EVOLUTION OF THE METHODOLOGY OF TECHNICAL AND ALLOCATIVE EFFICIENCY STUDIES IN ECONOMICS: A REVIEW OF LITERATURE[1]

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ABSTRACT

Efficiency measurements have been a great concern of researchers with an aim to study the efficiency levels of almost all economic activities. Empirical estimation and identifying the determinants of efficiency are the major tasks in efficiency analysis. The main objective of this study is to investigate major changes taken place in the methodology of technical and allocative efficiency in economics. The historical approach is used as the methodology of this study. There was no accepted statistical methodology to measure economic, technical and allocative efficiencies until the study of Farrell (1957); "The Measurement of Productive efficiency". In economics, economic efficiency has two components which are referred to as technical efficiency and allocative efficiency. Technical efficiency is associated with the ability to produce on the frontier isoquant, while allocative efficiency refers to the ability to produce at a given level of output using the cost-minimizing input ratios. Few alternative parametric methods are available in literature such as production, cost, profit, revenue and distance functions to analyze efficiency by estimating production technology. The nonparametric methodology involves mainly the use of linear programming techniques. According to available literature, it is clear that various approaches to efficiency analysis have been developed by two parallel traditions, the econometric method and the non-parametric data envelopment analysis. Each of these traditions incorporate its inherent merits and demerits. Findings of the study reveal that input distance function is the best methodology for measuring allocative efficiency if inputs quantities do not significantly vary across units of studies.

Keywords: Technical Efficiency, Allocative Efficiency, Economic Efficiency

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1. Introduction

Productive efficiency has two components namely technical efficiency and allocative efficiency. The technical efficiency component refers to ability to minimize wastages by producing as much output by given level of inputs or by using as little input to produce given level of output. Thus, the technical efficiency can be explained based on two alternative arguments; an output augmenting and an input orientation. The allocative (price component) is defined as the ability to combine resources and outputs in optimal proportions. Many researchers have paid their attention to define the concept of efficiency and its components. Debreu (1951) and Farrel (1957) introduced a measure of technical efficiency. Based on Farrel (1957), measure of technical efficiency can be obtained by using input and output quantity without introducing prices of these inputs and outputs. Technical efficiency can be decomposed into three components such as scale efficiency, congestion and pure technical efficiency.

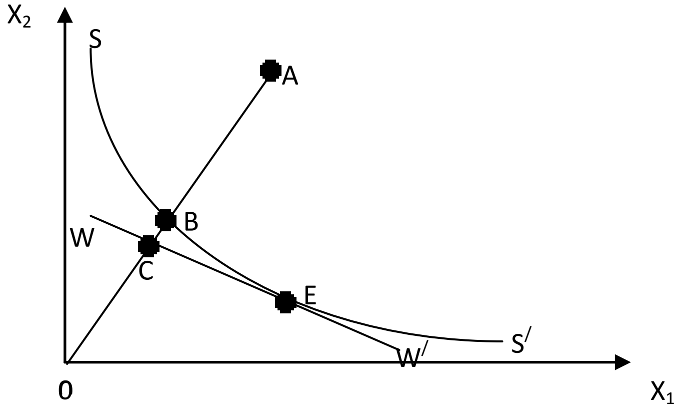
Technical efficiency is just one component of overall economic efficiency. However, a firm must first be technically efficient in order to be economically efficient. A firm should produce maximum output given the level of inputs employed in order to be technically efficient and should use the right mix of inputs in light of the relative price of each input in order to be allocativelly efficient (Kumbhaker and Lovell 2000). However, there are many examples in literature which show the difference between allocative efficiency and technical efficiency by using Isoquant curve.

In Figure 01 below, observation A utilizes two input factors to produce a single output. SS/ is the efficient isoquant curve estimated with an available technique. Point B on the isoquant represents the efficient reference of the observation A. The technical efficiency of a production unit operating at A is most commonly measured by the ratio TE = OB/OA, which is equal to one minus BA/OB. It will take a value between zero and one, and hence an indicator of the degree of technical inefficiency of the production unit. A value of one indicates that the firm is fully technically efficient, for instance, the point B is technically efficient because it lies on the efficient isoquant.

Allocative efficiency can be calculated if the input price ratio represented by the slop of the isocost line, $WW^{/}$ in Figure 01, is known, the allocative efficiency (AE) of a production unit operating at A is defined to be the ratio of AE = OC/OB.

Since the distance CB represents the reduction in production costs that would occur if production were to occur at the allocatively and technically efficient point E, instead of the technically efficient, but allocatively inefficient point B. The total economic efficiency (EE) is defined to be the ratio of EE = OC/OA where the distance CA can also be interpreted in terms of a cost reduction. Note that the product of technical efficiency and allocative efficiency measures provides the measure of overall economic efficiency.

FIGURE 01
Allocative and Technical Efficiency



Source: By the author based on literature survey

The research problem of the study is based on the following facts. Improving of economic efficiency is the key determinant in determining productivity of economic resources. In economic theory, achievement of both technical and allocative efficiencies is required in order to be economically efficient. There are different approaches and methods in the theory of economics in measuring technical and allocative efficiency, but there is no consistency among economists. There is a considerable number of studies in developing countries in which methods were selected without proper evidence. Within this context, the research problem of this study can be stated in the following manner; *How should we select a better methodology to estimate technical and allocative efficiencies with proper understanding of their merits and demerits?*

Thus, the main objective of the study is to investigate major changes taken place in the methodology of technical and allocative efficiency in economics. This study also aims at achieving the following objectives;

1. To identify differences among alternative approaches and methods in estimating technical and allocative efficiency.
2. To identify merits and demerits of alternative approaches and methods in estimating technical and allocative efficiency.
3. To identify a better methodology in estimating technical and allocative efficiency within the Sri Lankan context with special emphasis on agriculture sector.

The study aims to investigate major changes taken place in the methodology of technical and allocative efficiency in economics through analyzing available literature in this field. Historical approach is used as the methodology of this study to fulfill the aforementioned objectives. Most of the popular data bases have been referred for the survey of literature and the sections of the analytical part are divided considering common features of the studies conducted in this field.

2. Analysis and Discussion

2.1. Measurements of Technical Efficiency

Various approaches to efficiency analysis have been used by two parallel traditions, the econometric methods (Aigner, et al., 1977, Battese, 1992) and the non-parametric Data Envelopment Analysis (DEA) methods (Silkman, 1986, Sengupta, 1989).

Basically DEA method is based on linear programming techniques and consists of estimating a production frontier through a convex envelop curve formed by line segments joining observed efficient production unit. DEA method can be known as Programming approach. Especially it should be noted that in this method there is no functional form imposed on the production frontier and there are no any assumptions made on the error term. However, both strengths and weaknesses can be seen in the Data Envelopment Theory in estimating technical efficiency.

TABLE 01
Strengths and Weaknesses of DEA Method

Strengths	Weaknesses
-DEA can be used for multiple inputs and multiple outputs.	-Measurement error is not considered.
-DEA doesn't require relating inputs to outputs.	-DEA does not measure "absolute" efficiency.
-Comparisons are subjective.	-Statistical tests are not applicable.
-Inputs and outputs can have very different units.	-Computation of large data set is difficult.

Source: Literature survey by the author

With recent developments in efficiency analysis, methods have been designed to overcome some limitations of DEA. A deterministic frontiers statistical theory is one of such methods in efficiency analysis. Simar (2003) has proposed a method to improve the performance of FDH/DEA estimators in the presence of noise, while Cazals et at. (2002) developed a robust none parametric estimator. Argon (2003) developed a new none parametric estimator of the efficiency frontier based on the conditional quintiles of an appropriate distribution associated with production process. However, this method has not extended to cover the multivariate analysis.

The second approach is the parametric approach. It is based on econometric estimation of a production frontier whose functional form is specified in advance. In this approach, the Stochastic Frontier method is the most popular and also it is referred to as “composed error model”, the Stochastic Frontiers method has the advantage of taking into account the random error and the inefficiency component specific to every plantation.

The Stochastic Frontiers production method was proposed for the first time by Aigner (1977) and Meeusen, and Broeck (1977). By following different parameterizations such as those of Battese and Corra (1977), Battese et.al (1998), and Battese (1992), the likelihood function of the model defined by the equation:

$$y_i = f(x_i, \beta) + v_i - u_i = f(x_i, \beta) + \varepsilon_i$$

where, v_i is the two-sided “noise” component, and u_i is the nonnegative technical inefficiency component of the error term. The noise component v_i is assumed to be independently and identically distributed and symmetric, distributed independently of u_i. Thus the error term $\varepsilon_i = v_i - u_i$ is not symmetric, since $u_i \geq 0$. Assuming that v_i and u_i are distributed independently of x_i.

The two approaches, econometric and DEA use different techniques to envelope data more or less tightly in different ways. In so doing they make different adaptation for random noise and flexibility in the structure of production technology. It is these two different adaptations that generate strengths and weaknesses of the two approaches.

1. The econometric approach is stochastic, and thus attempts to distinguish the effects of noise from the effects inefficiency. The programming approach is non-stochastic, and lumps noise and inefficiency together and calls the combination inefficiency.
2. The econometric approach is parametric, and confounds the effects of misspecification of functional form with inefficiency. The programming approach is nonparametric and less prone to this type of specification error.

Even though the methodology of Stochastic Frontier is highly used in technical efficiency analysis, it also comprises both strengths and weaknesses.

TABLE 02
Strengths and Weaknesses of Stochastic Frontier Method

Strengths	Weaknesses
-Ability of using stochastic error term for advance analysis	-In many studies the choice of the functional form appears to be arbitrary
-Ability of conducting statistical tests	-Most researchers do not invest much time and effort in choosing a particular distributional form
-Frontier methodology can be used to measure absolute efficiency	-The Stochastic Production Frontier approach is suited only for single-output technologies
-Analyzing of a large set of data is very easy	-Sample size should be a large one for more accuracy of results.

Source: Literature survey by the author.

2.2. Methods for Identifying Technical Efficiency Determinants

This section is specially focused to discover the methods related with Stochastic Frontier Production Function. According to literature, generally, two approaches used in analyzing the determinants of technical efficiency from a stochastic frontier production function can be identified. The first is called the two-step approach; first the Stochastic Frontier Production function is estimated to determine technical efficiency indicators. Next, indicators thus obtained are regressed on explanatory variables that usually represent the firm's specific characteristic, using the ordinary least square (OLS) method. This two-step approach has been used by authors such as Pitt and Lee (1981), Kalirajan (1981), Parikh and shah (1995), and Belhassen (2000) in their relevant studies.

The major drawback with the two-step approach resides in the fact that, in the first step, inefficiency effects (uj) are assumed to be independently distributed. In the second step, however, the technical efficiency indicators thus obtained are assumed to depend on certain number of factors specific to the firm, which implies that the (uj) are not identically distributed unless all the coefficients of the factors considered happen to be simultaneously null.

Kumbhakar (1991) and Reifschneider and Stevenson (1991) developed a model in which inefficiency effects are defined as an explicit function of certain factors specific to the firm, and all parameters are estimated in one step using the maximum likelihood procedure. By following this second approach Huang and Liu (1994) developed a non natural Stochastic Frontier Production function, in which the technical inefficiency effects are a function of a number of factors specific to the firm and of interactions among these factors and input variables introduced in the frontier function. Battese and Coelli (1995) also proposed a Stochastic Frontier Production function for panel data in which technical inefficiency effects were specified in terms of explanatory variables, including a time trend to take into account changes in efficiency over time. The one step approach has since been used by such authors as Ajibefun (1996), Coelli and Battese (1996), Audibert (1971), Battese and Sarfaz (1998), and Lyubov and Jensen (1998) in their respective studies to analyze the factors affecting the technical efficiency/inefficiency of agricultural producers. According to available criticism, one-step approach is less criticized by researchers especially at the statistical level.

2.3. Measurements of Allocative Efficiency

Allocative efficiency is the second component of overall economic efficiency. Allocative efficiency is not highly addressed by researchers when compared with technical efficiency. According to the available literature, it is clear that, there are three alternative approaches in allocative efficiency analysis.

I. Computation of an allocative efficiency index through marginal value product and marginal factor cost (price) of resources

II. Computation of allocative efficiency through estimation of the cost function or implicit cost function

III. Computation of allocative efficiency through estimation of the input distance function

Allocative efficiency index is the ratio between marginal value product and marginal factor cost of a resource. This is the simplest method of analyzing allocative efficiency of factor inputs. There are two main drawbacks of this methodology. The first drawback is that, this method can be applied to analyze only individual allocative efficiency of factors and there is no way of measuring overall allocative efficiency. The second drawback is that the interrelationship among the factors of production is not considered by this method in estimating allocative efficiency. Oniah, Kuye and Idiong (2008), Suresh and Keshava Reddy (2006), Ogundari (2008) are some of the researchers who have applied this methodology for allocative efficiency analysis.

The issues of allocative and cost efficiency measurements through cost functions were addressed by Schmidt and Lovell (1979), who has described how one could estimate a Cobb-Douglas Stochastic Cost Frontier and then use duality to derive the implicit production frontier. With these two frontiers, one could then measure cost efficiency and technical efficiency, and calculate allocative efficiency residually. Schmidt and Lovell (1979) introduced the Cost Frontier method and it was extended to the very flexible translog functional form by various authors, such as Greene (1980) and Schmidt (1984). These new methods avoided the restrictions intrinsic in the Cobb-Douglas functional form, but at the cost of introducing considerable complexity to the modeling exercise.

Direct estimation of the Cost Frontier may not be much appropriate and practical in some cases, for instance, in a situation such as;

1. When there is no difference in input prices among firms
2. When there is a systematic deviation from cost minimization behavior in the industry; for example when political, union or regulatory factors cause shadow prices to deviate from market prices in a systematic way. In this situation, the duality between the cost and production functions break down, and the resulting bias in the cost frontier estimates will make the cost efficiency calculation and decomposition biased as well (T. Coelli, S. Singh, E. Fleming, 2003)

Basically there are two solutions; Implicit Cost Frontier and Input Distance Function could be identified in literature for the aforementioned issues. Implicit Cost Frontier is the direct estimation of the primal production technology, and then derivation of the implicit cost frontier; for example, Bravo-Ureta and Rieger (1991) estimated a Cobb-Douglas stochastic production frontier, and then derived the implicit cost frontier. This also has been criticized by many researchers. One particular contradiction in the Bravo- Ureta and Rieger (1991) approach is that a production function is estimated assuming that the input quantities are decision variables. Another weakness of the Bravo-Ureta and Rieger (1991) approach is that the use of the Cobb-Douglas functional form, which is a restrictive functional form. That is, it imposes unitary elasticities of substitution and constant production elasticities across all firms. In the empirical exercise in this paper we find that the more flexible translog functional form is not a statistically significant improvement over the Cobb-Douglas functional form. Although these weaknesses are reflected by the method introduced by Bravo- Ureta and Rieger (1991), it is being widely used in efficiency analysis.

Input Distance Function is another solution introduced by T. Coelli, S. Singh, E. Fleming in 2003. The specialty of the Input Distance Function can be summarized in the following aspects.

1. Prices of inputs that vary across the firms are not needed for this approach.
2. This is a strong solution for systematic deviations from cost minimization behavior.
3. It does not suffer from simultaneous equations bias when firms are cost minimizing firms or shadow cost minimizing firms.
4. The Input Function Approach can be used even for multiple products.

3. Conclusions

Various approaches to technical efficiency analysis have been used by two parallel traditions, the non-parametric Data Envelopment Analysis (DEA) and econometric methods. DEA method can be used for the researches associated with multiple inputs and multiple outputs but it is not a suitable method if the focus is an advanced statistical analysis, because this does not allow statistical significant tests of parameters. The second approach is the parametric approach. It is based on econometric estimation of a production frontier whose functional form is specified in advance. In this approach, the Stochastic Frontiers method is the most popular. It is also referred to as "composed error model"; the Stochastic Frontier method has the advantage of taking into account the random error and the inefficiency component specific to every plantation. Ability of measuring absolute efficiency and ability of applying hypotheses are the main advantages of this approach. Still, there are few limitations of this methodology associated with multiple input and multiple output problems. Researchers have to be very careful in specifying a correct functional form for the frontier, since a wrong functional from generates totally inaccurate results.

Allocative efficiency is the second component of overall economic efficiency. According to the available literature, it is clear that there are three alternative approaches in allocative efficiency analysis; allocative efficiency index method, cost and implicit cost function method and input distance function method. If the prices of goods and inputs are varied across study units, first two methods can be applied and input distance function method is much applicable when prices of goods and inputs are not significantly varied across the study units.

There is no significant issue in selecting an approach in estimating the technical efficiency in Sri Lanka. DEA method can be applied for comparative efficiency analysis and this is especially powerful for multiple inputs and outputs problems. The econometric approach could be used if the functional form is very clear. This method is very suitable for advanced statistical analysis of economic efficiency.

The researcher has a great role in selecting a method for estimating allocative efficiency. For instance, paddy is the main agricultural product in Sri Lanka. There are two irrigation systems; major (Mahaweli systems) and minor in Sri Lankan paddy sector. Input distance function is the best method for estimating allocative efficiency in major irrigation systems, since input usages and price of output are not significantly varied across households. Cost function approach is better for estimating allocative efficiency in minor irrigation systems of paddy since inputs usages and prices are significantly varied across households.

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