Revisiting the Efficiency of Indian Banking Sector: An Analysis of Comparative Models Through Data Envelopment Analysis

Jyoti Tanwar  
Research Scholar  
Department of Economics and Finance  
BITS-Pilani, Pilani Campus  
Jhunjhunu, Rajasthan- 333031, India  
E-mail: jyotanwar@gmail.com

Himanshu Seth  
Research Scholar  
Department of Management  
BITS-Pilani, Pilani Campus, India  
E-mail: hseth91@gmail.com

Arun Kumar Vaish  
Assistant Professor  
Department of Economics and Finance  
BITS- Pilani campus, India  
E-mail: arunkvaish@gmail.com

N V M Rao  
Professor  
Department of Economics and Finance  
BITS-Pilani, Pilani Campus, India  
E-mail: nvmrao@pilani.bits-pilani.ac.in

Abstract  
This study examines the efficiency of the overall Indian banking industry using Data Envelopment Analysis (DEA) and to perform a comparative efficiency analysis of public, private, and foreign banks using six varied forms. Also, providing ranks to the banks based on their efficiency. The study incorporates BCC output-oriented DEA model using a sample of 50 Indian banks (public banks = 17, private banks = 18, foreign banks = 15) for a period ranging from 2009-10 to 2018-19, hence incorporating the after-effects of the financial crisis and demonetization, this study uses panel data from 2009-10 to 2018-19. The results showed that most of the Indian banks fall on the efficient side or are near to full efficiency. However, public banks outperform private and foreign banks in terms of their average efficiency. Results also specify that the performance of banks is sensitive to input-output variables, units under evaluation, and choice of the model. The current study has just focused on the internal factors for analyzing the efficiency of Indian banks; however, certain external factors might also impact the banks’ efficiency.

Keywords: Banking, DEA, Efficiency, Ownership.

1. Introduction  
History of banking in India is as old as Vedic civilization where usury, as well as kusidin (money lender), has been commonly referred. In modern times the banking in India originated in the last decade of the 18th century and has evolved over the years to the present shape. After independence, India got a formal banking structure catering to the elite class of society comprising mainly traders, industrialists, and high net worth individuals. Banks act as a financial intermediary by converting deposits into productive investment, creating new capital, and thus accelerating economic development. Few significant events such as nationalization of scheduled banks, creation of Statutory liquidity ratio and Cash reserve ratio, entry of private banks, and introduction of income recognition and asset classification norms to determine Non-Performing assets led to greater competition and strengthening of the Indian banking sector. Reserve Bank of India has regulated the banking system from time to time to ensure that banks are resilient to global turmoil.

The working population of India is raising demand for banking services. Due to modernization and technological interference, banks have become accessible through mobile and internet. Mobile banking, internet banking, and ATMs have increased the volume of business for banks. Banks are also enjoying higher interest margins, which has led to competition. To curb competition and reduce NPAs, few public banks have decided to undergo a merger. Efficiency and productivity...
analysis of banks became essential to reduce costs and increase profitability. This critical analysis has gained importance, mainly due to the speediest dynamic environment where banks are facing heavy competition, and survival has become difficult.

The soundness and effectiveness of a banking system are often measured by efficiency, profitability improvement, increasing volume of funds flowing from savers to borrowers, and better-quality services for the customers. The efficiency and productivity analysis have caught the eye of the researcher in recent times. Researchers have faced one major hitch while measuring the effectiveness of banks. Banks provide products and services which are intangible. It is challenging to measure input injected, and output generated out of it.

A plethora of models were developed to calculate performance and efficiency. One such model was introduced in 1978 by Charnes et al., as Data Envelopment Analysis (DEA). DEA is a mathematical approach for evaluating the performance of a set of peer entities called Decision Making Units (DMU) that converts multiple inputs and multiple outputs. The simplicity of DEA over other models makes it a widely used method. In this model, its method and algorithm help in finding an optimization solution. Moreover, the input/output resulting in inefficiencies can be traced to every Decision-Making Unit.

Earlier, ratio analysis has been used as a cross-sectional technique to measure and compare the productivity of different industries. Ratio analysis is simple in use but also provides a limited explanation of results. Multiple data cannot be analyzed at once, limiting the use of ratio analysis. It loses its credibility when a comparison is made for firms having a different size. Results may also be ambiguous and incomplete. Data Envelopment overcame the limitations associated with ratio analysis.

DEA has been implemented to measure the performance of many other industries such as railways (Kwak et al., 2016; George & Rangaraj, 2008); hospitals (Sharma & Dipasha, 2018); Airport (Keskin & Köksal, 2019); schools (Mante & O’Brien, 2002); communication (Kwon et al., 2008; Sigala, 2003); Retail distribution network (Lau, 2012); Environment (Mehta et al., 2019); and Energy (Ashuri et al., 2019) etc.

In this research paper, an attempt is made to study efficiency analysis and performance benchmarking of Banks in India. The analysis is developed based on four areas of banking operational efficiency: deposit mobilization, fund conversion, non-core activities, and cost-revenue management. The efficiency of the bank as a whole is also estimated by following the intermediation approach and production approach. The BCC model of the DEA technique is implemented to evaluate the efficiency of banks.

The paper is comprised of an extensive literature review of DEA in banking, research methodology, sampling technique and data collection, the basis for selection of input and output, presentation and analysis of empirical findings, and conclusion.

2. Literature Review for DEA in Banking
DEA is a popular tool for the practitioner in deciding on a multidimensional framework. Initially, Charnes et al. (1978) extended Farrell’s efficiency measurement model. Charnes et al. (1978) developed a method that can incorporate multiple inputs and multiple outputs to determine single firm efficiency assuming Constant Return to Scale (CRS). Later, Banker et al. (1984) further extend the Charnes et al. (1978) CRS to variable returns to scale (VRS). In their study, they split the technical efficiency into pure technical efficiency and scale efficiency.

The use of DEA in the banking industry helps management to benchmark different Decision-Making Units (DMUs). DEA is a widely used tool to evaluate the performance of banks based on multiple inputs and outputs. In prior studies on banking efficiency using DEA, researchers have used either a production approach or an intermediation approach. In the production approach, the bank is viewed as a producer of products and services using physical labor, physical assets, and other resources as inputs while deposits, loans granted and the number of transactions done is treated as output (Ferrier & Lovell, 1990; Fried et al., 1993; Sherman & Gold, 1985). Whereas, the intermediation approach views the bank as an intermediate that transforms and transfers financial assets from saver to borrowers (Elyasiani & Mehdian, 1995; Rangan et al., 1988; Mercan et al., 2003). The production approach and an intermediation approach became the foundation for the selection of inputs and outputs.

The application of the DEA technique in recent literature is very vast. Wanke et al. (2019) studied the banking industry of MENA using Dynamic Network DEA. They tried to develop a relationship between financial and accounting indicators in banks used under the study. The banking industry is affected by the cultural and regulatory heterogeneity of MENA countries. Ownership, origin, and type of banks are also factoring that led to variation in efficiency scores of MENA banks.

Wang et al. (2019) estimated the efficiency of 18 large banks from all over the world by a dynamic slacks-based measure model in DEA. The Dynamic SBM model developed a new structure for interpreting the inputs and outputs. The findings of the study reveal the accurate efficiency of 18 banks to position them in the global market. Jreisat et al. (2018) undertake 14 Egyptian banks to investigate productivity changes using Malmquist indices in DEA model. Determinants of productivity change were further investigated using regression model. Maturity of banks, size of banks and higher loan to deposit ratio reflected higher potential for productivity.

Kamarudin et al. (2019) studied the revenue efficiency, cost efficiency, and profit efficiency of the domestic Malaysian Islamic banks and Malaysian foreign Islamic banks. The study revealed that Malaysian domestic banks are relatively revenue and cost-inefficient as compare to foreign banks operating in Malaysia. Profit inefficiency is influenced by higher revenue inefficiency. Further, Bank specific and external factors are analyzed to derive their relationship with domestic Malaysian
Islamic banks’ efficiency. The factors such as bank size, liquidity, and management quality have a positive effect on efficiency whereas, bank market power has negatively influenced the efficiency of banks in Malaysia.

Zhao et al (2019) developed a three-stage model to examine the efficiency of Listed Chinese banks for the year 2014-16. Inefficiencies of banks in three stages and different periods are evaluated. Unused assets were carried forward in this model. Employees’ cost and fixed assets are termed as shared inputs because these can be used as inputs for multiple outputs. Credit risk is reflected by NPAs that are treated as undesired output in the study. The study indicated that increasing business scale and identifying sensitive banks can improve the performance of banks in the future. Gormanòv & Ivanòv (2018) analyzed the efficiency of banks based in the Slovak Republic for the years 2009 and 2013. In the year 2009, most banks suffered the effects of the financial crisis. By the end of year 2013 most banks were able to overcome the ill-effects of the financial crisis. The efficiency of banks is determined using a combination of inputs and outputs. Ofori-sasu et al. (2019) studied the effect of the funding structure of 25 Ghana banks on technical efficiency. Deposit funding and non-deposit funding have a positive influence on technical efficiency. Ghana banks are generally inefficient as managers are unable to exploit technology, and optimally utilize inputs to generate outputs.

Yannick et al (2016) addressed the difficulty faced by banks of Côte d’Ivoire to convert deposits into credit. After investigating 25 banks, it is found that banks are inefficient in loan allocation due to incompatibility of production scale. Foreign Private banks are more efficient as comparative to pubic banks. Janet et al. (2015) examined the performance and productivity of state-owned commercial banks in China. Big four banks are analyzed from 1990 to 2008 to study the banks’ reaction to bank reform. The banks under study reacted positively during the reform period in terms of technical efficiency, scale efficiency, and productivity change. The results also indicate that protection, support, and intervention of the government has reduced innovation and motivation among employees.

Desta (2016) has shown various applications of the DEA model. The DEA model can be used to determine the firm’s efficiency, ranking of firms based on efficiency scores, and selecting the most efficient banks. Jemnic & Vujcic (2002); Hauner & Peiris (2005); Matthews & Ismail (2006); Isik (2007) studied the efficiency of banks based on their ownership structure and revealed that foreign banks are more efficient and productive than domestic banks. On the other hand, Hadad et al. (2008); Sufian (2009); Tahir et al. (2009); Fetbi et al. (2011) results presents that domestic banks are more efficient than foreign banks.

2.1 Literature Review on DEA in Indian Banking

Several studies have been carried out on Efficiency Analysis using DEA approach on Indian banking. Bhattacharyya et al. (1997) used DEA and stochastic frontier approach (SFA) to analyze the technical efficiency of banks and reasons for variations in efficiency scores, respectively. The results reveal that public sector banks performed way better than private and foreign banks in terms of technical efficiency. The performance is hindered by operational constraints, capital adequacy norms, and priority sector lending requirements.

The study of Kumar & Gwalani (2009) showed that the technical efficiency of Indian public banks has improved in the post-reform period. Most banks exhibit improvement in efficiency after the first phase of reform. By using the concept of convergence, it is discovered that the inefficient banks performed reasonably well, and few overtake the already existing efficient banks. The noteworthy reasons for the increase in performance are heightened competition due to entry of private sectors, increase in operational efficiency, reduction in the cost of financial transactions, rightsizing of the labor force, use of technology, and recovery of NPAs. A study conducted by Ray & Das (2010) during the post-reform period indicates that the profit efficiency of public banks is higher than private banks. The estimates of non-parametric kernel density manifest rightward-shift in the distribution of efficiency. The cause of inefficiency is the ineffective scale of economy, bank size, and product mix.

Sathy e (2003); Mohan & Ray (2004) undertake banks of a developing country, i.e., India, in the research. The productive efficiency of banks is measured, and the efficiency scores demonstrate that public sector banks and foreign banks perform better than private banks. The study recommends that efforts should be made to bring down NPAs and the cost of operations. However, the study of (Shanumugam & Das, 2004) indicated the supremacy of deposits input in generating outputs. The output of banks such as non-interest income, investments, and credits has shown steady improvement over a period of time. Progress in the productivity of Indian banks proclaims the success of the implementation of reforms.

Sanjeev (2006, 2009) studied the Indian banks during the reform period to ensure the improvement in the efficiency of banks. The average efficiency scores of public and private sector banks have increased significantly. A few banks in the public sector have declined in their performance due to increased competition. The competition has risen with liberalization policy, giving a green signal for entry of private sectors in the banking industry. An increase in NPAs has shown an inverse relationship with the efficiency of banks. Likewise, Tamatam et al. (2019) proves that Public sector banks had less efficiency and improvement in technology when compared with private banks.

Zhao et al. (2008) examined Indian banks based on ownership, where foreign banks have higher technical efficiency scores in the first phase of deregulation than private and public banks. In the second phase, public banks performed better than others due to the rise in competition and the advancement of technology. The NPLs are taking into consideration to determine the output efficiency. It is, however, observed that priority sector lending affected the credit quality of banks.

Rezvaman et al. (2008) conducted a study on the Indian banking industry covering the period between 1998 and 2003. An attempt is made to examine the effect of ownership, technological progress, and productivity growth on the efficiency of banks. Based on the efficiency scores calculated for three types of banks, foreign-owned banks ranked one in the efficiency,
whereas private banks ranked two, and public banks stood last in the ranking. The rationalization for inefficiency is the under-optimal scale of operations of most of the banks.

Das & Ghosh (2009) assessed that banks are cost-efficient in India and can control the wastage and underutilization of resources. However, in terms of profit efficiency, banks lie inside the efficient profit frontier. Higher capital and less Non-performing loans exhibit an increase in the efficiency of most banks.

Jagwani (2012) studied the pure technical and scale efficiency of Indian banks. The inefficiency of banks is justified by managerial sub-performance. Management is incapable of converting inputs into outputs optimally. Other than management quality, the sub-optimal scale of operation caused inefficiencies in the banking sector. The study of Mukherjee et al. (2002) showed the positive outcome of liberalization on banking sector performance measures. With the implementation of a multi-correlation clustering method, a strategic group of banks is identified based on efficiency measure. This approach will help bank managers to recognize their key competitors and plan for future strategies.

2.2 Literature Review on Input and Output

It is essential in DEA methodology to select appropriate inputs-output for estimating the efficiency of banks. There is no consensus on the choice of input-output, and input-output variables affect the derived efficiency level. For the banking industry, there are two approaches, mainly: the production approach and the intermediation approach. The selection of deposit as an input variable or output variable is the only difference between the two approaches. For the production, approach industry, there are two approaches, mainly: the product approach and the intermediation approach. The selection of appropriate inputs and outputs used by authors for deriving the efficiency of banks are given under in table I.

Table 1. Summary of Input-Output Literature

| S. No | Author and Year | Input | Output | No. of banks | Country |
|-------|-----------------|-------|--------|--------------|---------|
| 1.    | Kantor & Maital (1999) | Labour costs, services, area | Number of demand deposits, customer services transactions, credit cards, commission on import-export, commercial accounts activity | 230 | Mid-East |
| 2.    | Golany & Storbeck (1999) | Labour, area, marketing | Loans, deposits, number of accounts per customer, satisfaction | 182 | USA |
| 3.    | Mukherjee et al. (2002) | Net worth, borrowings, operating expenses, number of employees, number of bank branches | Deposits, Net Profits, advances, non-interest income, interest spread | 68 | India |
| 4.    | Sathy (2003) | Interest expense, non-interest expense | Interest income, non-interest income | 94 | India |
| 5.    | Ho & Zhu (2004) | Assets, employees, branches, capital stocks | Sales, deposits | 41 | Taiwan |
| 6.    | Howland & Rowse (2006) | Non sales FTE, sales FTE, size, city employment rate | Loans, deposits, average number of products/customers, customer loyalty | 162 | Canada |
| 7.    | Ariff & Can (2008) | Deposits and other funds, number of employees, physical capital | Loans, investments | 28 | China |
| 8.    | Das & Ghosh (2009) | Deposits, number of employees, capital-fixed asset, equity | Loans and advances, investments, other income | 71 | India |
| 9.    | Olson & Zoubi (2011) | Deposits, labour, physical capital | Net loans, dollar value of securities and other earning assets | 80 | MENA |
| 10.   | Jagwani (2012) | Net fixed assets, staff, deposits and borrowings, net worth, operating expenses, Non-performing assets, payments and provisions related to employees, other liabilities and provisions | Net interest income, non-interest income, investments, net profits, advances | 42 | India |
| 11.   | Řepková (2013) | Labour, deposits | Loans, net interest income | 11 | Czech Republic |
| 12.   | Malhotra et al. (2011) | Efficiency ratio, Interest expense to interest earned ratio, Loan to total fund ratio | Return on asset, Interest income relative total fund, Interest spread, Asset utilization ratio, Capital adequacy | 35 | India |
| 13.   | Yannick et al. (2016) | Deposits, Fund borrowed | Volume of loan granted | 14 | Côte d’Ivoire |
| 14.   | Desta (2016) | Interest expense, Non-interest expense, Transaction deposit, Non-transaction deposit | Gross loan, Other earning assets, Interest income, Non-interest income | 19 | Africa |
the practical scenario, using the BCC model for the analysis is more suitable. Considering varying economies of scale in the input-output dataset, also known as the CCR model which assumed a constant return to scale. Further, Banker et al. (1984) extended the CCR model for technologies exhibiting a variable return to scale. These DEA approaches involve constructing an efficient production frontier by applying linear programming techniques based on best practices over the data set. The efficiency of each DMU is then measured with this frontier. The DMUs with efficiency scores as '1' will lie on the frontier and would be efficient, and DMUs not lying on the frontier would be inefficient with scores less than 1. Most popularly, organizations involving multiple inputs for producing multiple outputs have been using the DEA technique for evaluating their organizations’ efficiency. The available literature on DEA models has used various mathematical approaches. Essentially, these models establish which DMUs govern the efficient frontier or best practice frontier or envelopment surface. Mainly, there are two types of models - input-oriented and output-oriented. Input oriented model aims at reducing the number of inputs keeping the output levels at the same levels. The objective of the Output-oriented model is maximizing the level of output, following the same level of inputs. The present study incorporates specific DEA model as prescribed by Kumar & Gulati (2009). It uses the BCC output-oriented model for identifying the banks on the output frontier provided with several inputs at their disposal. Considering varying economies of scale in the practical scenario, using the BCC model for the analysis is more suitable.

The following expression illustrates the DEA BCC model:

\[
\text{max } \varphi
\]

subject to

\[
\sum_{j=1}^{n} \lambda_j \cdot x_{ij} \leq x_{i0}
\]

\[
\sum_{j=1}^{n} \lambda_j \cdot y_{rj} \geq \varphi y_{r0}
\]

\[
\sum_{j=1}^{n} \lambda_j = 1
\]

Where,
- \(i = 1, 2, \ldots, m\);
- \(r = 1, 2, \ldots, s\);
- \(j \neq 0\); and,
- \(\varphi\) signifies efficiency scores
- \(\lambda_j\) denotes the weight of DMU (decision-making unit) \(j\)
- \(x_{ij}\) denotes the \(i\) input of DMU \(j\)
- \(y_{rj}\) denotes the \(r\) input of DMU \(j\)

There are \(m\) inputs and \(s\) outputs for all \(N\) decision-making units.
3.1 Sampling and Data
The present study selects 50 banks in India, consisting of 17 Public Banks, 18 private sector banks, and 15 foreign banks; the list is given Appendix 1. The selection of banks is made as per the availability of data for years 2010-2019. The data collected for the research paper is annual and collected from the secondary source. Annual bank-level data is obtained from ‘Capitaline Plus’ for the financial year 2009-2010 to 2018-2019, i.e., for 10 years. The time period taken in the study covers the post-financial crisis period and demonetization period effects. Therefore, the period is sufficient to study the drastic changes that occur in the economy.

3.2 Selection of Input and Output
The input and output variables selected for the study pertain to the existing literature. Mainly the input-output is guided by the operational pattern, performances, and objectives of the banks functioning in India. The input-output variables have been segregated in two headings: Area wise and Approach wise. Area-wise selection of input & output variables is further divided into four sets based on performance-based efficiency, whereas, Approach-wise selection of input & output variables is divided into two sets. The table 2 and table 3 shows the choice of input-output variables in the study.

Table 2. Area wise four sets of input & output variables

| S.No | Performance base efficiency | Input | Output |
|------|-----------------------------|-------|--------|
| 1.   | Deposit Mobilization Efficiency (DME) | Fixed Assets, Employee Cost, Interest expense on deposits | Deposits |
| 2.   | Fund Conversing Efficiency (FCE) | Fixed Asset, Employee Cost, Loanable fund | Earning Assets |
| 3.   | Off-Balance Sheet Activities Efficiency (OBE) | Fixed Assets, Employee Cost | Total Non-Interest Income |
| 4.   | Cost- Revenue Management Efficiency (CRE) | Total Interest Expense, Total Non-Interest Expense | Net total Income Profit After Tax (PAT) |

Table 3. Approach wise two sets of input & output variables

| S. No | Approach based efficiency | Input | Output |
|-------|---------------------------|-------|--------|
| 1.    | Intermediation Approach Efficiency (IAE) | Loanable funds, Operating Expenses | Earning Assets, Total Income, Profit After Tax (PAT) |
| 2.    | Production Approach Efficiency (PAE) | Fixed Assets, Employee Cost | Deposits, Earning Assets |

DME and FCE capture traditional functions of banks, whereas OBE measures the efficiency of the bank for non-traditional activities. CRE depicts the cost minimization and revenue maximization efficiency of banks. In the production approach, a bank is treated as a producer of services, while in the intermediation approach, it is treated as a facilitator.

In previous researched fixed assets and Number of employees were taken as a proxy for physical capital and labor. Here, in the present study, Fixed assets and Employee costs have been used instead. Here is a detail for inputs and outputs:

(a) Deposit = saving deposits + demand deposits + term deposits
(b) Loanable fund = deposits + borrowings
(c) Earning Assets = Investments + Advances
(d) Total Non-Interest Income = Commission & Brokerage + Other non-interest income
(e) Total Interest Expense = Interest expense on Deposits + Interest paid on borrowings
(f) Total Non-Interest Expense = Operating Expenses + Non-operating expenses
(g) Total Income = Interest income + Non-interest Income
(h) Net total Income = Non-Interest Income + Net Interest Income (Interest income – interest expense)

The study has undertaken six types of efficiency for each bank selected for 10 years using the VRS (BCC) model. The banks are segregated further based on ownership, i.e., public banks, private sector banks, and foreign banks. The purpose of the study is to find efficient banks as per the ownership structure based on all six types of efficiency and composite scores derived from the average of the above six types.

4. Results and Discussion
4.1 Private Sector Banks
The study was conducted on 18 private banks, and efficiency scores were calculated based on six sets of Input & Output variables. From the descriptive analysis of statistic of efficiency, it was revealed that private banks were most efficient in Intermediation Approach Based Efficiency (97.35%), followed by Fund Conversion Efficiency (96.99%), Cost- Revenue Efficiency (88.41%), Deposit Mobilization Efficiency (81.56%), Production Approach Based Efficiency (71.54%).
lowest efficiency of banks was found in Off-Balance sheet Activity Efficiency, i.e., 36.36%. The inefficiency of the bank also reveals that there is further scope for banks to increase output from the same inputs.

Table 4. Summary Statistics of efficiency of private banks

| Type of efficiency | IAE | PAE | DME | FCE | OBE | CRE | Composite Score |
|--------------------|-----|-----|-----|-----|-----|-----|-----------------|
| No. of DMU         | 18  | 18  | 18  | 18  | 18  | 18  | 18              |
| Average efficiency | 0.9735 | 0.7154 | 0.8186 | 0.9699 | 0.3636 | 0.8841 | 0.7870          |
| SD                 | 0.0275 | 0.2259 | 0.1488 | 0.0257 | 0.3336 | 0.0997 | 0.1113          |
| Maximum efficiency | 1   | 0.9751 | 0.9838 | 1   | 0.9972 | 1   | 1               |
| Minimum efficiency | 0.9061 | 0.3447 | 0.3589 | 0.9040 | 0.0390 | 0.6548 | 0.5819          |
| No. of efficient banks | 3   | 1   | 1   | 2   | 1   | 1   | 1               |

The table 5 shows the list of banks that were fully efficient in six types of efficiency calculated.

Table 5. List of fully efficient private banks

| Type of efficiency | Name of the bank                  |
|--------------------|-----------------------------------|
| IAE                | HDFC, Nainital Bank, RBL Bank Ltd |
| PAE                | HDFC                              |
| DME                | Jammu & Kashmir Bank              |
| FCE                | HDFC, Nainital Bank               |
| OBE                | ICICI Bank                        |
| CRE                | Nainital Bank                     |

It was observed that no bank was fully efficient in all six types of efficiencies. The composite score has been calculated by taking the average of IAE, PAE, DME, FCE, OBE, and CRE. The most efficient bank as per composite score is ICICI bank, followed by Axis bank, HDFC bank, IndusInd Bank, and Federal Bank.

Just after the financial crisis, the performance of most banks in the private sector is inefficient. However, few banks recovered in a later period, and their performance has also accelerated. During the demonetization phase 2016-17, the business of banks has undoubtedly flourished, which is reflected in their performance. Excess deposit growth in the banking system during this period has increased the performance of most of the banks in the private sector.

If we talk about non-traditional activities, then private banks are still lagging. Traditional activities generate a large portion of revenue, and non-traditional activities contribute a very insignificant amount.

Figure 1 shows the efficiency score of private banks. The average score for 10 years has been taken to determine the efficiency score for IAE, PAE, DME, FCE, OBE and CRE.

4.2 Public Sector Banks
Likewise, the analysis was conducted on 17 Public sector banks, and the results were similar to private sector banks. The efficiency of banks is highest in IAE with 98.58%, followed by FCE - 98.28%, CRE - 94.36%, DME - 92.32%, PAE - 84.94%, OBE - 78.92%. This analysis shows that the performance of banks is still based on traditional functions. Still, the
off-balance-sheet activity efficiency of Public banks is significantly better than private and foreign banks. Public banks deal in insurance, brokerage, and generate fair revenue.

Table 6. Summary statistics of efficiency of public sector banks

| The summary statistics of different efficiency | IAE       | PAE       | DME       | FCE       | OBE       | CRE       | Composite score |
|------------------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------------|
| No. of DMU                                      | 17        | 17        | 17        | 17        | 17        | 17        | 17              |
| Average efficiency                             | 0.9858    | 0.8494    | 0.9232    | 0.9828    | 0.7892    | 0.9436    | 0.9124          |
| SD                                             | 0.0158    | 0.1240    | 0.0668    | 0.0175    | 0.1594    | 0.0446    | 0.0554          |
| Maximum efficiency                             | 1         | 1         | 1         | 1         | 1         | 1         | 1               |
| Minimum efficiency                             | 0.9363    | 0.5913    | 0.7884    | 0.9472    | 0.4813    | 0.8761    | 0.8312          |
| No. of efficient banks                         | 3         | 4         | 3         | 4         | 2         | 2         | 2               |

The table 7 shows the list of banks that were fully efficient in six types of efficiency calculated.

Table 7. List of fully efficient public sector banks

| Type of efficiency | Name of the bank                                                  |
|--------------------|-------------------------------------------------------------------|
| IAE                | Indian Bank, Punjab & Sind Bank, State Bank of India              |
| PAE                | Bank of Baroda, Corporation Bank, Punjab & Sind Bank, State Bank of India |
| DME                | Bank of Baroda, Corporation Bank, Punjab & Sind Bank, State Bank of India |
| FCE                | Andhra Bank, Corporation Bank, Punjab & Sind Bank, State Bank of India |
| OBE                | Punjab & Sind Bank, State Bank of India                           |
| CRE                | Punjab & Sind Bank, State Bank of India                           |

State bank of India and Punjab & Sind Bank are fully efficient in all six types of efficiencies – IAE, PAE, DME, FCE, OBE, and CRE. The most efficient bank as per composite score is again State bank of India and Punjab & Sind bank. Apart from them, other efficient banks with rank 2, 3, 4 & 5 are Corporation Bank, Bank of Baroda, Andhira Bank, and Canara bank, respectively.

The efficiency of Public sector banks is generally stagnant even after the crisis. Most banks have recovered at a faster pace due to the governmental policies to revive the economy.

During demonetization, Public sector banks have lion share in deposits leading to lower cost of funds, yet the performance of banks has declined. Most banks were not able to discharge their day to day operations during the demonetization phase. There was excess deposit but also withdrawals from banks. Most banks were busy exchanging banned currency notes as per the RBI guidelines and could not perform their regular work. These events led to a decline in the performance of banks.

Figure 2 represents the efficiency score of public sectors banks. The average score for 10 years has been taken to determine the efficiency score for IAE, PAE, DME, FCE, OBE and CRE.
Foreign banks also showed a similar pattern of efficiency when compared with Public banks and Private Banks. Banks are highly efficient for IAE – 92.83% and least efficient in OBE – 55.88%.

### Table 8. Summary Statistics of efficiency of foreign banks

| Type of efficiency | No. of DMU | Average efficiency | SD | Maximum efficiency | Minimum efficiency | No. of efficient banks |
|--------------------|------------|--------------------|----|--------------------|--------------------|------------------------|
| IAE                | 15         | 0.9283             | 0.0911 | 1                 | 0.7409             | 4                      |
| PAE                | 15         | 0.7871             | 0.2354 | 1                 | 0.2443             | 4                      |
| DME                | 15         | 0.8696             | 0.1567 | 1                 | 0.5257             | 5                      |
| FCE                | 15         | 0.9374             | 0.0906 | 1                 | 0.6863             | 6                      |
| OBE                | 15         | 0.5588             | 0.3323 | 1                 | 0.0943             | 4                      |
| CRE                | 15         | 0.8532             | 0.1394 | 1                 | 0.6134             | 4                      |
| Composite Score    |            | 0.8224             | 0.1192 | 1                 | 0.6369             | 1                      |

The table 9 shows the list of banks that were fully efficient in six types of efficiency calculated.

### Table 9. List of fully efficient foreign banks

| Type of efficiency | Name of the bank                                                                 |
|--------------------|----------------------------------------------------------------------------------|
| IAE                | Standard Chartered Bank, Barclays, Bank of Ceylon, American Express               |
| PAE                | Standard Chartered Bank, Barclays, Shinhan Bank, Krung Thai Bank Public Company Ltd |
| DME                | Standard Chartered Bank, Barclays, AB Bank, Mashreq bank, PSC, Krung Thai Bank Public Company Ltd |
| FCE                | Standard Chartered Bank, Barclays, Bank of Ceylon, American Express, AB Bank, Krung Thai Bank Public Company Ltd |
| OBE                | Standard Chartered Bank, American Express, AB Bank, Krung Thai Bank Public Company Ltd |
| CRE                | Bank of Ceylon, American Express, Mashreq bank, Standard Chartered Bank           |

There is only one bank which is fully efficient in all six types of efficiency i.e., Standard Chartered Bank. When composite efficiency is calculated and banks are ranked, then also standard Chartered bank is ranked first. Banks that secured rank 2, 3, 4, and 5 are Krung Thai bank Public Company Ltd, AB Bank, Barclays, and Mashreq bank respectively. Figure 3 represents the efficiency score of foreign sectors banks.

![Figure 3. Efficiency score of foreign banks (Average of 10 years)](image-url)
4.4 Ownership Based Analysis

From the tables provide above on descriptive statistics of efficiency based on IAE, PAE, DME, FCE, OBE, and CRE for Private, Public and Foreign banks, a summary table is derived which shows the most efficient, moderately efficient and least efficient banking sector.

The analysis shows that Public sector banks are leading private and foreign banks in all six types of efficiency. In contrast, private banks are moderately efficient for IAE, FCE, and CRE and least efficient for PAE, DME, and OBE. As for Foreign banks, they are moderately efficient for PAE, DME, and OBE.

Table 10. Ownership-wise efficiency of banks

| Efficiency level   | IAE   | PAE   | DME   | FCE   | OBE   | CRE   |
|--------------------|-------|-------|-------|-------|-------|-------|
| Most efficient     | Public bank | Public bank | Public bank | Public bank | Public bank | Public bank |
| Moderately efficient| Private bank | Foreign bank | Foreign bank | Private bank | Foreign bank | Private bank |
| Least efficient    | Foreign bank | Private bank | Private bank | Foreign bank | Private bank | Foreign bank |

Later based on composite scores, it was revealed that public banks are leading, followed by private banks and foreign banks. Ownership of banks has a significant impact on the productivity and efficiency of banks. Public banks are more efficient than private and foreign banks (Jagwani, 2012). The efficiency of Public sector banks is 91.23%, Private bank – 78.71%, and Foreign Bank – 82.24%. Though the efficiency of foreign banks is significantly more than Private banks yet when compared with standard deviation, Private bank shows lesser deviation. The dispersion amongst the public banks is very less when compared with private and foreign banks, which reflects the single ownership of government. Moreover, Public banks generally follow identical practices and policies. The competition has also contributed towards increased efficiency of Public banks as they thrive for their survival with expansion of private and foreign sector banks (Zhao et al., 2008; Sanjeev, 2006, 2009; Kumar & Gulati, 2009). Rationalization of staff and branches has reduced cost burden on banks. The higher value of standard deviation in private and foreign banks indicates that the methods of banks might differ due to diverse management and ownership.

Minimum dispersion in public sector banks is consistent with the results of Bhattacharyya et al. (1997); Sathyé (2003). Public sector banks are more familiar with the regulatory system as compared to foreign banks. Bhattacharyya et al. (1997) justified the greater variability in the efficiency of foreign banks by showing that they depend on less stable wholesale or corporate resources, interbank borrowings, and refinancing of assets. On the other hand, the domestic banks have an extensive network of branches and rely on a more stable retail banking business.

Table 11. Summary of statistics based on ownership

| Summary of statistics | Public bank | Private bank | Foreign bank |
|-----------------------|-------------|--------------|--------------|
| No. of DMU            | 17          | 18           | 15           |
| Mean                  | 0.9124      | 0.7871       | 0.8224       |
| SD                    | 0.0554      | 0.1112       | 0.1191       |
| Maximum               | 1           | 1            | 1            |
| Minimum               | 0.8312      | 0.5819       | 0.6369       |
| No. of efficient banks| 2           | 1            | 1            |
| coefficient of variation | 0.0607    | 0.1415       | 0.1449       |

4.5 Overall Analysis

Lastly, the efficiency score of all 50 banks without segregating them sector-wise was calculated, and the results are unique. The top five banks for overall efficiency are State Bank of India, ICICI, YES Bank, Axis Bank, and HDFC. Fully efficient banks for IAE, PAE, DME, FCE, OBE and CRE is shown in the table 12 below:

Table 12. List of fully efficient banks in six types of efficiency

| IAE          | PAE          | DME          | FCE          | OBE          | CRE          |
|--------------|--------------|--------------|--------------|--------------|--------------|
| State Bank of India | Bank of Baroda | Bank of Baroda | State Bank of India | State Bank of India | State Bank of India |
| Barclays     | Bank of Ceylon | State Bank of India | Barclays | AB Bank Ltd | HDFC         |
| Bank of Ceylon | Krung Thai Bank | Public Company | AB Bank Ltd | AB Bank Ltd | Krong Thai Bank | Standard Chartered |
5. Conclusion
The study identified 50 banks operating in India for the period 2009-10 to 2018-19, segmented them based on ownership into public, private, and foreign banks. The study is comprehensive in nature, as it uses different inputs and outputs to calculate the efficiency of banks. It is noted that the DEA technique is sensitive to inputs and outputs, CCR and BCC model, Number of DMUs, and the number of inputs and outputs. The results of the study proved that by changing inputs and outputs, the efficiency score of banks has also fluctuated. The efficiency scores are based on technical efficiency in this study.

Here in this study, efficiency is calculated using four key performance areas. The choice of Input and Output changes the efficiency scores each performance area, i.e., DME, FCE, OBE, and CRE. The model has also determined overall efficiency scores of banks using intermediation and production approach (IAE and PAE). Analyzing the efficiency in such a broader way made it possible to capture the multidimensional performance of banking. It provides insight for banks to improve performance in their weak areas of efficiency. Banks can also improve their productivity by bringing down the Non-Performing Loans, reducing the cost in fixed assets, and reducing the number of branches (Sathye, 2003; Chaluvadi et al., 2018). Digitalization and online banking have the potential to reduce both fixed asset cost and employee cost.

The analysis depicts that the technical efficiency of Private Banks is relatively less in Off-balance sheet efficiency (OBE) and Production Approach efficiency (PAE) as compared to other efficiencies. Banks can improve performance by focusing more on commission-based activities, increasing brokerage income, and other non-interest income. The results are similar for public banks and foreign banks. All banks are relatively efficient in the Intermediation approach (IAE). Merger and Acquisition can also play a significant role in increasing the efficiency of banks. Many studies, like Ishwarya (2019); Patel (2018); Singh & Gupta (2015) have found significant positive impact on the productivity of banks. Through mergers & acquisitions, banks were able to pool resources and minimize cost.

Generally, all banks have shown an increasing trend in efficiency scores with few exceptions. The efficiency score of Dhanlaxmi Bank, Tamilnad Bank, RBL Bank Ltd, and DCB (from private sector banks) has shown a decreasing trend in most of the types of efficiency. As for public banks, the performance of banks as accelerated over the period, but banks like Bank of India, Andhra Bank, and Bank of Maharashtra performed poorly in OBE. In foreign banks, the growth is seen in Dhanalaxmi Bank, Tamilnad Bank, RBL Bank Ltd, and DCB (from private sector banks) has shown a decreasing trend in most of the banks apart from a few. The poor-performing bank is Societe Generale. Over a while, the efficiency of a few banks declined due to intense competition as banks fight for resources.

There are a few limitations of this study, which can become a further scope of research. The relevance of the inputs and outputs can be examined by using regression analysis. Moreover, in this study, only the internal factors affecting the efficiency of banks are taken whereas, environmental factors could also be tested to influence their efficiency. The analysis may go further by decomposing technical efficiency change and technological progress using the DEA-based Malmquist productivity index. Also, scale efficiency can be calculated for further refinement of analysis. Data for 10 years for each bank was unavailable; therefore, many banks are dropped in the sample. Data for a few inputs, such as the number of employees and branches of banks for 10 years, is not available, resulting in either the dropping off input or used with modification. More inputs and outputs can be used, but as the DEA model suggests that the Number of DMUs should be greater than 3(m+n) or (m*n); therefore, we have refined inputs and outputs in the model.

References
Ariff, M., & Can, L. (2008). Cost and profit efficiency of Chinese banks: A non-parametric analysis. China Economic Review, 19(2), 260–273. https://doi.org/10.1016/j.chieco.2007.04.001
Ashuri, B., Wang, J., Shahandashti, M., & Baek, M. (2019). A data envelopment analysis (DEA) model for building energy benchmarking. Journal of Engineering, Design and Technology, 17(4), 747–768.
Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science, 30(9), 1078–1092. https://doi.org/10.1287/mnsc.30.9.1078
Bhattacharyya, A., Lovell, C. A. K., & Sahay, P. (1997). The impact of liberalization on the productive efficiency of Indian commercial banks. European Journal of Operational Research, 98(2), 332–345.
Chaluvadi, S., Raut, R., & Gardas, B. B. (2018). Measuring the performance efficiency of banks in a developing economy: The case study of Indian public sector vs private sector. Benchmarking: An International Journal, 25(2), 575–606. https://doi.org/10.1108/BJ1-10-2016-0157
Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European Journal of
Das, A., & Ghosh, S. (2009). Financial Deregulation and Profit Efficiency: A Non-parametric Analysis of Indian Banks. Journal of Economic and Business, 61(6), 509–528.

Desta, T. S. (2016). Are the best African banks really the best? A Malmquist data envelopment analysis. Meditari Accountancy Research, 24(4), 588–610.

Elyasiani, E., & Mehdian, S. (1995). The Comparative Efficiency Performance of Small and Large US Commercial Banks in the Pre- and Post Deregulation Eras. Applied Economics, 27, 1069–1079.

Ferrier, G. D., & Lovell, C. A. K. (1990). Measuring Cost Efficiency in Banking: Econometric and linear programming evidence. Journal of Econometrics, 46, 229–245.

Fethi, M. D., Shaban, M., & Weyman-Jones, T. (2011). Liberalisation, Privatisation and the Productivity of Egyptian banks: a non-parametric approach. The Service Industries Journal, 31(7), 1143–1163.

Fried, H. O., Lovell, C. A. K., & Schmidt, S. S. (1993). The Measurement of Productive Efficiency: Techniques and Applications. Oxford university.

George, S. A., & Rangaraj, N. (2008). A performance benchmarking study of Indian Railway zones. Benchmarking: An International Journal, 15(5), 599–617.

Golany, B., & Storbeck, J. E. (1999). A data envelopment analysis of the operational efficiency of bank branches. Interfaces, 29(3), 14–26. https://doi.org/10.1287/inte.29.3.14

Grmanová, E., & Ivanová, E. (2018). Efficiency of banks in Slovakia: Measuring by DEA models. Journal of International Studies, 11(1), 257–272.

Hadad, M. D., Hall, M. J. B., Kenjegalieva, K., Santoso, W., Satria, R., & Simper, R. (2008). Efficiency in Indonesian banking: Recent evidence (WP 2008–13).

Haunder, D., & Peiris, S. J. (2005). Bank Efficiency and Competition in Low-Income Countries: The Case of Uganda (WP/05/240). IMF Working Paper.

Ho, C.-T., & Zhu, D.-S. (2004). Performance measurement of Taiwan’s commercial banks. International Journal of Productivity and Performance Management, 53(5), 425–434. https://doi.org/10.1108/17410400410545897

Howland, M., & Rowse, J. (2006). Measuring bank branch efficiency using data envelopment analysis: Managerial and implementation issues. Information Systems and Operational Research, 44(1), 49–63. https://doi.org/10.1080/03155986.2006.11732739

Ishwarya, J. (2019). A Study on Mergers and Acquisition of Banks and a Case Study on SBI and its Associates. International Journal of Trend in Research and Development, September, 22–26.

Isik, I. (2007). Bank ownership and productivity developments: Evidence from Turkey. Studies in Economics and Finance, 24(2), 115–139.

Jagwani, B. (2012). Efficiency Measurement in the Indian Banking Industry: An Application of Data Envelopment Analysis. Vision, 16(4), 315–331.

Janet, J. X., Gan, C., & Hu, B. (2015). An empirical analysis of China’s Big four state-owned banks’ performance: A data envelopment analysis. Journal of Banking Regulation, 16, 1–21.

Jemric, I., & Vujicic, B. (2002). Efficiency of Banks in Croatia: A DEA Approach. Comparative Economic Studies, XLIV(2), 169–193.

Jreisat, A., Hassan, H., & Shankar, S. (2019). Determinants of the Productivity Change for the Banking Sector in Egypt. Global Tensions in Financial Markets (Research in Finance), 34, 86–116. https://doi.org/10.1108/S0196-382120170000034011

Kamarudin, F., Sufian, F., Aina, N., Anwar, M., & Hussain, H. I. (2019). Bank Efficiency in Malaysia a DEA Approach. Journal of Central Banking Theory and Practice, 3(1), 133–162.

Kantor, J., & Maital, S. (1999). Measuring Efficiency by Product Group: Integrating DEA with Activity-Based Accounting in a Large Mideast Bank. Interfaces, 29(3), 27–36.

Keskin, B., & Köksal, C. D. (2019). A hybrid AHP/DEA-AR model for measuring and comparing the efficiency of airports. International Journal of Productivity and Performance Management, 68(3), 524–541.

Kordrostami, S., Amirtemoori, A., & Noveiri, M. J. S. (2016). Ranking of bank branches with undesirable and fuzzy data: A DEA-based approach. Iranian Journal of Optimization, 8(2), 71–77.

Kumar, S., & Gulati, R. (2009). Did efficiency of Indian public sector banks converge with banking reforms? International Review of Economics, 56(1), 47–84. https://doi.org/10.1007/s12232-008-0057-2

Kwak, N. K., Chun, Y. S., & Kim, S. (2016). Benchmarking of rail transport service performance through DEA for Indian railways. The International Journal of Logistic Management, 27(3), 629–649.

Kwon, H., Stoebel, P. A., & Joo, S. (2008). Measuring comparative efficiencies and merger impacts of wireless communication companies. Benchmarking: An International Journal, 15(3), 212–224.

Lau, K. H. (2012). Distribution network rationalisation through benchmarking with DEA. Benchmarking: An International Journal, 19(6), 668–689.

Malhotra, R., Malhotra, D. K., & Poteau, R. R. (2011). A DEA Based Multidimensional Framework for Analyzing Commercial Banks. Proceedings of the Northeast Business & Economics Association, 281.

Mante, B., & O’Brien, G. (2002). Efficiency measurement of Australian public sector organisations. Journal of Educational
Matthews, K., & Ismail, M. (2006). Efficiency and Productivity Growth of Domestic and Foreign Commercial Banks in Malaysia (E2006/2).

Mehta, K., Sharma, R., & Vyas, V. (2019). Efficiency and ranking of sustainability index of India using DEA-TOPSIS. Journal of Indian Business Research, 11(2), 179–199.

Mercan, M., Reisman, A., Yaldan, R., & Emel, A. B. (2003). The effect of scale and mode of ownership on the financial performance of the Turkish banking sector: results of a DEA-based analysis. Socio-Economic Planning Sciences, 37, 185–202.

Mukherjee, A., Nath, P., & Pal, M. N. (2002). Performance benchmarking and strategic homogeneity of Indian banks. International Journal of Bank Marketing, 20(3), 122–139. https://doi.org/10.1108/0265232021043965

Ofori-sasu, D., Abor, J. Y., & Mensah, Lord. (2019). Funding structure and technical efficiency - A data envelopment analysis (DEA) approach for banks in Ghana. International Journal of Managerial Finance, 15(4), 425–443.

Olson, D., & Zoubi, T. A. (2011). Efficiency and bank profitability in MENA countries. Emerging Markets Review, 12(2), 94–110. https://doi.org/10.1016/j.ememar.2011.02.003

Paradi, J. C., Sherman, H. D., & Tam, F. K. (2018). Bank Branch Operational Studies Using DEA. In Data Envelopment Analysis in the Financial Services Industry (pp. 145-158). Springer, Cham.

Patel, R. (2018). Pre & Post-Merger Financial Performance: An Indian Perspective. Journal of Central Banking Theory and Practice, 7(3), 181–200. https://doi.org/10.2478/jcbtp-2018-0029

Rezvanian, R., Rao, N., & Mehdian, S. M. (2008). Efficiency change, technological progress and productivity growth of private, public and foreign banks in India: evidence from the post-liberalisation era. Applied Financial Economics, 18(9), 701–713. https://doi.org/10.1080/09603100701222317

Sanjeev, G. M. (2006). Data Envelopment Analysis (DEA) for Measuring Technical Efficiency of Banks. Vision: The Journal of Business Perspective, 10(1), 13–27.

Sanjeev, G. M. (2009). Efficiency of Indian Public Sector Banks: An Application of DEA Approach. The IUP Journal of Applied Finance, 15(11), 52–61.

Sathye, M. (2003). Efficiency of banks in a developing economy: The case of India. European Journal of Operational Research, 148, 662–671.

Shannugam, K. R., & Das, A. (2004). Efficiency of Indian commercial banks during the reform period. Applied Financial Economics, 14(9), 681–686. https://doi.org/10.1080/0960310042000233458

Singh, G., & Gupta, S. (2015). An Impact of Mergers and Acquisitions on Productivity and Profitability of Consolidation Banking Sector in India. Journal of Research in Management & Technology, 4(9), 33–48.

Sufian, F. (2009). Determinants of bank efficiency during unstable macroeconomic environment: Empirical evidence from Malaysia. Research in International Business and Finance, 23, 54–77.

Tahir, I. M., Bakar, N. M. A., & Haron, S. (2009). Evaluating Efficiency of Malaysian Banks Using Data Envelopment Analysis. International Journal of Business and Management, 4(8), 96–106.

Tammatam, R., Dutta, P., Dutta, G., & Lessmann, S. (2019). Efficiency analysis of Indian banking industry over the period 2008–2017 using data envelopment analysis. Benchmarking: An International Journal.

Wang, C., Luu, Q., Nguyen, T., & Day, J.-D. (2019). Assessing Bank Performance Using Dynamic SBM Model. Mathematics, 7(1), 1–13.

Wanke, P., Kalam, A., Emrouznejad, A., & Antunes, J. (2019). A dynamic network DEA model for accounting and financial indicators: A case of efficiency in MENA banking. International Review of Economics and Finance, 61, 52–68.

Yannick, G. Z. S., Hongzhong, Z., & Thierry, B. (2016). Technical Efficiency Assessment Using Data Envelopment Analysis: An Application to the Banking Sector of Côte D’Ivoire. Procedia - Social and Behavioral Sciences, 235, 198–207. https://doi.org/10.1016/j.sbspro.2016.11.015

Zhao, T., Casu, B., & Ferrari, A. (2008). Deregulation and productivity growth: a study of Indian commercial banking.
Zhou, X., Xu, Z., Chai, J., Yao, L., Wang, S., & Lev, B. (2019). Efficiency evaluation for banking systems under uncertainty: A multi-period three-stage DEA model. *Omega, 85*, 68–82.

### Appendix -A

Table 1. List of banks

| S.No. | Private banks | Public banks | Foreign bank |
|-------|---------------|--------------|--------------|
| 1     | Axis bank     | Allahabad Bank | Standard Chartered Bank |
| 2     | DCB Bank Ltd. | Andhra Bank | Barclays Bank |
| 3     | HDFC Bank     | Bank of Baroda | AB bank Ltd. |
| 4     | ICICI bank Ltd.| Bank of India | BNP Paribas |
| 5     | IndusInd Bank Ltd. | Bank of Maharashtra | Societe Generale |
| 6     | Kotak mahindra bank Ltd. | Canara Bank | Shinhansen Bank |
| 7     | YES bank      | Corporation Bank | Bank of Ceylon |
| 8     | Dhanlaxmi bank | Indian Overseas Bank | Abu Dhabi Commercial Bank |
| 9     | City Union bank | Indian Bank | Credit Agricole Corporate Bank |
| 10    | Federal Bank  | Oriental Bank of Commerce | Bank of Bahrain & Kuwait bank |
| 11    | Jammu and Kashmir bank | Punjab & Sind Bank | Mashreqbank P S C bank |
| 12    | Karnataka Bank | Punjab National Bank | MUFG Bank Ltd |
| 13    | Karur Vysya Bank | State Bank of India | Firstrand Bank Ltd |
| 14    | Lakshmi Vilas Bank | Syndicate bank | Krung Thai Bank Public bank |
| 15    | Nainital Bank  | UCO Bank | American Express Bank Ltd. |
| 16    | RBL bank Ltd. | Union Bank of India |
| 17    | South Indian Bank | United Bank of India |
| 18    | Tamilnad Mercantile bank | |

### Appendix -B

Table 2. Average Efficiency score of private sector banks (10 years)

| DMU                | IAE  | PAE  | DME  | FCE  | OBE  | CRE  | Composite score | Composite rank |
|--------------------|------|------|------|------|------|------|-----------------|----------------|
| Axis bank          | 0.9660 | 0.9738 | 0.9289 | 0.9869 | 0.9614 | 0.9668 | 0.9690 | 2              |
| DCB Bank Ltd.      | 0.9834 | 0.5335 | 0.8124 | 0.9974 | 0.1360 | 0.7078 | 0.6951 | 15             |
| HDFC Bank          | 1    | 0.9752 | 0.8349 | 1    | 0.9449 | 0.9588 | 0.9523 | 3              |
| ICICI bank Ltd.    | 0.9999 | 0.9688 | 0.9517 | 0.9761 | 0.9972 | 0.9997 | 0.9822 | 1              |
| IndusInd Bank Ltd. | 0.9798 | 0.9092 | 0.9409 | 0.9621 | 0.6480 | 0.7640 | 0.8673 | 4              |
| Kotak mahindra bank| 0.9988 | 0.8611 | 0.7360 | 0.9988 | 0.6259 | 0.8947 | 0.8525 | 6              |
| YES bank           | 0.9657 | 0.9060 | 0.7042 | 0.9614 | 0.4144 | 0.9813 | 0.8222 | 8              |
| Dhanlaxmi bank     | 0.9305 | 0.3642 | 0.3590 | 0.9677 | 0.2154 | 0.6549 | 0.5819 | 18             |
| City Union bank    | 0.9635 | 0.4209 | 0.7985 | 0.9627 | 0.1497 | 0.8919 | 0.6979 | 14             |
| Federal Bank       | 0.9739 | 0.9071 | 0.9182 | 0.9679 | 0.3933 | 0.9550 | 0.8526 | 5              |
| Jammu & Kashmir bank| 0.9335 | 0.9391 | 0.9839 | 0.9490 | 0.3557 | 0.8568 | 0.8363 | 7              |
| Karnataka Bank     | 0.9525 | 0.7310 | 0.9030 | 0.9387 | 0.0779 | 0.8249 | 0.7380 | 11             |
| Karur Vysya bank   | 0.9753 | 0.6274 | 0.8567 | 0.9508 | 0.0537 | 0.8734 | 0.7229 | 13             |
| Lakshmi Vilas bank | 0.9764 | 0.5899 | 0.9301 | 0.9532 | 0.2284 | 0.8162 | 0.7490 | 10             |
| Nainital bank      | 1    | 0.6345 | 0.6913 | 1    | 0.2031 | 1    | 0.7548 | 9              |
| RBL bank Ltd.      | 1    | 0.4404 | 0.6728 | 0.9856 | 0.0518 | 0.9589 | 0.6849 | 16             |
| DMU                        | IAE      | PAE      | DME      | FCE      | OBE      | CRE      | Composite score | composite rank |
|---------------------------|----------|----------|----------|----------|----------|----------|-----------------|----------------|
| South Indian bank         | 0.9061   | 0.7505   | 0.8762   | 0.9040   | 0.0391   | 0.9350   | 0.7352          | 12             |
| Tamilnad Mercantile Bank  | 0.9884   | 0.3448   | 0.7839   | 0.9963   | 0.0495   | 0.8751   | 0.6730          | 17             |

Note: Composite score = IAE+PAE+DME+FCE+OBE+CRE / 6

Appendix -C

Table 3. Average Efficiency scores of public sector banks (10 years)

| DMU                        | IAE      | PAE      | DME      | FCE      | OBE      | CRE      | Composite score | composite rank |
|---------------------------|----------|----------|----------|----------|----------|----------|-----------------|----------------|
| Allahabad Bank            | 0.9745   | 0.7154   | 0.8397   | 0.9768   | 0.6787   | 0.9350   | 0.8533          | 14             |
| Andhra Bank               | 0.9835   | 0.9125   | 0.9753   | 0.9868   | 0.8061   | 0.9031   | 0.9438          | 4              |
| Bank of Baroda            | 0.9363   | 0.8897   | 0.9223   | 0.9486   | 0.8061   | 0.9031   | 0.9734          | 3              |
| Bank of India             | 0.9993   | 0.5913   | 0.9811   | 0.9750   | 0.4813   | 0.9797   | 0.8312          | 8              |
| Tamilnad Bank             | 0.9884   | 0.3448   | 0.7839   | 0.9963   | 0.0495   | 0.8751   | 0.6730          | 17             |

Appendix -D

Table 4. Average Efficiency scores of foreign banks (10 years)

| DMU                        | IAE      | PAE      | DME      | FCE      | OBE      | CRE      | Composite score | composite rank |
|---------------------------|----------|----------|----------|----------|----------|----------|-----------------|----------------|
| Standard Chartered Bank   | 1        | 1        | 1        | 1        | 1        | 1        | 1               | 1              |
| Barclays Bank             | 1        | 1        | 1        | 1        | 0.5192   | 0.8471   | 0.8944          | 4              |
| AB bank Ltd               | 0.9862   | 0.7845   | 1        | 1        | 1        | 0.8423   | 0.9355          | 3              |
| BNP Paribas               | 0.9635   | 0.9766   | 0.9766   | 0.9789   | 0.5777   | 0.9225   | 0.8660          | 8              |
| Societe Generale          | 0.8656   | 0.5855   | 0.6774   | 0.8466   | 0.1692   | 0.6774   | 0.6369          | 15             |
| Shinhan Bank              | 0.9069   | 0.8052   | 0.8983   | 0.9804   | 0.5911   | 0.9278   | 0.8654          | 11             |
| UCO Bank                  | 0.9960   | 0.8542   | 0.9260   | 0.9612   | 0.5724   | 0.8761   | 0.8643          | 12             |
| Union Bank of India       | 0.9875   | 0.8638   | 0.8486   | 0.9880   | 0.1993   | 0.8343   | 0.8327          | 9              |
| United Bank of India      | 0.9687   | 0.7876   | 0.9819   | 0.9725   | 0.1993   | 0.8343   | 0.9203          | 7              |
| Masreer Bank              | 0.9730   | 0.5375   | 0.9409   | 0.8737   | 0.8875   | 0.8862   | 0.6579          | 13             |

Copyright © CC-BY-NC 2020, CRIBFB | IJFB
### Table 5. Average Efficiency score of all banks without segregation (10 years)

| DMU                        | IAE  | PAE  | DME  | FCE  | OBE  | CRE  | Composite score | Composite rank |
|----------------------------|------|------|------|------|------|------|-----------------|----------------|
| AXIS BANK                  | 0.9632 | 0.9745 | 0.9135 | 0.9985 | 0.9958 | 0.9320 | 0.9629 | 4               |
| DCB Bank Limited           | 0.8725 | 0.4363 | 0.6764 | 0.7869 | 0.1934 | 0.6851 | 0.6084 | 48              |
| HDFC Bank                  | 0.9994 | 0.8694 | 0.9286 | 0.9989 | 0.9334 | 1.0000 | 0.9549 | 5               |
| ICICI bank Ltd             | 0.9875 | 0.9522 | 0.9897 | 0.9782 | 0.9896 | 0.9776 | 0.9791 | 2               |
| IndusInd Bank Limited      | 0.9710 | 0.6729 | 0.7292 | 0.9199 | 0.7726 | 0.8666 | 0.8220 | 17              |
| Kotak mahindra Bank        | 0.9797 | 0.4698 | 0.7968 | 0.9729 | 0.5232 | 0.9591 | 0.7836 | 27              |
| YES bank                   | 0.9935 | 0.9335 | 0.9213 | 0.9969 | 0.9741 | 0.9586 | 0.9630 | 3               |
| Dhanalaxmi bank            | 0.7995 | 0.4011 | 0.6483 | 0.7059 | 0.1251 | 0.6145 | 0.5491 | 50              |
| City Union bank            | 0.9185 | 0.8029 | 0.8317 | 0.8781 | 0.3652 | 0.7850 | 0.7636 | 29              |
| Federal Bank               | 0.9501 | 0.7264 | 0.8084 | 0.9315 | 0.4039 | 0.8883 | 0.7848 | 26              |
| Jammu&Kashmir Bank         | 0.9849 | 0.5429 | 0.8220 | 0.8851 | 0.2222 | 0.8699 | 0.7212 | 38              |
| Karnataka Bank             | 0.9294 | 0.6908 | 0.7781 | 0.9004 | 0.4001 | 0.7810 | 0.7466 | 34              |
| Karur Vysya Bank           | 0.9548 | 0.6836 | 0.7353 | 0.9059 | 0.3646 | 0.8217 | 0.7443 | 35              |
| Lakshmi Vilas Bank         | 0.9214 | 0.6361 | 0.7020 | 0.8169 | 0.2514 | 0.6778 | 0.6676 | 43              |
| Nainital Bank              | 0.9093 | 0.6709 | 0.8312 | 0.5953 | 0.1013 | 0.7409 | 0.6415 | 46              |
| RBL bank ltd               | 0.8810 | 0.5598 | 0.7421 | 0.8391 | 0.3074 | 0.7481 | 0.6796 | 42              |
| South Indian Bank          | 0.9113 | 0.6515 | 0.7327 | 0.8702 | 0.2462 | 0.8715 | 0.7139 | 39              |
| Tamilnad Mercantile Bank   | 0.9790 | 0.7116 | 0.7945 | 0.8670 | 0.3243 | 0.8485 | 0.7541 | 32              |
| Allahabad Bank             | 0.9488 | 0.6896 | 0.7652 | 0.9226 | 0.3850 | 0.7753 | 0.7478 | 33              |
| Andhra Bank                | 0.9596 | 0.8159 | 0.8869 | 0.9425 | 0.5114 | 0.8081 | 0.8207 | 18              |
| Bank of Baroda             | 0.9118 | 1.0000 | 1.0000 | 0.9471 | 0.4908 | 0.8685 | 0.8697 | 12              |
| Bank of India              | 0.9887 | 0.8751 | 0.9058 | 0.8907 | 0.4034 | 0.7899 | 0.8090 | 20              |
| Bank of Maharashtra        | 0.9312 | 0.5676 | 0.7864 | 0.8845 | 0.2622 | 0.7688 | 0.7001 | 41              |
| Canara Bank                | 0.9770 | 0.8886 | 0.8540 | 0.9211 | 0.4313 | 0.8920 | 0.8273 | 16              |
| Corporation Bank           | 0.9693 | 0.9785 | 0.9805 | 0.9781 | 0.7143 | 0.7616 | 0.8971 | 8               |
| Indian Overseas Bank       | 0.9623 | 0.6564 | 0.7347 | 0.8900 | 0.3558 | 0.7565 | 0.7260 | 36              |
| Indian Bank                | 0.9922 | 0.6579 | 0.7638 | 0.9356 | 0.2978 | 0.8790 | 0.7544 | 31              |
| Oriental Bank of Commerce  | 0.9737 | 0.8329 | 0.8446 | 0.9434 | 0.3906 | 0.7503 | 0.7892 | 22              |
| Punjab & Sind Bank         | 0.9819 | 0.6107 | 0.7135 | 0.8898 | 0.1816 | 0.8599 | 0.7062 | 40              |
| Punjab National Bank       | 0.9946 | 0.8186 | 0.8726 | 0.9307 | 0.5097 | 0.8615 | 0.8313 | 15              |
| State Bank of India        | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1               |
| Syndicate bank             | 0.9811 | 0.7065 | 0.8232 | 0.9249 | 0.3321 | 0.8018 | 0.7616 | 30              |
| UCO Bank                   | 0.9828 | 0.8295 | 0.8620 | 0.9203 | 0.3338 | 0.7183 | 0.7744 | 28              |
| Union Bank of India        | 0.9782 | 0.8383 | 0.8229 | 0.9338 | 0.4175 | 0.8394 | 0.8050 | 21              |
United Bank of India 0.9400 0.6266 0.7956 0.8810 0.3938 0.6992 0.7227 37
Standard Chartered Bank 0.9946 0.4601 0.9700 0.9813 0.6425 1.0000 0.8414 14
Barclays Bank 1.0000 0.9353 0.9098 1.0000 0.5638 0.8416 0.8751 10
AB bank ltd 0.9862 0.7715 1.0000 1.0000 1.0000 0.8423 0.9333 7
BNP Paribas 0.9209 0.7404 0.8763 0.9785 0.3510 0.8652 0.7887 24
Societe Generale 0.8630 0.5250 0.6279 0.8466 0.1692 0.6708 0.6171 47
Shinhan Bank 0.9017 0.9626 0.9497 0.9441 0.3134 0.8285 0.8167 19
Bank of Ceylon 1.0000 0.8785 0.7476 1.0000 0.5935 1.0000 0.8699 11
Abu Dhabi Commercial Bank 0.7312 0.6280 0.8401 0.6630 0.0943 0.6897 0.6077 49
Credit Agricole Corporate Bank 0.9794 0.7409 0.7992 0.9428 0.4313 0.8400 0.7889 23
Bank of Bahrain & Kuwait Bac 0.7717 0.6658 0.8223 0.8157 0.1755 0.6105 0.6436 45
Mashreqbank P S C 0.9730 0.5292 1.0000 0.9409 0.8737 1.0000 0.8861 9
MUFG Bank Ltd 0.9819 0.9175 0.8967 0.9742 0.4471 0.9781 0.8659 13
Firststrand Bank Ltd 0.9314 0.4453 0.6348 0.9021 0.3860 0.6305 0.6550 44
Krung Thai Bank Public Company Ltd 0.7960 1.0000 1.0000 1.0000 1.0000 0.9071 0.9505 6
American Express Bank Ltd. 1.0000 0.2113 0.5224 1.0000 0.9871 1.0000 0.7868 25

Copyrights
Copyright for this article is retained by the author(s), with first publication rights granted to the journal. This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).