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Efficiency Analysis of Banks using DEA: A Review

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Abstract

In this paper an attempt has been made to review research conducted on the efficiency measurement and performance of the Indian banking sector. Many research have been performed over the past decade in the area of measuring efficiency of firms,companies,banks,and other decision making units.Studies in the past used conventional ratios such as return on assets to evaluate the efficiency. Most of these studies which look at the efficiency concentrate on cost ,profit ,income or revenue efficiencies.Later research in the area used various measure of performance which include financial index,a non parametric approach-Data Envelopment Approach(DEA) and parametric approach – Stochastic Production Approach (SPA).

1. Introduction

The Banking sector plays an important role in the mobilization and allocation of savings. It plays the role of mediator between the net savers and net borrowers. The gains to the real sector depend on how efficiently the financial sector performs their function of intermediation. Financial sector comprises a network of banks, financial institutions and wide range of financial instruments.

Banks deal with people's most liquid asset (cash), and run country's economy. The banking system in India is significantly different from that of other nations because of the country's unique economic, social and geographic characteristics. India has a large population and land size, a diverse culture, and extreme disparities in income, which are marked among its regions. There are high levels of illiteracy among a large percentage of its population but, at the same time, the country has a large reservoir of managerial and technologically advanced talents. Around 30 to 35 percent of the population resides in metro and urban cities and the rest is spread in several semi-urban and rural centres.

The country's economic policy framework combines socialistic and capitalistic features with a heavy bias towards public sector investment. However, the last couple of decades have witnessed continuous change in regulation, technology and competition in the global financial services industry. Rising cost-income ratios and declining profitability, reflect increased competitive pressure. To assess the stability of the banking system, it is therefore crucial to benchmark the performance of banks operating in India. An efficient banking system contributes in an extensive way to higher economic growth in any country. Thus, studies of banking efficiency are very important for policy makers, industry leaders and many others who are reliant on the banking sector.

DEA has been used widely to evaluate efficiency of various banks. In microeconomic production theory a firm's input and output combinations are depicted using a production function. Using such a function one can show the maximum output which can be achieved with any possible combination of inputs, that is, one can construct a production technology frontier (Seiford & Thrall 1991). Some 30 years ago DEA (and frontier techniques in general) set out to answer the question of how to use this principle in empirical applications while overcoming the problem that for actual firms (or other DMU's) one can never observe all the possible input-output combinations.

Based on Farrell's ideas (1975), Charnes, Cooper & Rhodes' seminal work "Measuring the efficiency of decision making units"(1978) applies linear programming to estimate an empirical production technology frontier for the first time. Since then, a number of books and journal articles have been written on DEA or applying DEA on various sets of

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problems. Other than comparing efficiency across DMU's within an organization, DEA has also been used to compare efficiency across firms. There are several types of DEA with the most basic being CCR based on Charnes, Cooper & Rhodes, however there are also DEA which address varying returns to scale (VRS).The main development of DEA in the 1970s and 1980s are documented by Seiford & Thrall (1990).

DEA is defined by Charneset. Al.(1978) as a 'mathematical programming model applied to observational data that provides a new way of obtaining empirical estimates of relations-such as the production functions and/or efficient production possibility interfaces – that are cornerstones of modern economics'. The CRS assumption in CCR model limits its application to efficiency studies. It is appropriate only when all the firms are operating at optimal scale. However, in a market driven economy where completion, price differences and constraints with resources are present, all firms may not be operating at optimal scale. Hence, Banker, Charnes and Cooper (1984) came out with a DEA model for firms operating under variable returns to scale (VRS) popularly known as BCC model. In the CCR model, the technical efficiency calculated is composed of both pure technical efficiency and scale efficiency. The BCC model decomposes the technical efficiency obtained from CCR model into components of pure technical efficiency and scale efficiency by relaxing the CRS assumption in the model. The BCC model can be applied to multiple inputs and multiple output situations also.

Data envelopment analysis (DEA) is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMU's). Non-parametric approaches have the benefit of not assuming a particular functional form/shape for the frontier; however they do not provide a general relationship (equation) relating output and input. There are also parametric approaches which are used for the estimation of production frontiers (Lovell and Schmidt 1988). These require that the shape of the frontier be guessed beforehand by specifying a particular function relating output to input. One can also combine the relative strengths from each of these approaches in a hybrid method (Tofallis, 2001) where the frontier units are first identified by DEA and then a smooth surface is fitted to these. This allows a best-practice relationship between multiple outputs and multiple inputs to be estimated.

"The framework has been adapted from multi-input, multi-output production functions and applied in many industries. DEA develops a function whose form is determined by the most efficient producers. This method differs from the Ordinary Least Squares (OLS) statistical technique that bases comparisons relative to an average producer. Like Stochastic Frontier Analysis (SFA), DEA identifies a "frontier" on which the relative performance of all utilities in the sample can be compared: DEA benchmarks firms only against the best producers. It can be characterized as an extreme point method that assumes that if a firm can produce a certain level of output utilizing specific input levels, another firm of equal scale should be capable of doing the same. The most efficient producers can form a 'composite producer', allowing the computation of an efficient solution for every level of input or output. Where there is no actual corresponding firm, 'virtual producers' are identified to make comparisons" (Berg 2010)

2. Data envelopment analysis (DEA)

Data envelopment analysis (DEA) is a linear programming methodology to measure the efficiency of multiple decision-making units (DMUs) when the production process presents a structure of multiple inputs and outputs.DEA has been used for both production and cost data. Utilizing the selected variables, such as unit cost and output, DEA software points to the lowest unit cost for any given output, connecting those points to form the efficiency frontier. Any company not on the frontier is considered inefficient. A numerical coefficient is given to each firm, defining its relative efficiency. Different variables that could be used to establish the efficiency frontier are: number of employees, service quality, environmental safety, and fuel consumption. An early survey of studies of electricity distribution companies identified more than thirty DEA analysis-indicating widespread application of this technique to that network industry (Jamasb, T.J.,Pollitt, M.G.(2001). A number of studies using this technique have been published for water utilities. The main advantage of this method lies in its ability to accommodate a multiplicity of inputs and outputs. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing or efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/ exclusion of variables can affect the results.(Berg 2009)

Advantages of DEA are:

- No need to explicitly specify a mathematical form for the production function.

- Proven to be useful in uncovering relationships that remain hidden for other methodologies.
- Capable of handling multiple inputs and outputs.
- Capable of being used with any input-output measurement.
- The sources of inefficiency can be analyzed and quantified for every evaluated unit.

Disadvantages of DEA are:

- Results are sensitive to the selection of inputs and outputs.
- Cannot test for the best specification.
- The number of efficient firms on the frontier tends to increase with the number of inputs and outputs variables.

Data Envelopment Analysis (DEA) has been recognized as a valuable analytical research instrument and a practical decision support tool. DEA has been credited for not requiring a complete specification for the functional form of the production frontier nor the distribution of inefficient deviations from the frontier. Rather, DEA requires general production and distribution assumptions only. However, if those assumptions are too weak, inefficiency levels may be systematically underestimated in small samples. In addition, erroneous assumptions may cause inconsistency with a bias over the frontier. Therefore, the ability to alter, test and select production assumptions is essential in conducting DEA-based research. However, the DEA models currently available offer a limited variety of alternative production assumptions only.

3. CCR Model

CCR-Model was introduced by Charnes, Cooper and Rhodes (1978). This model measures the efficiency of each DMU which is obtained as a maximum of the ratio of total sum of weighted outputs to total sum of weighted inputs. Consequently, the efficiency can be defined as follow.

Efficiency = Weighted sum of outputs/ Weighted sum of inputs

The weights for the ratio are determined by the restriction that the similar ratios for every DMU have to be less than or equal to unity, thus reducing multiple inputs and outputs to a single "virtual" input and single "virtual" output without requiring pre-assigned weights. Therefore, the efficiency score is a function of the weights or the "virtual" input-output combination. Suppose that there are n DMUs, each with n inputs and s outputs, relative efficiency score of a given DMU_0 is obtained by solving the following linear programming model.

$$\max\ (\theta = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{r=1}^{m} v_i x_{i0}})$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{r=1}^{m} v_i x_{ij}} \le 1\ ; j = 1,2,\dots,n$$

Where

$$v_i \ge 0; i = 1,2,\dots,m$$
$$u_i \ge 0; r = 1,2,\dots,s$$

And

x_{ij}= the amount of input i utilized by the jth DMU

y_{rj}= the amount of output r produced by the jth DMU

v_i= weight given to input i

u_r= weight given to output r

Following the Charnes – Cooper transformation (1962), one can select a representative solution (v,u) for which

$$\sum_{r=1}^{m} v_i x_{i0} = 1$$

Hence, the denominator in the efficiency score θ shown above is set equal to one, the transformed linear programming model for DMU_0can be written as follow.

Max $\theta = \sum_{r=1}^{s} u_r y_{r0}$

Subject to

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{r=1}^{m} v_i x_{ij} \le 0\ ; j = 1,2,\dots,n$$

$$\sum_{r=1}^{m} v_i x_{i0} = 1$$

$v_i \ge 0; i = 1,2,\dots,m$

$u_i \ge 0; r = 1,2,\dots,s$

The linear programming model shown above will be run n times in identifying the relative efficiency score of all the DMUs. Each DMU selects input and output weights that maximize its efficiency score. Generally, a DMU is considered to be efficient if it obtains a score of 1.00, implying 100% efficiency; whereas a score of less than 1.00 implies that it is relatively inefficient.

4. BCC Model

Max output (y)
Subject to: output constraint

$$\sum_{n=1}^{N} y_n \lambda_n - \theta y_i \geq 0$$

Input constraint

$$\sum_{n=1}^{N} z_n \lambda_n - \theta z_i \geq 0$$

For $\lambda_n > 0,\ n = 1,2, \dots, N$

λ represents the Lagrange multiplier and in the solution it indicates the efficient peer DMUs. **θ**represents the factor by which the current levels of input constraints are solved for overall $TE\ (CSR_{TE}) = \frac{1}{\theta}$ under CRS assumption.

Pure $TE(VRS_{TE})$ of DMU can be arrived at by relaxing CRS assumption and new θ value (θ^*) is computed by imposing additional constraints i.e.

$$\sum_{n=1}^{N} \lambda_n = 1$$

Scale efficiency is given by

$$SE = \frac{CRS_{TE}}{VRS_{TE}} = \frac{\theta}{\theta^*}$$

Whether the DMUs are operating under DRS, IRS or CRS all previously mentioned constraints are solved for$\theta^{**}$with additional constraints

$$\sum_{n=1}^{N} \lambda_n \leq 1 \text{ at}$$

$$NIRS_{TE} = \frac{1}{\theta^{**}}$$

$$if\ NIRS_{TE} \neq VRS_{TE} \Rightarrow IRS$$

and

$$if\ NIRS_{TE} = VRS_{TE} \Rightarrow DRS$$

The Data considering the various inputs and outputs is written in the form of linear programming equations. Then, the equations are solved using DEA technique. Analysis will be presented in a descriptive statistical format using the graphs and tables.

5. Literature Review

A lot of research has been performed over the past decade in the area of measuring efficiency of firm companies, banks and other decision making units. Studies in the past used conventional ratios such as return on assets to evaluate efficiency. Most of these studies which look at the efficiency concentrate on cost, profit income or revenue efficiencies. Later research in the area used various measures of performance which include financial index (Wu et. al 2006), [Ref 30] a non parametric approach- Data Envelopment Approach (DEA) (Wu, 2005), parametric approach and Stochastic Production Approach (SPA) (Radam et. al 2008). [Ref 19] DEA is frequently used to measure relative efficiency of decision making units. DEA is defined by Charnes et al (1978) [Ref 8]as a mathematical programming model applied to observations data that provide a new way of obtaining empirical estimate of relations such as the production functions or efficient production possibility surface which are considered to be the corner stone of modern economics. It is a non-parametric multiple input output efficiency technique that measures the relative efficiency of decision making units.

Lim and Shumway (1992) [Ref 17] believed that the use of wrong functional forms results in failure of hypothesis testing in parametric model. Depending on the assumption makes the SFA (Stochastic Frontier Analysis) approach restrictive. The above view is also endorsed by Chavas and Cox(1995). [Ref 9] The use of DEA for measuring efficiencies has increased over the years. Seiford & Thrall argue in favour of DEA by stating that parametric description of the production technology is possible only if production function is correctly known though in reality production function is not known. The choice of functional forms like cost and profit function influences the outcome of parametric approach.

DEA approach is very popular and has been applied widely in different areas of studies like measuring efficiency of Indian banks by Pramodh et al (2008) and bankruptcy prediction by Feroz et al (2003). [Ref 12] It has been widely used in measuring efficiency in manufacturing sector. Berger and Humphery (1997) [Ref 6]reviewed 130 efficiency studies of financial institutions including commercial banks and explained that efficiency estimates of financial institutions in 21 countries vary across studies due to use of different methods in different studies. They found that the various efficiency methods do not essentially yield consistent results and suggest some ways that these methods might be improved to bring about findings that are more consistent.

Avkiran [Ref 3]used two DEA models, taking interest expense and non-interest expense as input variable and interest income and non-interest income as output variables to examine the efficiency of Australian trading banks for the period 1986 to 1995 and found that their efficiency rose in the post regulation period and acquiring banks were more efficient than target banks. Chen and Yeh (1998) [Ref 10]calculated the operating efficiencies of 34 commercial banks of Taiwan's banks using the DEA model where in input variables including staff employed, interest expense and output variables include loans investment and interest revenue, non-interest revenue and bank assets. The author concluded that a bank with better efficiency does not always mean that it has better effectiveness.

In the case of Tukish Banks, (Mehmet Hasan Eken Suleyman Kale, A J B M vol 5(3) PP 889-901, 4 Feb, 2011), it is apparent that branch size and scale efficiency are related to each other. As branch size increases scale efficiency increases too and after the most productive scale size, however, as the size increases efficiency decreases.

Al-Shammari and Salimi (1998) [Ref 1] have examined the comparative operating efficiency of Jordanian commercial banks from 1991-1994 using a modified version of DEA and found that the majority banks are fairly inefficient over the period 1991-1994. Noulas (2001) [Ref 2] employed both DEA model and the traditional approach to study the effect of banking deregulation on private and public owned banks. The interest expense and non-interest expense were the input variable and interest revenue and non-interest revenue were the output variables. The result reveals that the state banks were less efficient than the private and the gap widened during the study period.

In India also several studies have been carried out on Efficiency Analysis using DEA approach. It has been applied widely in different areas like study of efficiency of Indian banks by Pramodh et al., bankruptcy prediction by Cielen et al. (2004), [Ref 11] efficiency of mutual funds by Lozanno and Gutierrez (2008) and analysis of financial statement by Feroz et al. (2003). [Ref 12]

R.P. Sinha and Bishwajit Chatterjee, [Ref 28]in their paper, make use of window analysis developed by Klopp (1985) [Ref 14] to compare the performance of major life insurance companies operating in India using two output one input framework. The window approach evaluates firms on the basis of panel observations and thus is different from conventional DEA. In the conventional DEA, the technical efficiency of any particular decision making units is measured by evaluating DMU in light of all the DMUs under observation for the time period. Their study suggests that there still exists a huge gap between the LIC and other Life Insurance companies in terms of technical efficiency.

Arpita Ghosh and Paramita Roy Bishwas [Ref 13] have analyzed inter-industrial variation in total factor productivity growth of Manufacturing Sector of West Bengal. They have measured Malmquist Productivity Index (MPI) of Total Factor Productivity Growth (TFPG) of 14 manufacturing industries using the DEA. Using DEA, considering 3-digit annual survey of industries' data of West Bengal, Decomposition of MPI into technical efficiency change reveals that technical change is the prime source of productivity increase. Badri Narayan Rath and Poulomi Bhattacharya have studied productivity growth, efficiency change, and technical progress in case of registered manufacturing sector in Odisha, using DEA. Their study indicates that the mean Total Factor Productivity Growth (TFPG) of aggregate the manufacturing sector is mainly driven by the technical change, not by technical efficiency. At the dis-aggregated level, the results find that labour-intensive industries are regressing in technical progress, whereas capital intensive industries lack in efficiency change.

Some of the applications of DEA in manufacturing sector and other sectors covering the efficiency of cement industry in India are listed below:

Saranga (2009) [Ref 23] analyses the Indian auto manufacture and component suppliers operational efficiency using DEA. His study shows that technology licensing in auto industry does not affect the efficiency of firms. They recommend reforms in Indian Labor Laws and better working capital management to improve efficiency in the sector.

Bhattacharya et al (1997) [Ref 7] used DEA to measure the productive efficiency of Indian commercial banks in the late 80s to early 90s and studied the impact of policy on liberalizing measures taken in 1980s on the performance of various categories of banks. They found that Indian Public banks were the best performing banks as the banking sector was overwhelmingly dominated by Indian public sector banks while the new private sector banks were yet to emerge fully in the Indian banking scenario.

Sarkar et al (1998) [Ref 24] compared public, private and foreign banks in India to find the effect of ownership type on different efficiency measures.

Sathye (2001) [Ref 25] studied the relative efficiency of Indian banks in late 1990s and compared the efficiency of Indian banks with that of banks of other countries. He found that public sector banks have a higher mean efficiency score as compared to the private sector banks in India, but found mixed results when comparing public banks and foreign commercial banks in India. He also found that most banks on efficient frontier are foreign owned.

Rammohan (2002-03) [Ref 20,21]also used financial measures for comparing operational performance of different categories of bank over a period of time.

Kumbhkar and Sarkar (2003) [Ref 15,16]found evidence on Indian banks that while private sector banks have improved their performance mainly due to the freedom to expand output, public sector banks

Rammohan and Ray (2004) compared the revenue maximizing efficiency of public, private and foreign banks in India using physical quantities of inputs and outputs in 1990s with deposits and operating costs as input and loans, investment and other income as outputs. They found that public sector banks were significantly better than private banks on revenue maximization efficiency, but between public and private sector banks the difference in efficiency was not significant

Shanmugam and Das (2004) [Ref 27] studied banking efficiency using a Stochastic Frontier Production function model during the reform model period 1992-99. The study considers the input variables (viz deposits, borrowings, labour and fixed assets) and four output variables (viz net interest income, non-interest income, credits and investments). They found that deposits are dominant in producing all outputs and technical efficiency of raising interest margin is varied across the banks. In particular they found that reform measures introduced since 1992 have not helped the banks in raising their interest

have not responded well to the deregulation measures.

margin. Also, in general, they found that private foreign banks performed better than public banks.

Sanjeev (2006) [Ref 22] studied efficiency of private, public and foreign banks operating in India during the period 1997-2001 using DEA. He also studied if any relationship can be established between the efficiency and non-performing assets of the bank. He found that there is an increase in efficiency in post reform period and that non-performing assets and efficiency are negatively related.

6. Conclusion

In this review paper, efficiency measurement models-BCC and CCR have been discussed and literature review has been done in the area of efficiency analysis in banking sector. Most of the studies have used DEA to measure the efficiency of banking sector in India. The DEA is Capable of handling multiple inputs and outputs and is useful in uncovering relationships that remain hidden for other methodologies. The advantage of DEA is also that the sources of inefficiency can be analyzed and quantified for every evaluated unit.

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