CHAPTER 5

METHODOLOGY OF THE STUDY

This study will explore the labor productivity and the effect of public capital and private capital to labor productivity. The partial labor productivity is used to evaluate the labor productivity. Although, TFP evaluation is occasionally used to determine the growth of labor productivity, it is not aimed to evaluate the actual labor productivity.

The best functional form of production function is the key point to estimate the effect of public and private capital to labor productivity since it will identify the most accurate characteristic to produce each sector. Thus, it helps to clarify the exact roles and benefit to the effective policy implication.

In order to seek the best functional form of production function, the human capital with catch-up technology and the technical progress are augmented to the function in the study. The various functional form is also considered. Although, there are many functional forms of production function such as the Transcendental Logarithmic Production Function (Translog Production Function), and Variable Elasticity of Substitution Funciton (VES Production Function). Only 2 types of production function are selected because they are universally used, have no cross term between variables, which helps to signify the effect of public and private capital to labor productivity clearly. Those 2 functional forms are the Cobb-Douglas Production Function, and the Constant Elasticity of Substitution Production Function.

There is an empirical study by Kraipornsak (2000) who estimated production function by different functions. With the question that whether a traditional method with the most effective use of output behavior, the dual function production function via cost function, and the production function with the inefficient mix of output bring the same result of estimations by using Thai's data. He found that the 3 estimated production functions seem to give quite the same result. Then, the assumption that maximize the effectiveness of input will be allowed in this research.

The methodology and procedure of the study will be clearified in this chapter.

5.1 The Model

The production function is given below:

Y	=	$F(A(H), L, K, G,(Land),D_{crisis})$	(5-1)

Where, $A(H)$	=	the state of technical knowledge utilized by human capital in the production process (describe in the equation (5-2))
L	=	the unit of labor, the amount of employed person in each sector (1,000 persons)
K	=	the net private capital stock (Million Baht)
G	=	the net public capital stock (Million Baht)
$Land$	=	the unit of planted area(only in agricultural sector) (Rai)
D_{crisis}	=	the dummy of economic crisis in 1997

Due to the difference in production, the estimation will be classified into 3 sectors: agriculture, industry and service.

"Land" is added variable into the analysis of agricultural sector as an argument about its necessity in agricultural sector during the period of low technology, and extensive cultivation.

D_{crisis} represents the dummy of economic crisis in 1997. Given the prior year of 1998 as zero,and the later year as one, the impact of economic crisis will express in the estimation.

In order to find the most appropriate production funcition, which concerns greatly to the conclusion for the policy implication, the human capital as the catch-up approach, and the technical approach is taken into account as in section 5.1.1 and 5.1.2.

5.1.1 Human Capital with the Catch-up Technology

Human capital is considered as the source of technology progress through the assumption that the human capital affected the production by technology innovation and technical adaptation. The technology innovation tends to gradually transfer across the country depending on which country is the inventor; then, the human with the ability to adapt carries on the technology advance in the produce process. This study uses **the catch-up approach** as Benhabib and Spiegel, Nelson and Phelps and, Bernard and Charles's studies (mentioned in section 3.2.2.3). The equation is similar to Benhabib and Spiegel's (equation (3-14)) but the income of Japan and Thailand is utilized as the proxies.

$$\frac{\dot{A}(H)}{A(H)} = g(H) + c(H) * \frac{Y_{jap} - Y_{th}}{Y_{th}} \qquad (5\text{-}2)$$

Where $g(H)$ = The growth rate of human capital, which is proxied by the growth rate of people who graduate upper secondary, vocational and technical, teacher training, academic and higher technical education

$c(H)$ = The level of Human capital, which is the number of educated people of $g(H)$

Y_{jap} = The income of the leading country, Japan, as the proxies of technological change, which is Gross Domestic Product at 1988 price

Y_{th} = The income of Thailand, which is Gross Domestic Product at 1988 price

The leading country in this study is Japan, due to the major foreign direct investment into Thailand with the higher technology.

5.1.2 Technological Progress

In this study, the functional augmenting of Hick, Harrod, and Solow will be tested based on assumption that the technology is adopted and used by human beings. The objective to test the 3 different methods is due to searching for the most appropriate model to get rid of the problem of wrong form in the technology progress.

Why only 3 functional forms are chosen from 10 channels[1]. The reasons are:

- the empirical study of M. Beckman and R. Sato(1969), testing the various definitions of neutrality in the United States, Japan, and Germany, found that each country could be charecterized by different types of technical progress.
- Hicks. Harrod and Solow focuses on various aspects of techical approach. Hick emphasized on the increase value of the level of output at the constant number, Harrod underlined on the technological change on labor, and Solow stressed on the technological change on capital.
- As can be seen in the Table 5, the traditional types of Hicks, Harrod, and Solow neutrality are at least as good as the unconventional types of neutrality.

Table 5 Value of R^2 and their ranks in various technical approach of log-linear regressions for the United states, Japan and Germany.

Type	The United States		Japan		Germany	
	R^2	Rank	R^2	Rank	R^2	Rank
Hicks	0.831	4	0.785	**2**	0.708	4
Harrod	0.933	**2**	0.855	**1**	0.422	7
Solow	0.944	**1**	0.758	**3**	0.980	**1**
Labor-combining	0.897	**3**	0.021	8	0.770	**3**
Capital-combining	0.818	5	0.039	7	0.272	9
Labor-decreasing	0.466	8	0.755	4	0.692	5
Capital-decreasing	0.702	7	0.001	9	0.653	6
Labor-additive	0.411	9	0.633	5	0.347	8
Capital-additive	0.779	6	0.473	6	0.950	**2**

Source: Beckman and Sato(1969:95)

[1] All 10 technical approaches is shown in the subject 3.2.2.2, Technological Progress

Therefore, Those 3 technical neutralities, Hick, Harrod, and Solow, are selected and will be utilized in this study.

To cover the general idea of those 3 technological progresses, Barro and Sala-I-Martin (1995: 33) mentioned in his book that:

Hicks indicates that a technological innovation is neutral if the ratio of marginal products remains unchanged for a given capital/labor ratio. This propery corresponds to a renumbering of the isoquents, so Hicks-neutral production function can be (3-15).

Harrod defines an innovation as neutral if the relative input shares remain unchanged for a given capital/output ratio. It is so called labor-augmenting technological progress because it raises output in the same way as an increase in the stock of labor. It can be shown as (3-18).

Finally, Solow defines an innovation as neutral if the relative input share remain unchanged for a given labor/output ratio. It is so called capital-augmenting because a technological improvement increases production in the same way as an increase in the stock of capital and shown in equation (3-20).

5.2 The Methodology

In order to answer the objectives of this study, the methodology might be classified into 2 major means: calculate labor productivity by mathematic approach, and estimate the effect of public and private capital to the labor productivity through production function by the econometric and mathematic approach.

5.2.1 Calculation Labor Productivity

To estimate the value of labor productivity of Thailand during 1970-2002, the formula of labor productivity as (3-2) is applied. 4 series of data, which are agricultural sector, industrial sector, service sector and whole economy, are used to calculate. The definition of each variable are obviously explained in section 1.4.

Labor Productivity	=	Q/L	(3-2)
Q	=	the value of GDP of each sector at 1988 price	
L	=	the amount of employed persons in each sector.	

The growth rate of labor productivity is also calculated as the instantaneous(at the point of time) rate of growth and compound rate of growth. To find out the growth rate, the well-known compound interest formula is applied; therefore the the following formula is used to calculate.

$$L\_P_{it} = L\_P_{i0}\,(1+r)^t \qquad (5\text{-}3)$$

Where,

L_P_{it} = labor producitivity of sector i at time t

L_P_{i0} = The initiate value of the labor productivity in this study (i.e.the value of labor producitivity in 1970)

i = agricultural sector, industrial sector, service sector and whole economy.

r = the compound (i.e. over time) rate of growth of labor productivity.

Taken the natural logarithm of above equation, the following equation is written as:

$$ln\,L\_P_{it} = lnL\_P_{i0} + t\ \ln(1+r) \qquad (5\text{-}4)$$

Now letting

$$\beta_1 = lnL\_P_{i0} \qquad (5\text{-}5)$$

$$\beta_2 = ln(1+r) \qquad (5\text{-}6)$$

Thus,

$$ln\,L\_P_{it} = \beta_1 + \beta_2 t \qquad (5\text{-}7)$$

Adding the disturbance term to (5-7) for the reason that the compound interest formula will not hold exactly, we obtain

$$ln\,L\_P_{it} = \beta_1 + \beta_2 t + u_t \qquad (5\text{-}8)$$

This characteristic of (5-8) is called semilog model because only one variable appears in the logarithmic form. It is so called a log-lin model as the regressand is logarithmic. The parameters β_1 and β_2 are linear.

In the (5-8), the slope coefficient measures the constant proportional or relative change in Y for a given absolute change in the value of the regressor (or t), this is,

$$\beta_2 = \frac{\text{relative change in labor productivity}}{\text{absolute change in time}} \qquad (5\text{-}9)$$

Multiplied by 100, β_2 gives the percentage change or the growth rate in the labor productivity which is the instantaneous rate of growth or the growth at a point of time.

In order to calculate the compound rate of growth, it can be easily found by antilog β_2, and then subtract 1 from it and multiply by 100. The yielded value is the growth rate over the period of time

Therefore, those estimated figures as well as the percentage increase in labor productivity and the GDP and labor share will be calculated and analyzed.

5.2.2 Investigation of the Impact of Public and Private Capital to Labor Productivity

In order to investigate the impact of public capital to labor productivity and compare the role between public and private capital, the best fit of functional form of production function is the key factor to clearify the precise roles of public and private capital and enhance the effective policy implication.

Besides the public capital, private capital and labor, the human capital with catch-up technology and the technical progress are augmented to the function in the study. Two types of production function, Cobb-Douglas Production Function, and Constant Elasticity of Substitution Production Function, are chosen because they are universally used and have no cross term between independent variables, which facilitates to signify the effect of public and private capital to labor productivity clearly.

The models in Table 6 and Table 7 will be run and tested whether public capital and private captital are significant by using three different forms in various technical approach of Hicks, Harrod, and Solow augmenting using the data of Thailand, classified by sector. Moreover, the Hicks neutrality will be added 2 more functional form: Hicks neutrality without *A(H)* or the traditional style of economic approach, and Hicks neutrality which human capital with catch-up technology works as a factor of production.

The dummy variable to capture the unusual fluctuation of crisis during 1998-1999 will be added in the equations. The number of planted area will also be the additional factor to estimate in the agricultural sector.

The following chart describes the procedure of seeking for the fit model. The data which are collected will firstly be investigate the time trend and check for their stationary property. Then, they are estimated in the various forms and test coefficient by the Wald test to find the acceptable technical approach. Finally, the test whether the elasticity of substitution equals to one by the Wald test is brought to select the type of production function between Cobb-Douglas and CES Production Function.

Not only will the above 2 testings about coefficient and elasticity of substitution be done, but the major statistics will also be used to determine the estimation, which are t-statistic, Adjusted R Square(Adj R^2), Akaike Information Criterion(AIC), Schwarz Criterion(SC), and the F-statistics. They are practiced in order to indicate the best fit model and compare among estimations.

The t-statistic is computed by the ratio of an estimated coefficient to its standard error, it is used to test the hypothesis that a coefficient is equal to zero. This probability computation is also interested as the value that indicate the probability of that coefficient with t-statistic.

The Adjusted R-squared statistic measures the goodness of fit of the regression. In standard settings, may be interpreted as the fraction of the variance of the dependent variable explained by the independent variables. The statistic will equal one if the regression fits perfectly, and zero if it fits no better than the simple mean of the dependent variable. For poorly fitting models, it may be negative.

The Akaike Information Criterion (AIC), and Schwarz Criterion (SC) are used to provide a measure of information that strikes a balance between this measure of goodness of fit and parsimonious specification of the model.

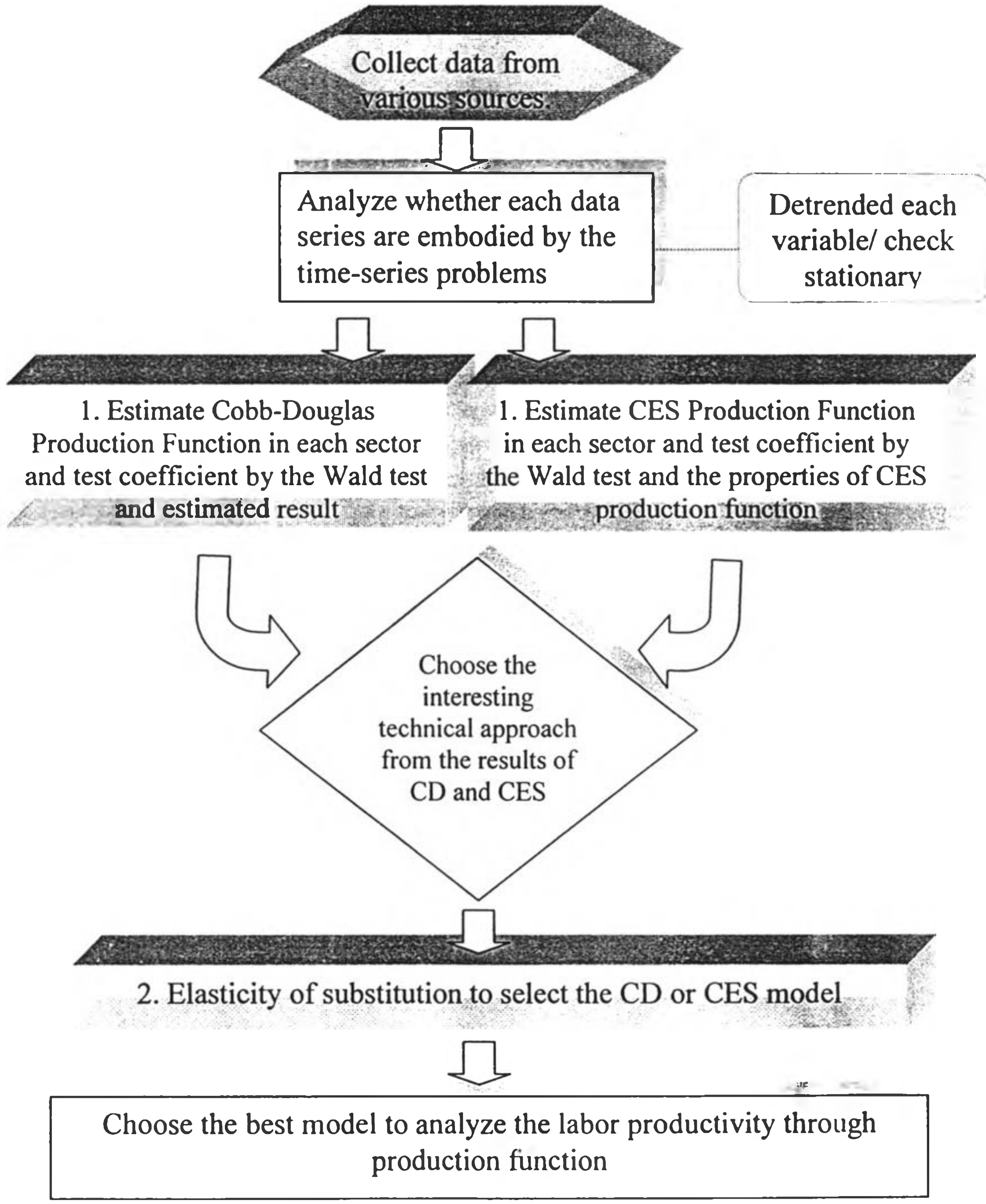
The AIC is often used in model selection for non-nested alternatives- smaller values of the AIC are preferred. Whereas, the SC is an alternative to the AIC that imposes a larger penalty for additional coefficients.

Finally, The F-statistic reported in the regression output is from a test of the hypothesis that of the slope coefficients (excluding the constant, or intercept) in a regression are zero. The *p*-value of the F-statistic is also performed, denoted Prob(F-statistic) or the marginal significance level of the F-est. If the p-value is less than the significance level, it can decisively reject the null hypothesis that all slope coefficients are equal to zero. Note that the F-statistic is a joint test so that even if all the t-statistics are insignificant, the F-statistic can be highly significant.

Then, divided by labor, the selected equations will show the relation between labor productivity and public capital and private capital. The coefficients, as well as other statistic values, will identify the value of effect of public capital and private capital to the labor productivity. The advantage of fit functional form derived from the procedure will benefit the intense analysis and policy implication.

To summarize the analytical procedure, the framework are demonstrated as the following chart.

Chart 1: Framework of seeking for the fit production model to estimate the roles of public and private capital to labor productivity



Hence, there are 10 main models in this study: 5 technical approach and 2 type of production function. As we categorized the data into 3 sectors, and whole economy, 40 production functions are estimated. Thus, the main model should be acknowledged in order to perceptionally carry on in the empirical chapter.

5.2.2.1 Cobb- Douglas Production Function

Five various technical approach which are Hicks neutrality with human capital and catch-up technology as a factor of production, Hicks neutrality without A(H), Hicks, Harrod, and Solow augmenting using the data of Thailand will be estimated as section 5.2.2.1.1-5.2.2.1.5

5.2.2.1.1 Cobb-Douglas Production Function: Hicks Neutrality with Human Capital and Catch-up Technology as a Factor of Production.

Since the Hicks technical progress is neutrity, the production function with 4 factors of production is performed below. The definitions of variables are described in (5-1) and section 1.4.

$$Y = f[\gamma(t)A(H), \gamma(t)K, \gamma(t)G, \gamma(t)L] \qquad (5\text{-}10)$$

γ(t) is an efficiency factor, which effect every factors of production. It does not alter the price proportion of factor of production. One of its properties is as equation (5-11).

$$\frac{dA(H)}{dt} = \frac{dK}{dt} = \frac{dG}{dt} = \frac{dL}{dt} = 0 \qquad (5\text{-}11)$$

It can be written in the Cobb-Douglas production function as the following function.

$$Y = c[\gamma(t)A(H)]^{\beta_{A(H)}}[\gamma(t)K]^{\beta_K}[\gamma(t)G]^{\beta_G}[\gamma(t)L]^{\beta_L}\varepsilon_t \qquad (5\text{-}12)$$

A(H),K, G and *L* are the factor inputs, *c* is the value of γ at time *t=0*, and ε_t is a genuinely random distribance reflecting such factor as strikes, flood, terrorism, and etc.

The technical progress in Hicks definition is

$$\frac{d\gamma}{dt} * \frac{1}{\gamma} = F \qquad (5\text{-}13)$$

The F measures the proportionate change in output per time period when input levels are held constant. It is therefore the proportionate change in output that occurs because of technical progress.

Thus; $\gamma(t) = e^{Ft}$ (5-14)

$$Y = c\left[e^{Ft}A(H)\right]^{\beta_K}\left[e^{Ft}K\right]^{\beta_K}\left[e^{Ft}G\right]^{\beta_G}\left[e^{Ft}L\right]^{\beta_L}\varepsilon_t \qquad (5\text{-}15)$$

Where c = constant term[2]

Transform (5-15)

$$Y = ce^{Ft}A(H)^{\beta_{A(H)}}K^{\beta_K}G^{\beta_G}L^{\beta_L}\varepsilon_t \qquad (5\text{-}16)$$

Adding the dummy variable of economic crisis since 1997 into (5-16) and transforming to double log form.

$$\ln Y = c + Ft + \beta_{A(H)}\ln A(H) + \beta_K \ln K + \beta_G \ln G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t \, (5\text{-}17)$$

The crisis dummy is estimated by given the earlier year of 1997 equals to 0; otherwise is 1. Thus, this dummy term will signify its value by its coefficient. Then, we will find the role of public capital and private capital to labor productivity by below equation .

$$\ln(Y/L) = c + Ft + \beta_{A(H)}\ln A(H) + \beta_K \ln K + \beta_G \mathrm{Ln} G + (\beta_L - 1)\ln L + \tau D_{crisis} + \varepsilon_t \, (5\text{-}18)$$

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[2] To make estimated equations more flexible,the study includes an intercept term in the equations; generally, these may reflect other factors not included in the specification. If the constant really should not exist the estimation may still lead to a zero or insignificant near zero value. However, if this coefficient is quite large, it may imply the obmitted variable of the functional form. In this study, the constant term is quite important especially while comparing the overall estimated result of equations to select the best equation among the technical approaches.

For the agicultural sector, the number of planted area is added as an input factor in the model (5-17) and (5-18).

5.2.2.1.2 Cobb-Douglas Production Function: Hicks Neutrality Without A(H)

Similar to others Hicks production function, the following model is shown.

$$Y = f[\gamma(t)K, \gamma(t)G, \gamma(t)L] \quad (5\text{-}19)$$

γ(t) is an efficiency factor works similar to (5-10). The property of Hicks neutrality without *A(H)* is:

$$\frac{dK}{dt} = \frac{dG}{dt} = \frac{dL}{dt} = 0 \quad (5\text{-}20)$$

It can be written in the Cobb-Douglas production function as the following function.

$$Y = c[\gamma(t)K]^{\beta_K}[\gamma(t)G]^{\beta_G}[\gamma(t)L]^{\beta_L}\varepsilon_t \quad (5\text{-}21)$$

K, G and *L* are the factor inputs, *c* is the value of γ at time t=0, and ε_t is now a genuinely random distribance.

As the technical progress in Hicks definition is as (5-13). The *F* measures the proportionate change in output per time period when input levels are held constant. It is therefore the proportionate change in output that occurs because of technical progress. We will gain (5-22)

$$Y = c[e^{Ft}K]^{\beta_K}[e^{Ft}G]^{\beta_G}[e^{Ft}L]^{\beta_L}\varepsilon_t \quad (5\text{-}22)$$

Where c = constant term

$$Y = ce^{Ft}K^{\beta_K}G^{\beta_G}L^{\beta_L}\varepsilon_t \quad (5\text{-}23)$$

Adding the dummy variable of economic crisis in 1997 and transforming to log- linear form.

$$\ln Y = c + Ft + \beta_K \ln K + \beta_G \ln G + \beta_L \ln L \ \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}24)$$

Then, we will estimate the role of public capital and private capital to labor productivity by below equation .

$$\ln(Y/L) = c + Ft + \beta_K \ln K + \beta_G \mathrm{Ln} G + (\beta_L - 1)\ln L + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}25)$$

5.2.2.1.3 Cobb-Douglas Production Function: Hicks Neutrality

The production function of Hicks technical approach is shown in (5-26)

$$Y = f\left[\gamma(t)K, \gamma(t)G, \gamma(t)L\right] \qquad (5\text{-}26)$$

Similar to (5-10) , γ(t) is an efficiency factor that effects both factors of production. It can be written in the Cobb-Douglas production function similar to (5-23). The technical progress in Hicks definition is as same as (5-13).

Since the definition of growth rate of technology captures the concept of growth and time by catch-up proxy as shown in (5-2); thus, in this study the time *(t)*[3] is not required. The growth rate of technology is replaced instead of f to define the proportionate change in output per time period.

Thus; $\dot{A}(H) = e^{Ft}$ (5-27)

$$Y = c\left[A(H)K\right]^{\beta_K}\left[A(H)G\right]^{\beta_G}\left[\left[A(H)\right]L\right]^{\beta_L}\varepsilon_t \qquad (5\text{-}28)$$

Where c = constant term

Consequently, the Cobb-Douglas production function in Hick approach appears as below.

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[3] It is not require to be considered as the technical approach moving by time, but each variable must be checked whether time trend embodies in the variable.

$$Y = cA(H)^{(\beta_K + \beta_G + \beta_L)} K^{\beta_K} G^{\beta_G} L^{\beta_L} \varepsilon_t \qquad (5\text{-}29)$$

It should be noted that the traditional analysis of most economists is given $\beta_K + \beta_G + \beta_L = 1$. The dummy variable of economic crisis in 1997 is added. Then, transforming (5-30) it into log- linear form.

$$lnY = c + (\beta_K + \beta_G + \beta_L) lnA(H) + \beta_K LnK + \beta_G LnG + \beta_L \, lnL + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}30)$$

Then, The following equation shows the role of public capital and private capital to labor productivity.

$$ln(Y/L) = c + (\beta_K + \beta_G + \beta_L) lnA(H) + \beta_K lnK + \beta_G lnG + (\beta_L - 1) lnL + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}31)$$

5.2.2.1.4 Cobb-Douglas Production Function: Harrod Neutrality

The production function in the Harrod approach is

$$Y = f[K, G, \varepsilon(t) L] \qquad (5\text{-}32)$$

$\varepsilon(t)$ is an efficiency factor in the Harrod approach, depending on time and effect only Labor. As $\varepsilon(t)$ increases twice, the labor is as same as 2 time used. It can be written in the Cobb-Douglas Production Function as

$$Y = cK^{\beta_K} G^{\beta_G} [\varepsilon(t) L]^{\beta_L} \qquad (5\text{-}33)$$

Assume that an efficiency factor constantly increases.

$$\frac{d\varepsilon}{dt} * \frac{1}{\varepsilon} = h \qquad (5\text{-}34)$$

Where h is an increase rate of labor efficiency due to technical progress, we will gain. Since the definition of growth rate of technology captures the concept of growth and time by catch-up proxy; thus, it is substituted by $A(H)$.

$$\dot{A}(H) = e^{ht} \tag{5-35}$$

$$Y = cK^{\beta_K} G^{\beta_G} \left[A(H)L\right]^{\beta_L} \varepsilon_t \tag{5-36}$$

$$Y = cA(H)^{\beta_L} K^{\beta_K} G^{\beta_G} L^{\beta_L} \varepsilon_t \tag{5-37}$$

Adding dummy of crisis 1997 and transforming into log linear functional form, we will gain:

$$lnY=c+\beta_K LnK+ \beta_G LnG+\beta_L \, ln(A(H)*L) + \tau D_{crisis} + \varepsilon_t \tag{5-38}$$

Then, the following model will be estimated to find the role of public capital and private capital to labor productivity.

$$lnY/L=c+\beta_K LnK+ \beta_G LnG+\beta_L \, lnA(H)+(\beta_L-1)lnL+\tau D_{crisis}+ \varepsilon_t \tag{5-39}$$

5.2.2.1.5 Cobb-Douglas Production Function: Solow Neutrality

The technical progress of Solow approach points on the effect through capital. Since the public capital and private capital are both concerned in this study; therefore, the functional form is as (5-40)

$$Y = f\left[\theta(t)(K,G), L\right] \tag{5-40}$$

The $\theta(t)$ is an efficiency factor in the Solow approach depends on time and effect only capital. It can be written in the Cobb-Douglas production function as:

$$Y = c\left[\theta(t)K\right]^{\beta_K} \left[\theta(t)G\right]^{\beta_G} L^{\beta_L} \tag{5-41}$$

Not different to Harrod approach, the assumption that an efficiency factor constantly increases is made.

$$\frac{d\theta}{dt} * \frac{1}{\theta} = m \qquad (5\text{-}42)$$

Where m is an increase rate of capital efficiency due to technical progress. Because human capital definition covers the concept of growth and time by catch-up proxy as shown in equation (5-2), the time *(t)* is left. The technical progress of Solow neutrality is replaced by *A(H)*. Thus, the following equation shows Cobb-Douglas with Solow neutrality in this study is:

$$Y = c[A(H)K]^{\beta_K} [A(H)G]^{\beta_G} L^{\beta_K} + \varepsilon_t \qquad (5\text{-}43)$$

$$Y = cA(H)^{(\beta_K + \beta_G)} K^{\beta_K} G^{\beta_G} L^{\beta_L} + \varepsilon_t \qquad (5\text{-}44)$$

Thus,

$$\ln Y = c + (\beta_K + \beta_G)\ln A(H) + \beta_K \ln K + \beta_G \ln G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}45)$$

The role of private capital and private capital to labor productivity is investigated by the following equation.

$$\ln(Y/L) = c + (\beta_K + \beta_G)\ln A(H) + \beta_K \ln K + \beta_G \ln G + (\beta_L - 1)\ln L + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}46)$$

5.2.2.1.6 The Coefficient Test : Choose the Technological Progress of Cobb-Douglas Production Function

First of all, it must be remarked that *A(H)* embodies in section 5.2.2.1.1-5.2.2.1.5 can be classified into 2 parts. The first part is to investigate the existence as a factor of production in the function. Whereas the second part helps to identify the technological progress.

The first part is to test the coefficient of *A(H)* or $\beta_{A(H)}$ of (5-17) whether it rejects the null hypothesis of $\beta_{A(H)}$ equals to zero by the Wald test. If it can not reject the null hypothesis, it is possible to be the Hicks neutrality with *A(H)* as a factor. Then, it wili be carried on the result according to the second part. The estimations of Hicks without *A(H)*, which is the traditional style of economist's analysis, will also benefit to indicate its fit comparing to other approaches by their yield estimated statistic. Being note that the dummy of economic crisis shall not be neglected.

$$\ln Y = c + Ft + \beta_{A(H)}A(H) + \beta_K \ln K + \beta_G \mathrm{Ln} G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}17)$$

The Wald test is brought to select the technological approach in each sector by taking the test whether $\beta_{A(H)}$ in equation (5-47) equals to $\beta_K + \beta_G + \beta_L$, β_L and $\beta_k + \beta_G$, which implies to be the Hicks neutrality, Harrod neutrality, and Solow neutrality sequently.

$$\ln Y = c + \beta_{A(H)}A(H) + \beta_K \ln K + \beta_G \mathrm{Ln} G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t \qquad (5\text{-}47)$$

As the $\beta_{A(H)}$ is not reject to equal to $\beta_K + \beta_G + \beta_L$ of equation (5-30), it implies to the acceptable assumption as the Hicks neutrality. Similarly, if it equals to β_L and $\beta_k + \beta_G$ of (5-39) and (5-45) respectively, it implies to be the Harrod and Solow neutrality.

Besides the coefficient test, every equation will be estimated and considered each variable and statistic compared to others. In case that each sector accepts more than one technological progress, the left equations will be taken into deep consideration in each variables and the statistics yielded from estimation with the results of CES.

It should be remarked that *land* will be added as an input factor in the estimations of the agricultural sector.

To summarize, the following table shows the estimated hypotheses and estimations used in coefficient test.

Table 6 The hypothesis testing of coefficient test of Cobb-Douglas Production Function in various technological approaches

Techonological Approach	**Test coefficient of *A(H)* or $\beta_{A(H)}$**	**The estimation**
Main estimation: $\ln Y = c + Ft + \beta_{A(H)}A(H) + \beta_K lnK + \beta_G LnG + \beta_L lnL + \tau D_{crisis} + \varepsilon_t$ (5-17)		
Hicks neutrality $Y = A(H)\ F(K,G,L)$ **with** *A(H)* **as a factor**	-	$\ln Y = c + Ft + \beta_{A(H)}A(H) + \beta_K \ln K + \beta_G \mathrm{Ln}G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-17)
Hicks neutrality ***Without A(H)*** $Y = F(K,G,L)$	$\beta_{A(H)} = 0$	$\ln Y = c + Ft + \beta_K \ln K + \beta_G \mathrm{Ln}G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-24)
Main estimation: $\ln Y = c + \beta_{A(H)}A(H) + \beta_K \ln K + \beta_G \mathrm{Ln}G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-48)		
Hicks neutrality $Y = A(H)\ F(K,G,L)$	$\beta_{A(H)} = B_K + \beta_G + \beta_L$	$\ln Y = c + (\beta_K + \beta_G + \beta_L)A(H) + \beta_K \ln K + \beta_G \mathrm{Ln}G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-30)
Harrod neutrality $Y = F(K,G,A(H)L)$	$\beta_{A(H)} = \beta_L$	$\ln Y = c + \beta_L \ln A(H) + \beta_K \ln K + \beta_G \mathrm{Ln}G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-38)
Solow neutrality $Y = F(AK,A(H)G,L)$	$\beta_{A(H)} = B_K + \beta_G$	$\ln Y = c + (\beta_K + \beta_G)\ln A(H) + \beta_K \ln K + \beta_G \ln G + \beta_L \ln L + \tau D_{crisis} + \varepsilon_t$ (5-45)

5.2.2.2 Constant Elasticity of Substitution Production Function

The CES Production Function represents the production function with an unspecified constant elasticity of substitution, the other assumptions are similar to Cobb-Douglas Production Function. The general form of CES Production Function is as below.

$$Y = \upsilon(\delta_K K^{-\rho} + \delta_G G^{-\rho} + (1 - \delta_K - \delta_G)L^{-\rho})^{-(\frac{V}{\rho})} \qquad (5\text{-}48)$$

Where V = Return to scale parameter

υ = The scale of operation

ρ = The substitution parameter it is the determinant of the value of the constant elasticity of substitution

δ = The distribution parameters, the relative factor shares in the product

When, $\rho = \dfrac{V}{\sigma - 1}$ (5-49)

σ = The elasticity of substitution

The results of the 3 difference technical augmentations will be estimated as following equations.

5.2.2.2.1 CES Production Function: Hicks Neutrality with Human Capital and Catch-up Technology as a Factor of Production.

The production function with catch-up technology as a factor of Hicks technical progress in CES production function is shown below. The definitions of variables are explained in (5-1) and section 1.4.

$$Y = f\left[\gamma(t)A(H), \gamma(t)K, \gamma(t)G, \gamma(t)L\right] \quad (5\text{-}50)$$

Replace $A(H)$ with catch up technology instead of Hick neutrality $\gamma(t)$. Thus, CES production function in Hick neutrality is

$$Y = \upsilon(\delta_{A(H)}A(H)^{-p} + \delta_K K^{-p} + \delta_G G^{-p} + (1-\delta_K-\delta_G)L^{-p})^{-(v/p)} \quad (5\text{-}51)$$

The dummy of economic crisis in 1997 is included by denote it as zero in the year earlier 1997, otherwise is one. Thus, the effect of crisis will be shown when we estimate the following estimation.

$$Y = \upsilon(\delta_{A(H)}A(H)^{-p} + \delta_K K^{-p} + \delta_G G^{-p} + (1-\delta_{A(H)}-\delta_K-\delta_G)L^{-p})^{-(v/p)} e^{\tau Dcrisis}\varepsilon_t \quad (5\text{-}52)$$

To estimate the roles of public and private capital to the labor productivity, the below model is used.

$$Y/L = \upsilon(\delta_{A(H)}A(H)^{-p} + \delta_K K^{-p} + \delta_G G^{-p} + (1-\delta_{A(H)}-\delta_K-\delta_G)L^{-p})^{-(v/p)} L^{-1} e^{\tau Dcrisis}\varepsilon_t \quad (5\text{-}53)$$

To generate the most appropriate and precise model, the direct and powerful functional form as linear one should be estimated due to its easiness, and accuracy to use as the economics tools. Furthermore, it is the tool for coefficient test in order to seek the fit technological progress. The CES functional form is transformed into linear by Taylor's Series Expansion.

First of all, we assume the equation in the parentheses of the CES production function (5-54) as z(p), which is:

$$Z(p) = \delta_{A(H)}A(H)^{-p}+\delta_K K^{-p} + \delta_G G^{-p} + (1-\delta_{A(H)}-\delta_K-\delta_G)L^{-p} \qquad (5\text{-}54)$$

Taylor's Series Expansion, a power series and a polynomial of infinite degree, is used to simplify CES. Many operations on polynomials are also legitimate for Taylor's series, provided the restricted attention to values if x within as appropriate interval. For example, a Taylor series expansion of $f(x)$ may be differentiated the series term by term to obtain the Taylor series expansion of $f'(x)$. An analogue results hold for antiderivatives. Other permissible operations that produce Taylor series include multiplying a Taylor series expansion by a constant or power of x, replacing x by a power of x or by a constant times a power of x, and adding or subtracting two Taylor series expansions. The use of such operation often makes it possible to find the Taylor series of a function without directly using the formal definition of a Taylor series.

$$f(x) = f(0) + \frac{f'(0)}{1!}x + \frac{f''(0)}{2!}x^2 + ... + \frac{f^{(k)}(0)}{k!}x^k + ... \qquad (5\text{-}55)$$

The above entire equation is called the Taylor series expansion of $f(x)$ at x=0. The Taylor series are applied to calculate the non-linear functional form of CES at the third power of x where assume that the later power is only an tiny value or approach to zero.

$$f(\rho) = \log Z(\rho) \qquad (5\text{-}56)$$

$$f'(\rho) = \frac{Z'(\rho)}{Z(\rho)} \qquad (5\text{-}57)$$

$$f''(\rho) = \frac{Z''(\rho)Z(\rho) - Z'(\rho)Z'(\rho)}{Z(\rho)^2} = \frac{Z''(\rho)}{Z(\rho)} - \left(\frac{Z'(\rho)}{Z(\rho)}\right)^2 \quad (5\text{-}58)$$

The Taylor series is:

$$\phi(\rho) = \phi(0) + \rho\phi'(0) + \frac{\rho^2}{2}\phi''(0) + \ldots \quad (5\text{-}59)$$

$$= \log Z(0) + \rho\frac{Z'(0)}{Z(0)} + \frac{\rho^2}{2}\left[\frac{Z''(0)}{Z(0)} - \left(\frac{Z'(0)}{Z(0)}\right)^2\right] + \ldots.. \quad (5\text{-}60)$$

$$\begin{aligned} &= -p(\delta_{A(H)}logA(H)+\delta_K logK+ \delta_G logG \\ &\quad + (1-\delta_{A(H)}-\delta_K-\delta_G)logL) +(p^2/2)[(\delta_{A(H)}log^2A(H) \\ &\quad +\delta_K log^2K+\delta_G log^2G+(1-\delta_{A(H)}-\delta_K-\delta_G)log^2L) \\ &\quad -(\delta_{A(H)}logA(H)+ \delta_K logK + \delta_G logG \\ &\quad + (1-\delta_{A(H)}-\delta_K-\delta_G)logL)^2] \end{aligned} \quad (5\text{-}61)$$

Simplifiled the functional form by taking log of equation (5-61)

Thus, $log(Y) = c - \upsilon(v/p)logz(p)$ (5-62)

Where c = constant term

$$\begin{aligned} log(Y) &= c - \upsilon\, (v/p)\{-p(\delta_{A(H)}logA(H)+\delta_K logK+ \delta_G logG \\ &\quad + (1-\delta_{A(H)}-\delta_K-\delta_G)logL) +(p^2/2)[(\delta_{A(H)}log^2A(H)+\delta_K log^2K \\ &\quad +\delta_G log^2G+(1-\delta_{A(H)}-\delta_K-\delta_G)log^2L)-(\delta_{A(H)}logA(H)+ \delta_K logK \\ &\quad + \delta_G logG + (1-\delta_{A(H)}-\delta_K-\delta_G)logL)^2]\} \end{aligned} \quad (5\text{-}63)$$

Transforming into linear and adding dummy of crisis and error term. Thus, the model is expressed below.

$$\begin{aligned} log(Y) &= c + \upsilon v\delta_{A(H)}logA(H)+ \upsilon v\delta_K logK+ \upsilon v\delta_G logG \\ &\quad +\upsilon v\, (1-\delta_{A(H)}-\delta_K-\delta_G)logL) -\upsilon(vp/2)\, \delta_{A(H)}\, (1-\delta_{A(H)})log^2A(H) \\ &\quad +\upsilon\delta_K(1-\delta_K)log^2K+\upsilon\delta_G(1-\delta_G)log^2G+\upsilon(1-\delta_{A(H)}-\delta_K-\delta_G) \\ &\quad (\delta_{A(H)}+\delta_K+\delta_G)log^2L)+ \upsilon vp\delta_{A(H)}\, \delta_K\, logA(H)*logK \\ &\quad +\upsilon\, vp\delta_{A(H)}\, \delta_G\, logA(H)logG+ \upsilon vp\delta_{A(H)}\, (1-\delta_{A(H)}-\delta_K-\delta_G) \\ &\quad logA(H)*logL+\upsilon vp\delta_K\delta_G logK*logG \\ &\quad +\upsilon vp\delta_K\, (1-\delta_{A(H)}-\delta_K-\delta_G)logK*logL \\ &\quad +\upsilon vp\delta_G\, (1-\delta_{A(H)}-\delta_K-\delta_G)\, logG*logL+ \tau D_{crisis}+\varepsilon_t \end{aligned} \quad (5\text{-}65)$$

5.2.2.2.2 CES Production Function: Hicks Neutrality without A(H)

Hick approach without *A(H)* is the universal, and traditional style used in the economic study. It characterized by function (5-19). The working process is as same procedure as 5.2.2.1.1 or 5.2.2.1.2. Thus, CES production function in Hick neutrality is

$$Y = \upsilon[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-\nu/\rho} \varepsilon_t \qquad (5\text{-}66)$$

The dummy of economic crisis in 1997 is included in the following equation:

$$Y = \upsilon[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-\nu/\rho} e^{\tau Dcrisis} \varepsilon_t \qquad (5\text{-}67)$$

Thus, the roles of public and private capital to the labor productivity is calculated by the following model.

$$Y / L = \upsilon[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-\nu/\rho} L^{-1} e^{\tau Dcrisis} \varepsilon_t \qquad (5\text{-}68)$$

For the agricultural sector, the model will be as follow.

$$Y = \upsilon[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-\nu/\rho} e^{\tau Dcrisis} \varepsilon_t \qquad (5\text{-}69)$$

The estimated model for agricultural sector is:

$$Y / L = \upsilon[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-\nu/\rho} L^{-1} e^{\tau Dcrisis} \qquad (5\text{-}70)$$

To generate the most appropriate and precise model, the CES functional form is calculated to linear by Taylor's Series Expansion. The working process is similar to (5-54)-(5-60). First of all, we assume the equation in the parentheses of the CES production function as z(*p*), which is:

$$Z(\rho) = \delta_K K^{-\rho} + \delta_G G^{-\rho} + (1 - \delta_K - \delta_G) L^{-\rho} \qquad (5\text{-}71)$$

Then, we gain.

$$Z(p) = -p(\delta_K logK + \delta_G logG + (1-\delta_K-\delta_G)logL) + (p^2/2)[(\delta_K log^2K + \delta_G log^2G + (1-\delta_K-\delta_G)log^2L) - (\delta_K logK + \delta_G logG + (1-\delta_K-\delta_G)logL)^2] \quad (5\text{-}72)$$

Taking log of equation (5-66)

$$\log(Y) = c - \frac{\upsilon\nu}{\rho}\log Z(P) \quad (5\text{-}73)$$

Replace $z(p)$ by equation in (5-72), arrange and add the dummy of crisis.

$$log(Y) = c + \upsilon v\delta_K logK + \upsilon v\delta_G logG + \upsilon v(1-\delta_{A(H)}-\delta_K-\delta_G)logL - \upsilon(vp/2)\delta_K(1-\delta_K)log^2K - \upsilon(vp/2)\delta_G(1-\delta_G)log^2G - \upsilon(vp/2)(1-\delta_K-\delta_G)(\delta_K+\delta_G)log^2] + \upsilon vp\delta_K\delta_G logK*logG + \upsilon vp\delta_K(1-\delta_K-\delta_G)logK*logL + \upsilon vp\delta_G(1-\delta_K-\delta_G)logG*logL + \tau D_{crisis} + \varepsilon_t \quad (5\text{-}74)$$

5.2.2.2.3 CES Production Function: Hicks Neutrality

Hick approach in this section replaces $A(H)$ as the technical approach; it is defined in production function as equation (5-19). The principal process is similar to section 5.2.2.1.1. Thus, the CES Production Function of this section is as the following model.

$$Y = cA(H)^v[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-v/\rho}\varepsilon_t \quad (5\text{-}75)$$

The dummy of economic crisis in 1997 is included in the following equation:

$$Y = cA(H)^v[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-v/\rho} e^{\tau Dcrisis}\varepsilon_t \quad (5\text{-}76)$$

Thus, the roles of public and private capital to the labor productivity is calculated by the following model.

$$Y/L = cA(H)^v[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho}]^{-v/\rho}L^{-1} e^{\tau Dcrisis}\varepsilon_t (5\text{-}77)$$

For the agricultural sector, the model will be as follow.

$$Y = cA(H)^{v}[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-v/\rho} e^{\tau Dcrisis} \varepsilon_t \quad (5\text{-}78)$$

The estimated model for labor productivity of agricultural sector is:

$$Y = cA(H)^{v} [\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-v/\rho} L^{-1} e^{\tau Dcrisis} \varepsilon_t \quad (5\text{-}79)$$

To generate the most appropriate and precise model, the CES functional form is altered to be linear by Taylor's Series Expansion. The working process is similar to (5-54)-(5-60). We assume the equation in the parentheses of the CES Production Function as z(p), which is:

$$Z(\rho) = \delta_K K^{-\rho} + \delta_G G^{-\rho} + (1 - \delta_K - \delta_G) L^{-\rho} \quad (5\text{-}80)$$

Working as same process as (5-56) to (5-60), we will gain:

$$\begin{aligned}\phi(p) = \; & -p(\delta_K logK + \delta_G logG + (1-\delta_K-\delta_G) logL \\ & -(p^2/2)[\delta_K(1-\delta_K) log^2 K + \delta_G(1-\delta_G) log^2 G \\ & +v(1-\delta_K-\delta_G)(\delta_K+\delta_G) log^2] - 2\delta_K\delta_G logK logG \\ & +2\delta_K(1-\delta_K-\delta_G) logK logL + 2\delta_G(1-\delta_K-\delta_G) logG logL] \quad (5\text{-}81)\end{aligned}$$

Taking log of (5-79), the estimation is (5-84)

$$\log(Y) = c + v \log A(H) - \frac{v}{\rho} \log Z(P) \quad (5\text{-}82)$$

The log $Z(P)$ is changed into the estimation of $\phi(p)$ in (5-84). The final equation is:

$$\begin{aligned}log(Y) = \; & c + v logA(H) + v\delta_K logK + v\delta_G logG + v(1-\delta_K-\delta_G) logL \\ & -(vp/2)\delta_K(1-\delta_K) log^2 K - (vp/2)\delta_G(1-\delta_G) log^2 G \\ & -(vp/2)(1-\delta_K-\delta_G) log^2 L + vp\delta_K\delta_G logK * logG \\ & +vp\delta_K(1-\delta_K-\delta_G) logK * logL + vp\delta_G(1-\delta_K-\delta_G) logG logL \\ & +\tau D_{crisis} + \varepsilon_t \quad (5\text{-}83)\end{aligned}$$

5.2.2.2.4 CES Production Function: Harrod Neutrality

The CES of Harrod approach is as equation (5-14). Therefore, the CES production function with crisis dummy and error terms is as follow.

$$Y = c[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L (A(H)L)^{-\rho}]^{-v/\rho} \; e^{\tau Dcrisis} \, \varepsilon_t \qquad (5\text{-}88)$$

The estimated model to answer the value of roles of public and private to labor productivity is:

$$Y/L = c[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L (A(H)L)^{-\rho}]^{-v/\rho} L^{-1} \; e^{\tau Dcrisis} \, \varepsilon_t \; (5\text{-}89)$$

For agricultural sector, it is (5-90).

$$Y = c[\delta_K K^{-\rho} + \delta_G G^{-\rho} + \delta_L (A(H)L)^{-\rho} + \delta_{Land} Land^{\rho}]^{-v/\rho} \; e^{\tau Dcrisis} \, \varepsilon_t (5\text{-}90)$$

The estimated model to answer the value of roles of public and private to labor productivity is:

$$Y/L = c[\delta_K K^{-\rho} + \delta_G G^{\rho} + \delta_L (A(H)L)^{-\rho} + \delta_{Land} Land^{\rho}]^{-v/\rho} L^{-1} \; e^{\tau Dcrisis} \, \varepsilon_t \; (5\text{-}91)$$

In case of Harrod neutrality, the working process is similar to the above mathematic process. Considering with the particular considering in the parentheses of CES:

$$Z(\rho) = \delta_K K^{-\rho} + \delta_G G^{-\rho} + (1 - \delta_K - \delta_G)(A(H)L)^{-\rho} \qquad (5\text{-}92)$$

Simplifiled the functional form of Harrod neutrality, taking log of equation (5-106)

Thus, $$\log(Y) = c - \frac{v}{\rho} \log Z(P) \qquad (5\text{-}93)$$

Finally, we gain

$$log(Y) = c + (1\text{-}\delta_K\text{-}\delta_G)logA(H) + \delta_K logK + \delta_G logG +(1\text{-}\delta_K\text{-}\delta_G)logL\text{-}(vp/2)[\delta_K(1\text{-}\delta_K)log^2K +\delta_G(1\text{-}\delta_G)log^2G+v(1\text{-}\delta_K\text{-}\delta_G)(\delta_K+\delta_G) log^2A(H)L]+vp\delta_K\delta_G logK*logG +vp\delta_K(1\text{-}\delta_K\text{-}\delta_G)logK*logA(H)L+vp\delta_G (1\text{-}\delta_K\text{-}\delta_G)logG*logA(H)L+\tau D_{crisis}+\varepsilon_t \quad (5\text{-}94)$$

5.2.2.2.5 CES Production Function: Solow Neutrality

Solow neutrality takes part in the production function as (5-45). Hence, the principal model is performed below.

$$Y = c[\delta_K(A(H)K)^{-\rho} + \delta_G(A(H)G)^{-\rho} + \delta_L L^{-\rho}]^{-v/\rho}\ e^{\tau Dcrisis}\ \varepsilon_t \quad (5\text{-}95)$$

Thus,

$$Y = c[A(H)(\delta_K K^{-\rho} + \delta_G G^{-\rho}) + \delta_L L^{-\rho}]^{-v/\rho}\ e^{\tau Dcrisis}\ \varepsilon_t \quad (5\text{-}96)$$

The labor producitivity is evaluated by (5-97).

$$Y / L = c[A(H)(\delta_K K^{-\rho} + \delta_G G^{-\rho}) + \delta_L L^{-\rho}]^{-v/\rho} L^{-1}\ e^{\tau Dcrisis}\ \varepsilon_t \quad (5\text{-}97)$$

The production function and labor productivity of agricultural sector are (5-98) and (5-99).

$$Y = c[A(H)(\delta_K K^{-\rho} + \delta_G G^{-\rho}) + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-v/\rho}\ e^{\tau Dcrisis}\ \varepsilon_t \quad (5\text{-}98)$$

$$Y / L = c[A(H)(\delta_K K^{-\rho} + \delta_G G^{-\rho}) + \delta_L L^{-\rho} + \delta_{Land} Land^{-\rho}]^{-v/\rho} L^{-1}\ e^{\tau Dcrisis}\ \varepsilon_t \quad (5\text{-}99)$$

For the Solow neutrality, working similar to the above mathematic process. Begin with the particular considering in the parentheses of CES:

$$Z(\rho) = \delta_K(A(H)K)^{-\rho} + \delta_G(A(H)G)^{-\rho} + (1-\delta_K-\delta_G)(A(H)L)^{-\rho} \quad (5\text{-}100)$$

Simplifiled the functional form of Solow neutrality, taking log of equation (5-96). Finally, we gain:

$$log(Y) = c + (\delta_K+\delta_G)logA(H)+ \delta_K logK+\delta_G logG$$
$$+(1-\delta_K-\delta_G)logL-(vp/2)[\delta_K(1-\delta_K)log^2A(H)K$$
$$+\delta_G(1-\delta_G)log^2A(H)G+v(1-\delta_K-\delta_G)(\delta_K+\delta_G)log^2L]$$
$$+vp\delta_K\delta_G log\, A(H)K*logA(H)G$$
$$+vp\delta_K(1-\delta_K-\delta_G)logA(H)K*logL+vp\delta_G(1-\delta_K-\delta_G)$$
$$logA(H)G*logL + \tau D_{crisis} +\varepsilon_t \qquad (5\text{-}101)$$

5.2.2.2.6 The Coefficient test : Choose the Technological Progress of CES Production Function

The similar method to the Cobb-Douglas coefficient test is brought to used with CES. The coefficient test by the Wald test is required to reaffirm with the Cobb-Douglas Production Function. The test is devided into 2 major parts: examine whether it is an input factor or a part of technological approach. It is possible that *A(H)* is working as a factor of production. Thus, the estimation (5-65) will be estimated in order to test whether $\upsilon v\delta_{A(H)}$ *A(H)* is equals to zero. If it does not reject the hypothesis tested by the Wald test, it might imply to Hicks neutrality without *A(H)*.

Moreover, the transformed model into linear is used to test the coefficient test in order to select the technological neutrality: Hicks, Harrod, Solow neutrality. It is checked by the Wald test in each model of technological progress. The transformed model, though yielded the tremendous number of variable, will directly benefit the coefficient test particularly for testing Solow model which cannot be seperated each independent variable in the original model.

To examine the production function whether it is charecterized by Hicks approach, the term v of equation (5-83) is altered to be "A" coefficient and test by the hypothesis that v of log*A(H)* equals to the v in other term. If the coefficient does not reject the hypothesis, or in other words, it equals to v, this approach is applicable to the production function of that sector.

On the other hand, for the Harrod neutrality, the equation (5-94) is run, and test the coefficient of *A(H)*, $(1-\delta_K-\delta_G)$, whether it equals to $(1-\delta_K-\delta_G)$ of logL. The rejection will indicate it as an unapplicable functional form.

The Solow neutrality is also examined by the similar method to Harrod. The different point is the tested model which is (5-101), and the testing term is $\delta_K + \delta_G$. "A" coefficient is inserted as the coefficient of *A(H),* and then tested the availablity to equals to $\delta_K + \delta_G$. If it does not reject, thus it might be acceptable to Solow neutrality.

It should be noted, again, that land will not be neglected to putting it as an input factor in the agricultural sector.

Those processes of coefficient test can be summarized as the following table.

Table 7 The hypothesis testing of coefficient test of CES Production Function.

Techonological Approach	**Test coefficient of *A(H)***	**The estimation**
Hicks neutrality ***With A(H) as a factor*** ***Y =F(A(H),K,G,L)***	$\upsilon v\delta_{A(H)} = 0$ (If it does not reject, it implies to Hicks neutrality without *A(H)*)	$log(Y) = c + \upsilon v\delta_{A(H)}logA(H) + \upsilon v\delta_K logK + \upsilon v\delta_G logG + \upsilon v(1-\delta_{A(H)}-\delta_K-\delta_G)logL - \upsilon(vp/2)\delta_{A(H)}(1-\delta_{A(H)})log^2A(H) + \upsilon\delta_K(1-\delta_K)log^2K + \upsilon\delta_G(1-\delta_G)log^2G + \upsilon(1-\delta_{A(H)}-\delta_K-\delta_G)(\delta_{A(H)}+\delta_K+\delta_G)log^2L) + \upsilon vp\delta_{A(H)}\delta_K\, logA(H)*logK + \upsilon vp\,\delta_{A(H)}\,\delta_G\, logA(H)*logG + \upsilon vp\delta_{A(H)}(1-\delta_{A(H)}-\delta_K-\delta_G)logA(H)*logL + \upsilon vp\delta_K\delta_G logK*logG + \upsilon vp\delta_K(1-\delta_{A(H)}-\delta_K-\delta_G)logK*logL + \upsilon vp\delta_G(1-\delta_{A(H)}-\delta_K-)logG*logL + D_{crisis}+\varepsilon_t$ (5-65)
Hicks neutrality without *A(H)* ***Y = A(H) F(K,G,L)***	-	$log(Y) = c + \upsilon v\delta_K logK + \upsilon v\delta_G logG + \upsilon v(1-\delta_{A(H)}-\delta_K-\delta_G)logL - \upsilon(vp/2)[\delta_K(1-\delta_K)log^2K + \delta_G(1-\delta_G)log^2G + (1-\delta_K-\delta_G)(\delta_K+\delta_G)log^2] + \upsilon vp\delta_K\delta_G logK*logG + \upsilon vp\delta_K(1-\delta_K-\delta_G)logK*logL + \upsilon vp\delta_G(1-\delta_K-\delta_G)logG*logL + D_{crisis}+\varepsilon_t$ (5-77)

Techonological Approach	Test coefficient of $A(H)$	The estimation
Hicks neutrality $Y=F(K,G,L)$	coefficient of $A(H)=v$	$log(Y) = c + vlogA(H) + v\delta_K logK + v\delta_G logG + v(1-\delta_K-\delta_G)logL-(vp/2)[\delta_K(1-\delta_K)log^2K + \delta_G(1-\delta_G)log^2G + \upsilon(1-\delta_K-\delta_G)(\delta_K+\delta_G)log^2] + vp\delta_K\delta_G logK*logG + vp\delta_K(1-\delta_K-\delta_G)logK*logL + vp\delta_G(1-\delta_K-\delta_G)logG*logL + D_{crisis} + \varepsilon_t$ (5-86)
Harrod neutrality $Y = F(K,G,A(H)L)$	coefficient of $A(H) = (1-\delta_K - \delta_G)$	$log(Y) = c + (1-\delta_K-\delta_G)logA(H) + \delta_K logK + \delta_G logG + (1-\delta_K-\delta_G)logL-(vp/2)[\delta_K(1-\delta_K)log^2K + \delta_G(1-\delta_G)log^2G + \upsilon(1-\delta_K-\delta_G)(\delta_K+\delta_G) log^2A(H)L] + vp\delta_K\delta_G logK*logG + vp\delta_K(1-\delta_K-\delta_G)logK*logA(H)L + vp\delta_G(1-\delta_K-\delta_G)logG*logA(H)L + D_{crisis} + \varepsilon_t$ (5-94)
Solow neutrality $Y = F(AK,A(H)G,L)$	coefficient of $A(H) = \delta_K + \delta_G$	$log(Y) = c + (\delta_K+\delta_G)logA(H) + \delta_K logK + \delta_G logG + (1-\delta_K-\delta_G)logL-(vp/2)[\delta_K(1-\delta_K)log^2 A(H)K + \delta_G(1-\delta_G)log^2 A(H)G + \upsilon(1-\delta_K-\delta_G)(\delta_K+\delta_G)log^2L] + vp\delta_K\delta_G log A(H)K*log A(H)G + vp\delta_K(1-\delta_K-\delta_G)logA(H)K*logL + vp\delta_G(1-\delta_K-\delta_G)log A(H)G*logL + D_{crisis} + \varepsilon_t$ (5-101)

The results will be considered and analyzed with the results of CD and their estimated statistics yielded. Therefore, the fit model will be selected to analyze the roles of each composition to the labor productivity.