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Research Paper

Measuring Cost Efficiency of Private Sector banks in India using Fuzzy Data Envelopment Analysis

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Abstract:

This study uses the traditional DEA and Fuzzy DEA models to evaluate the cost efficiency of Indian private banks. This study includes 21 Indian private banks, with each serving as decision-making units (DMU). Each DMU comprises four outputs, namely investments, loans/advances, Interest earned and other income, and five inputs, including the number of workers, branches, deposits, borrowing funds, and fixed assets. The RBI's official website was used to get the information needed. Each DMU's cost efficiency scores have been determined using both traditional and fuzzy DEA, and ranked. It is discovered that just one bank is efficient when using the fuzzy DEA approach, but two banks are efficient when using the classic DEA.AMS Subject Classification: 90C08; 93C42

Key words and Phrases: DEA, Fuzzy DEA, Ranking DMU, Cost Efficiency, Banks.

1. Introduction:

Indian banking sector plays vital role in the economic development of the country.

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The Indian banking sector is properly capitalized and well-regulated by the Reserve Bank of India (RBI). According to studies on credit, market, and liquidity risk, Indian banks are generally strong and have done well during the global recession. The country's financial and economic situation is much better than that of any other country in the world especially during the pandemic period.

The Indian banking industry has recently adopted cutting-edge banking formats including payments and small financing banks. Through a number of programmes like the Pradhan Mantri Jan Dhan Yojana and Post Payment Banks, India has recently focused on broadening the reach of its banking industry. These programme's have significantly improved India's financial status, along with significant banking sector reforms like digital payments, neo-banking, the expansion of Indian NBFCs, and fintech.

The Indian banking system includes12 public sector banks, 22 private sector banks, 46 foreign banks, 56 regional rural banks, 1485 urban cooperative banks and 96,000 rural cooperative banks in addition to cooperative credit institutions. There were 213,145 ATMs in India as of September 2021, with 47.5% of them located in rural and semi-urban areas (RBI 2021).

Data Envelopment analysis (DEA.) is used to assess the efficiency of decision making units when the data are in crisp nature. Whereas the Fuzzy DEA is a method to evaluate the efficiency of decision making units where the data are imprecise, vague and fuzzy.

This paper strives to find the cost efficiency of Indian private banks using Data envelopment analysis and fuzzy data envelopment analysis.

1.1. Objective of the Study:

The objectives of this research study are

1. To find the Cost efficiency of Indian Private Sector banks using Classical DEA and Fuzzy Data envelopment analysis.
2. To compare the classical and fuzzy cost efficiency score of private sector banks in India.
3. To rank the private sector banks based on their fuzzy efficiency Score.

2. Literature Review:

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Farrell, M.J. (1957) [2] introduced a ratio to evaluate the overall efficiency and price efficiency of a decision making units. Fare et.al (1985)[3] made some changes in the Farrell's assumptions on the efficiency measure and proposed a measure to find the cost efficiency of a DMU using linear programming. Tone (2002) [17] found that the cost efficiency model is same as technical efficiency when there is single input under Farell[2] and Fare model. He has introduced a model to find the cost efficiency under the assumption that the cost for each input differ from DMU to DMU. Later on, many researchers have applied the fuzzy set concept in DEA to find the efficiency score when the inputs and outputs are fuzzy in character.

Kao and Liu (2000)[9] developed a model to assess the fuzzy efficiency score by converting the Fuzzy DEA model into family of traditional parametric model using alpha cut approach.

Satti et.al. (2002)[16] developed a model to convert the fuzzy CCR DEA model into interval programming model using alternative alpha cut approach. And also they have proposed one ranking method to rank the DMU's based on their fuzzy efficiency scores. Jahanshahloo G. R. et . al. (2008)[6] developed a cost efficiency model to measure the cost efficiency score for fuzzy data. They proposed a ranking function which is equivalent to linear programming model. Puri, J., Yadav, S.P (2016)[12] proposed a fully fuzzy cost efficiency and fully fuzzy revenue efficiency where the input , output and price data are in triangular fuzzy form. Jayarani K and Prakash V(2018)[7] measured the cost efficiency, profit and revenue efficiency of Indian private sector baks using DEA. Jasmine Rathi S and Prakash V(2019)[8] analyzed the efficiency of Indian life Insurance companies by using DEA and Fuzzy DEA approach for the triangular fuzzy number. Jafar Pourmahmoud and Naser Bafekr Sharak (2020)[15], proposed a new model to find the cost efficiency score for triangular fuzzy data using alpha cut approach and shown that the efficiency score obtained by this model is more reliable as compared to the previous methods. And also they have proposed one ranking method to rank the DMU's based on their fuzzy efficiency score. In this paper the author have used the latest model to assess the cost efficiency of the Indian private banking sector.

3. Research Design and Methodology:

3.1. Data Structure:

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The required data has been collected from the RBI official websites over the period of time 2018-2021.In this study, the 21 private sector banks are considered as decision making units. The following were considered as the inputs and outputs for this study.

Table No.1 (Inputs and Outputs)

Inputs	Outputs
1. No. of Employees	1. Investments (in crores)
2. No. of Branches	2. Loans/Advance(in crores)
3. Deposits (in crores)	3.Interest Earned(in crores)
4. Borrowing Funds(in crores)	4. Other Income(in crores)
5. Fixed Assets	

3.2. Methodology:

The traditional and the Fuzzy -Data Envelopment analysis method has been employed to assess and compare the cost efficiency of 21 private sector banks over the period of time 2018-2021.

3.2.1. Data Envelopment Analysis:

Data Envelopment analysis is a non parametric technique which has been used to assess the efficiency of DMU's with multiple inputs and Outputs. In this paper, the author uses the following Cost efficiency model proposed by Tone (2002)[17] to find the cost efficiency . The Multiplier form of cost efficiency model is,

$$CE_k = Max \sum_{r=1}^{s} u_r . y_{rk}$$

subject to

$$\sum_{r=1}^{s} u_r . y_{rj} - \sum_{i=1}^{m} v_i . \bar{x}_{ij} \le 0$$

$$v_i \le \frac{1}{C_k} \quad ; \forall i$$

$$u_r \ge 0 \quad ; \forall r$$

$$v_i \ge 0 \quad ; \forall i$$

where u_r and v_i are the relative weights of the i^{th} input and r^{th} output respectively

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By solving the above cost efficiency model, one can find the cost efficiency score for each DMU. A DMU is said to be cost efficient if its efficiency score is equal to one otherwise it is cost inefficient.

3.2.2. FUZZY DATA ENVELOPMENT ANALYSIS:

When the inputs and outputs are fuzzy in character, fuzzy data envelopment analysis would be performed to determine the effectiveness of decision-making units. In this paper, the author applied the Fuzzy cost efficiency model proposed by Jafar Pourmahmoud and Nasar Bafekr Sharak [15], and presented below.

The Lower bound Fuzzy Cost efficiency Model is ,

$$(CE)_{\alpha}^{L} = Max \sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{L})$$

subjectto

$$\sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{L}) - \sum_{i=1}^{i} v_i (\alpha . \bar{x}_{ik}^{M} + (1-\alpha) . \bar{x}_{ik}^{U}) \le 0$$

$$\sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{U}) - \sum_{i=1}^{i} v_i (\alpha . \bar{x}_{ik}^{M} + (1-\alpha) . \bar{x}_{ik}^{L}) \le 0 \quad ; \forall j, j \neq k$$

$$v_i \le (\alpha . q_k^{M} + (1-\alpha) . q_k^{L}) \quad ; \forall i$$

$$u_r \ge 0 \quad ; \forall r$$

$$v_i \ge 0 \quad ; \forall i$$

The Upper bound Fuzzy Cost efficiency Model is ,

$$(CE)_{\alpha}^{U} = Max \sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{U})$$

subjectto

$$\sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{U}) - \sum_{i=1}^{i} v_i (\alpha . \bar{x}_{ik}^{M} + (1-\alpha) . \bar{x}_{ik}^{L}) \le 0$$

$$\sum_{r=1}^{s} u_r (\alpha . y_{rk}^{M} + (1-\alpha) . y_{rk}^{L}) - \sum_{i=1}^{i} v_i (\alpha . \bar{x}_{ik}^{M} + (1-\alpha) . \bar{x}_{ik}^{U}) \le 0 \quad ; \forall j, j \neq k$$

$$v_i \le (\alpha . q_k^{M} + (1-\alpha) . q_k^{U}) \quad ; \forall i$$

$$u_r \ge 0 \quad ; \forall r$$

$$v_i \ge 0 \quad ; \forall i$$

Where $\tilde{y}_{rk} = (y_{rk}^{L}, y_{rk}^{M}, y_{rk}^{U})$ and $\tilde{x}_{ij} = (x_{ij}^{L}, x_{ij}^{M}, x_{ij}^{U})$ are the triangular fuzzy numbers and the lower bound and upper bound of alpha cuts can be found by using the method which is proposed by Saati. et.al.[14] and is

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$$\left[\tilde{\bar{x}}_{ij}\right]_{\alpha} = (\alpha.\bar{x}_{ij}^{\ M} + (1-\alpha).\bar{x}_{ij}^{\ L}, \alpha.\bar{x}_{ij}^{\ M} + (1-\alpha).\bar{x}_{ij}^{\ U})$$

$$\left[\tilde{y}_{rk}\right]_{\alpha} = (\alpha.y_{rk}^{\ M} + (1-\alpha).y_{rk}^{\ L}, \alpha.y_{rk}^{\ M} + (1-\alpha).y_{rk}^{\ U})$$

By solving the above two models, we can get the fuzzy cost efficiency score for different level of alpha cuts for each DMU.

3.2.3 Ranking Model:

In this paper, The ranking model proposed by Chen and Kelin [2] is applied to rank the DMU's based on their fuzzy cost efficiency scores.

$$I_{j,} = \frac{\sum_{t=0}^{T}((CE_j)_{\alpha_t}^{U} - c)}{\sum_{t=0}^{T}((CE_j)_{\alpha_t}^{U} - c) - \sum_{t=0}^{T}((CE_j)_{\alpha_t}^{L} - d)}$$

$$where\ c = \underset{\forall t,j}{Min}\left\{(CE)_{\alpha_t}^{L}\right\} and c = \underset{\forall t,j}{Max}\left\{(CE)_{\alpha_t}^{U}\right\}$$

$$and\ \mathrm{I}_j \in [0,1]$$

4. Analysis and Interpretation:

In this section, the descriptive measures of Inputs and outputs, Cost efficiency Scores, Fuzzy cost efficiency Score and Ranking of each DMU has been presented.

4.1. Descriptive Measures of Inputs and Outputs:

Descriptive measures of the collected inputs and outputs of 21 private banking sectors is presented in the following table which will help to summarize the nature of inputs and outputs.

Table 4.1.

Descriptive Statistics

Measures		**Min.**	**Max.**	**Mean**	**Std**
Inputs	**No. of Employees**	**2769**	**335125**	**75905.2**	**94188.57**

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	No. of Branches	**435**	**15821**	**4755.24**	**5100.31**
	Deposits (in crores)	**22378.2**	**3405703**	**603728**	**877936.2**
	Borrowing Funds(in crores)	**0.01**	**443603**	**105752**	**150871.9**
	Fixed Assets	**106.83**	**25219.3**	**5389.98**	**7359.945**
Outputs	**Investments (in crores)**	**5528.77**	**1128671**	**191146**	**284207.1**
	Loans/Advance(in crores)	**10992.4**	**2945941**	**516979**	**758082.8**
	Interest Earned(in crores)	**1933.36**	**334643**	**61391.1**	**84264.08**
	Other Income(in crores)	**772.04**	**165064**	**31198.8**	**43310.55**

The above table (4.1) reveals that on an average 75905 employees are working in private sector bank with S.D. = 94188..57 and the private sector banks having 4755 branches on an average with S.D= 5100.31. It is also noted that the private sector banks on an average received 877936(in crores) and 105752(in crores) respectively as borrowing funds and deposits. And they have earned much more through interest as compared to from other modes.

4.2. Conventional DEA- Cost efficiency Score:

The following table shows the traditional cost efficiency score of 21 Indian private banks.

Table 4.2.
Cost Efficiency Score

Name of the Bank(DMU)	Technical eff.	Allocative Eff.	Cost Efficiency Score
Axis Bank Limited	**0.943**	**0.776**	**0.731**
Bandhan Bank Limited	**1**	**0.863**	**0.863**
City Union Bank Limited	**1**	**0.748**	**0.748**
CSB Bank Limited	**0.979**	**0.576**	**0.564**
DCB Bank Limited	**0.991**	**0.707**	**0.7**
Federal Bank Ltd	**1**	**0.925**	**0.925**
HDFC Bank Ltd.	**1**	**1**	**1**

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ICICI Bank Limited	**0.919**	**0.717**	**0.659**
IDBI Bank Limited	**1**	**0.82**	**0.825**
IDFC First Bank Limited	**1**	**0.983**	**0.983**
Indusind Bank Ltd	**1**	**0.942**	**0.942**
Jammu & Kashmir Bank Ltd	**0.983**	**0.57**	**0.56**
Karnataka Bank Ltd	**0.935**	**0.722**	**0.675**
Karur Vysya Bank Ltd	**1**	**0.687**	**0.687**
Kotak Mahindra Bank Ltd.	**1**	**0.752**	**0.752**
Nainital Bank Ltd	**1**	**0.604**	**0.604**
RBL Bank Limited	**1**	**0.977**	**0.977**
South Indian Bank Ltd	**0.989**	**0.681**	**0.673**
Tamilnadu Mercantile Bank Ltd	**1**	**0.785**	**0.785**
The Dhanalakshmi Bank Ltd	**1**	**0.75**	**0.751**
Yes Bank Ltd.	**1**	**1**	**1**
Mean Score	**0.988**	**0.79**	**0.781**

It is observed from the above table(4.2) that out of 21 Indian private banks, only two are cost efficient since its efficiency score equal to one and they are HDFC bank and Yes bank.
Likewise Jolly Puri and Yadavs(2013)[13] found that Axis , ICICI and Yes banks were efficient in the year 2013 and now the yes bank is only efficient DMU .

4.3. Fuzzy DEAScore:

The following table (4.3.) presents lower and upper bound cost efficiency score of 21DMU's under fuzzy cost efficiency model which is calculated based on fuzzy inputs (triangular) and fuzzy outputs (triangular) for different level of alpha.

Table No.4.3.

Fuzzy Cost Efficiency Scores At alpha = 0,0.5 ,1

Name of the Bank		**$(CE)_{\alpha=0}$**	**$(CE)_{\alpha=.5}$**	**$(CE)_{\alpha=1}$**
Axis Bank Limited	$(CE)_{\alpha}^{L}$	**0.032**	**0.208**	**0.449**
	$(CE)_{\alpha}^{U}$	**0.723**	**0.856**	**0.449**

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Bandhan Bank Limited	$(CE)_{\alpha}^{L}$	**0.038**	**0.252**	**0.47**
	$(CE)_{\alpha}^{U}$	**0.441**	**0.693**	**0.47**
City Union Bank Limited	$(CE)_{\alpha}^{L}$	**0.037**	**0.228**	**0.434**
	$(CE)_{\alpha}^{U}$	**0.672**	**0.828**	**0.434**
CSB Bank Limited	$(CE)_{\alpha}^{L}$	**0.035**	**0.219**	**0.427**
	$(CE)_{\alpha}^{U}$	**0.56**	**0.764**	**0.427**
DCB Bank Limited	$(CE)_{\alpha}^{L}$	**0.027**	**0.177**	**0.358**
	$(CE)_{\alpha}^{U}$	**0.82**	**0.908**	**0.358**
Federal Bank Ltd	$(CE)_{\alpha}^{L}$	**0.036**	**0.23**	**0.447**
	$(CE)_{\alpha}^{U}$	**0.692**	**0.838**	**0.447**
HDFCBank Ltd.	$(CE)_{\alpha}^{L}$	**0.034**	**0.226**	**0.561**
	$(CE)_{\alpha}^{U}$	**0.647**	**0.814**	**0.561**
ICICI Bank Limited	$(CE)_{\alpha}^{L}$	**0.04**	**0.261**	**0.526**
	$(CE)_{\alpha}^{U}$	**0.648**	**0.815**	**0.526**
IDBI Bank Limited	$(CE)_{\alpha}^{L}$	**0.0403**	**0.271**	**0.573**
	$(CE)_{\alpha}^{U}$	**0.689**	**0.834**	**0.573**
IDFC First Bank Limited	$(CE)_{\alpha}^{L}$	**0.027**	**0.179**	**0.368**
	$(CE)_{\alpha}^{U}$	**0.54**	**0.752**	**0.368**

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Indusind Bank Ltd	$(CE)_{\alpha}^{L}$	**0.0319**	**0.189**	**0.34**
	$(CE)_{\alpha}^{U}$	**0.507**	**0.733**	**0.34**
Jammu & Kashmir Bank Ltd	$(CE)_{\alpha}^{L}$	**0.031**	**0.209**	**0.466**
	$(CE)_{\alpha}^{U}$	**0.739**	**0.865**	**0.466**
Karnataka Bank Ltd	$(CE)_{\alpha}^{L}$	**0.032**	**0.204**	**0.445**
	$(CE)_{\alpha}^{U}$	**0.771**	**0.882**	**0.445**
Karur Vysya Bank Ltd	$(CE)_{\alpha}^{L}$	**0.0303**	**0.195**	**0.401**
	$(CE)_{\alpha}^{U}$	**0.744**	**0.867**	**0.401**
Kotak Mahindra Bank Ltd.	$(CE)_{\alpha}^{L}$	**0.033**	**0.208**	**0.498**
	$(CE)_{\alpha}^{U}$	**0.692**	**0.839**	**0.498**
Nainital Bank Ltd	$(CE)_{\alpha}^{L}$	**0.035**	**0.147**	**0.113**
	$(CE)_{\alpha}^{U}$	**0.096**	**0.311**	**0.113**
RBL Bank Limited	$(CE)_{\alpha}^{L}$	**0.276**	**1.19**	**0.945**
	$(CE)_{\alpha}^{U}$	**0.069**	**0.404**	**0.945**
South Indian Bank Ltd	$(CE)_{\alpha}^{L}$	**0.035**	**0.206**	**0.388**
	$(CE)_{\alpha}^{U}$	**0.569**	**0.77**	**0.388**
Tamilnad Mercantile Bank Ltd	$(CE)_{\alpha}^{L}$	**0.023**	**0.158**	**0.26**
	$(CE)_{\alpha}^{U}$	**0.385**	**0.606**	**0.26**

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The Dhanalakshmi Bank Ltd	$(CE)_{\alpha}^{L}$	**0.0313**	**0.172**	**0.251**
	$(CE)_{\alpha}^{U}$	**0.311**	**0.603**	**0.251**
Yes Bank Ltd.	$(CE)_{\alpha}^{L}$	**2.18**	**3.99**	**1**
	$(CE)_{\alpha}^{U}$	**0.027**	**0.353**	**1**

The above table explores the fuzzy cost efficiency score of 21 Indian private sector banks and it is concluded that out of those only one bank is cost efficient at alpha = 1 at both lower and upper bound level .

As per Jafar Pourmahmoud1, Naser Bafekr Sharak[15], the lower and upper efficiency score should be equal at alpha equal to one and in this study we found that the cost efficiency score at both the lower and upper bound level is equal at alpha = 1.

4.4. Ranking Index:

The rank of eachDMU has been calculated using Chen – Klin index[2] and the same has been presented in the following table.

Table No. 4.4.

Rank of DMU

D.M.U No.	Name of the Bank(DMU)	Rank
1	**Axis Bank Limited**	**6**
2	**Bandhan Bank Limited**	**16**
3	**City Union Bank Limited**	**12**
4	**CSB Bank Limited**	**13**
5	**DCB Bank Limited**	**9**
6	**Federal Bank Ltd**	**11**
7	**HDFC Bank Ltd.**	**5**
8	**ICICI Bank Limited**	**8**
9	**IDBI Bank Limited**	**2**
10	**IDFC First Bank Limited**	**15**
11	**Indusind Bank Ltd**	**17**

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12	**Jammu & Kashmir Bank Ltd**	**4**
13	**Karnataka Bank Ltd**	**3**
14	**Karur Vysya Bank Ltd**	**10**
15	**Kotak Mahindra Bank Ltd.**	**7**
16	**Nainital Bank Ltd**	**21**
17	**RBL Bank Limited**	**18**
18	**South Indian Bank Ltd**	**14**
19	**Tamilnadu Mercantile Bank Ltd**	**19**
20	**The Dhanalakshmi Bank Ltd**	**20**
21	**Yes Bank Ltd.**	**1**

It is inferred from the above table that the 21st DMU has been ranked as 1st (Yes Bank) followed by 9th (IDBI Bank),13th (Karnataka Bank), 12th(Jammu & Kashmir Bank) and 7th (HDFC Bank)DMU respectively.

5. Summary and Conclusion:

In this study, 21 Indian private sector banks were taken with 5 inputs and 4 outputs to assess the cost efficiency by applying the classical DEA and Fuzzy DEA models over the period of time 2018-2021. The empirical investigation yields that out of 21 Indian private sector banks, only two are cost efficient under conventional – cost efficiency model and only one is cost efficient under Fuzzy cost efficiency model at both the lower level and upper bound level at alpha =1. Henceforth, it is concluded that the Fuzzy cost efficiency model helps the banks to know their level of performance and can increase their performance by referring the efficient banks.

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