CHAPTER III

RESEARCH METHODS

This section focuses on describing methodology of the study. Conceptual framework, sampling technique, data collection, data analysis, and theoretical framework of the stochastic frontier analysis are presented in detail.

3.1 Conceptual framework

Litchi is a perennial crop and is one of the most environmentally sensitive fruit trees, so it has the characteristics that are different from the annual crop. To consider the factors influencing litchi yield of the individual farm, they can be classified into three groups: 1) Effects of the production environment on the location of farm, 2) Characteristics of litchi orchard that the farm holding that show the litchi orchard status as the number of trees or tree density, average tree age, irregular bearing, etc. that form the differences of litchi yield among the farms, 3) Cultivation practices that reflect ability of each farmer in litchi orchard management through the awareness of litchi cultivation techniques, input utilization, etc. The characteristics of production environment, orchard property and cultivation practices created differences in individual litchi yield and technical efficiency among the farms are modeled (Figure 3).

Once we have records of the selected litchi farms that were randomly sampled given the selected criteria representing the whole population, we can obtain a production function for litchi in the region. A stochastic frontier production function for litchi in the region can be estimated using the maximum likelihood estimation method, so that it presents the potential outputs from different set of inputs. From the coefficients of the stochastic frontier estimated, we can make an evaluation of the factors influencing litchi yield in terms of production aspect as well as market aspect.

The difference between the actual output and frontier output of each farm can be addressed as the technical inefficiency index. The causes of technical inefficiency are later on defined by its determinants that related to the characteristics of the farms and the quality of human resources.

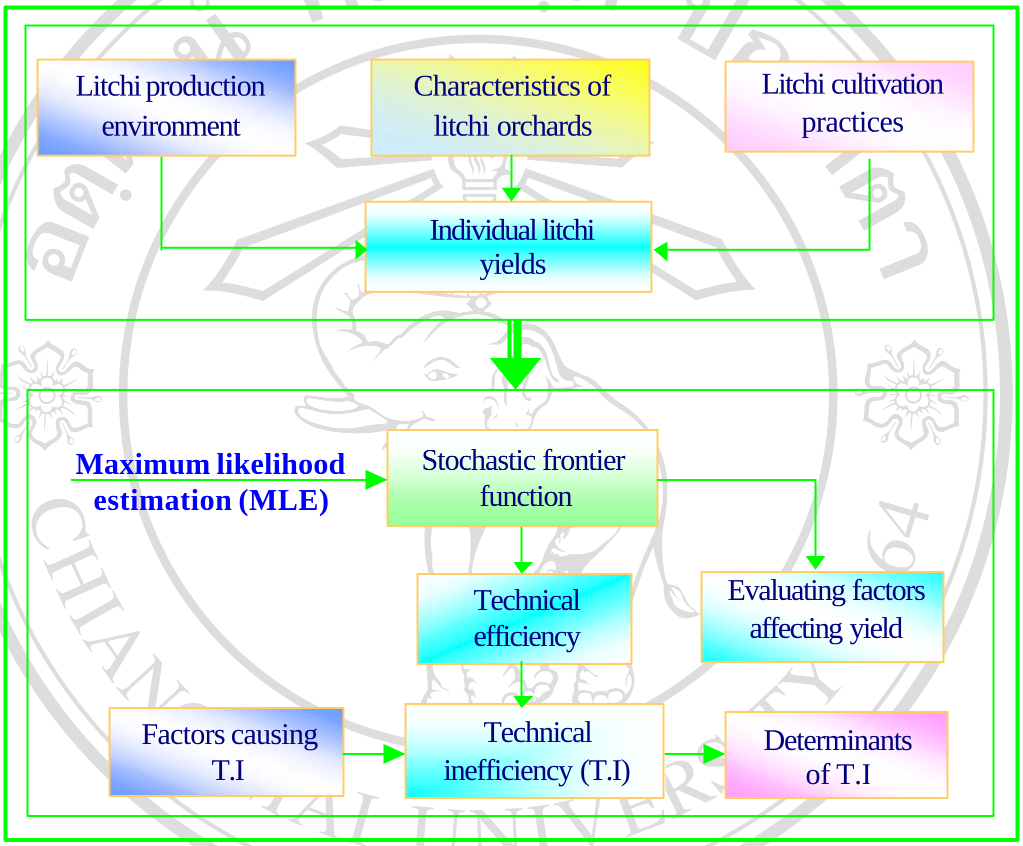

Figure 3 Conceptual frameworks of the factors influencing litchi productivity

3.2 Scope of the study

The study focused on the litchi farmers in Bacgiang province, northern Vietnam. Cross-sectional data and information of litchi production in crop year 2002 were collected, after farmers had harvested, based on the memory recall of the respondents. This crop was considered as a year of normal production condition due to no severe disease and no bad climate condition. Ideally, if the data for this study were time series to observe variations in the production trends then the making conclusion would be more meaningful. Therefore, such data were not available, the findings might partly have limitation.

3.3 Site selection

Bacgiang province consists of 10 districts, namely Lucngan, Lucnam, Langgiang, Sondong, Yenthe, Hiephoa, Yendung, Vietyen, Tanyen and Bacgiang town (Figure 4).

Lucngan district is known as a big center of litchi production in Vietnam, its gross output share occupied about 90 percent of the provincial litchi output, and its planted area accounted for 30 percent of that of the province in 2000. Lucngan also converges the topographical features of its province such as lowland, hills and mountains. Therefore, the field survey focused on litchi farmers in Lucngan as the representatives of litchi producers in Bacgiang province. Beside that, litchi trees have been expanding to other districts such as Lucnam, Yenthe, Sondong, but their yields were low due to young trees and limited suitable land for growing litchi.

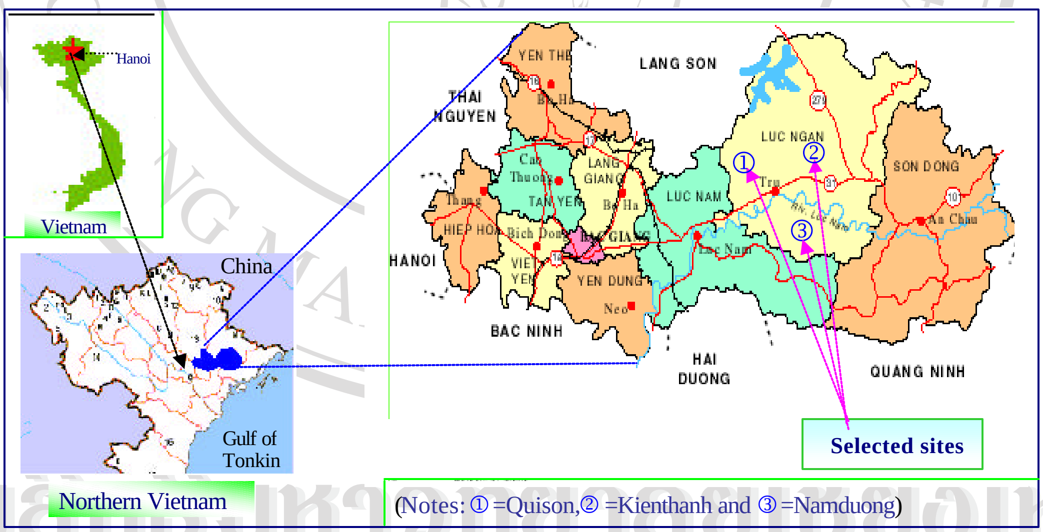

Figure 4 Map of Bacgiang Province

The survey was conducted in Lucngan during Oct.-Nov., 2002. Majority of the information was collected from the interviews with a total of eighty (80) interviewees at three representative communes, namely Kienthanh (30), Namduong (27), and Quison (23). These communes covered the features of sampling for the study area such as ethnic minority and majority groups, different soil type structures and other characteristics. Commonly, litchi was grown in the two basic soil types such as ferralitic soil and old alluvial soil in Lucngan district in particular, and in Bacgiang province in general (Dan *et al.*, 2002). Therefore, Quison and Kienthanh represented the ferraritic soil sites, whilst Namduong was selected as a site of the old alluvial soil located in the left bank of Lucnam river (Figure 4).

3.4 Data collection

Field survey focused on understanding the litchi production system in the study area in order to identify factors affecting litchi production and to evaluate their effects on litchi productivity via the stochastic frontier approach. Data sources include secondary data, and data from the litchi farm survey in the study area.

3.4.1 Primary data

The structured questionnaire was designed and pre-tested before conducting the formal survey in order to get adequate data and to omit ambiguous data. A random sample of 80 litchi farms was selected for the interview. Criteria for the feld survey included as follows:

1. General information of the household such as age, ethnic, education attainment and farming experience of household heads, family size, etc.

2. Characteristics of litchi orchard such as farm size, tree density, tree's age distribution, proportion of irregular bearing, productivity and yield,

3. Cultivation practices such as breaking up the earth, pruning, fertilizing, irrigation, spray and harvesting that relate to utilization levels of inputs, labor and capital,

4. Economic aspects in litchi production such as litchi fruit consumption, inputs and output prices, and additional information of agricultural production performances and off-farm income activities, access to credit program and new advances, etc.

In addition, informal surveys were conducted with key informants with special questionnaire for specific purposes, including local leaders and experts on litchi production fields. A number of experienced people in litchi research also gave valuable information to this study.

3.4.2 Secondary data

To be aware of the factors affecting litchi production and evaluating their effects on litchi productivity via the stochastic frontier function approach in the study area, a number of relevant publications were reviewed. Researches on litchi cultivation, quantitative studies on orchards, annual reports, and the data on biophysical, socio-economic and demographic characteristics of the study area were also gathered from various sources. The data and information came from the following sources: statistical yearbook, statistical data of the district and province, Bacgiang Department of Agriculture and Rural Development, Lucngan Agricultural and Land Management Office, websites of related institutions

3.4.3 Data analysis

Descriptive method was employed to explain the production litchi system, cultivation practices and input utilization including simple statistics i.e. mean, minimum, maximum, standard deviation, first quartile and third quartile.

Quantitative methods were applied for evaluation of the factors influencing litchi yield and technical inefficiency, and for analysis of input utilization efficiency based on the stochastic frontier function analysis as presented in the next section.

Data gathered from field survey were entered and then synthesized using the EXCEL in order to calculate the indicators and make descriptive statistics for litchi production system. The advanced analyses for evaluating the factors influencing litchi productivity was done by using some econometric packages such as LIMDEP 7.0 and

FRONTIER 4.1 to test data and estimate frontier production function and technical efficiency.

3.5 Theoretical framework

3.5.1 Production functional form

Production function describes the technical relationship between the inputs and outputs of a production process (Coelli *et al.*, 2001). It is a meaningful instrument of representing production technology and is a basic approach for productivity measurement.

A production function, in agriculture generally is a bio-physical concept which indicates the relationship between the physical quantities of a crop grown and the set of inputs used to produce the crop under consideration (Ozsabuncuoglu, 1998). In other words, $Y = f(X_1, X_2, \ldots, X_n)$

Where, Y is the physical amount of the crop and X_i is quantities of respective inputs consumed to produce a given amount of product.

The development of production functions is very important, particularly in agricultural sector because agricultural production depends significantly on climatic and environmental factors. There are many numerous input-output relationships in agriculture because the rate at which inputs are transformed into outputs will vary among soil types, animals, technologies, rainfall amounts, and so forth. Any given input-output relationship specifies the quantities and qualities of resources needed to produce a particular product (Doll and Orazem, 1978). In mathematical form, general production function form can be written as follows:

$$Y_{jt} = f(X_{ij}, \beta_i) \exp(\varepsilon_j) \qquad (3)$$

where, Y_{jt} = output level of farm j,

X_{ijt} = input i used by farm j,

β_i = vectors of parameters to be estimated,

ε_j = error term

exp = exponential term (basis of natural logarithm)

There are two basic types of production function form that have been used widely in the studies and researches on the stochastic frontier analysis that are Cobb-Douglas and translog functions.

Translog production function is the most popular flexible function form in applied research since the translog form imposes no restrictions upon returns to scale or substitution possibilities. However, it also has the drawback of being susceptible to multicollinearity and degrees of freedom problems because there are too many interactions among the pair of variables. The general form can be written as,

$$Y = \alpha + \Sigma\beta_i \ln X_i + 1/2\Sigma_i\Sigma_j\delta_{ij} (\ln X_i)(\ln X_j) + \Sigma\gamma_i D_i + U \qquad (4)$$

where, $X_{i,} X_j$ = inputs,

α = constant term,

β_i, δ_{ij} , γ_i = parameters to be estimated

D_i = dummy variables,

U = error term.

The Cobb-Douglas functional form has been commonly used in the empirical estimation of frontier models and its simplicity is a very attractive feature. A logarithmic transformation provides a model, which is linear in the logarithms of the inputs and output, hence, the Cobb-Douglas form is easy to estimate and interpret. However, it also has a number of restrictive properties such as unitary elasticities of substitution, constant input elasticities and returns to scale for all firms in the sample. The general Cobb-Douglas functional form is defined as follows:

$$LnY_{jt} = \alpha_0 + \Sigma\alpha_{ij} \ln X_{ij} + \Sigma\theta_{kj} D_{kj} + \varepsilon_j \qquad (5)$$

where, Y_j = output level obtained by farm j,

X_{ij} = input i used by farm j,

ε_j - error terms,

α_i , θ_k = parameters to be estimated, α_0 = constant term,

D_k = dummy variables,

$\Sigma\alpha_i$ is returns to scale parameter; α_i = partial elasticity of input X_i,

A number of studies have estimated both the Cobb-Douglas and the translog functional forms and then tested null hypothesis that the Cobb-Douglas form is an adequate representation of the data, given the specifications of the translog form. In this study, the Cobb-Douglas production function form was employed to consider the effects of the factors on litchi yield, and some basic theories of economics were applied for production economic analysis as stated below

Factor elasticity or partial elasticity of production (E_i): Output elasticity of input X_i, denoted by E_i, is defined as the proportionate rate of change of output Y with respect to X_i (Henderson and Quandt, 1988). It shows the degree of flexibility of an output's production level as a response to the variation in input-i. Output elasticity can be calculated as follows:

$$E_i = \frac{\text{\% change in output (Y)}}{\text{\% change in input (X)}} = \frac{\delta Y/\delta X_i}{Y/X_i} = \frac{MPP_{Xi}}{APP_{Xi}} \qquad (6)$$

where, MPP= marginal physical product, APP= average physical product

Profit maximization: to maximize profit, the allocation of each input follows the principle of marginal value of product (MVP) of each input must equal its price:

$VMP_{Xi} = P_{Xi}$ (where, P_{Xi} = price of input i)

3.5.2 Stochastic frontier production function

The terms, productivity and efficiency, have been used frequently in the media for over the last ten years by a variety of commentators. They are often used interchangeably, but this is unfortunate because they are not precisely the same things. The distinction between the terms can be illustrated by a production frontier, which may be used to define the relationship between input and output. The production frontier represents the maximum output attainable from each input level. Hence it reflects the current state of technology in the industry. Firms operate either on that frontier, if they are technically efficient, or beneath the frontier, if they are not technically efficient (Coelli *et al.*, 2001).

The parameters of the stochastic frontier production function in Eq.(7), as defined in Eq.(2), can be estimated using the maximum likelihood function of Y_i. The method is estimated by the density function of ε as follows (Aigner *et al.*, 1977):

$$Y = f(X_i, \beta)\exp(V_i - U_i) \quad i=1,2\ldots N \qquad (7)$$

$$f(\varepsilon) = 2\delta^{-1}\phi^*(\varepsilon/\delta_\varepsilon)\,[1-\Phi^*(\varepsilon\lambda\delta_\varepsilon^{-1})] \qquad (8)$$

where, $\varepsilon = V_i - U_i$, $-\infty < \varepsilon < +\infty$

$\delta_\varepsilon = \sqrt{(\delta_v^2 + \delta_u^2)}$

$\lambda = \delta_u / \delta_v$

exp = exponential term (basis of natural logarithm)

$\phi^*(.)$ is the standard normal density function, $\Phi^*(.)$ is standard normal distribution function, estimated at ε/δ^* and $\varepsilon\lambda\delta^{-1}$, respectively.

The stochastic version of the output-oriented technical efficiency measure of an individual farm is given by the following expression

$$TE_i = Y_i / Y^* = f(X_i, \beta)\exp(V_i - U_i) \,/\, f(X_i, \beta)\exp(V_i) = \exp(-U_i) \qquad (9)$$

Since $U_i \geq 0$; $0 \leq \exp\{-U_i\} \leq 1$

The term U is assumed to be a one sided-nonnegative random error term and independently and identically distributed as $N^+(\mu, \sigma_u^2)$, reflecting technical inefficiency with mean μ and variance σ_u^2. Therefore, to estimate U for each observation derived from the conditional distribution of U, given (ε = V- U), with a normal distribution for V and a half normal distribution for U, the method used for estimating mean of technical efficiency (Jondrow *et al.*, 1982) for each farm is as follows:

$$E(u_j/\varepsilon_j) = \frac{\delta_u.\delta_v}{\delta_\varepsilon} * \left[\frac{\phi(.)}{1-\Phi(.)} - \varepsilon\frac{\lambda}{\delta_\varepsilon}\right] \qquad (10)$$

Where, Y_i is scalar output of producer i, X_i is a vector of N inputs used by producer i, $f(x_i, \beta)$ is the production frontier, and β is a vector of technology parameters to be estimated.

We assume that in order to produce a single output, N inputs used are available for each producer. Technical efficiency is defined as a ratio of observed output to maximum feasible output. The frontier output Y^* can either exceed or be less than deterministic output Y_i, depending upon the values of random error V_i as illustrated in Figure 5.

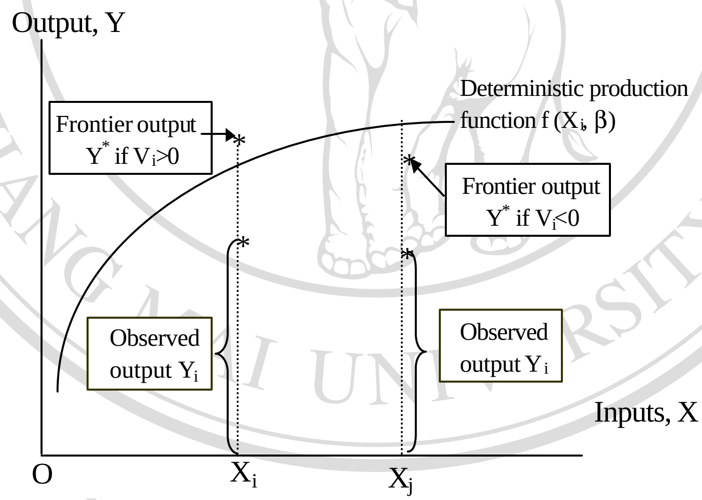

Figure 5 Stochastic frontier production function (Battese, 1992)

3.5.3 Technical efficiency

Technical efficiency reflects the ability of a decision-making unit to produce maximum output given a set of inputs and technology. According to Farrell (1957), technical efficiency is one component of economic efficiency where the latter is defined as the product of technical efficiency and allocative efficiency. In turn, allocative efficiency refers to ability to produce a given level of output using cost minimizing input ratios.

Many studies have shown that a firm or an industry could not fully obtain technical efficiency due to inadequate information, insufficient technical skills, and untimely input supply (Chinh, 2002). Estimates on extent of inefficiency can also help the policy makers decide whether to improve efficiency or develop new technologies to raise agricultural productivity in case the industry is fully efficient.

To express technical efficiency, the best way is to provide a functional characterization of the boundary of the graph of production technology. Since the boundary represents the maximum output that can be obtained from any given input vector or the minimum input usage required to produce any given output vector, it represents another standard against which to measure technical efficiency of production. From the input-oriented aspect which uses two inputs (X_1 and X_2) to produce a single output (Y), under assumption of constant returns to scale, the basic model to measure efficiency is illustrated in Figure 6. The I.I' represents a unit isoquant. Every point lies on this curve showing the combinations of two inputs used to produce one unit of output, and using less inputs than other points lying on the northeast of I.I' to produce one unit of output. In other words, the curve I.I' denotes the various combinations of inputs that the efficient firms might use to produce one unit of output. The points lying to northeast of the I.I' curve are inefficient since they use more resources than the points lying on this curve.

If a given firm uses quantities of inputs, defined by the point P, to produce a unit of output, technical inefficiency of the firm could be presented by the distance QP, which is the amount by which all inputs could be proportionally reduced without any reduction in output. This is often expressed in percentage terms by the ratio of QP/OP, which represents the percentage by which all inputs need to be reduced to achieve a technically efficient production. Technical efficiency (TE) is then measured as

$$TE = OQ/OP = 1\text{-}QP/OP. \quad (11)$$

The allocative efficiency (or price efficiency) represents the ability of farmers to achieve the maximum profit from the application of conventional inputs with a given set of firm specific input and output prices and a given technology.

Since the distance, RQ represents the reduction in production costs that could obtain at the allocatively efficient point Q', instead of at the technically efficient but allocatively inefficient point Q. The BB' is a minimum isocost line that could produce the I.I' isoquant. The causes of allcative inefficiency can be considered as inadequate information, different risk effects of inputs and capital, institutional constraints, and interdependence of production and consumption (Song, 1997).

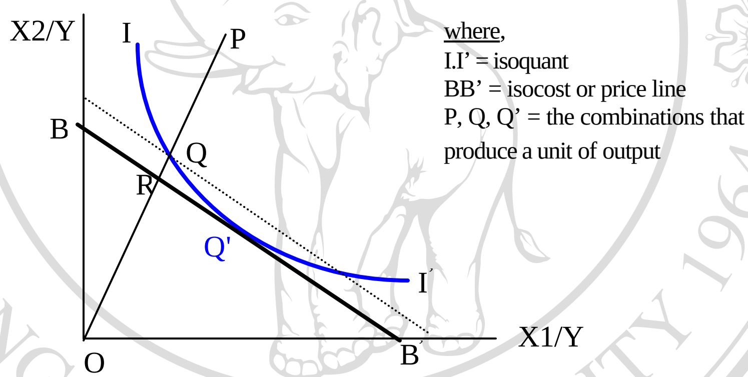

Figure 6 Technical and allocative efficiencies (Farrell, 1957)

Allocative efficiency obtains if and only if the marginal physical product (MPP_{xi}) of input X_i equals the ratio of input price to output price (P_{xi} / P_y). In Figure 6, point Q' is the allocatively efficient point because at this point, the isoquant curve I.I' tangents the isocost line BB'. According to economic theory, point Q' is optimal point due to it's minimum cost.

The economic efficiency (EE) is defined as an overall efficiency of technical and allocative efficiency (OQ/OP $\times$ OR/OQ =OR/OP). The firm using input combination P is both technically and price efficient. The firm using input combination Q is technically efficient but price inefficient. Only the firm which uses input combination Q' is both technically price efficient.

To understand the whole picture of the frontier production function, we can express a full production surface via the graphical approach as shown in Figure 7 (based on Doll and Orazem, 1978). Thus, many output levels can be found from the production function surface. From a given level of output that is produced from the combinations of inputs, we can draw an isoquant by projecting those combinations on a plane.

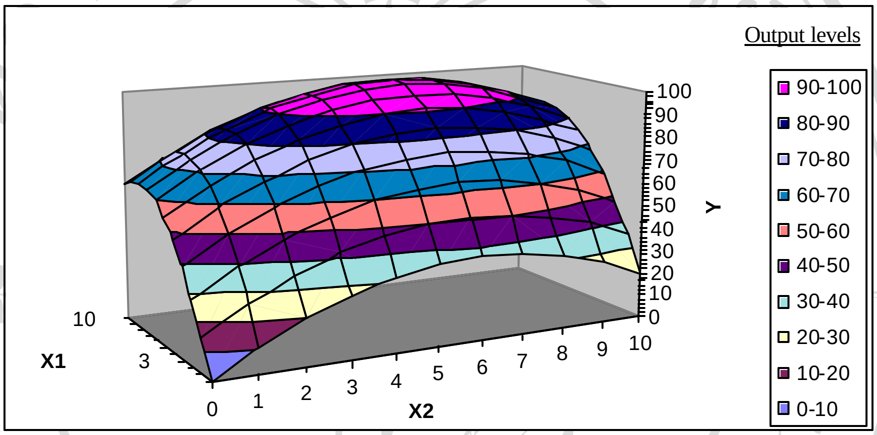

Figure 7 Frontier production function surface

From the output-oriented aspect, in the case of single input and output, the basic model used to measure efficiency is shown by the Figure 8. The curve Y_{MLE} shows the maximum possible output that can be obtained given a vector of inputs and technology. All points lying below Y_{MLE} curve are technically inefficient. All points on Y_{MLE} curve are technically efficient. If a farmer utilizes level X_2 of input and attains level Y_2 of output in a technically efficient response but at this level he has not achieved allocative efficiency yet. The other farmer uses level X_1 of input and gains level Y_1 of output (point M). He achieves both technical and allocative efficiencies since M is the optimal point.

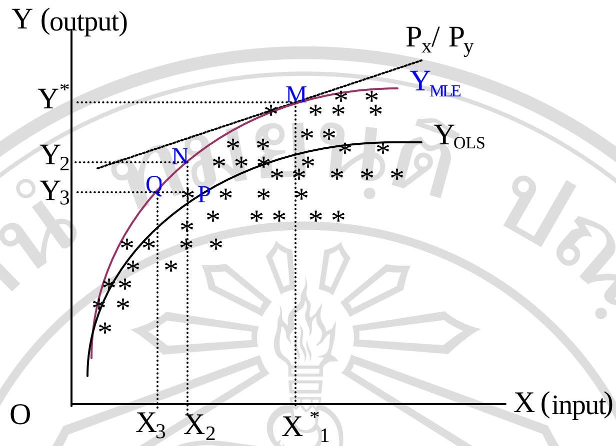

Figure 8 Output-Oriented Productive Efficiency Measures

Notes: Y_{MLE} = maximum possible output

Y_{OLS} = average output

P_x = price of input X

P_y = price of output Y

(*) = actual outputs

Thus technical efficiency is defined as the ratio of output to the technically maximum possible output given a vector of inputs and technology.

Technical efficiency: $TE = Y_3/Y_2$

Allocative efficiency: $AE = Y_2/Y_1$

Economic efficiency: $EE = TE \times AE = Y_3/Y_1$