Measuring the Efficiency of Public Service Sector Banks in India Using Two-Stage Closed System DEA approach

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Received: 15 December 2020; Revised: 26 February 2021; Accepted: 3 March 2021

Abstract

This paper examines the efficiency of public service sector banks in India using two stage Data Envelopment Analysis [DEA] technique. The proposed model investigates the efficiency of banks of with various input and production standards in each level. While comparing banks, it was determined that some banks are efficient in their profit earning, whereas other banks are efficient in functioning smoothly. The methodology defines the profit efficiency in stage 1 and performance effectiveness in phase 2 of the selected public sector banks in India. The objective of the study is to investigate the efficiency of the Indian Public Sector Banks in their two different stages using DEA Approach. The study demonstrates the comparative assessment and efficiency rankings among the selected bank in India.

Keywords: banking-sector, efficiency, two-stage DEA approach, input measure and output measures.

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1. Introduction

The public sector organizations continue to enhance their operation to serve their customers as well as improve their efficiency. In this study, a Data Envelopment Analysis (DEA) technique was applied to gauge the efficiency of the banking industry in India. The DEA methodology, a non-parametric linear programming technique, is generally applied to compare the efficiency of several entities that has been used to evaluate the efficiency of entities. Charnes et al. [2] was the forefather of this technique. The theoretical framework was introduced by Farrel [4] for computing the relative efficiencies of multiple Decision-Making Units (DMUs). This methodology is considered to be a part of fractional programming model where the method adds up with a relative ratio for every unit in terms of yield and input. The total efficiency of any DMU always lies between 0 and 1. If the score is close to 1 then the firm performs well. On the other hand, if the measure tends to 0 then the efficiency is considered to be nil. One of the significant roles of DEA is that the efficiency scores indicate the gap for potential improvements and developments for the inefficient DMUs [8].

Two stage DEA model produces the separate efficiency measures for the corresponding phases. Most of these models are considered to be in the form of the DEA network system and they are applied in several "real-world" situations. As an example, consider the output procedure and saving process in a particular type of manufacturing Industries. In a production process stage, labor and new materials can be considered as inputs and whereas goods/products can be represented as the end products. The finished goods, drivers and trucks can be viewed as input and the outputs could be the final delivered product.

Types of Two-stage DEA

- Two-stage Closed DEA System
- Two-stage Open DEA System.

DEA Closed System Approach:

This method generates separate efficiency measures for stage one and stage two with a chain relation. In other words, the effectiveness of the DMU's can be evaluated without considering the intermediate interactions between these two stages.

DEA Open System Approach:

In this type of system, each sub process utilizes distinct resources other than first-stage resources and produces results.

1.1 Two-stage Closed DEA System Model:

In the two-stage closed DEA system model, the output measures of the first stage are considered as the input measures of the second stage. The Two-Stage Closed DEA System is presented in Figure 1.

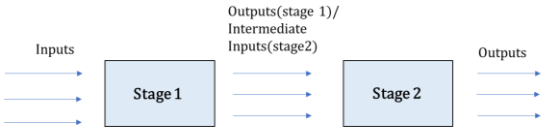

Figure 1. Two-stage Closed DEA System

1.2 Two-stage Open DEA System Model:

In the two-stage open DEA system model, the second stage has the new input measures in addition to the intermediate variables and the output quantities of the first stage are not necessarily inputs of the second phase. The Two-Stage Open DEA System is shown in Figure 2.

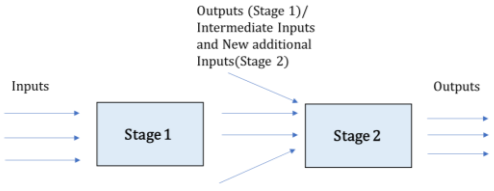

Figure 2. Two-stage Open DEA System

2. Review of Literature

Seiford and Zhu [9] proposed a two-stage closed network DEA model to evaluate the profitability and marketability of American banks. Zhu [11] discussed the performance efficiency frontier of fortune global 500 companies using two stage network DEA model and verifies the reliability of the best practice frontier. Chen and Zhu [3] analyzed an efficiency model that investigates the efficiency frontier of a two-stage production process linked by intermediate variables. The model studied the performance of first stage measuring the efficiency level of the other due to any type of intermediate measures.

Yang [10] used a two-stage DEA model to evaluate the overall performance of Canadian life and health insurance companies. The study reveals the overall management performance by analyzing the production performance in the first stage and investment performance in second stage for the insurance company. Kao and Hwang [5] studied the performance combination of the two stages with a chain relation between them by using the data on the Taiwanese Insurance company. Wanke and Barros [7] applied the two-stage DEA model data pertaining to Brazilian banks using the network DEA centralized efficiency model.

This paper presents a distinct application of the two-stage closed data envelopment analysis model in the banking industry. The objective of the study is to investigate the efficiency of the Indian Public Sector Banks in their two different stages using DEA Approach. Based on this analysis, one can determine which Public Sector Indian banks are performing well. The findings of the study are based upon nineteen public banks in India. First stage evaluates the profitability of the selected banks and second stage evaluates the effectiveness of the Banks using Charnes, Cooper and Rhodes (CCR) model as well as Banker, Charnes and Cooper (BCC) model [1].

3. Mathematical Modeling

3.1 Constant Returns to Scale Model:

The structure of the Output Maximization DEA [CRS] model can be viewed in the form of Fractional Programming problem as follows [6]:

Here the general model is constructed to maximize the efficiency of the q[th] output variable:

$v_{jq} -$ j^{th} output value of the q^{th} DMU of stage 1

$y_{jq} -$ j^{th} output variable of the q^{th} DMU of stage 1

$u_{iq} - i^{th}$ input valueof the q^{th} DMU of stage 1

$x_{iq} - i^{th}$ input valueof the q^{th} DMU of stage 1

$E_q -$ Efficiency of the q^{th} DMU of stage 1

$$Max\ E_q = \frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq} x_{iq}}$$

Subject to the constraints

$$\frac{\sum_{j=1}^{m} v_{jq} y_{jq}}{\sum_{i=1}^{s} u_{iq} x_{iq}} \leq 1; q = 1,2, \dots, n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0\ for\ all\ i = 1,2,..s; j = 1,2,..m, q = 1,2,...n$$

The Equivalent Linear programming problem for the above fractional model can be defined as follows:

$$Max\ E_q = \sum_{j=1}^{m} v_{jq} y_{jq}$$

Subject to the constraints

$$\sum_{i=1}^{s} u_{iq} x_{iq} = 1$$

$$\sum_{j=1}^{m} v_{jq} y_{jq} - \sum_{i=1}^{s} u_{iq} x_{iq} \leq 0\,; \quad q = 1,2, \dots n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0\ for\ all\ i = 1,2,..s; j = 1,2,..m, q = 1,2,...n$$

The general form of Input Minimization DEA [CRS] Linear Programming model can be represented as follows [7]:

$$Min\ E_q = \sum_{i=1}^{s} u_{iq} x_{iq}$$

Subject to the constraints

$$\sum_{j=1}^{m} v_{jq} y_{jq} = 1; \quad \sum_{j=1}^{m} v_{jq} y_{jq} - \sum_{i=1}^{s} u_{iq} x_{iq} \leq 0; \quad q = 1,2,\dots,n$$

$$v_{jq}, y_{jq}, u_{iq}, x_{iq} \geq 0 \ for\ all\ i = 1,2,..s; j = 1,2,..m, q = 1,2,\dots n$$

3.2 Variable Returns to Scale Model:

The Input-Oriented DEA envelopment program for considering variables return to scale referred by Banker et al [1] is as follows:

$$Min\ \theta_m$$

Subject to the Constraints

$$Y\lambda \geq Y_m; \quad X\lambda \leq \theta X_m$$

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

$$\lambda \geq 0; \quad \theta_m\ free\ variable$$

$$\lambda \geq 0; \quad \theta_m\ free\ variable$$

4. Research Methodology

In any type of Organization, Finance is their Life Blood. Normally, one can see cash inflows and cash outflows as a major player. In the area of Financial Management, the element called ratio analysis which considers only one variable at a time to evaluate the performance of any organization. It is quite obvious that every organization having more number of Inputs (Cash out flows) and more number of outputs (Cash inflows).

For the study of effectiveness of their organization general Data Envelopment Analysis [DEA] is a remedial measure to study more number of inputs and outputs at a time. This DEA helps to know efficiency based on profit. The intensive research reveals the reasons to consider the outputs as inputs and the special outputs as the total income and total assets etc. This concept leads to stage two of the DEA. According to this principle researcher considered Two Stage model for this study.

Data Envelopment Analysis [DEA]

The efficiency of any company is a highly important thing to observe. The measurement of performance has never been a simple push-bottom technology. DEA is a non-parametric linear programming technique that has been applied to calculate entities' performance efficiency. It is employed to assess the relative performance of a group of any firms that utilize a range of identical inputs to get a range of identical outputs.

In the general DEA model, one can find the efficiency of any firm in one single step by considering only the initial inputs and the final outputs. That is, the intermediate variables or products are neglected. For this reason, the Two Stage DEA models are applied. That is, the Two-stage DEA model generates distinct effectiveness measures for the corresponding phases. For Example, if a firm wants to analyze the efficiency for each stage of their performance such as production process, supplier selection and delivery process, they can make use of Two Stage or Network DEA Models.

Two Stage Data Envelopment Analysis

The existing DEA models can be classified into two categories:

- ✓ Two Stage Closed DEA System
- ✓ Two Stage Open DEA System.

These methods produce separate efficiency measures for the first stage and second stage. In the closed-system DEA models, the intermediate outputs remain unchanged from one stage to another. In contrast, in the open-system DEA models, the intermediate outputs in one stage are partial inputs in a subsequent stage.

Advantage of Two Stage Closed DEA System

- This approach helps to analyze the performance of the DMU in different stages with a chain relation between them. It can also be referred to as the DEA Network system.
- It is capable of being applied with any input – output measurement in a closed system.

For this study, the required data for the selected public service sector Indian banks have been collected from their official websites respectively for the financial years 2009-2019.

4.1 Selection of Input and Output Variables:

The main purpose of this study is to determine the effectiveness of banks in two different phases. The variables associated with the relevant stages are considered in the study. In the first stage, the authors decide to evaluate the profitability of the selected banks, therefore, profit-related variables have been selected. In the second stage, the authors assess the overall efficiency of performance. As a result, the authors considered the output variables of stage one as the input variables of stage two with a chain relationship between two stages.

The choice of input and output measures were derived using the literature on the application of data envelopment analysis (DEA). In this study, the authors considered two sets of indexes. The first set of indexes evaluated the profitability in stage 1, and the second set of indexes that evaluated evaluates the performance effectiveness of the selected banking sector in state 2. The variables are presented in Figure 3.

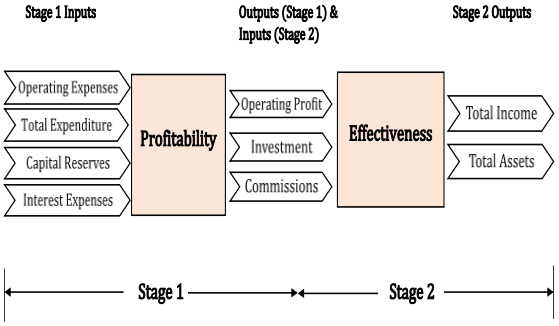

Figure 3: Variables Considered in Stage 1 and State 2

5. Empirical Results

5.1 Stage 1: Constant Returns to Scale [CCR Model]

Table 1 presents that the DEA profit efficiency score based on Input-Oriented Technical Efficiency under the Constant Returns to Scale Model in Stage 1. The Analysis reveals that two banks attained the maximum efficiency score as 1 out of 19 banks considered for this study.

Table 1. Input Oriented Technical Efficiency [CRS Model] in Stage 1

DMUs	Mean Score (2009 – 2019)
IDBI	1
State Bank of India	1
United Bank of India	0.9962
UCO Bank	0.9927
Punjab & Sind Bank	0.9926
Bank of Maharashtra	0.989
Oriental Bank of Commerce	0.9444
Allahabad Bank	0.9396
Corporation Bank	0.9263
Punjab National Bank	0.9057
Central Bank of India	0.8978
Indian Bank	0.8695
Indian overseas Bank	0.8614
Canara Bank	0.8326
Union Bank of India	0.8141
Bank of Baroda	0.8097
Syndicate Bank	0.7853
Andhra Bank	0.7786
Bank of India	0.7713

5.2 Stage 1: Variable Returns to Scale [BCC Model]

Table 2 shows that the DEA efficiency score based on Input Oriented Technical Efficiency under Variable Returns to Scale Model in stage 1. The Analysis report vindicates that only 5 out of 19 banks attained the maximum efficiency score as 1.

Table 2. Input Oriented Technical Efficiency [VRS Model] in Stage 1

DMUs	Mean Score (2009-2019)
Bank of Maharashtra	1
IDBI	1
Punjab & Sind Bank	1
State Bank of India	1
United Bank of India	1
UCO Bank	0.9942
Punjab National Bank	0.9646
Central Bank of India	0.9611
Oriental Bank of Commerce	0.9548
Allahabad Bank	0.9507
Canara Bank	0.9423
Corporation Bank	0.9406
Indian Bank	0.8836
Indian overseas Bank	0.8738
Union Bank of India	0.872
Bank of Baroda	0.8532
Andhra Bank	0.8148
Bank of India	0.8115
Syndicate Bank	0.7962

5.3 Stage 2: Constant Returns to Scale [CCR Model]

Table 3 shows that the DEA Efficiency score based on Input-Oriented Technical Efficiency under the Constant Returns to Scale Model in Stage 2. The outcome of the study states that out of the nineteen banks none of the banks has the maximum efficiency score value 1.

5.4 Stage 2: Variable Returns to Scale [BCC Model]

Table 4 shows that the DEA Efficiency score based on Input-Oriented Technical Efficiency under the Variable Returns to Scale Model in Stage 2. The Analysis reveals that among the selected 19 public sector banks taken for the study only 4 banks attained the maximum efficiency score of 1.

Table 3. Input Oriented Technical Efficiency [CRS Model] in Stage 2

DMUs	Mean Score (2009 – 2019)
Bank of Baroda	0.9935
Union Bank of India	0.9888
Syndicate Bank	0.9737
Bank of India	0.9651
Andhra Bank	0.9583
Punjab National Bank	0.9488
IDBI	0.9422
Central Bank of India	0.922
Indian Bank	0.9202
Canara Bank	0.9195
State Bank of India	0.9062
Punjab & Sind Bank	0.8939
Indian overseas Bank	0.888
Oriental Bank of Commerce	0.8845
UCO Bank	0.8774
Bank of Maharashtra	0.8666
Allahabad Bank	0.8483
Corporation Bank	0.8419
United Bank of India	0.7713

5.5 Mean of Mean Efficiency-Constant Returns to Scale Model

Table 5 shows that the mean of the mean DEA efficiency score by comparing the profit efficiency and effectiveness of constant returns to scale model. The mean of the mean of efficiency indicates that none of the banks

achieved the efficiency score in terms of their overall performance.

5.6 Mean of the Mean Efficiency-Variable Returns to Scale Model

Table 6 shows the mean of mean DEA efficiency score by comparing the profit efficiency and effectiveness of variable returns to scale model. The results show that only 4 banks attained the efficiency score in their overall performance.

Table 4. Input Oriented Technical Efficiency [VRS Model] in Stage 2

DMUs	Mean Score (2009 – 2019)
Bank of Maharashtra	1
Punjab & Sind Bank	1
State Bank of India	1
United Bank of India	1
Union Bank of India	0.9976
Bank of Baroda	0.9969
Andhra Bank	0.9882
Syndicate Bank	0.9852
Bank of India	0.9794
Canara Bank	0.9779
Punjab National Bank	0.9728
IDBI	1
Indian Bank	0.9505
UCO Bank	0.9322
Central Bank of India	0.9295
Oriental Bank of Commerce	0.9118
Indian overseas Bank	0.905
Allahabad Bank	0.8816
Corporation Bank	0.8811

Table 5. Mean of Mean Efficiency [CRS Model]

DMUs	CRS Mean Efficiency -Stage 1	CRS Mean Efficiency - Stage 2	CRS - Mean of Mean Efficiency
IDBI	1	0.9422	1
State Bank of India	1	0.9062	1
Punjab & Sind Bank	0.9926	0.8939	0.94
UCO Bank	0.9927	0.8774	0.93
Bank of Maharashtra	0.989	0.8666	0.93
Punjab National Bank	0.9057	0.9488	0.93
Oriental Bank of Commerce	0.9444	0.8845	0.91
Central Bank of India	0.8978	0.922	0.91
Bank of Baroda	0.8097	0.9935	0.90
Union Bank of India	0.8141	0.9888	0.90
Indian Bank	0.8695	0.9202	0.89
Allahabad Bank	0.9396	0.8483	0.89
Corporation Bank	0.9263	0.8419	0.88
United Bank of India	0.9962	0.7713	0.88
Syndicate Bank	0.7853	0.9737	0.88
Canara Bank	0.8326	0.9195	0.88
Indian overseas Bank	0.8614	0.888	0.87
Andhra Bank	0.7786	0.9583	0.87
Bank of India	0.7713	0.9651	0.86

Table 6. Mean of Mean Efficiency [VRS Model]

DMU	VRS Mean Efficiency - Stage 1	VRS Mean Efficiency - Stage 2	VRS- Mean of Mean Efficiency
Bank of Maharashtra	1	1	1
Punjab & Sind Bank	1	1	1
State Bank of India	1	1	1
United Bank of India	1	1	1
IDBI	1	1	1
Punjab National Bank	0.9646	0.9728	0.97
UCO Bank	0.9942	0.9322	0.96
Canara Bank	0.9423	0.9779	0.96
Central Bank of India	0.9611	0.9295	0.95
Union Bank of India	0.872	0.9976	0.93
Oriental Bank of Commerce	0.9548	0.9118	0.93
Bank of Baroda	0.8532	0.9969	0.93
Indian Bank	0.8836	0.9505	0.92

DMU	VRS Mean Efficiency - Stage 1	VRS Mean Efficiency - Stage 2	VRS-Mean of Mean Efficiency
Allahabad Bank	0.9507	0.8816	0.92
Corporation Bank	0.9406	0.8811	0.90
Andhra Bank	0.8148	0.9882	0.90
Bank of India	0.8115	0.9794	0.90
Syndicate Bank	0.7962	0.9852	0.89
Indian overseas Bank	0.8738	0.905	0.89

Table 7. Overall Mean Efficiency [VRS Model]

DMU	CRS - Mean of Mean Efficiency	VRS-Mean of Mean Efficiency	Overall Mean
IDBI	1	1	1
State Bank of India	1	1	1
Punjab & Sind Bank	0.94	1	0.97
Bank of Maharashtra	0.93	1	0.965
Punjab National Bank	0.93	0.97	0.95
UCO Bank	0.93	0.96	0.945
United Bank of India	0.88	1	0.94
Central Bank of India	0.91	0.95	0.93
Oriental Bank of Commerce	0.91	0.93	0.92
Canara Bank	0.88	0.96	0.92
Bank of Baroda	0.9	0.93	0.915
Union Bank of India	0.9	0.93	0.915
Allahabad Bank	0.89	0.92	0.905
Indian Bank	0.89	0.92	0.905
Corporation Bank	0.88	0.9	0.89
Andhra Bank	0.87	0.9	0.885
Syndicate Bank	0.88	0.89	0.885
Bank of India	0.86	0.9	0.88
Indian overseas Bank	0.87	0.89	0.88

5.7 Overall Mean Efficiency

Table 7 shows the mean of mean DEA efficiency score by comparing mean of mean efficiencies of CRS and VRS model. The results show that only 2 banks attained the efficiency score in their overall performance.

6. Conclusion

The aggregate two stage DEA reports based on CRS and VRS communicates that State Bank of India and IDBI are performing efficiently. Since this DEA approach helps to study the efficiency analysis only, the banks which are not up to the mark should use suitable forecasting DEA model to identify the lacking area and should devise proper appropriate methodology to improve their performance. This Two Stage model can be adopted to any kind of organization.

7. References

[1] R. D. Banker, A. Charnes and W. W. Cooper, "Some models for the estimation of technical and scale inefficiencies in data envelopment analysis", *Management Science.*, vol. 30, no. 9, pp. 1078-1092, 1984.

[2] A. Charnes, W. W. Cooper and E. Rhodes, "Measuring the efficiency of decision-making units", *European Journal of Operational Research.*, vol. 2, pp. 429-444, 1978.

[3] Y. Chen and J. Zhu, "Measuring information technology's indirect impact on firm performance", *Information Technology and Management Journal.*, vol. 5, no. 1-2, pp. 9 -22, 2004.

[4] M. J. Farrel, "The measurement of productive efficiency", *Journal of Royal Statistical Society Series A.*, vol. 120, no. 3, pp.253 -281, 1957.

[5] C. Kao and S. Hwang, "Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan", *European Journal of Operational*

Research., vol. 185, no. 1, pp. 418-429, 2008.

[6] P. Mariappan, Introduction to data envelopment analysis [DEA], LAP LAMBERT Academic publishing, 2016.

[7] P. Wanke and C. Barros, "Two-stage DEA: An application to major Brazilian banks", *Expert Systems with Applications.*, vol. 41, no. 5, pp. 2337-2344, 2014.

[8] R. Ramanathan, An Introduction to data envelopment analysis-A tool for performance measurement, Sage publications, 2003.

[9] L. M. Seiford and J. Zhu, "Profitability and Marketability of the top 55 US commercial banks", *Management science.*, vol. 45, no. 9, pp. 1270-1288, 1999.

[10] Z. Yang, "A two-stage DEA model to evaluate the overall performance of Canadian life and health insurance companies", *Mathematical and Computer Modeling.*, vol. 43, no. 7-8, pp. 910-919, 2006.

[11] J. Zhu, "Multifactor performance measure model with an application to fortune 500 companies", *European Journal of Operational Research.*, vol. 123, no. 1, pp. 105-124, 2000.