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# Data Envelopment Analysis Recent Applications in Banking Sector: A Survey

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**Abstract:** *The present study review and surveys the number of research papers based on the applications of Data Envelopment Analysis (DEA) in the banking sector. This study focus on the development of DEA application only in the banking sector and includes the papers from 2016 to 2019, which published in reputed journals. Data envelopment analysis is one of the most effective and popular methods applied to measuring efficiency of banking sector. The author made a search for DEA application in banking industry related papers in Google Scholar database. The number of papers I get is rather impressive. I select the recent papers on DEA application.*

**Keywords:** *Data Envelopment Analysis, efficiency, performance, banking sector etc.*

## I. INTRODUCTION

The banking sector plays an important and critical role in the economic stability of any country. The service provided by banks in the form of personal saving, loans, payments, business etc. The main challenge in banking sector is the issue of managing and evaluating the performance, which can be defined in terms of efficiency, profitability, productivity, competition etc. Traditionally the bank productivity measured by single ratios, such as return to equity (ROE) or Cost-to-income ratio approaches. These traditional methods do not provide the reliable results because of complex environment of banking system. DEA models are effectively used to find the relative efficiency and performance of a set of Decision making units (DMUs). As we are aware of, a limited literature exist on the applications of DEA in real world problems.

The real world problems like Banking, transportation, education, health care sector, finance, agriculture & farm, tourism, Energy environment, sustainability, insurance, automobile, sport, manufacturing and many has been solved by DEA. Due to the existence of applications of DEA in large areas, I have selecting the research papers which focus only on the DEA application in the field of banking sector.

I have listed some standard and informative bibliography already existing in the literature for more information and better understanding of how much research is going on the DEA and its application see [1,2,3,4,5].

The paper is organized as follows. Section 2 describes DEA models and some extended form of DEA models. Section 3 present review of the papers published on the field DEA applications in banking sector. Section 4 present conclusion and references given in last section.

## II. THE BASIC DEA AND EXTENDED MODELS

In this section, we discussed two primary models that play a significant role in DEA methodology development. To measure the performance of financial assets such as hospitals, business firms, educational institutions, government agencies etc. DEA models applied widely in the literature. In DEA models performance calculated in the form of ratio of Output and Input. There are two types of DEA models; one is CRS (constant return to scale) or CCR model and other is VRS (variable return to scale) or BCC model. CCR model proposed by Charnes, Cooper & Rhodes [6] and VRS proposed by Banker, Cooper & Charnes [7]. Both CCR and BCC models can be use in input-orientation and in output-orientation form. In input-oriented

Form DEA models try to attempt maximum possible reduction in input with output levels held constant and in output-oriented form DEA models try to attempt maximum possible

Proportional increase in output with input levels held constant.

### A. CCR Model (Input Oriented)

Let there are  $n$  decision making units in the portfolio. Each DMU involve some amount of  $m$  different inputs to produce  $s$  different outputs. The  $DMU_j$  involve  $x_{ij}$  amount of  $i^{th}$  input used by  $j^{th}$  DMU and  $y_{rj}$  amount of  $r^{th}$  output produced by  $j^{th}$  DMU. Then mathematical formulation of CCR model in input-oriented form given as model (1).

Model (1)

$$Z_p = \min \theta_p \tag{1.1}$$

$$s. t. \quad \sum_{j=1}^n \lambda_j x_{ij} - \theta_p x_{ip} \leq 0, \quad i = 1, 2, \dots, m \tag{1.2}$$

$$\sum_{j=1}^n \lambda_j y_{rj} \geq y_{rp}, \quad r = 1, 2, \dots, s \tag{1.3}$$

$$\lambda_j \geq 0, \quad j = 1, 2, \dots, n \tag{1.4}$$

Where  $\lambda_j$  represent the weight associated  $DMU_j$ .  $Z_p$  Defines the DEA efficiency score for the DMUp. To obtain the score of relative efficiency of all DMUs, we have to solve above model n times. The DMU which attains the efficiency score 1, will be considered as efficient DMU and the DMU attains efficiency score less than 1, will be considered as inefficient DMU.

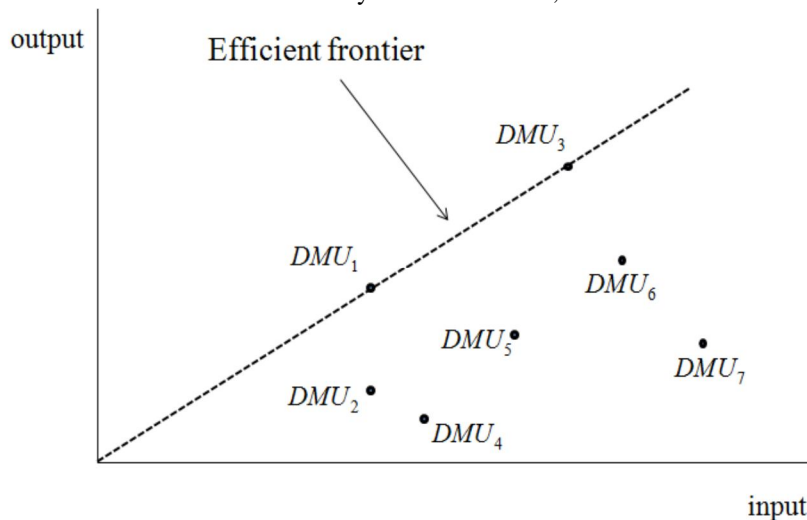


Figure 1: Efficient frontier - CCR model

In single input single output, case the efficient frontier for the CCR model in case of seven DMU given in fig.1. The figure 1 show that  $DMU_1$  and  $DMU_3$  are efficient.

**B. CCR Model (Output- Oriented)**

To derive CCR output oriented model, we minimize the inefficiency by the ratio of input to output. The mathematical formulation is as follows:

$$\text{Model (2)} \quad H_p = \text{Max } \varphi_p \tag{2.1}$$

$$s. t. \quad \sum_{j=1}^n \lambda_j x_{ij} \geq x_{ip} \quad i = 1, 2, \dots, m \tag{2.2}$$

$$\sum_{j=1}^n \lambda_j y_{rj} \leq \varphi y_{rp} \quad r = 1, 2, \dots, s \tag{2.3}$$

$$\lambda_j \geq 0 \quad j = 1, 2, \dots, n \tag{2.4}$$

**C. BCC model (INPUT –Oriented Model)**

BCC model is first extensions of the CCR model where the efficient frontiers set represent a convex curve passing through all efficient DMUs. The basic difference between CCR and BCC models is the addition of convexity constraints  $\sum_{j=1}^n \lambda_j = 1$  in the BCC model.

BCC model in input-oriented form given as in model (3):

$$\text{Model (3)} \quad Z_p = \min \theta_p \tag{3.1}$$

$$s. t. \quad \sum_{j=1}^n \lambda_j x_{ij} - \theta_p x_{ip} \leq 0, \quad i = 1, 2, \dots, m \tag{3.2}$$

$$\sum_{j=1}^n \lambda_j y_{rj} \geq y_{rp}, \quad r = 1, 2, \dots, s \tag{3.3}$$

$$\sum_{j=1}^n \lambda_j = 1, \tag{3.4}$$

$$\lambda_j \geq 0 \quad j = 1, 2, \dots, n \tag{3.5}$$

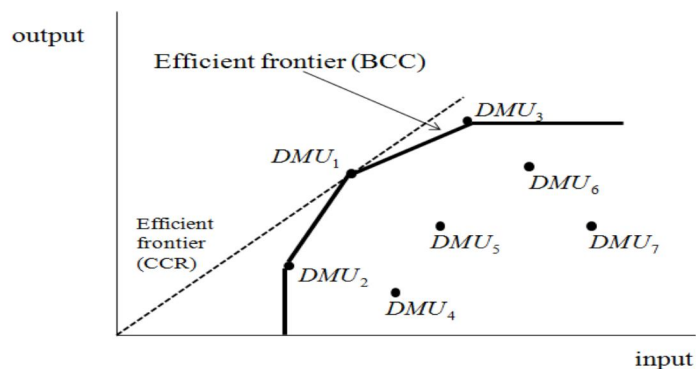


Figure 2: Efficient frontier – BCC model.

The figure 2 described the BCC efficient frontier for seven DMUs.

*D. BCC Model (OUTPUT-Oriented Model)*

BCC model in output-oriented form given in model (4):

$$\text{Model (4)} \quad H_p = \text{Max } \varphi_p \quad (4.1)$$

$$s. t. \quad \sum_{j=1}^n \lambda_j x_{ij} \geq x_{ip} \quad i = 1, 2 \dots m \quad (4.2)$$

$$\sum_{j=1}^n \lambda_j y_{rj} \leq \varphi y_{rp} \quad r = 1, 2 \dots s \quad (4.3)$$

$$\sum_{j=1}^n \lambda_j = 1 \quad (4.4)$$

$$\lambda_j \geq 0 \quad j = 1, 2 \dots n \quad (4.5)$$

*E. Some Extensions in the DEA Models*

There are several extensions exist to overcome some of the limitations of CCR and BCC models, such as the problem of presence of slack in the optimal solution ,the problems having negative input-output, the problem of not having clear information about input output etc.

Some well-known methods to deal with these limitations are slack-based measure (SBM) by Tone in 2001 [8], Range adjust measure (RAM) by Cooper et.al. [9], Range directional measure (RDM) by Portela et.al. Semi-oriented radial measure (SORM) etc. for more information on DEA models see [5].

**III. DATA ENVELOPMENT ANALYSIS (DEA): RECENT APPLICATIONS**

In this section we discuss briefly the DEA applications in banking system in the recent time. We have selected most papers for study between the years 2016-2019 to make it more updated, useful and informative. The application of DEA and DEA based methods in banking sector is rather old but due to the effectiveness of the DEA methods it is continuously increasing in recent times also. we have selected 40 papers from 2016, 2017, 2018, 2019 for review.

*A. DEA Applications Papers in Banking Sector Publish in Year 2016*

- 1) Singh and Kaur [10] calculated the relative efficiency of public and private sector banks of India by applying DEA approach. They also identify the slacks to locate the inefficiency of the banks. The main finding of the paper was that the efficiency of public banks is less than the efficiency of private sector banks. The results shows that the banks like HDFC, Federal bank, Yes bank and other private banks achieve 100% efficiency in all the observed ten years, but the public banks like United Bank of India, State Bank of Hyderabad, Central Bank of India etc. could not achieve 100% efficiency not in an observed single year.
- 2) Zha et.al. [11] Introduce a dynamic two-stage slacks-based measure model based on DEA to analyze of performance of Chinese’s banks. They calculate technical and scale efficiency and inefficiency of Chinese banks during 2008-2012 period. They have identify the reason of inefficiency of banks as inefficiencies at the stage of productivity stage as well as inefficiencies at stage of profitability. In stage, one Deposit considered as an output then as input in stage-2, and in stage -2, a nonperforming loan considered as an undesirable output.

- 3) Tuskan and Stojanovic [12] analyze and compare the efficiency of 28 European banks. They declare that the DEA are efficient in identifying the poor business parts or strategies at very early stage that can create problems in the growth of the banks. They find the efficiency of banks by two approaches, one is DEA by taking expenses as input and income as output, the other is financial indicators approach such as Return on Assets - ROA, Return on Equity – ROE and Cost to Income Ratio – CIR. The main contribution of the paper was to find a relation between the efficiency measured by two approaches and they establish that in post-transition countries have higher cost efficiency.
- 4) Wong and Deng [13] apply the DEA method to calculate the technical efficiency of 39 bank branches of four ASEAN countries for the period 2000-2010. Malaysia, Indonesia, Philippines and Thailand were four countries and the efficiency of Malaysian banks is more than the efficiency of other three banks. They find that the ASEAN countries less cost efficient due to increasing operating and labor cost.
- 5) Wild [14] uses DEA and Stochastic Frontier analysis (SFA) to develop efficiency matrices. With the help of efficiency matrices, they find the convergence of savings, commercial and cooperative banks in the Eurozone for the period 1999 – 2012. Wild found that the cooperative banks are only SFA convergence, efficiency for commercial banks, converges in both cases however, savings banks show no signs of convergence.
- 6) Wanke et.al. [15] Evaluate the overall efficiency of 13 Mozambican banks for the period 2003-2011 by using Fuzzy-DEA  $\alpha$ -level based approach. The significant factors affecting the efficiency found as price of capital Price of labor, and market-share. They use production approach and intermediation approach to find input and output. Fuzziness found to be better than randomness in analyzing the estimated results. They estimate fuzzy efficiency score of each banks and then use conditional bootstrapped truncated regressions by taking efficiency score as dependent variables.
- 7) Branco et al. [16] use DEA-BCC (VRS) approach to estimate the efficiency of Brazilian banks in 2013. They estimate efficiency scores based on capital origin, bank size, market niche, and rating and their study suggest that public banks are more efficient.
- 8) Ray [17] estimate the overall cost efficiency of branches of public sector banks in India.
- 9) He take data within the Calcutta city for the period 2012 and reported over branching in result by using DEA. The result of this paper shows that in some areas if number of branches reduced in number it can give more cost efficient result as well as if the number of branches increased in number within market area also can be optimal (more cost efficient).
- 10) Fukuyama & Matousek [18] develop DEA two-stage network bank technology, in which all outputs of a bank's first stage enter into a second stage. They used data from regional banks of Japan for period 2001 to 2013. They also show how Regional Banks operated during the global financial crisis. The main finding of the paper is implementing the concept of Nerlove's revenue indicator to the revenue inefficiency of Regional Banks.
- 11) Lozano [19], develop general networks slacks-based inefficiency (GNSBI) measure to measure the efficiency of the problems that produces both desirable and undesirable outputs.

#### B. DEA Applications Papers in Banking Sector Publish in year 2017

- 1) Huang et al. [20] Introduce stochastic network model to evaluate technical efficiency of the Chinese banks for the period 2002-2015. they find that the technical efficiency of the joint-stock banks are higher than larger commercial banks which include four state-owned banks.
- 2) In [21], the authors study on the efficiency of Mauritian banks for the period 2011-2015 by using DEA .The authors conclude that Mauritian banks should concentrate more on being efficient rather than on being only effective and profitable.
- 3) Hada et.al. [22], use DEA approach to make frontier of efficiencies TE (technical efficiency), PTE and SE (scale efficiency) between Nepalese and Chinese commercial banks in 2012 and 2013 in input –oriented form. They examine the variation in the efficiency scores corresponding to change in input and output variables.
- 4) Puri and Yadav [23], develop DEA model in the condition of imprecise data and undesirable output. In this paper final efficiency, score obtained as an interval bounded by the best lower bound efficiency and the best upper bound efficiency at that  $\alpha$  for each DMU and the method is valid for interval data, fuzzy data, and the mixture of interval and fuzzy data. The numerical data for the validity of the method has taken from Public Sector Banks and Private Sector Banks in India for the year 2012–2013.
- 5) Balcerzak et.al. [24], use CCR model in input and output orientation to evaluate and compare the efficiency of the banks in European Union member countries. They differentiate the efficiency between the European Monetary Union members and Countries, which do not belong to the Euro-zone. They measure the inefficiency of the banks and give suggestion to remove inefficiency.

- 6) Tlig and Hamed [25], estimate the efficiency of Tunisian banks by using DEA in the case of imprecise data (fuzzy data). They use fuzzy DEA by using two approaches, possibility and based on relations between fuzzy numbers (BRONF) approach. They evaluate the efficiency score of Tunisian banks for the period 2011-2013 by possibility and BRONF approaches.
- 7) Aggelopoulos & Georgopoulos [26] calculate the profit efficiency, branch management efficiency, and technical efficiency, of Greece banks by using Bootstrap input oriented profit DEA. They form a bootstrap DEA-based Decision Tree to examine the potential upgrading of underperforming branches.
- 8) Moudud-UI-Huq [27] apply DEA technique to find the performance of 10 private commercial banks (PCBs) from Bangladesh banking industry for the period 2013–2014. They find that the performance of banks depend on the formulation of strategy and proper implementation of strategies. They suggest that the decision makers of Bangladesh banking industry should focus on the good quality of assets and proper use of it.
- 9) Silva et.al. [28], select a sample of Chinese local banks and study the efficiency of the selected banks by using DEA and SFA (stochastic frontier approach). They also calculate the rank correlation which indicate that the models provide the efficiency of the banking system as a whole but can be ineffective at the individual level.
- 10) Gulati and Kumar [29], use two-stage network data envelopment analysis (NDEA) model to obtain intermediation, operational and overall bank efficiency of the Indian banking industry. They also apply bootstrapped truncated regression to measure the variation in intermediation efficiency and suggest that the efficiency depend on the bank size, liquidity position, directed lending and intermediation cost.

*C. DEA Applications Papers in Banking Sector Publish in year 2018*

- 1) In 2018, Diallo [30] analyzed the effect of bank performance of industrial growth in the problem of financial crisis. The efficiency, which obtained by DEA model highly related to crisis and affected highly the growth of the banks. Results also show that the efficiency relaxed the constraints of credit.
- 2) Quaranta et al. [31] use a multidimensional approach to measure the bank branch performance of 23 branches of an Italian regional bank. They have used three-step approach. In step-one, the efficiency calculated by ratio method, in step-2, they use collinearity analysis to reduce the unnecessary information and in their step, three a clustering procedure applied to categorize the bank branch in to efficiency classes. They suggested that the multidimensional approach could be effective when individual methods provide contradictory results.
- 3) In [32], Authors, use DEA (CCR and BCC) models to evaluate the technical efficiency (TE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE) of 37 Brazilian banks for the period March 2012 - March 2016. They select input output variables using intermediation approach. They also focus on the how and what can done to make inefficient bank, an efficient one. For this purpose they analysis return to scale (RTS) of the banks. They conclude that the inefficiency of Brazilian banks depend on less on the technical and administrative issues and more depend to the scale of operations.
- 4) Grmanová and vanová [33] analyze the efficiency of Slovak Republic banks for the period 2009 and 2013. In the Slovak national banking market the three largest bank were efficient in both years 2009 and 2013 with different combinations of inputs and outputs. They compare the relative efficiencies of the bank and provide the information regarding important indicators for the efficient bank in terms of efficiency sustainability.
- 5) Novickyt'e & Droždž [34] study the Lithuanian banking sector's efficiency by input oriented DEA under the VRS and the CRS assumptions in low investment environment. They compared validate the result obtained by the DEA method with the return on assets (ROA). They state that during the period 2012–2016 the efficiency of the larger Lithuanian banks (subsidiaries) was higher than smaller (local) banks operating in Lithuania. They discuss the performance of the banks along three dimensions as production, intermediation and profitability.
- 6) In [35] Goyel et al. apply directional distance based meta-frontier DEA approach to 66 Indian banks from the period 2015-2016. The results of this paper shows that Indian banking system is not fully efficient (only 73.44%). They confirmed that there exist different production functions according to different ownership structures such as Public, Private and Foreign. The group frontier of foreign banks coincides with meta-frontier; the second closest frontier is the frontier of the group private sector banks is the second closest to the meta-frontier.
- 7) Zhu and Zhang [36], calculate the operational efficiencies of banks of China and India in 2012 and 2013. They show variations in the efficiency scores by variation in the input-output variables. The result shows that the mean technical efficiency score of Chinese banks are higher than the Indian banks in 2012-2013. They suggest to collect more sample to apply Malmquist index method for further analysis.

- 8) Kaffash et. al. [37], propose a new directional semi-oriented model (DSORM) by selecting a proper direction to deal positive and negative input output variables. They claim the superiority of their method from the computational and target settings point of view. They take the sample from banks operating in Persian Gulf Council Countries (GCC) for the period 2002–2011 to show the practical application of the DSORM.
- 9) Toloo et. al. [38], present a new non-radial directional distance method to deal the cases when input and output not known. They suggest two pessimistic and optimistic approaches to get appropriate decision for flexible measures. The proposed method applied to the sample collected from the banking system of the countries Czech Republic, Hungary, Poland, and Slovakia.
- 10) Pham et. al. [39], extend the slack-based directional distance function to evaluate the efficiency of the Vietnamese commercial banks by considering undesirable output. They show the comparison of the results with directional distance function, the enhanced hyperbolic efficiency model and Farrell-type technical efficiency.
- 11) Basri et.al. [40], study the efficiency of 16 Islamic banks (IBs) from Malaysia from 2008 to 2015, using CRS and VRS DEA methods. They measure the efficiency of each bank and draw a comparison between the efficiency of domestic and foreign IBs in the country. Domestic Islamic banks found more efficient than foreign Islamic banks, in the results.

*D. DEA Applications Papers in Banking Sector Publish in year 2019*

- 1) In [41] Peter et al. proposed two-stage DEA model to measure IT impact on performance of the large data set of 444 Ghanaian bank branches. They use robust DEA package in R programming to handle the large data set of 444 DMUs. The result suggest that IT impact on the performance evaluation was positive and significant.
- 2) Ying et.al. [42] Propose a new method SBM (slack based model)-max and SBM min model based on Slack Based Model (SBM) given by Tone (2001). The method apply to evaluate efficiencies of 37 Taiwanese banks for the period 2012 – 2016. In this paper, input was Number of employees, Deposits, Fixed assets and output as Deposits, Investments other income.
- 3) In [43] Kwateng et al. properly examine the effect of internet banking on the performance of 20 banks of Ghana in the year 2016. they use DEA-bootstrap method with cluster analysis and
- 4) principal component analysis. They found the positive effect of internet banking in the banking industry of Ghana. They conclude that major banking strategies for improving the banks performance are integrated banking service strategy and the internet banking service-oriented strategy.
- 5) Tamatam et al. [44] evaluate three efficiencies (overall technical, pure technical and scale)
- 6) Of Indian banking sector for the year 2008-2017 by using 18 different DEA models. They select 17 private and 21 public sector banks and compare the results using non-parametric statistical tests. They find that the efficiency calculated by different DEA models depend upon the ownership type and size of the banks.
- 7) Partovi et al. [45] use modified version of DEA, based on directional distance model to analyze the allocative and technical efficiency of banks in Turkey for the period 2002-2017.
- 8) They use DEA in constant returns to scale form and assume Non-Performing Loans (NPLs) as an undesirable output. The result show the negative effect of (NPLs) on the performance of Turkish banks.
- 9) Sharifa et.al. [46], provide a relation between the productivity and efficiency in financial sectors. They use DEA-MPI (Malmquist Productivity Index) to estimate the efficiency and productivity of 26 financial companies selected from Malaysian stock exchange (Bursa Malaysia) for the period 2007-2016.
- 10) Belas et.al. [47], propose new cost efficiency model to find macroeconomic and specific variables that influenced the efficiency of banks. They use data from the banks of 28 European Union countries like Austria, Germany, Denmark, and France etc. for the period 2008-2017. They states that banking sectors having different unit cost can be considered as efficient, but in new cost efficiency model, where the banking sector having high cost per unit cannot be considered as efficient.
- 11) In [48] the authors present a new directional output distance function based on directional distance function to evaluate the economic efficiency. They states that the economic efficiency depend on the current year's operation also the evaluation of risk depend on the minimization
- 12) Non-performing loans (NPLs) in the current loan. They provide the numerical illustration of the proposed method on the sample of 30 Chinese banks for the period 2005-2012.
- 13) Ghaelia R [49], compare the relative efficiencies of five Canadian banks with 6 US big bank for 2017 year by using input-oriented CCR model. In his study, he assumes the number of employees and total assets as input and net revenue as the output. He conclude with the statement that the US banks perform better than Canadian banks.

#### IV. CONCLUSION

In this survey paper, I try to give a brief discussion on the efficiency analysis of banking sector.

Most studies include in this paper used the DEA and extended methods of the DEA to measure the efficiency of banks in different countries and in different scenario's. On the basis of existing literature, I draw the conclusion that the research on DEA methodology, its extension methodology and DEA applications not only in banks but also in different real life problems are flourishing all over the world. I hope that this study will benefit to some range of users who wish to apply DEA in banking and in other field also.

I acknowledge that some more important study on application of DEA in banking sector may not include here, due to due to limited space, and possibly to ignorance on my part.

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