CHAPTER 2

THEORIES AND RELATED WORKS

This study on the economic and environmental impacts of peeled golden brown dried longan processing community enterprises proposes to employ the Social Accounting Matrix, a commonly used method at present, as a tool for benchmarking the relevant variables and constructing the database table of the local economy. The information from SAM will then be used for analysis by a Computable General Equilibrium model which is popularly applied in economic impact analysis of a comprehensive and complex sector or economy. This study also has an interest in the impacts of different processing technologies used by the community enterprises on the environmental conditions and production performance particularly the comparison between conventional drying-oven type and the improved version. The theories, concepts, and related research works of relevancy to the present study thus are those general equilibrium and neo-classical production in essence, especially Walras' Law which is a principle in general equilibrium theory and the technical efficiency concepts and theories which will be presented in the rest of this chapter.

2.1 Theoretical framework for assessing economic impacts

1) Walras' Law

An economic system is in general equilibrium if every market as well as every decision making unit: DMU in the economy is in long run equilibrium simultaneously and consistently. All prices and outputs are allowed to change in the general equilibrium analysis. A market of a particular goods or resource is in general equilibrium and the quantity demanded equals the quantity supplied. Every producer in a market or an economic system has cost minimization behavior and thus seeks to produce at the optimal level. Therefore, optimal output level is ensured if the market or economy is in general equilibrium. Leon Walras' general equilibrium model is expressed mathematically as a simultaneous equation system consisting of 1) commodity market in which each producer's profit equals zero, 2) factor endowment market where consumer's income equals his expenditure, 3) structural equation of a competitive market system in which all markets are cleared and thus in equilibrium with neither shortages nor surpluses of any commodities, which can be formulated for an economy as follows: (Suriya, 2012)

Commodity market

$X_1,X_2,X_3,\ldots, X_n$ = quantity of commodity 1, 2, 3,…,n

$P_1, P_2, P_3,\ldots, P_n$ = price of commodity 1, 2, 3,…,n

$F_1, F_2, F_3,\ldots, F_n$ = quantity of factor 1, 2, 3,…,n

$W_1, W_2, W_3,\ldots,W_m$ = price of factor 1, 2, 3,…,m

The commodity market is governed by consumer behavior in neo-classic theoretical tradition. The demand function is determined by the utility function of all consumers who will buy and consume bundle of commodities to maximize their utility given their budget constraint. This set of simultaneous equations is presented below:

1) utility function $U = U(X_1, X_2, X_3,..., X_n)$ (2.1)

2) budget constraint $I = P_1X_1 + P_2X_2 + P_3X_3 + ... + P_nX_n$ (2.2)

3) demand function $X_1 = D(P_1, P_2, P_3,..., P_n, I)$ (2.3)

4) income function $I = F_1W_1 + F_2W_2 + F_3W_3 + ... + F_mW_m$ (2.4)

A household's income comes from rent, wage, interest, and profit from selling its factor endowment in the markets. Substituting equation (2.4) into demand function (2.3) only with the price of factor variables, we obtain

$$X_1 = D(P_1, P_2, P_3,..., P_n; W_1, W_2, W_3,..., W_m) \quad (2.5.1)$$

It can be seen from equation (2.5.1) that the change in the price of factor 1 will affect the quantity demanded for X_1 (demand for X_1). In an economy where there are n commodities, there exist n demand functions as in (2.5.2).

$$X_1 = D_1(P_1, P_2, P_3,..., P_n; W_1, W_2, W_3,..., W_m) \quad (2.5.2)$$

$$X_2 = D_2(P_1, P_2, P_3,..., P_n; W_1, W_2, W_3,..., W_m)$$

$$X_3 = D_3(P_1, P_2, P_3,..., P_n; W_1, W_2, W_3,..., W_m)$$

$$\begin{array}{cc} . & . \\ . & . \\ . & . \end{array}$$

$$X_n = D_n(P_1, P_2, P_3,..., P_n; W_1, W_2, W_3,..., W_m)$$

The demand function system comprises independent variables including n commodities, n commodity prices, m factor and m factor prices which explain the dependent variables $X_1, X_2, X_3,..., X_n$. Therefore, the demand function can be defined as:

$$X_n = \psi(P_n, W_m) \quad (2.6.1)$$

The above equation system demonstrates the relationship between commodity market and factor market. The change in factor price will affect consumer's income and consequently affect the demand for commodities according to the law of demand. Meanwhile, the supply equation is established under the assumptions that the economic system is perfectly competitive and firm will produce for profit maximization objective. Therefore, we can determine a set of supply equations in the economy having n commodities and m factors, other things being equal, as follows:

$$X_1 = S_1(P_1; W_1, W_2, W_3, ..., W_m) \quad (2.6.2)$$

$$X_2 = S_2(P_1; W_1, W_2, W_3, ..., W_m)$$

$$X_3 = S_3(P_1; W_1, W_2, W_3, ..., W_m)$$

$$\begin{matrix} . & & . \\ . & & . \\ . & & . \end{matrix}$$

$$X_n = S_n(P_1; W_1, W_2, W_3, ..., W_m)$$

This equation system contains n commodities, n commodity prices, and m factors, while $S_1, S_2, S_3, ..., S_n$ represent the functional relationship of supply of commodity *1* to commodity *n*.

Factor market

Factor demand functions of an economy can be expressed as follows:

$$Z_1 = Z_1(P_1, P_2, P_3, ..., P_n; W_1, W_2, W_3, ..., W_m) \quad (2.7)$$

$$Z_2 = Z_2(P_1, P_2, P_3, ..., P_n; W_1, W_2, W_3, ..., W_m)$$

$$Z_3 = Z_3(P_1, P_2, P_3, ..., P_n; W_1, W_2, W_3, ..., W_m)$$

$$\begin{matrix} . & & . \\ . & & . \\ . & & . \end{matrix}$$

$$Z_m = Z_m(P_1, P_2, P_3, ..., P_n; W_1, W_2, W_3, ..., W_m)$$

Where $Z_1, Z_2, Z_3, ..., Z_m$ are the quantity demanded in various factor markets and commodity prices are also the explanatory variables in the factors demand function because they generate the derived demand for factors.

In an economy, there also exist a set of factor supply functions which can be written as

$$T_1 = T_1(W_1; P_1, P_2, P_3, ..., P_n) \quad (2.8)$$

$$T_2 = T_2(W_1; P_1, P_2, P_3, ..., P_n)$$

$$T_3 = T_3(W_1; P_1, P_2, P_3, ..., P_n)$$

$$\begin{matrix} . & . \\ . & . \\ . & . \end{matrix}$$

$$T_m = T_m(W_1; P_1, P_2, P_3, ..., P_n)$$

Where $T_1, T_2, T_3, ..., T_m$ are the quantity supplied of various factors which depend on factor prices as well as commodity prices. The supply and demand equations in both commodity market and factor market together form a system of simultaneous equations that contains 2*n* + 2*m* equations and 2*n* + 2*m* variables and therefore a unique value can be solved for each variable because the number of equations equals that of variables.

2) Computable General Equilibrium: CGE

Computation of general equilibrium is undertaken under the following principles:

2.1) Zero profit condition, when the commodity market is in Walrasian general equilibrium, defined by equation (2.9).

$$r_f(p) + c_f(p) = 0 \quad (2.9)$$

p = price, the unknown variable

r_f = revenue function

c_f = cost function

f = any firm

2.2) Balance budget condition when households exhaust their income on commodity purchases, or revenue = expenditure.

$$e_h(p,u_h) - E_h.p = 0 \tag{2.10}$$

u_h =household's utility, the unknown variable

$e_h(p,u_h)$ =revenue function

$E_h.p$ =expenditure function

h =any household

3) Market clearance condition, when there are no surpluses nor shortages in both commodity market and factor market as they both are perfectly competitive.

$$\sum_f x_f(b_{if} - a_{if}) = \sum_h (d_{ih} - E_{ih}) \tag{2.11}$$

Where $x_f b_{if}$ =total output of firm *f*

$x_f a_{if}$ =factor inputs purchased by firm *f*

d_{ih} = demand for goods and services of household *h*

E_{ih} = supply of labor and capital of household *h*

from equation (8)

$$\sum_f x_f(b_{if} - a_{if}) = \sum_f x_f b_{if} - \sum_f x_f a_{if}$$

$$\sum_h (d_{ih} - E_{ih}) = \sum_h d_{ih} - \sum_f E_{ih}$$

$$\sum_f x_f b_{if} - \sum_f x_f a_{if} = \sum_h d_{ih} - \sum_h E_{ih}$$

$$\sum_f x_f b_{if} + \sum_h E_{ih} = \sum_h d_{ih} + \sum_f x_f a_{if} \tag{2.12}$$

The left-hand term in (2.12) comprises the aggregate supply of commodities and the aggregate supply of labor and capital, which are completely absorbed by the aggregate demand for commodities and the aggregate demand for factor inputs and (2.12) represents the condition of market clearance.

4) Partial equilibrium theory of Alfred Marshall (1920)

Partial equilibrium is an economic equilibrium condition which takes into account only a part of the market like goods to attain equilibrium, given other things such as prices of substitutable and complementary goods, and consumer's taste being constant. Partial equilibrium model considers only one particular variable while the general equilibrium analysis involves more than one variable or all variables in an economic system and thus the GE model is represented by a simultaneous equation system. In partial equilibrium model, the prices of all inputs, goods (substitutes and complements) and the taste, behavior and income level of consumers are held constant. Furthermore, it assumes the free movement of factor inputs between different production sectors as well as different regions thus implying the market operation in a perfect competition environment. The partial equilibrium model allows the analysis of backward linkages with other production sectors. For example, the increase in investment in golden brown dried longan processing will have the bearings on the demand for raw materials like fresh longan fruits and fuel as well as labor. This relationship can be expressed in terms of demand-side model from which direct input coefficients or technical coefficients can be determined. Given a_{ij} = A matrix, the subtraction of A from the identity matrix, I, to obtain (I –A) and solving for the values in $(I - A)^{-1}$ or Leontief inverse matrix then the direct and indirect coefficients can be found. Given $(I - A)^{-1} = \alpha_{ij}$, it can be explained that the increase in 1 unit in final demand of production sector *i* will result in direct and indirect increases in production sector *j* by α_{ij} units of value. The forward linkage means the distribution of products from one sector for use as input in another sector, like the use of golden brown dried longan as a raw material for producing longan cakes and this relationship can be represented by a supply-side model from which direct output coefficients can be determined. Given b_{ij} = B matrix, the subtraction of B from the identity matrix I to obtain (I – B) and solving for the values in $(I - B)^{-1}$ or output inverse matrix then the direct and indirect output coefficients can be found. Given $(I - B)^{-1} = \bar{\alpha}_{ij}$, one can tell how far an increase in value addition in production sector *j* by 1 unit will affect directly and indirectly the expansion in terms of monetary unit of production sector *i*. The application of such input – output relationship in the present study makes it possible to trace the effects of the employment and income linkages on the local community which will be discussed in the next chapter.

2.2 Review of the literature on measuring economic impacts

Many analytical tools prevail for measuring the impacts of local economic activities like production of goods and provision of services on community or village and one of which is the Social Accounting Matrix: SAM (Table 3.1), a summary table depicting the effect of one economic sector on the others and applicable for the whole country, region, province, sub-district or even a village (Taylor et al., 1999). SAM is indeed an extension of Input – Output tables by adding income which is wage, rent interest and profit, as well as household income and expenditure accounts into I – O table (Roland-Holst and Heft-Neal, 2010). Entry in an account cell of the matrix column, for example, records the purchase of factor inputs of firms that produce commodities for distribution to other economic sectors or other account cells in the matrix row like a rice mill in the column heading buying grain raw material and paying wage and energy costs to produce rice for distribution to household, restaurant, or export destinations in the row heading. SAM technique was refined for use with developing economies in 1970 and since 1980 SAMs have become in more widespread use in many countries (Sen et al., 1996). For Thailand, SAM was first adopted in 1988 (Jennifer Chung-I Li, 2002). SAMs have been applied in the cases of India, Indonesia, China, and Pakistan (Hartono and Resosudarmo, 2008; Naqvi, 1998; Shi et al., 2009; Subramanian and Qaim, 2009) to investigate the impacts of structural changes in village or community's socio-economic and environmental conditions on local income, employment, occupation, and uses of energy and other production resources. Typically, a survey is first conducted for gathering data and information on production, consumption, saving, investment, income, income distribution, and circular flow of trade, then a SAM is constructed for evaluations by such models as CGE, GAM, and GTAP to measure the impacts of any changes in the system.

The studies on the socio-economic impacts at community and Tambon levels in Thailand have gained more interests after the Institute for Sufficiency Economy Research and Promotion at Chiang Mai University undertook a study on economic planning at local community level using SEM (Sriboonchitta et al., 2009). SEM stands for Sufficiency Economy Matrix or a table for sufficiency economy planning. It is an application of SAM concepts by the inclusion of the sufficiency economy principles into the table to reflect the numerical values of the moderation, reasonableness, immunization, ethical integrity, and knowledge elements in a village economy (Wiboonpongse et al., 2009). The above study demonstrated the impacts of any activities pursued at the current period on other components of the system and thus the useful information for development of community's master plan. For example, SEM can suggest the extent of labor employment impacts on total income, value addition, income distribution, human resource development, and environmental problem alleviation. The information enables the community to make better planning and decision. The development plan formulated from SEM is also useful for policy decision makers to decide on budget allocation that can be claimed to be right, transparent, and efficient. This planning device was recommended for use in every local government like Tambon Administration Organization. However, the whole process of planning with the use of SEM demands substantial budget and lengthy time for the collection of sizeable data. Therefore, not all communities or local governments can be able to develop their plan along this line. However, SAM for planning should receive prior attention in the cases of important area or production sector that can generate positive impacts in social, economic, and environmental aspects. It thus becomes the intention of the present researcher to explore the impacts of golden brown dried longan processing community enterprises on local economy and environment of Tambon Makhue Chaea in Mueang District of Lamphun Province.

Most community enterprises are functionally related to local agricultural systems as most of their processed products use farm outputs as raw materials and thus they play vital roles in helping alleviate the problem of output glut, preserving seasonal and perishable farm produces for later consumption, creating a diversity of processed products, and keeping alive the local production and consumption traditions and cultures (Wiboonpongse, 2005). Some parts of the processed agricultural products may be set aside for home consumption, but the parts sold to local and outside markets definitely contribute to an improvement of local income and employment and eventually help reduce the extent of rural poverty. The studies on community enterprises which are small and medium sized businesses predominantly involve their problems, performance, situations as well as factors explaining their business performance, success, or failure (Koc and Bozdag, 2009; Nontakode, 2001; Sambasivan et al., 2009; Shaw, 2004; Wiboonpongse, 2005, 2006). There exists a meager extent of studies in Thailand on the impacts of community enterprises' operations on local income, employment, and environment and the only published work in this subject area is that of Wiboonponse et al. (2010) However, there are a number of international publications on similar interests and those at the macro-economic level include works of Adams(1995), Tarp (2003) Ariyasajjakorn (2009), Barron and Rello (2000), Mbaiwa (2003), Neumark et al.(2006), Psaltopoulos et al. (2010) and Taylor et al. (2005) that address the impacts of macro-economic variables on socio-economic conditions such as employment, infrastructure development, rural development, trade, wage rate, and the environment.

The impacts of SMEs at the micro level have been studied by Koc and Bozdag (2009), Kooijman-van Dijk and Clancy (2009), Obeng and Evers (2010), Shi et al. (2009) and Subramanian and Qaim (2009) in the aspects of trade, rural development policies, rural – to – town migration, the changes due to increase in off-farm income, the adoption and consequences of agricultural technologies, as well as the agricultural policy impacts on income, trade, production, employment, rural migration, and rural energy use. Those studies on policy impacts from agricultural reform or structural change in village or community socio-economic and environmental conditions on various local economic activities quite commonly used the SAM technique. To construct a SAM for impact study, development planners or researchers have to compile a comprehensive set of data on production, consumption, savings, investment, income and income distribution, and circular flow of transactions. However, there are some limitations about policy analysis in SAM framework particularly the SAM based multiplier which is often over-estimated, the rejection of error from substitution effect, the use of fixed price criterion, and the interaction between internal and external impacts (Roland-Holst and Heft-Neal, 2010). Furthermore, the SAM multiplier portrays only the economic structure and living standard but does not capture the economic behavior while the constant or fixed price principle renders no use in qualitative sense as the impact on price cannot be estimated. As a result of SAM's limitations, recent works on policy impact analysis have switched to employ Computable General Equilibrium – CGE models as analytical tool such as the works by Taylor et al. (1999), Ariyasajjakorn et al. (2009), Lu et al. (2009), Naqvi (1998), Scrimgeour et al. (2005), Wang and Chen (2006), Allan et al. (2007) and Gerard Adams (1995) because CGE models are more comprehensive and complex and allow for price variation which subsequently causes the changes in household income, expenditure, consumption as well as in local employment.

2.3 Theoretical framework for efficiency measurement

2.3.1 Economic efficiency concept

Farrell (1957) proposed a concept of production efficiency that the total economic efficiency of a producing firm comprises the components of technical efficiency: TE and allocative efficiency or cost efficiency: CE. Technical efficiency means the firm's intention to produce a single output with minimum inputs given a technological level while allocative efficiency means the decision to use inputs at appropriate proportion given input price ratio. The product of technical and allocative efficiency provides the overall economic efficiency.

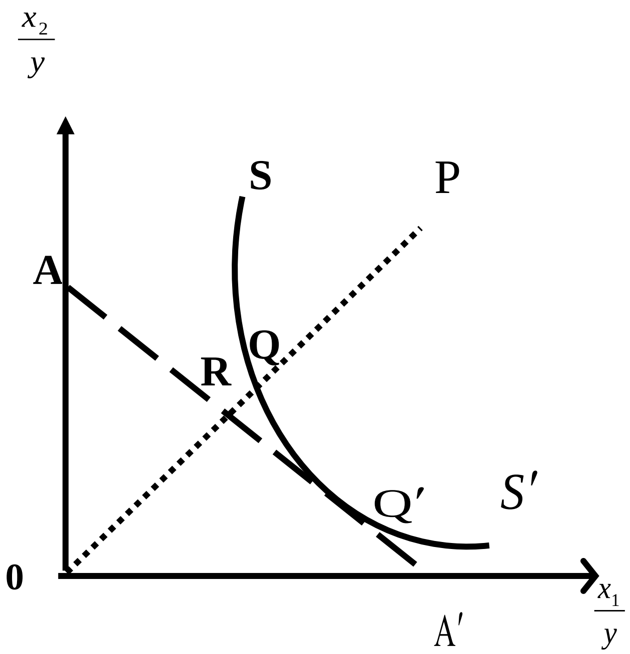

Figure 2.1 Measurements of economic, technical, and allocative efficiencies

The above figure illustrates the measurement of economic efficiency by asking how a firm can allocate its inputs to maximize output. A simple example involves a firm that uses two inputs, x_1 and x_2, to produce a single output, y, under the assumption of constant returns to scale. *SS'* is the unit isoquant: IQ of a fully efficient firm. If a given firm uses quantities of inputs at point *P* which does not lie on the efficient isoquant to produce a unit of output, the technical inefficiency of that firm can be measured by the distance *QP* which is the amount by which all inputs could be proportionally reduced without a reduction in output, or the reduction of inputs by the ratio *OQ/OP* (or 1- *QP/OP*) which is the measure of the technical efficiency of the firm. To attain technical efficiency, the firm must reduce its input combination at *P* to *Q on* the isoquant. Although the point *Q* is technically efficient, it may not give the best economic return which varies with factor prices. If the input price ratio represented by the slope of the line *AA'* is known, the allocative efficiency of the firm operating at point ***P*** can be measured by the ratio *OR/O*Q. The firm can maintain its technically efficient production while reducing production cost by producing at point *Q'* instead of point *Q*. At *Q'*, therefore, the firm is operating with both technical and allocative efficiency. Meanwhile, the economic efficiency or overall efficiency can be defined to be the ratio *OR/OP* which is also equivalent to the product of technical and allocative efficiency, *TE* x *AE = (OQ/OP* x *OR/OQ).*

2.3.2 Fundamental concepts on the measurement of efficiency

Measurement of efficiency is one of the important means for assessing the operational performance of a firm and efficiency levels can be calculated for comparison across firms. Generally, efficiency can be measured by the following simple formula:

$$Efficiency = \frac{Output}{Input} \tag{2.13}$$

The most popular concept for operational performance analysis is that of relative efficiency. The calculated efficiency of a firm will be compared to the benchmark values representing the best practice firms on the production frontier. Any firms operating below the frontier are considered relatively inefficient. The relative efficiency score is defined as:

$$\text{Relative efficiency} = \frac{\text{Weighted sum of outputs}}{\text{Weighted sum of inputs}} \qquad (2.14.1)$$

which can be expressed mathematically as:

$$\text{Relative efficiency} = \frac{\sum_{j=1}^{n} \mu_r y_{rj}}{\sum_{i=1}^{m} \omega_i x_{it}}; i = 1,\dots, m, r = 1,\dots, s,\ j = 1,\dots, n \qquad (2.14.2)$$

where x_{ij} = amount of input *i* utilized by firm *j*

y_{rj} = amount of output *r* produced by firm *j*

μ_r = weight given to output *r*

ω_i = weight given to input *i*

n = number of firms

s = quantities of outputs

m = quantities of inputs

The most popular concept for measuring relative efficiency is Farrell's frontier analysis principle which has become a foundation for many economic scholars to extend and develop further methodologies and models for efficiency study such as Data Envelopment Analysis (DEA), Stochastic Frontier Approach (SFA), Thick Frontier Approach (TFA) and Distribution Free Approach (DFA)

2.3.3 Data Envelopment Analysis (DEA) method for evaluating efficiency

DEA is a widely used technique for evaluating the operational performance of firm or organization as it requires no specification of functional form and allows for multi inputs and multi outputs consideration. Charnes et al. (1978) are the pioneering group to use the linear programming procedure for a frontier analysis of inputs and outputs and their DEA method is a non-parametric approach to efficiency study.

Banker, Charnes and Cooper (1984b) proposed a mathematical model for measuring the efficiency of n firms that utilize i inputs to produce r outputs. The efficiency of individual firm is determined by solving the following mathematical model proposed by Charnes et al. (1978) which is an input oriented approach and has the assumption of constant returns to scale: CRS:

$$\min_{i} \sum_{i=1}^{m} \omega_i x_{ij0} \tag{2.15}$$

$$\text{s.t.} \quad \sum_{j=1}^{n} \mu_i y_{rj0} = 1$$

$$\sum_{i=1}^{n} \mu_r y_{rj} - \sum_{j=1}^{m} \omega_j x_{ij} \leq 0$$

$$\mu_r, \omega_i \geq \varepsilon > 0; i = 1,\ldots,m, r = 1,\ldots,s, j = 1,\ldots,n$$

where x_{ij} = amount of input *i* utilized by firm *j*

y_{rj} = amount of output *r* produced by firm *j*

μ_r = weight given to output *r*

ω_i = weight given to input *i*

n = number of firms

s = quantities of outputs

m = quantities of inputs

ε = small positive quantities

The above model is in multiplier form of DEA. To simplify the evaluation of efficiency levels of various firms, one can use the dual problem of (2.15) presented below as an alternate formulation to find the mathematical solutions:

$$\max\theta + \varepsilon\left(\sum_{i=1}^{m} s_{ij0}^{-} + \sum_{r=1}^{s} s_{rj0}^{+}\right) \qquad (2.16)$$

$$\text{s.t.} \quad \sum_{j=1}^{n} \lambda_j x_{ij} + s_{ij0}^{-} = x_{ij0},$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - \theta y_{rj0} - s_{ij}^{+} = 0$$

$$\lambda_j, s_{ij0}^{-}, s_{ij0}^{+} \geq 0; i = 1,\ldots,m, r = 1,\ldots,s, j = 1,\ldots,n$$

$$\theta = \text{(unconstrained)}$$

The necessary and sufficient conditions for firm j_0 to be efficient are j_0 = θ^* = 1 , s_{ij0}^{-*} = s_{ij0}^{+*} = 0 which are provided by the solutions from problem optimization, and the efficiency score of the firm will be 1 or the value on the production frontier. The values of inefficient firm j_0 are determined by $x_{ij0}^{\prime}$ = x_{ij0} - s_{ij0}^{-*} and $y_{rj}^{\prime}$ = $\theta^* y_{rj0} - S_{ij0}^{+}$ where s_{ij0}^{-} is surplus input and s_{ij0}^{+} is slack output.

The above dual model has fewer constraints than its primal multiplier form and therefore the dual formulation becomes more popular for finding solutions from DEA technique. θ is the efficiency score of firm *i* to be no greater than 1; if $\theta = 1$, then the firm is operating on the frontier and is technically efficient in the concept of Farrell (1957). The above model assumes constant returns to scale which is appropriate as far as all firms or production units are operating at the optimal scale. However, firms in the imperfectly competitive market are not able to produce at the optimal scale. Banker, Charnes and Cooper (1984a) then developed a new DEA model with variable returns to scale by adding the convexity constraint into the original model to ensure that efficiency comparison is made across firms operating at the same production scale. The model was further generalized with inclusion of another constraint, $N1'\lambda \leq 1$, to allow for Non – Increasing Returns to Scale: NIRS. The most widely used form of DEA with VRS assumption now becomes as follows:

$$
\begin{aligned}
& Min_{\theta,\lambda}\theta \\
& \text{Subject to } -y_i + y\lambda \geq 0 \\
& \qquad \theta x_i - x\lambda \geq 0 \\
& \qquad N1\lambda \leq 1 \\
& \qquad \lambda \geq 0
\end{aligned}
\tag{2.17}
$$

The two tables below summarize the formulation of DEA LP models under the assumptions of constant returns to scale and variable returns to scale in input oriented and output oriented approaches.

Table 2.1 DEA models assuming constant returns to scale

Input oriented	**Output oriented**
$Min_{\theta,\lambda}\theta$ Subject to $-y_i + y\lambda \geq 0$ $\theta x_i - x\lambda \geq 0$ $\lambda \geq 0$	$Min_{\varphi,\lambda}\varphi$ Subject to $-\varphi y_i + y\lambda \geq 0$ $x_i - x\lambda \geq 0$ $\lambda \geq 0$

Table 2.2 DEA models assuming variable returns to scale

Input oriented	**Output oriented**
$Min_{\theta,\lambda}\theta$ Subject to $-y_i + y\lambda \geq 0$ $\theta x_i - x\lambda \geq 0$ $N1\lambda \leq 1$ $\lambda \geq 0$	$Min_{\varphi,\lambda}\varphi$ Subject to $-\varphi y_i + y\lambda \geq 0$ $x_i - x\lambda \geq 0$ $N1\lambda \leq 1$ $\lambda \geq 0$

Measuring technical efficiency under VRS assumption is more realistic in the imperfectly competitive input and/or output markets in which some firms are unable to produce at optimal scale. Meanwhile, the CRS assumption implies all firms are operating at optimal scale and thus the technical efficiency (TE_{crs}) is to be decomposed into two components, scale efficiency (SE) and pure technical efficiency (TE_{vrs}), to help explain the inefficiency of firms as due to the business size. Therefore, firms not operating at optimal scale will get different scores for TE_{CRS} and TE_{VRS} and the scale efficiency is measured by TE_{CRS}/TE_{VRS} as depicted in figure 2.2 for the case of one input and one output.

$$TE_{CRS} = AP_c / AP$$

$$TE_{VRS} = AP_V / AP$$

$$SE = AP_C / AP_V \text{ ซึ่งก็คือ } TE_{CRS} / TE_{VRS}$$

The scores of TE_{CRS}, TE_{VRS} and SE range between 0 and 1. From the above three equations, we can find that $TE_{CRS} = TE_{VRS} \times SE$. Therefore, the overall technical efficiency under CRS assumption comprises two exclusive and non – additive components of pure technical efficiency and scale efficiency.

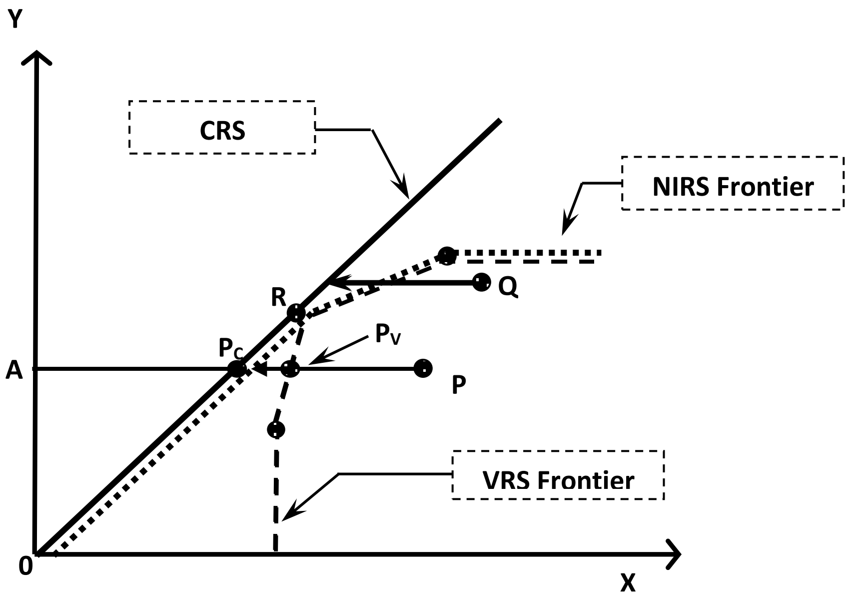

Figure 2.2 Graphic illustration on measuring scale efficiency

Furthermore, the VRS DEA model presented above can indicate whether a particular firm is operating at the stage of increasing returns to scale: IRS or decreasing returns to scale: DRS. With the addition of $N1\lambda \leq 1$ constraint, the model also allows for efficiency evaluation at Non – increasing Returns to Scale: NIRS stage.

Therefore, if $TE_{NIRS} = TE_{VRS}$ or $TE_{NIRS} \neq TE_{CRS}$ for a particular firm, it means this firm is in decreasing returns to scale stage.

If $TE_{NIRS} \neq TE_{VRS}$ หรือ $TE_{NIRS} = TE_{CRS}$ for a particular firm, it means this firm is in increasing returns to scale stage.

The measurements of cost efficiency and allocative efficiency are based on the estimated production cost frontier which represents the minimum cost curve. The mathematical formulation of a model for determining the cost efficiency under the variable returns to scale assumption can be expressed as follows:

$$Min_{\lambda,x_i} - w_i^t x_i^* \tag{2.18}$$

$$\text{Subject to} \quad -y_i^* + y\lambda \geq 0$$

$$-x_i x\lambda \geq 0$$

$$N1\lambda \leq 1$$

$$\lambda \geq 0$$

where w_i^t is price of input

x_i^* is vector of optimal input quantity at least cost level.

The above model has the objective to find the least cost position through linear programming method and to solve for the optimal input quantities, given the prices of input $\left(w_i^t\right)$ and the output quantities (x_i^*). The total cost efficiency: CE of firm i can be measured by

$$CE = w_i^t x_i^* / w_i^t x_i \tag{2.19}$$

and allocative efficiency: AE can be found from the equation below:

$$AE = CE / TE \tag{2.20}$$

DEA can also be used for income study by determining the optimal output quantities which provide maximum revenue, given output prices $\left(p_i^t\right)$ and input quantities (x). The mathematical model for evaluating revenue efficiency under variable returns to scale assumption can be expressed as follows:

$$Min_{\lambda, y_i} \text{ - } p_i^t y_i^* \tag{2.21}$$

Subject to $-y_i + y\lambda \geq 0$

$$x_i^* - x\lambda \geq 0$$

$$N1\lambda \leq 1$$

$$\lambda \geq 0$$

Where p_i^t is output price

y_i^* is a vector of optimal input quantities providing maximum revenue

Similarly, the revenue efficiency of firm i can be measured by

$$RE = p_i^t y_i^* / p_i^t y_i \tag{2.22}$$

and the allocative efficiency can be found from the equation below:

$$AE = RE / TE \tag{2.23}$$

2.3.4 Measuring technical efficiencies by meta-frontier approach

Meta-frontier is a means to indicate the comparative performance of individual firm with reference to benchmarks or the best practice input combinations on the overall production frontier and thus individual frontiers lie below it. In other words, all firms under study are relatively inefficient in terms of DEA. It is constructed by solving a linear programming problem covering the input – output data of various firms. Any firms locating on the frontier will be the most efficient. Specifically, the DEA method for meta-frontier construction uses input and output information of all decision making units: DMUs in the group. Assuming there are k groups of producers with different technologies and each group contains L_k producers, the linear programming problem with constant returns to scale assumption for solving for the input – oriented DEA frontier becomes

$$
\begin{aligned}
&Min_{\theta,\lambda}\theta \\
\text{s.t.}\quad & -y_i + y_k\lambda \geq 0, \\
& \theta x_i - x_k\lambda \geq 0, \\
& N1\lambda \leq 1 \text{ and} \\
& \lambda \geq 0 .
\end{aligned}
\tag{2.24}
$$

Where

y_i = M×1 vector of output of producer *i*

x_i = N ×1 vector of input of producer *i*

y_k = M×L_k matrix of output of producers L_k

x_k = N×L_k matrix of input of producers L_k

$N1$ = L_k×1 vector of 1

λ = L_k×1 vector of weight given to producer *i* and

θ = scalar matrix

θ from solving the linear program in (2.24) will have the value less than 1. It measures the extent of possible input reduction without affecting the output level of firm *i*, and therefore it is a measurement of technical efficiency in the input – oriented approach.

Construction of a meta-frontier

A meta-technology set contains all input – output combinations that are technologically feasible, to be defined as:

$$T=\{(x.y) : x \geq 0; y \geq 0; x \text{ can produce } y\} \quad (2.25)$$

Associated with this meta-technology set are input and output sets. An example of the output set defined by any input vector x can be expressed as follows:

$$L(y) = \{x: (x,y) \in T\} \quad (2.26)$$

The above expression represents the boundary of the input set of the meta-frontier with the assumption that the input set satisfies the standard regularity properties (O'Donnell, 2008). Consequently, an input meta-frontier function or meta-distance function can be defined as:

$$D(x,y) = \sup_{\lambda} \{ \lambda > 0 : (x/\lambda \in L(y)\} \quad (2.27)$$

This function gives the minimum level of input use which is possible for a firm, given its fixed output vector. A firm operating at (x,y) is considered technically efficient with respect to the meta-frontier if and only if D (x,y) =1. The meta-frontier can be constructed by first using DEA technique to find the group frontiers, $L=\sum_{i=1}^{k}$ L_k of the k group and then solving the linear programming optimization problem for all groups as defined by the model below:

$$Min_{\theta^*,\lambda^*} \theta^*$$

$$\text{s.t.} \quad -y_i + y^* \lambda^* \geq 0,$$

$$\theta^* x_i - x^* \lambda^* \geq 0,$$

$$N1\lambda^* \leq 1 \text{ and}$$

$$\lambda^* \geq 0. \tag{2.28}$$

where

y_i = M×1 vector of output quantities for the producer *i*

x_i = N ×1 vector of input quantities for the producer *i*

y^* = M×L matrix of output quantities for all the producers *L*

x^* = N×L matrix of input quantities for all the producers *L*

N1= L×1 vector of 1

λ^* = L×1 vector of weight given to producer *i* and

θ^*= scalar matrix

Group frontiers

A population of firms can be divided into k groups according to group – specific technologies governed by the differences in resource, environment, and other constraints. The feasible output-input combinations of firms in a group-specific technology set can be written as follows:

T^k = {(x.y): x ≥ 0; y ≥ 0; x can be used by firms in group k to produce y} (2.29)

The k group-specific technologies can also be expressed in terms of group-specific output sets and output distance functions:

L^k (y) = {x: (x,y) $\in$ T^k }, k=1,2,…,K; and (2.30)

D^k (x,y) = $\sup_\lambda$ { λ >0 : (x/ λ $\in$ L^k (y)}, k=1,2,…,K. (2.31)

The boundaries of the group-specific output sets therefore give the group frontiers. If the output sets, L^k (y), k=1, 2,…,K, satisfy the standard regularity properties, then the distance functions, D^k (x,y), k=1,2,…,K, also do. Therefore, it can be concluded that:

1) If $(x, y) \in T^k$ for any k, then $(x, y) \in T$

2) If $(x, y) \in T$ then $(x, y) \in T^{k}$ for some k

3) $T = \{T \cup T^{2} \cup ... T^{k}\}$

4) $D^{k}(x, y) \geq D(x, y)$ for all k=1,2,…,K.

Technical efficiencies and meta-technology ratios

Generally, an input-oriented measure of technical efficiency of an input-output pair with respect to the meta-technology is:

$$T(x, y) = D(x, y) \tag{2.32}$$

and we can also measure an input-oriented technical efficiency with respect to the group k technology from:

$$T^{k}(X, Y) = \frac{1}{\mathrm{D}^{k}\ (\mathrm{x, y})} \tag{2.33}$$

It is clear from 4) above that the group k distance function, group-k, $D^{k}(x, y)$, can take the value no less than the meta-distance function, $D(x, y)$. This means the meta-frontier envelops the group frontier. We can then obtain the meta-technology ratio (O'Donnell, 2008) (Battese et al., 2004) or technology gap ratio (Battese et al., 2004) from the following definition:

$$MTR^{k}(X, y) = \frac{\mathrm{D(x, y)}}{\mathrm{D}^{k}(\mathrm{x, y})} = \frac{T(x, y)}{T^{k}(x, y)} = \frac{\mathrm{T(x, y)}}{\mathrm{T}^{k}(\mathrm{x, y})} \tag{2.34}$$

From (2.32), technical efficiency of a particular input-output combination can be rewritten as:

$$T(x, y) = T^{k}(x, y) \times MTR^{k}(x, y) \tag{2.35}$$

2.4 Review of the literature on the analysis of production efficiency

Efficiency concept was first proposed by Farrell (1957) to analyze economic efficiency: CE which can be decomposed into two components including technical efficiency: TE to measure firm's ability to maximize output given the available inputs, and allocative (or price) efficiency: AE to measure firm's ability to use appropriate input combinations given the input prices. The efficiency study by DEA approach was applied by Battese (1992) to analyze technical efficiencies in agricultural production but the DEA technique assumes homogenous technology making the results not comparable across technologies (Battese et al., 2004). Meta-frontier approach was thus developed for efficiency analysis in the case that technological heterogeneity exists. Efficiency analysis based on production frontier can be performed by two popular approaches: 1) Stochastic Frontier Analysis (SFA) such as in the works of Battese (2004; Battese, 2002), Azadeh et al.,(2009), Thiam et al.,(2001), R. Villano (2010), Dong-hyun (2010), Yi-Ju Huang (2010) and Lee and Hwang (2011); 2) Data Envelopment Analysis (DEA) such as in the works of Sala-Garrido et al. (2011), Liou and Wu (2011), Portela and Thanassoulis (2010), Kontolaimou and Tsekouras (2010), Tiedemann (2011) and Assaf et al.(2010). DEA has been widely applied because it is a non-parametric approach. As meta-technology is the abstraction of all technologies in reality, the meta-frontier analysis thus allows for comparison across technologies (Battese et al., 2004; Battese, 2002). Meta-frontier concepts and functions have been widely applied for studies in various fields and industries including agriculture (Battese and Tessema, 1993; Chen and Song, 2008; R. Villano, 2010; Thiam et al., 2001), football (Torben Tiedemann, 2011), banking business (Bos and Kool, 2006; Kontolaimou and Tsekouras, 2010), hotel business

(Assaf et al., 2010), communications (Lee and Hwang, 2011), energy and environment (Dong-hyun, 2010; Kounetas et al., 2011; Liou and Wu, 2011; Sala-Garrido et al., 2011), electricity (Yi-Ju Huang, 2010), and manufacturing business (Battese et al., 2004; Kounetas et al., 2009; O'Donnell. , 2008). Meta- frontiers can be estimated for comparative or relative efficiency study at national level like in the work of O'Donnell (2008) as well as at regional level like the study by Battese (2004) that estimated the technical efficiencies and technology gaps of garment production firms in 5 different regions of Indonesia. Chen and Song (2008) used meta-frontier approach to study efficiency and technology gap in China's agriculture while Kontolaimou (2010) used it for comparing the efficiencies of banks in European countries. Sala-Garrido et al.(2011) estimated a DEA meta-frontier model for comparing the efficiencies of four different wastewater treatment technologies.

Villano (2010), however, conducted a study to test whether meta-frontier analysis was appropriate for estimating the varietal effect on technical efficiency of three different pistachio varieties in Iran and found very slight differences in technical efficiency among the three varieties. This is because the study did not take into account the production constraints presenting beyond the capability of the pistachio growers to improve their efficiencies and adopt better technology. The findings also led to the notion that it would be misleading to compare the varietal performances solely on the yield criteria. In the present study, as the dried longan processors adopted improved ovens or changed to another production technology, measurement of technical efficiency will not be made solely in terms of yield per oven but extended to cover the efficiencies in fuel consumption, raw material input as well as labor usage. No constraining factors are presumably likely to exist to prevent the processors from adopting new technology because the cost for oven modifications is relatively low compared to the overall business investment. The DEA model applied in the present study takes the form of variable returns to scale (VRS) developed by Banker, Charnes and Cooper (1984b) because the alternative constant returns to scale (CRS) form has the limitation from the inability to separate technical efficiency from scale efficiency (Coelli, 1998); therefore, the use of VRS DEA model can avoid the problem of compounding effect (Chaovanapoonphol et al., 2009).

In a nut shell, the theory underlying the evaluation of economic impacts is Walras' principle in General Equilibrium theory. A Social Accounting Matrix or SAM is to be constructed to obtain organized data sets for processing in Computable General Equilibrium (CGE) model. SAM is adopted because the CGE model has the assumption that firms maximize profit given prices and quantities of input and output. The Sufficiency Economic Matrix or SEM is not utilized for the present investigation due to its inherent objective to strive for sufficiency economy development by analyzing the extent of practices according to the principles of moderation, reasonableness, immunization, as well as knowledge and morality in the Sufficiency Economy Philosophy. DEA meta-frontier function will be used for estimating the difference in efficiency among processors in different technological groups in this study because it is a non-parametric technique and thus is relatively less complicated in the analysis.