CHAPTER II

LITTERATURE REVIEW

Measurement of efficiency of economic activity is an attempt to assess the performance of industries or individual firms in using real resources to produce goods and services. The requirement of technical efficiency is that the maximum possible amount is produced with the resources used; or to put it another way, it must be impossible to reduce the volume of any input without reducing the volume of output. Assuming that a deviation from optimum is possible in real production, an efficiency measure should reflect the difference between actual performance and potential performance.

2.1 Conceptual efficiency

Farrell (1957) proposed that the efficiency of a firm consists of two components: technical efficiency, which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices and the production technology. These two measures are combined to provide a measure of total economic efficiency. This study concerns only technical efficiency.

Farrell illustrated his idea using a simple example involving a firm, which uses two inputs (x1 and x2) to produce a single output (y), under the assumption of constant returns to scale. The unit isoquant of fully efficient firms, represented by SS' in Figure 2.1, permits the measurement of technical efficiency. The technical efficiency (TE) of the firm is most commonly measured by the ratio

$$TEi = 0Q/0P \qquad (1)$$

which is equal to one minus QP/0P. It will take a value between zero and one, and hence provides an indicator of the degree of technical inefficiency of the firm. A value of one indicates the firm is fully technically efficient. For example, the point Q is technically efficient because it lies on the efficient isoquant.

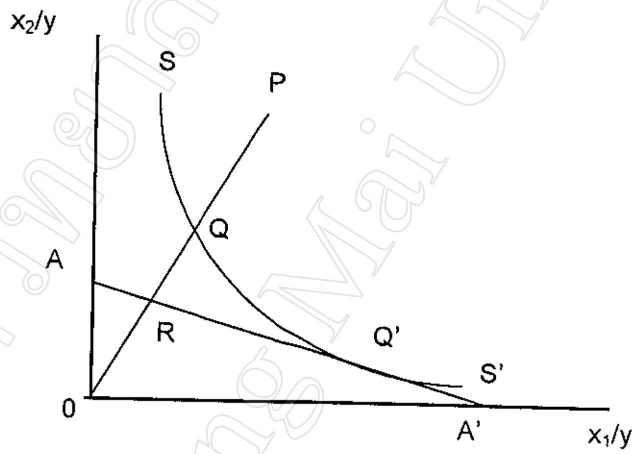

Figure 2.1 Technical Efficiency

2.1.1 Input-output efficiency

The concept of technical efficiency refers to the producer's ability to avoid wasting resources by producing as much output as input usage allows, or by using as little input as output maximizing production allows. Thus the concept of technical efficiency can have naturally an output orientation or an input conserving orientation.

An input-oriented evaluation seeks a projected point such that the proportional reduction in inputs is maximized. The primary concern of management implicit in this orientation that the DMU (Decision Making Unit) being evaluated keeps operating with its current technique, characterized by the actual input ratios, and gains efficiency by maintaining its current levels of outputs and decreasing its inputs.

An output-oriented evaluation seeks a projected point such that the proportional augmentation in output is maximized. In this situation, the primary objective is to reach efficiency by focusing on productivity gains while preserving current input mix (Färe, Grosskopf and Lovell, 1994).

2.1.2 Scale

One of the limitations of Farrell's approach was an assumption of Constant Return to Scale (CRS) which itself is very restrictive. This assumption implies that scale of production does not affect efficiency. Allowing a technology rendering Variable Returns to Scale (VRS), opens the possibility that scale of production could affect efficiency.

If the technology of the production process exhibits VRS, it is clear that some of the existing inefficiency could be due to in-optimal scale. In that case it would be necessary to distinguish between total technical efficiency and pure scale efficiency. This can be done by estimating the efficiency using both CRS assumption and a VRS assumption.

Figure 2.2 illustrates the difference between an efficiency measure estimated under CRS assumption and VRS assumption. The figure is simplified to showing five firms producing one output, y, using a single input, x. Best practice reference technology based on CRS is represented by the line from origin through C[2], while a frontiers based on VRS technology goes through the points A, C, D. The Farrell distance efficiency measure for firm B, under VRS assumption, requires firm B to be compared against a VRS frontier. The point a_{VRS} on the frontier shows how much of input x is needed to produce the same amount of output y, and serves as the reference point for firm B. Total technically efficiency show the relationship between maximum productivity and observed productivity. The point a_{CRS} shows the necessary input usage if the firm was both technical efficient and operated at optimal scale.

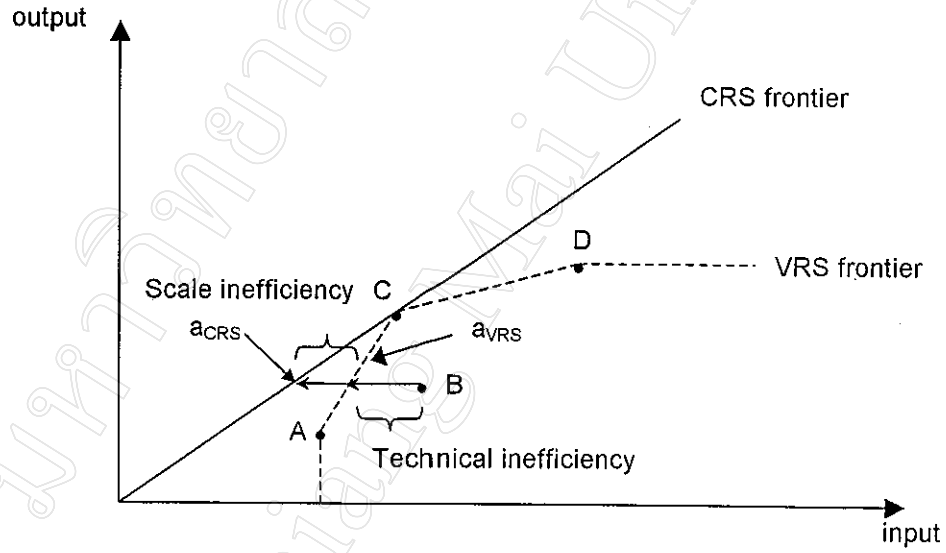

Figure 2.2 Production frontiers in the case of one input and one output. Constant (CRS) and Variable (VRS) returns to scales.

From the figure, it can also be see in what way a firm is scale inefficient. Firm C is the only producer at the CRS frontier and the one that has the highest output per input. It is therefore quite clear that a firm like B should increase the scale to reduce inefficiency that is caused by too small a scale.

2.2 Previous studies related to technical efficiency

Sirikannokvilai (1986) measured the mean level of technical efficiency in the rice mill industry with the efficiency level for each particular firm of the sample mills in Saraburi province. The general Cobb-Douglas production function was employed to estimate the production function of the rice milling industry by using linear programming technique. The empirical findings from the study revealed that the rice mill industry in Saraburi province as a whole operated in a manner of constant return to scale and the technical efficiency index was about 0.81, which was considered a high level. The factors influencing the technical efficiency level were management skill, skill of labor, age of plant, and vintage of capital.

Tepkasetkul (1993) studied the general situation of large-scale rice mills and estimated the revenue equation, cost equation and the optimum processing level of paddy by using Ordinary Least Square (OLS). His data was collected from large-scale rice mills in Ubon Ratchathani province in the production year of 1991. The total number of samples was 22. The capacities of each sample rice mill were more than 60 tons per day. He found that the average amount of paddy processed was 1,922 tons per rice mill per year. The average capacities of rice mill and its warehouse were 85 tons and 5,168.8 tons, respectively. He also found that the optimum processing level of paddy was 3,221 tons per year but the observation found that most large mills in Ubon Ratchathani have processing levels lower than optimum levels. Due to a weak point in measuring technical efficiency by OLS method, which represents only an average function, it might not be able to determine "the best practice" in this study.

However, in contrast to the study findings of Sirikannokvilai (1986), in which technical efficiency was identified, the study of Tepkasetkul (1993) failed to determine the technical efficiency of rice mill in Ubon Ratchathani. However, the technical efficiency obtained in Saraburi was actually the efficiency levels at a specific point of time in the past. It therefore cannot be cited as the technical efficiency of the rice milling industry for the whole country. Moreover, it is also believed that firms' behavior, for instance due to changes in technology, may have been changed with time.

In addition to the application of OLS in which only the average function is covered, the Data Envelopment Analysis (DEA) is a nonparametric form of estimation; no "a priori" assumption on the analytic form of the production function is required. As noted by Charnes (1985), a variable that is neither an economic resource nor a product but is an attribute of the environment or of the production process can be easily included in a DEA-based production model. More importantly, DEA that solves problems by using standard techniques of linear programming also has an advantage in that we can calculate the potential output of both all firms and each individual firm. Thus the benefit of computation, dual variables, etc is made available. Therefore, this study will use the DEA method to evaluate technical efficiency for rice mills and analyze the involved factors influencing technical efficiency by regression.

2.3 Concept of Data Envelopment Analysis and application

2.3.1 Data Envelopment Analysis (DEA)

Data Envelopment Analysis is the optimization method of mathematical programming that generalizes Farrell's (1957) single-input/ single-output technical efficiency measure to the multiple-input/ multiple-output case. Thus DEA became a new tool in operational research for measuring technical efficiency. It was originally developed by Charnes, Cooper and Rhodes (1978) with constant returns to scale, and was extended by Banker, Charnes and Cooper (1984) to include variable returns to scale. So the basic DEA models are known as CCR and BCC. In this study DEA Model(s) were used to derive input-oriented measure of technical and scale efficiency in the data sample.

2.3.1.1 The constant returns to scale input orientation model

Assuming that there is data available on K inputs, M outputs and N decision unit (i.e. firms, farms or regions.) Input and output vectors are represented by the vectors x_i and y_i, respectively for the i-th firm. For the entire data set, therefore, they have a $K \times N$ input matrix X and an $M \times N$ output matrix Y. In essence, we are going to assess efficiency means of a ratio, i.e. efficiency is defined as the ratio of weighted sum of outputs divided by the weighted sum of inputs. Using the notation introduced above this yields:

$$u'y_i/q'x_i \qquad (2)$$

where u is an $M \times 1$ vector of output weights and q is $K \times 1$ vector of input weights. To find the optimal weights to allow us to measure efficiency, The envelopment form of the input-oriented CRS DEA model is specified as:

$$\text{Max } x_{u,q}(u'y_i/q'x_i) \quad (3)$$

Subject to $$u'y_i/q'x_i \leq 1,\ j= 1,2,\ldots,N \quad (4)$$

$$u,q \geq 0 \quad (5)$$

This problem involves solving for u and q such that the measure of efficiency for the i-th firm is maximized subject to the constraint that all efficiency measures must be less than or equal to 1. The above formulation yields infinite solutions so it is necessary to reformulate the problem as follows:

$$\text{Max } x_{\mu,\nu}(\mu' y_i) \quad (6)$$

Subject to $$\nu' x_i = 1 \quad (7)$$

$$\mu' y i - \nu' x_j \leq 0,\ j= 1,2,\ldots,N \quad (8)$$

$$\mu,\ \nu \geq 0 \quad (9)$$

In this formulation, there is introduced an additional equation (Eq. (7)) and the notation has been changed from u and q to μ and ν. This formulation of the DEA constant returns to scale model is referred to as the multiplier form.

Alternatively, the DEA problem can be expressed using duality and this is the envelopment form:

$$\mathrm{Min}_{\theta,\lambda}\theta \qquad (10)$$

Subject to $$Y\lambda - y_i \geq 0 \qquad (11)$$

$$\theta x_i - X\lambda \geq 0 \qquad (12)$$

$$\lambda \geq 0 \qquad (13)$$

where θ is a scalar and λ is an $N\times1$ vector of constants. The estimated value of θ is the efficiency score for each of the N firms. The estimate will satisfy the restriction $\theta \leq 1$ with a value θ = 0 indicating a technically efficient farm. To derive a set of N technical efficiency scores, the problem needs to be solved N times, once for each firm.

2.3.1.2 The variable returns to scale input orientation model

In using the constant returns to scale formulation we are explicitly assuming that the firm is operating at its optimal scale. There are many reasons why this may not be the case in practice, such as imperfect competition. To allow for this possibility, we can reformulate the DEA problem. This alternative formulation follows Banker et al. (1984). By allowing for variable returns to scale our measure of technical efficiency can be decomposed into pure technical efficiency and scale efficiency. The variable returns to scale mathematical programming formulation is as follows:

$$\text{Min}_{\theta,\lambda}\theta \quad (14)$$

Subject to

$$Y\lambda - y_i \geq 0 \quad (15)$$

$$\theta x_i - X\lambda \geq 0 \quad (16)$$

$$N'\lambda = 1 \quad (17)$$

$$\lambda \geq 0 \quad (18)$$

where N is N×1 vector of ones. The inclusion of the convexity constraint (Eq. (17)) means that the data are enveloped more closely than with the constant returns to scale model. This means that the technical efficiency scores derived under a variable returns to scale formulation are greater than or equal to those obtained under constant returns to scale. Eq (17) ensures that a firm is only compared to other firms of a similar size. This means that benchmarking is in terms of relative sized firms, which need not be the case in the constant returns to scale formulation.

The relationship can be used to measure scale efficiency (SE) of the i-th firm as:

$$SE = \frac{TE_{CRS}}{TE_{VRS}} \quad (19)$$

where SE = 1 implies scale efficiency or CRS and SE < 1 indicates scale inefficiency.

2.3.2 Application of Data Envelopment Analysis

Cloutier and Rowley (1993) used DEA to consider technical efficiency of dairy farms in Quebec. They had a sample of 187 farms over 2 years. Using a constant returns to scale specification, they found more efficient farm in 1989 than 1988, although the mean and minimum score increased in 1988. Although they draw inferences about the robustness of their results between years they performed no statistical analysis to test to see if the differences are statistically meaningful. They do suggest that their results show that larger farms are much more likely to appear efficient than smaller ones.

Jaforullah and Whiteman (1998) analyzed scale efficiency in the New Zealand dairy industry with a sample of 264 farms for 1993. They found that average technical efficiency was high at 89%. In term of returns to scale they found that more farms were operating at below optimal scale. However, it is not obvious from the analysis if the sample farms are drawn from a homogenous geographical region. Given the large variations in weather and soil in New Zealand it is not clear if important exogenous factors were taken into account satisfactorily.

Sharma *et al.* (1999) studied technical, allocative and economic efficiency measures of swine production in Hawaii using Data Envelopment Analysis. Data were collected from a sample of 53 commercial swine producers in Hawaii during the fall of 1994. Swine production features multiple outputs and inputs. For the purpose of efficiency analysis, output is aggregated into one category and inputs are aggregated into four categories, namely, feed, labor, other variable inputs and fixed input. The results found that the TE measure for the sample swine producers estimated here from the input-based DEA frontiers were quite comparable with those estimated from the output based frontiers (Shama et al. (1997)). Although the mean scale efficiency from the output-based DEA frontier (89.2%) was higher than that from the input-based frontier (84.1%), this difference was not significant at the 0.05 level. However the two frontiers differed considerably with respect to returns to scale properties. About 21% of sample farmers showed decreasing returns to scale in input-based DEA analysis compared to 45% in output based analysis.

Shafiq and Rehman (2000) had worked on "The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: an application of Data Envelopment Analysis. It was used to explain the relative technical and allocative efficiencies of individual farms. The data were a collected sample consisting of 120 farms from the cotton-wheat area of the southern part of Pakistan's Punjab. The DEA model developed to study the efficiency of cotton production was the input minimization version (dual) of CCR model. This procedure also showed how the increase in the number of inputs affected the efficiency rating of individual farms. It was found that the proceeding analysis points towards the existence of a significant extent of resource use inefficiency on cotton farms in the cotton-wheat production system of Pakistan's Punjab. In many instances, the quantities of inputs used were unjustifiably higher than what would be required to achieve their present levels of crop output.