1.54	-1.65	-1.51	-1.02	-1.37
8. Fishery	0.03	-	7.36	-0.10	0.18	-0.10	1.32	-0.26	7.09	-0.36	-0.15	-0.36
9. Mining and Quarrying	-0.01	-0.02	-0.03	-0.02	-0.01	-0.02	-0.42	-0.14	-0.01	-0.15	-0.30	-0.19
10. Food Manufacturing	0.01	0.01	0.01	0.01	-0.02	-	-0.34	-2.01	-2.12	-1.95	0.81	-1.38
11. Textile Industry	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	0.74	0.32	0.34	0.31	-0.03	0.24
12. Paper Industries and Printing	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.14	-0.01	-0.02	-0.01	0.08	0.01
13. Rubber Chemical and Petroleum Industries	-	-0.01	-0.01	-0.01	-	-0.01	-0.42	-0.52	-0.49	-0.53	-0.88	-0.63
14. Non Metallic Products	-0.05	-0.03	-0.03	-0.03	-0.03	-0.03	0.10	-0.06	-0.05	-0.08	-0.27	-0.12
15. Metal Product and Machinery	-0.04	-0.03	-0.03	-0.03	-0.02	-0.03	0.12	0.09	0.10	0.08	-0.13	-0.04
16. Agricultural Machinery	1.12	0.29	-0.31	0.31	0.17	0.24	-7.65	-2.05	-2.25	-2.05	-5.06	-3.43
17. Other Manufacturing	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	0.08	-0.16	-0.17	-0.16	-0.12	-0.14
18. Electricity, Water Work and Public Utilities	-0.09	-0.04	-0.12	-0.04	-0.02	-0.04	0.90	0.15	0.07	0.15	0.12	0.15
19. Construction and Trade	-0.01	-0.03	-0.10	-0.03	-0.04	-0.03	0.11	-	-0.01	-	-0.04	-
20. Service Transportation and Communication	-0.03	-0.02	-0.02	-0.02	-	-0.01	-0.08	-0.28	-0.29	-0.28	-0.18	-0.26

Source: Model Simulations 1 – 4

4.2.3 Income Effects

In this section we show the simulation results on incomes of domestic institutions (enterprises, households and government). The base year values of labour and capital income were 1,607,749.5 and 2,488,845.5 million baht. Household income and enterprise income were 3,320,133.9 and 834,770.6 million baht, respectively. Finally, government income in the base year was 776,031.9 million baht.

Simulation 1 induced negative income effects in domestic institutions. The increase in α_{fa} of capital by approximately five percent resulted in the decrease in α_{fa} of labour in all agricultural sectors (Sectors 1 – 8) by approximately 8 – 21% while α_{fa} of capital and labour in other sectors remained the same. This resulted in a decline in the average price (WF_f) of labour in the economy. Considering equation (15) in section 2.2.3, ($YF_f = \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa}$), therefore, there was a decrease in income of factor f (YF_f). This factor income is divided into household and enterprise in fixed shares as described in equation (16). Labour and capital incomes accrue to households whereas only capital income flows to enterprises. Finally, overall labour income dropped by 0.84 % while capital income dropped by 0.82 % (See Table 8).

Households and enterprise own input factors, therefore, when there is a decrease in labour and capital income that means these institutions earn less income. For this reason, Simulation 1 simultaneously affected enterprise income and household income negatively by 0.82 and 0.79 %. Finally, government revenue was decreased by 0.69 % because the government received less income tax from both households and enterprises (see Table 8).

The result of Simulation 2 in terms of domestic income effects on institutions was completely opposite from Simulation 1. When the 5% of capital stock was injected into agricultural sectors, it caused an increase in the supply of agricultural capital input (QF of capital) in total but the supply of overall labour in economy was still the same. Considering equation (15) again, as a result of a 5% increase of agricultural capital stock (QF) there was an increase in factor income (YF). Similar reasons were attributed to Simulation 1 but in the opposite direction. The increase in factor income (0.41% from labour income and 0.43% from capital income) brought about the increase in enterprise and household income by 0.41%. Finally, it affected the increase in government income by 0.34% (see Table 8).

On the other hand, Simulation 3 resulted in a negative change in domestic income. Labour income decreased slightly by 0.02%, because there was a movement of the supply of labour from the non-agricultural sectors to the agricultural sectors and the wages in non-agricultural sectors are higher than in agricultural sectors. Capital income decreased by 0.10% because rents declined in some non-agricultural sectors (Sectors 6, 14, 15, 19 and 20). The decline of these factor incomes resulted in a decrease of enterprise and household income by 0.01 and 0.02% respectively. Government income eventually decreased by 0.07% (see Table 8).

The domestic income effects in Simulation 4 are similar to Simulation 1's results, but the negative effect on domestic income was approximately half that of Simulation 1's results. For example, there was a decrease in all domestic income by 0.4% from the base year. The main reason is because the negative income effects of Simulation 1 were compensated for by the positive income effects of Simulation 2 (see Table 8).

Table 8: Percentage changes from base year of the main policy simulations on factor income (YF), enterprise income ($YENT$), household income (YH), and government income (YG)

Variables	SIM 1 (%Δ)	SIM 2 (%Δ)	SIM 3 (%Δ)	SIM 4 (%Δ)
Factor income (YF)				
Labour (L)	-0.84	0.41	-0.02	-0.48
Capital (K)	-0.82	0.43	-0.10	-0.44
Enterprise income ($YENT$)	-0.79	0.41	-0.01	-0.42
Household income (YH)	-0.82	0.41	-0.02	-0.45
Government income (YG)	-0.69	0.34	-0.07	-0.45

Source: Model Simulations 1 – 4

4.2.4 Macroeconomic Effects

Based on the CGE model, in 2000 private ($PRVCON$) and government consumption ($GOVCON$) of Thai economy were 2,223,860 and 555,841 million baht, respectively, while investment ($INVEST$) stood at 1,156,525 million baht. Export (EXP) and Import values (IMP) were at 3,625,078 and 2,972,099 million baht, respectively. The GDP of Thailand in 2000 was 4,614,222 million baht.

In the model, private consumption is calculated from the summation of household consumption (QH_{ch}) multiply by composite commodity price (PQ_c). Moreover, household consumption is also based on income (see equation (18)). Because of a decline in household income in Simulation 1 (described in the previous section), private consumption decreased by 0.82%, and government consumption decreased by 0.31% because government revenue declined. The overall level of investment demand decreased by 1.04% because there was a decrease in quantity of investment demand in every sector. Simulation 1 also affected a drop in imports and exports by 0.98 and 0.96% respectively because the exchange rate depreciated. As a result of the decrease in private consumption, government consumption, investment, exports and imports in Simulation 1, the Gross Domestic Product (GDP) decreased by 0.80% (see Table 9).

Simulation 2, on the other hand, resulted in positive effects on all macroeconomic variables. Because of a rise in household income, there was a 0.41% increase in private consumption. The demand for government consumption increased by 0.08%. Investment increased by 0.57%, whereas exports and imports increased by 0.48 and 0.49%, respectively. On balance, these effects increased GDP by 0.41% (see Table 9).

Free trade in the Agricultural Machinery sector (Simulation 3) slightly harmed macroeconomic variables as shown in Table 9. Investment decreased by 0.06% because of the overall decrease in composite commodity price (PQ), while private consumption decreased 0.02% due to the decline in household income. Exports, imports and GDP decreased by 0.02%. Government consumption increased slightly, only 0.005% (see Table 9)

The last results from Simulation 4, macroeconomic effects, are shown in Table 9. A combination of the three macroeconomic results from each main simulation shows clearly that the effects on macroeconomic indicators in Simulation 4 were still somewhat analogous to those in Simulation 1. Overall, private consumption, exports and imports declined by around 0.5%. Government consumption and investment decreased by approximately 0.2 and 0.6%, respectively. Because of these falls, GDP dropped by 0.5% (see Table 9).

Table 9: Percentage changes from base year of the main policy simulations on macroeconomic indicators

Macroeconomic Variables	SIM 1 (%Δ)	SIM 2 (%Δ)	SIM 3 (%Δ)	SIM 4 (%Δ)
Private Consumption (*PRVCON*)	-0.82	0.41	-0.02	-0.45
Government Consumption (*GOVCON*)	-0.31	0.08	0.005	-0.19
Investment (*INVEST*)	-1.04	0.57	-0.06	-0.61
Export (*EXP*)	-0.96	0.48	-0.02	-0.54
Import (*IMP*)	-0.98	0.49	-0.02	-0.55
Gross Domestic Product (*GDP*)	-0.80	0.41	-0.02	-0.46

Source: Model Simulations 1 – 4

5. Conclusion and Policy Implication

5.1 Conclusion

This 20 sector CGE model was constructed in order to empirically investigate the impacts of capital intensive farming in Thailand by two different concepts: technological change and free trade. The effects of four shocks were simulated in this study. The first shock was generated by increasing the share parameter (α_{fa}) of capital input in agricultural sectors by five percent. The second simulation comprises direct five percent increases in capital stock in agricultural sectors. The third simulation is the removal of import tariffs on agricultural machinery sector, and the last simulation is the combination of all three simulations.

The results of the four policy simulations were quite different in terms of sectoral input and output effects, institution income effects and macroeconomic indicators. The changes in α_{fa} in Simulations 1 and 4 led to the reallocation in the supply of labour (QF) in the economy. Specifically, the levels of QF in four agricultural sectors (Sectors 3, 4, 6 and 7) and some non-agricultural sectors (Sectors 9, 10, 13, 16 and 20) decreased. However, Simulation 2 resulted in a decrease in the supply of labour in only three agricultural sectors (Sectors 1, 2 and 3) and some non-agricultural sectors (Sectors 11, 12, 15, and 17 –19). However, there was an increase in the supply of labour in almost all agricultural sectors but there was a decrease in this supply in the non-agricultural sectors except the Agricultural Machinery sector (Sector 16) in Simulation 3.

The reallocation of the supply of labour in each simulation leads to different changes in the K/L ratio, which is the measure of capital intensity. Simulation 1 led to capital intensification in four agricultural sectors (Sectors 3, 4, 6, and 7), and five non-agricultural sectors (Sectors 9, 10, 13, 16 and 20). In contrast, Simulation 2 spurred a rise in the capital-intensive sectors in all agricultural sectors and six non-agricultural sectors (Sectors 11, 12, 15 and 17 – 19). However, Simulation 3 resulted in less capital-intensity in most agricultural sectors but more capital-intensity in the non-agricultural sectors. Simulation 4 resulted in more capital-intensive farming except in Sector 2. In addition, Simulation 4 produced more capital-intensive operations in non-agricultural sectors, as in Simulation 1.

The input changes directly affected sectoral outputs in the economy. Simulations 1 and 4 led to a fall in almost all outputs in the agricultural sectors. On the contrary, Simulations 2 and 3 resulted in an increase in agricultural output. However, Simulation 2 caused a decrease in non-agricultural outputs in only a few sectors but the other simulations mostly showed negative output changes in non-agricultural sectors.

Regarding institutional income effects, Simulation 1 led to a drop in factor income belonging to households and enterprises because the average price of labour (WF_f) decreased. Consequently, government income declined due to a fall in tax revenues. In contrast, Simulation 2 resulted in an increase in the income of household, enterprise, and government sectors due to the increase in factor incomes. However, in Simulation 3, institutional incomes decreased slightly from the base year. The directions of change in domestic income effects in Simulation 4 were similar to Simulation 1 results but the negative effect on domestic income in Simulation 4 was approximately half that of Simulation 1 due to the influence of the positive income effects from Simulation 2.

Finally, the last set of effects, the macroeconomic effects, the policy simulation was simultaneously impacted by the four effects. In Simulation 1, all macroeconomic variables, such as private consumption, government consumption, investment, export, import and Gross Domestic Product (GDP), decreased nearly 1%. Simulation 2 had a positive impact on the above variables of around 0.5%, but Simulation 3 had a slight negative effect on the macro variables. Lastly, in Simulation 4, the negative effects on the macro variables from Simulation 1 were stronger than those in Simulation 2. Therefore, the levels of all macro variables decreased. However, the decrease was less than those in Simulation 1 because of the positive effects from Simulation 2.

5.2 Policy Implications

The findings from this study will aid in the formation of guidelines for capital input policy in Thailand, especially concerning the agricultural sectors. It seems that capital-intensive farming in the perspective of the increase in net capital stock in agricultural sector (Simulation 2) had a positive effect in every economic variable, in contrast to the increase in share parameter of capital input (α_{fa}) (Simulation 1) and the removal of tariff in Agricultural Machinery sector (Simulation 3).

Simulation 2 reveals that the agricultural sector would be more capital intensive and resulting in the output of all agricultural sectors (Sectors 1 – 8), institutional incomes and macroeconomic variables (consumption, investment, export, import and GDP) to increase. However, there was mobility in labour in each sector in the economic system as we assumed that labour is fully employed. Therefore, if government is planning to achieve these results, additional capital stock, for examples, tractors, water pumps, harvesting machine and other equipment, need to be injected into agricultural sectors. Nevertheless, government should be aware of labour relocation between agricultural sectors to non-agricultural sectors and be prepared to provide skill training to those workers who would be moving from one sector to another.

On the other hand, the increase in share parameters (α_{fa}) of capital input in the agricultural sectors (Simulation 1) brought negative effects to output in almost all sectors, institution's income and macro variables. Nevertheless, this case may be chosen when the government would like to bring more capital intensity into agricultural sectors, with its negative effects on other economic variables, in order to slow down economic growth in the case of an overheating economy. The question is how can share parameter (α_{fa}) of capital input in agricultural sectors be increased in practice?

From Cobb-Douglas production function (Chung 1994; pp95):

$$y = f(x_1,...,x_n) = A\prod_{i=1}^{n} x_i^{a_i}$$

Where

y = output

x_i = input

$A > 0, 0 < a_i < 1$ and $\sum_i a_i = 1$

Its marginal product (MP) is $\frac{\partial y}{\partial x} = a_i \frac{y}{x} > 0$ (37)

At the optimum, we have $MP_i = \frac{w_i}{p}$ (38)

Where

w_i = the price of input

p = the price of output

From equation (37) and (38) we obtain $a_i = \frac{w_i \cdot x_i}{p \cdot y}$ (39)

Hence, the share parameter in a production function (α_{fa}) or a_i in equation (39) can be increased in two different ways; namely, by an increase in w_i or x_i (or both), or by a decrease in p or y (or both). This means that if government would like to secure the results obtained in Simulation 1, policies such as an increase in the minimum rent in agricultural capital stock needs to be imposed. In addition, a minimum price guarantee for selected agricultural products needs to be determined or a restriction on agricultural production levels would be required. Nonetheless, other policy measures would need to be prepared to compensate for its negative effects.

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Appendix A
Sectoral Index

Sector No.	Activity, commodity	Description
1	a01, c01	Paddy and Maize Activity
2	a02, c02	Cassava Beans and Nuts Activity
3	A03, c03	Vegetables Sugarcane and Fruits Activity
4	A04, c04	Rubber and Latex Activity
5	A05, c05	Other Crops Activity
6	A06, c06	Livestock Activity
7	A07, c07	Forestry Activity
8	A08, c08	Fishery Activity
9	A09, c09	Mining and Quarrying Activity
10	a10, c10	Food Manufacturing Activity
11	a11, c11	Textile Industry Activity
12	a12, c12	Paper Industries and Printing Activity
13	A13, c13	Rubber Chemical and Petroleum Industries Activity
14	A14, c14	Non Metallic Products Activity
15	a15, c15	Metal Product and Machinery Activity
16	a16, c16	Agricultural Machinery Activity
17	a17, c17	Other Manufacturing Activity
18	a18, c18	Electricity Water Work Public Utilities Activity
19	a19, c19	Construction and Trade Activity
20	a20, c20	Service Transportation and Communication Activity

Appendix B

B 1: SETS

$a \in A$	a set of activities with Cobb-Douglas function
$c \in C$	commodities
$c \in CM(\subset C)$	imported commodities
$c \in CE(\subset C)$	exported commodities
$f \in F$	factors (Labour and Capital)
$h \in H(\subset ID)$	households
$ent \in ENT(\subset ID)$	enterprise
$i \in ID(\subset I)$	institutions (ID = household, enterprise), (I = household, enterprise, government and the rest of the world.)

B 2: PARAMETERS

ad_a	production function efficiency parameter
ag_a	government subsidy for activity a
aq_c	shift parameter for composite supply (Armington) function
at_c	shift parameter for output transformation (CET) function
$capital_a$	net capital stock at 2000 cost (million baht)
$\cos tgap_{fa}$	gap calibrated factor cost-SAM value (should be zero)
cpi	consumer price index
$cwts_c$	commodity weight in cpi
$finv$	Thailand's foreign investment
ica_{ca}	quantity of c as intermediate input per unit of activity a
$\text{int}_{ent,h}$	rate of interest and insurance payments from household to enterprises
$labour_a$	quantity of labour employed by activity (million persons)
pwe_c	export price (foreign currency)
pwm_c	import price (foreign currency)
qg_c	government commodity demand
$qinvbar_c$	based year investment demand
$shryid_{id,f}$	share for domestic institutions except government in income of factor f
$tcap_f$	rate of tax on capital income
te_c	export tax rate
$tent_{ent}$	rate of corporate tax
tic_c	sale tax rate (indirect tax)
tia_c	value added tax rate (indirect tax)
tm_c	import tax rate
$tr_{i,i}$	transfer from institution i to institution i
ty_h	household income tax rate
wfa_{fa}	wage (rent) for factor f in activity a (for calibration only)

α_{fa}	production function share parameter or value-added share for factor f in activity a
β_{ch}	share of household consumption spending on commodity c
δ_c^q	share parameter for composite supply (Armington function)
δ_c^t	share parameter for output transformation (CET) function
θ_{ac}	yield of commodity c per unit of activity a
ρ_c^q	exponent for composite supply (Armington function) $-1 < \rho_c^q < \infty$
ρ_c^t	exponent for output transformation (CET) function $1 < \rho_c^t < \infty$
σ_c^q	elasticity of substitution between domestic goods and imports for commodity c
σ_t^q	elasticity of transformation between domestic sales and exports for commodity c

B 3: VARIABLES

EG	government expenditure
EXR	foreign exchange rate (domestic currency per unit of foreign currency
$ENTSAV_{ent}$	enterprise savings
FSAV	foreign savings
IADJ	investment adjustment factor
MPS_h	marginal propensity to save for household h
PA_a	activity price
PD_c	domestic output price
PE_c	export price (domestic currency)
PM_c	import price (domestic currency)
PQ_c	composite commodity price
PVA_a	value added price
PX_c	producer price
QA_a	activity level
QD_c	quantity of domestic output sold domestically
QE_c	export quantity
QF_{fa}	quantity demand of factor f by activity a
QFS_f	supply of factor f
QH_{ch}	quantity of consumption of commodity c by household h
$QINT_{ca}$	quantity of intermediate use of commodity c by activity a
$QINV_c$	quantity investment demand
QM_c	import quantity
QQ_c	composite supply (quantity supplied to domestic commodity demand)
QX_c	domestic output quantity
WALRAS	dummy variable (zero at equilibrium)
WF_f	average wage (rental rate) of factor f
$WFDIST_{fa}$	wage distortion factor for factor f in activity a
$YENT_{ent}$	enterprise income
YF_f	income of factor f
$YFID_{id,f}$	income transfer from factor f to domestic institutions
YG	government revenue
YH_h	household income

Appendix C

C.1: Constant elasticity of substitution (CES) between domestically produced and import commodities (Armington elasticities)

Sector No.	Description	CES
1	Paddy and Maize	1.0694
2	Cassava, Beans and Nuts	1.9097
3	Vegetables, Sugarcane and Fruits	1.6296
4	Rubber and Latex	0.11
5	Other Crops	0.6954
6	Livestock	0.7587
7	Forestry	0.3646
8	Fishery	1.6722
9	Mining and Quarrying	0.1151
10	Food Manufacturing	1.6171
11	Textile Industry	1.463
12	Paper Industries and Printing	0.9807
13	Rubber Chemical and Petroleum Industries	0.8326
14	Non Metallic Products	0.5172
15	Metal Product and Machinery	0.9735
16	Agricultural Machinery	0.7359
17	Other Manufacturing	0.9692
18	Electricity, Water Work, Public Utilities	0.953
19	Construction and Trade	0.12
20	Service Transportation and Communication	0.8486

Source: Warr and Lapiz (1994)

C.2: Elasticity of transformation (CET) between domestically sold and exported commodities

Sector No.	Description	CET
1	Paddy and Maize	0.9777[1/]
2	Cassava, Beans and Nuts	0.9546[1/]
3	Vegetables, Sugarcane and Fruits	0.1
4	Rubber and Latex	0.1
5	Other Crops	0.1
6	Livestock	0.1
7	Forestry	0.1
8	Fishery	0.1
9	Mining and Quarrying	0.1
10	Food Manufacturing	0.1
11	Textile Industry	0.1
12	Paper Industries and Printing	0.1
13	Rubber Chemical and Petroleum Industries	0.1
14	Non Metallic Products	0.1
15	Metal Product and Machinery	0.1
16	Agricultural Machinery	0.1
17	Other Manufacturing	0.1
18	Electricity, Water Work, Public Utilities	0.1
19	Construction and Trade	0.12
20	Service Transportation and Communication	0.1

Source: [1/]Warr and Lapiz (1994)
Wattanakuljarus and Coxhead (2006)

Appendix D

D.1: Quantity of labour employed by activity in Thailand, 2000

Unit: Persons

Sector No.	Description	Number of workers
1	Paddy and Maize	4,301,954
2	Cassava, Beans and Nuts	570,585
3	Vegetables, Sugarcane and Fruits	2,769,017
4	Rubber and Latex	997,168
5	Other Crops	962,316
6	Livestock	1,146,515
7	Forestry	252,294
8	Fishery	442,050
9	Mining and Quarrying	68,730
10	Food Manufacturing	929,460
11	Textile Industry	860,159
12	Paper Industries and Printing	101,820
13	Rubber Chemical and Petroleum Industries	690,281
14	Non Metallic Products	200,337
15	Metal Product and Machinery	1,483,844
16	Agricultural Machinery	5,065
17	Other Manufacturing	869,115
18	Electricity, Water Work, Public Utilities	101,630
19	Construction and Trade	6,588,070
20	Service Transportation and Communication	7,104,260

Sources: National Statistical Office (2001)

D.2: The quantity of net capital stock of Thailand in each sector, 2000

Unit: Million baht

Sector No.	Description	Net Capital Stock
1	Paddy and Maize	211,526
2	Cassava, Beans and Nuts	31,719
3	Vegetables, Sugarcane and Fruits	255,477
4	Rubber and Latex	109,524
5	Other Crops	98,921
6	Livestock	145,024
7	Forestry	13,252
8	Fishery	181,324
9	Mining and Quarrying	229,649
10	Food Manufacturing	589,372
11	Textile Industry	380,767
12	Paper Industries and Printing	152,406
13	Rubber Chemical and Petroleum Industries	435,473
14	Non Metallic Products	128,573
15	Metal Product and Machinery	814,478
16	Agricultural Machinery	1,464
17	Other Manufacturing	469,945
18	Electricity, Water Work, Public Utilities	1,253,577
19	Construction and Trade	1,912,144
20	Service Transportation and Communication	9,247,325

Sources: NESDB (2006a)