Concept and Measurement of Efficiency: A Review

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ABSTRACT

This paper reviews the concept of efficiency and its measurement. Basically, efficiency comprises two important components. First is technical efficiency and second is allocative efficiency or economic efficiency. There are two measurements of efficiency i.e parametric and non-parametric approaches. The parametric approach assumes an explicit functional form to estimate the frontier and is categorised into three techniques, known as SFA, DFA and TFA. The non-parametric approach designates the best practice firms on the frontier. This approach consists of two frontier models, which are well-known as DEA and FDH.

Keywords: Efficiency, Technical efficiency, Allocative efficiency, Parametric approach, Non-parametric approach

1. Introduction

Measuring efficiency is an important aspect of a firm’s performance. Efficiency is a process of how best a firm utilizes the resources (inputs) to produce the desired products or services (outputs). Efficiency will indicate the success of the firm. If the firm attains a high level of efficiency, it proves that the firm works well in the operating condition and is able to manage all the resources. Eventually, this will lead to further developments such as improvement in the products and services, higher shareholder’s value and higher economic growth if the funds are invested into more profitable ventures. In the next section, this paper reviews briefly the concept of efficiency and measurement of efficiency, and finally provides conclusions.
2. Concept of Efficiency

The concept of measuring efficiency was first discussed in 1951 by Koopmans and Debreu. Later in 1957, it was followed by Farrell who empirically measured efficiency. Hollingsworth and Parkin (1998) defined efficiency as “the allocation of scarce resources that maximizes the achievement of aims” (as cited in Bdour & Al-khoury, 2008, p. 167). Farrell classified efficiency into two components (Kumbhakar & Lovell, 2003). First is technical efficiency (TE). According to Kumbhakar and Lovell, technical efficiency is achieved when the firm is able to produce a maximum level of outputs given a certain level of inputs or minimise inputs given a certain level of outputs. Specifically, according to Koopmans “a producer is technically efficient if it is impossible to produce more of an output without producing less of some other outputs or using more of some inputs” (as cited in Mokhtar, AlHabshi, & Abdullah, 2006 p. 2). In other words, there is no wastage incurred in its production. Second is allocative efficiency (AE). It refers to the optimal combination of inputs and outputs at a given price. Allocative efficiency is also known as economic efficiency. The aim of the producer might include such objectives: to produce given outputs at minimum costs (cost efficiency); to use given inputs to maximize revenue (revenue efficiency); and to allocate inputs and outputs in order to maximize profit (profit efficiency) (Mokhtar et al., 2006). On the other hand, the cost and profit efficiency are regarded by Berger and Mester (1997) as the most important economic efficiency concepts. Accordingly, based on Farrell’s concept, the combination of the two components will create overall economic efficiency (OE). This concept is illustrated in Figure 1.

3. Measurement of Efficiency

There are various types of measurements which have been applied in assessing the efficiency of firms, institutions and organizations. The difference between these methods is based on the assumptions of the data relating to “(a) the functional form of the best-practice frontier, (b) whether random error is taken into account or not, and (c) if there is random error, the probability distribution assumed for the inefficiencies” (Berger & Humphrey, 1997, p. 5). In other words, the approaches for measuring efficiency diverge in how much shape is presumed on the frontier and the distributional assumptions imposed on the random error and inefficiency. The efficiency measurement is categorized into two approaches, parametric and non-parametric.

3.1 Parametric approach

Parametric approach presumes an explicit functional form to estimate the frontier of either cost or profit functions. According to Molyneux and Iqbal
“this approach is stochastic since it allows random disturbance along with inefficiency residuals to be accounted for when estimating the efficient frontier” (Molyneux & Iqbal 2005, p. 202). There are three major parametric frontier techniques, i.e stochastic frontier approach (SFA), distribution-free approach (DFA) and thick frontier approach (TFA).

3.1.1 Stochastic frontier approach (SFA)

The stochastic frontier approach (SFA) was developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) and, later, by Jondrow, Materov and Schmidt (1982) (as cited in Molyneux & Iqbal, 2005). This approach is also known as the econometric frontier approach. According to Berger and Humphrey (1997), the SFA specifies a functional form for the cost, profit, or production relationship among inputs, outputs, and environmental factors, and allows for random error. In response to the weaknesses of the deterministic frontier or non-parametric approach, especially the non-consideration of random noise, an estimation of a frontier comprising both inefficiency and stochastic (random noise) terms was developed by Aigner et al. (1977), and Meeusen and van den Broeck (Molyneux & Iqbal, 2005). The stochastic term is included because it can consider random noise which raise or reduce the frontier due to fate or other measurement error factors (Berger & Humphrey, 1991). Furthermore, it is presumed that the frontier moves from one observation to another. At this point, the inefficiency term means increasing costs above the minimum estimated cost frontier (in cost efficiency) or reducing profit below the profit frontier (in profit efficiency). The distributional assumption for the stochastic term components is depicted by two-sided normal distribution, while the inefficiency term is assumed to be one-sided distribution. One problem of SFA is the non existence of consensus on the type of distribution to be selected in order to arrive at the inefficiency measure. Examples of studies based on SFA are Yildrim and Philippatos (2007), Drake and Hall (2003), Reinhard, Lovell and Thijssen (2000) and others.

3.1.2 Distribution-free approach (DFA)

Distribution-free approach (DFA) was introduced by Berger (1993) following his criticism of the stochastic frontier approach. DFA specifies a functional form for the frontier, but separates the inefficiencies in a different way. The DFA assumes that the efficiency of each firm is stable and does not change over time, whereas random errors will average out to zero in the end (Berger, Hunter, & Timme, 1993). Thus, in contrast to the SFA, this approach sets no specific type of distribution to the inefficiency term. Generally, it needs a panel data set so that the cancellation of the error terms finds enough time to retain a zero value. Studies using this approach include the work of
Prateanu-Podpiera, Weill, and Schobert (2008), Hardy and di Patti (2001), Maudos, Pastor, Perez, and Quesada (1999), Berger and Mester (1997) and others.

3.1.3 Thick frontier approach (TFA)

The Thick frontier approach (TFA) was proposed by Berger and Humphrey in 1992. The TFA estimates the cost function of banks in the lowest average cost quartile (thick-frontier), and compares it with the highest average cost quartile (Molyneux & Iqbal, 2005). Then, it decomposes the deviations into random noise and inefficiency residual. This approach assumes that the deviations from the predicted costs of each quartile represent random error. Meanwhile, the differences between the lowest and the highest average cost quartiles denote inefficiencies. TFA does not enforce any distributional assumptions on inefficiency as well as random error, and does not provide exact estimates of efficiency for individual firms (Berger & Humphrey, 1997). Generally, this method is less popular amongst researchers. A few researchers who employed this method are Bauer, Berger, Ferrier and Humphrey (1998), Lozano-Vivas (1997) and Mahajan, Rangan and Zardkoohi (1996).

The drawback of the parametric approaches lies on imposing a specified functional form that assumes the shape of the frontier. If it is misspecified, the calculated efficiency may be confounded with the specification error.

3.2 Non-parametric approach

Non-parametric or linear programming approach does not specify functional form to estimate the best practice frontier. It designates the best practice firms on the frontier and other firms are considered less efficient relative to the ones defining the frontier. This approach does not allow for any random disturbances. Deviations of the data from the frontier are inefficiency residuals that are strictly one-sided and negative (for production model) or positive (for cost model). This is due to the fact that the data cannot lie above the estimated maximum production or fall below the minimum cost function (Molyneux & Iqbal, 2005). There are two techniques under non-parametric approach i.e data envelopment analysis (DEA) and free disposal hull approach (FDH).

3.2.1 DEA

Data envelopment analysis (DEA) was developed by Charnes, Cooper and Rhodes (1978) who reformulated Farrell’s idea into mathematical problem. It is defined as “a linear programming technique where the set of best-practice or frontier observations are those which no other decision making unit or linear combination of units has as much or more of every output (given inputs)
or as little or less of every input (given outputs)” (Berger & Humphrey, 1997, p. 5). In other words, DEA computes a ratio of outputs to inputs for each decision making unit (DMU) and the result is reported as the relative efficiency score which ranges between zero and one or 0 and 100 percent (Avkiran, 1999, p. 206). Thus, the unit which scores one is fully efficient while those with results lower than one are inefficient relative to other units. The DEA frontier is shaped as the piecewise linear combinations that join the set of these best practice observations, ceding a convex production possibilities set. Because of that, it does not require the explicit specification of the form of the underlying production relationship (Berger & Humphrey, 1997). One of the DEA’s benefits is its ability to create prospective improvements for inefficient units and identify the units for benchmarking (Avkiran, 1999). Besides, it also does not require information about the process or relationship between the inputs and outputs (McEachern & Paradi, 2007). Hence, DEA is more flexible compared to those of parametric approach. For that reason, this method is quite popular among researchers. In a survey done by Berger and Humphrey (1997), they found that 53% of the 130 studies used this technique. Another 46% employed the SFA approach. Examples of new studies using DEA approach are Tahir, Bakar, and Haron (2009), Gaganis, Liadaki, Dounpos, and Zopounidis (2009), Donatos and Giokas (2008), Hussein and Ahmad (2007), Porembski, Breitenstein, and Alpar (2005), Drake and Howcroft (2002) and others.

3.2.2 Free disposal hull approach (FDH)

Free disposal approach (FDA) was introduced in 1984 by Deprins, Simar and Tulkens (as cited in Molyneux & Iqbal, 2005). It differs from DEA as it does not take into account the convexity assumption. In referring to Tulkens (1993), Berger and Humphrey (1997) stressed that “the points on lines connecting the DEA vertices are not included in the frontier. Instead, the FDH production possibilities set is composed of only the DEA vertices and the free disposal hull points interior to these vertices. Because the FDH frontier is either congruent with or interior to the DEA frontier, FDH will typically generate larger estimates of average efficiency than DEA” (p. 177). The major disadvantage of FDH is similar to that of DEA, i.e ignoring the random error. Nevertheless, “it considers the variation of efficiency over time and makes no assumption as to the type of the distribution of the inefficiency component, and thus the measured distance between the estimated observation and the frontier is wholly considered as inefficiency” (Molyneux & Iqbal, 2005, p. 202). Amongst the researchers who employed FDH in their studies are Cummins and Zi (1998), Borger and Kerstens (1996) and others.

Unlike the parametric approaches, the disadvantage of the non-parametric approaches is due to the fact that they enforce less structure on the
frontier but do not allow for random error due to luck, data problems, or other measurement errors. If random error presents, then the calculated efficiency may be perplexed with these random deviations from the right efficiency frontier.

4. Conclusion

The paper reviews some basic concept of efficiency and its measurement. There are two components of efficiency i.e technical efficiency and allocative efficiency. The latter is also known as economic efficiency and subdivided into cost efficiency, revenue efficiency and profit efficiency. The efficiency of firms can be measured using parametric or non-parametric approaches. There are three techniques for the parametric approaches i.e SFA, DFA and TFA. Meanwhile, the non-parametric approaches consist of two models known as DEA and FDH. Both approaches have their own benefits as well as weaknesses. Therefore, the researchers must determine which approach and model to be applied so as to suit the objectives and nature of their studies on efficiency.

References


**Figure 1: Overall, Technical and Allocative Efficiency**

![Figure 1: Overall, Technical and Allocative Efficiency](source: Coelli, Prasada Rao & Battese (1998, p. 135))

The above figure illustrates a firm using two inputs (X1 and X2) to produce an output (y) at point P. SS’ slope shows the probable combination of inputs the firm can produce if it is perfectly efficient. The slope AA’ is the input price ratio and it shows a variety of combinations of inputs that require the same level of expenditure. If the firm’s production is efficient, it should take place at point Q’, which implies the cost minimization. That is where SS’ and AA’ slopes intersect, which denotes the input combination Q’ is technically and
allocatively efficient. Since the firm produces using the combination of input at point P, two types of inefficiency occur. First, it is technically inefficient, as by moving to point Q, it could produce a similar output with less input. Therefore, to measure the magnitude of a firm’s technical efficiency (TE), the ratio is calculated as OQ/OP, which is equal to 1 – QP/OP. Second, it is also allocatively inefficient. Producing at point P demonstrates that the firm made a wrong choice as to the combination of inputs at the given prices, thus increasing cost more than if it had produced at point Q. To measure the allocative efficiency (AE), the ratio is calculated as OR/OQ. Hence, based on Farrell’s concept, the overall efficiency (OE) is calculated as technical efficiency (TE) multiplied by allocative efficiency (AE), which can be written as OE = TE X AE = (OQ/OP) X (OR/OQ).