

Input oriented super efficiency evaluation of Indian commercial banks

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Abstract

The purpose of this research paper is to measure and compare the super efficiency of Indian public and private sector banks having frequently scoring standard efficiency scores. The data of total 20 banks including 10 public sector banks and 10 private sector banks operating in India has been endorsed for 10 years (2013-2014 to 2021-22) as per highest the market capitalization of the banks. Using Data Envelopment Analysis, the paper evaluates the input oriented super efficiency scores of selected Indian public and private sector banks as per CRS and VRS approaches. Further, comparison of both the sectors is also done on the basis of the input oriented super efficiency scores and ranking of all the banks is also done. This study offers insights to policy makers, bank executives, and banking regulators about the super efficiency scenario of the selected Indian banks. This comparative examination of DEA models with various input and output variables using a sample of Indian banks is few of its type in the Indian context and aids in the selection of a suitable model for further study.

Subject Classification: 90C05.

Keywords: *Super efficiency, Comparative super efficiency analysis, Data envelopment analysis.*

1. Introduction

The efficiency of Indian banks plays a crucial role in the overall economic development of the country. It is a key indicator of how well financial institutions manage their resources to provide services to customers, support economic activities, and contribute to sustainable growth. The efficiency of Indian banks is influenced by various factors, including regulatory frameworks, technology adoption, competition, and the overall economic environment. Determining the efficiency of Decision Making Units (DMUs) is one of the most significant subjects in management science. An efficiency score of one in various DEA models indicates that a DMU is operating at peak performance. Several DMUs frequently get this efficiency score. Super-efficiency methods are a group of techniques that have been created to rank and compare efficient units. The super-efficiency model by Andersen and Petersen, [3] and the slack-based measure presented by Tone [19] are two examples of these techniques. Super efficiency (Input Oriented) of Indian public and private sector banks is measured in order to rank the banks which are found efficient based on super efficiency evaluation. The super efficiency model in DEA excludes each observation from its own reference set, so that it is possible to obtain efficiency scores that exceed one [32]. The difference between a super efficiency model and a standard efficiency model is that in super models the DMU evaluated is excluded from the analysis. Super efficiency model is developed by Andersen and Petersen [3] provides the strict ranking to

all DMUs in the sample [27]. Super efficiency model is run to rank the efficient banks obtained from the first stage by calculating their super efficiency scores [20]. This section focuses on evaluation of Super efficiency (Input Oriented) scores of Indian public and private sector banks. In addition, all the banks under study are ranked according to the Super efficiency (IO) Scores measured at different Returns to Scale.

Organization of the Study

The current research is systematized as follows: “Review of Literature” includes review of literature and input and output variable details, “Research Gap” includes the contribution of the current research to the existing literature, “Research Objectives” mentions the aims of the current study, “Research Methodology” covers the study’s research methodology; “Data analysis” covers the detailed analysis of the research data; “Results and discussion” includes the results obtained after the analysis; “Conclusion and implications” includes the study’s conclusion and utility for the researchers ; and “Limitations and Scope for Future Research” highlights the study’s limitations and opportunities for future research.

Review of Literature

Salafiyah, [6]; Yu & Huang, [30]; Amalia and Ekowati, [2]; Chen *et al.*, [21]; Shah *et al.*, [25]; Chen and Wang, [9]; Dar, Mathur and Mishra *et al.* [11] Cvetkoska and Cikovic, [10]; Fatehian and Fatehian [13] evaluated the super efficiency of banks along with Malmquist productivity of banks and revealed the improvement in the efficiency levels of the banks. Panel Tobit Regression is also been used by Antunes *et al.*, [4]; Dar, Ahn, and Dar [12] to know the impact of various bank specific variables on the super efficiency. Zhong *et al.*, [31]; Gerami *et al.*, [14]; Yang *et al.*, [29]; M. He *et al.*, [15]; measured and compared the performance through the super efficiency model using DEA. Some of the studies like Taleb *et al.*, [28]; Singh, Yadav, and Tyagi [26]; Jiang, Zhang, and Jin [18] evaluated the super efficiency of different other industries than banking sector. Sengupta and De [24]; Ab Rahim, [1]; Asmild and Matthews, [5] evaluated the performance based on Super efficiency of Indian banking sector. Using a Data Envelopment Analysis (DEA)-based super efficiency model Sengupta and De [24]; Minh *et al.*, [22]; Tone, [19] examined the performance of the banking sector in India and the authors found that the performance of public sector banks improved from during the selected time frame.

Furthermore, when compared to the newly established private sector and foreign banks, the efficiency scores of public sector banks exhibited a relatively lower degree of variation. Kasim *et al.*, [20], Noura *et al.*, [23] measured the super efficiency of nine banks in Malaysia from 2004-2013 and ranked according to their efficiency scores and authors revealed that efficiency scores and ranking of banks fluctuated over the study period, suggesting the banks to improve their efficiency.

Andersen and Pertersen, [3] created a adapted version of DEA that compared efficient Decision Making Units (DMUs) to a reference technology that encompassed all other units. The approach establishes a framework for evaluating efficient units and allows for comparison with parametric rankings. Zimkova, [32], Du, Liang, and Zhu [17] measured the technical efficiency and super efficiency of banks of Slovakia and ranked the same and authors suggested that the banks with lower level of efficiency should improve their managerial processes and the regulatory authority should anticipate an endeavour by financial institutions licenced by the local central to establish international bank branch offices. Spaho, Mitre, and Shehu, [27] and Avkiran, [7] analysed the TE and Super efficiency of banks in Albania by intermediation approach in DEA. Ranking of commercial banks was also done under Input Oriented Variable Returns to Scale and authors revealed that twelve out of sixteen banks were technically efficient. Charles and Kumar, (2013); Doyle and Green [16] measured super efficiency of Peruvian banks and gave ranking with the super efficiency from 2008 to 2010 and authors revealed that the ranking of Decision Making Units (DMUs) under VRS might not be risk free with the existence of outliers which may unpredictably affect the rankings. Major part of the literature discovered that the efficiency of public banks increased and there was less difference in efficiency scores when compared to private and foreign sector banks. According to the authors, non-traditional operations are the most important factor in bank efficiency however asset quality has a negative impact on bank efficiency.

Research Gap

By conducting an empirical examination and critical analysis of the input oriented super efficiency as per Constant Returns to Scale and Variable Returns to Scale of a subset of Indian banks, the current study contributes to the body of literature by incorporating a variety of input and output variables that have been previously discussed in the literature. This study contributes to the extant literature by addressing a lacuna in

the previous research by conducting a comparative analysis of super efficiency parameters across a sample of public and private sector banks in India which have already been proved technically efficient. Conducting a comparative analysis of the super efficiency levels of banks in the public and private sectors provides regulators and researchers with a comprehension of the performance of these banks in relation to their ownership. Hence, it is imperative that public and private sector banks in India are informed of the research findings from time to time in order to enable them to conduct research into the factors contributing to the performance of banks.

Research Objectives

- To measure and evaluate the input oriented super efficiency as per Constant Returns to Scale and Variable Returns to Scale approaches of selected Indian commercial banks.
- To compare the performance of selected Indian public and private sector banks as per the input oriented super efficiency scores.

Research Methodology

This research compares and measures the input oriented super efficiency of major public and private sector banks in India using Intermediation and Production Models. This section describes the study's sample, timeframe, variables, database, and statistical procedures. The research is descriptive and exploratory in character, and it covers the time span from April 1, 2011 to March 31, 2022. Following the calculation of a three-year moving average, the study period is extended from 2013-14 to 2021-22. The research paper presents a data analysis of twenty banks in India, both public and private, based on market capitalization as reported by the RBI as of March 31, 2022. The current research is entirely dependent on secondary data. The research data is gathered from the Central Bank of India (RBI), the CMIE Prowess database, and the websites of the selected institutions.

Statistical Models and Techniques

DEA is widely used in the banking, education, retail, sports, health care, and other service industries to assess and enhance the performance of DMUs (Chandrasekar et al., 2018). DEA was developed by Charnes,

Cooper, and Rhodes as a mathematical programming paradigm that could be used with the designated DMUs that had different inputs and outputs. In this study, the technical efficiency and decomposition of selected Indian banks are computed using the input-oriented models of DEA and further super efficiency of the technically efficient banks have been evaluated.

CCR Model

Charnes, Cooper, and Rhodes created the CCR model of DEA in Charnes (1978) to enumerate the comparative efficiency of DMUs, and later in 1984, it was prolonged by Banker, Charnes, Cooper (BCC) to accomplish the Pure Technical and Scale Efficiency scores. The efficiency score of uniform DMUs with many input and output variables is defined as:

Efficiency = Weighted sum of outputs / Weighted sum of inputs

$$\text{Max} \quad e_s = \frac{\sum_{i=1}^m u_i y_{is}}{\sum_{j=1}^n v_j x_{js}} \quad \text{For } i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad \text{Equation [1]}$$

Subject to:

$$\frac{\sum_{i=1}^m u_i y_{ir}}{\sum_{j=1}^n v_j x_{jr}} \leq 1 \quad \text{For } r = 1, 2, \dots, n$$

$$U_i > 0; v_j > 0$$

Where:

e_s = the efficiency score;

y_{is} = the amount of the i^{th} output produced by the s^{th} bank;

x_{js} = the amount of the j^{th} input used by the s^{th} bank;

u_i = the output weight;

v_j = the input weight;

x_{jr} = the amount of input j utilized by the r^{th} DMU; and

y_{ir} = the amount of output i produced by the r^{th} DMU

So the fitness function in equation [1] is in fractional form, it must be rewritten as follows to a linear equation [2] in order to execute DEA on a normal linear software package:

$$\text{Maximize} \quad e_s = \sum_{j=1}^n v_j x_{js} \quad \text{Equation [2]}$$

$$\text{Subject to :} \quad \sum_{i=1}^m u_i y_{is} = 1$$

$$\sum_{i=1}^m u_i y_{is} - \sum_{j=1}^n v_j x_{jr} = 0$$

$$u_i, v_j > 0$$

$$j = 1, \dots, n; i = 1, \dots, m; r = 1, \dots, n$$

BCC Model

Overall Efficiency = Pure Technical Efficiency $\times$ Scale Efficiency

BCC model relax the constant returns restriction on CCR. BCC includes restriction and can be computed as shown below:

$$\text{Maximise} \quad \sum_{r=1}^s u_r y_{ro} - C_k \quad \text{Equation[3]}$$

$$\text{Subject to :} \quad \sum_{i=1}^m v_i x_{io} = 1$$

$$\sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} - C_k \leq 0 \quad j = 1, \dots, n$$

$$U_r \geq 0 \quad V_i \geq 0$$

Input and Output Variables

There are two primary methods in the literature on banking theory: the production approach and the intermediation approach (Sealey & Lindley, 1977). The current research uses the Intermediation Method to identify input and output variables. Input variables include deposits, borrowings, fixed assets and operating expenses while loans/advances, investments and operating income are considered as the output variables of the current research.

Data Analysis

Super efficiency (IO) ratings of public and private sector banks as per CRS approach has been presented in Table 1. Indian Bank has achieved the

highest Super efficiency (IO) score while the lowest score has been attained by ICICI (Table 1). In the year 2012-13, Super efficiency score of all the banks diverges from 0.675 to 3.046 and average Super efficiency (IO) score is 1.240. Ten banks are super-efficient namely Kotak, Federal, Yes Bank, City, Karur, DCB, Canara, BOI, Indian and Corporation while remaining ten banks are having their Super efficiency (IO) score less than one. DCB has achieved the highest Super efficiency (IO) score while BOB has achieved the lowest. In the year 2013-14, Super efficiency score of all the banks varies from 0.831 to 2.100 and average Super efficiency score of all the banks is 1.227. Number of Efficient banks scoring Super efficiency scores more than one is fifteen which includes HDFC, Kotak, ICICI, Axis, Federal, City, Karur, DCB, SBI, BOB, IDBI, Canara, Central, Indian and Andhra while remaining five banks have scored less than one. HDFC has scored the maximum Super efficiency (IO) while minimum score is achieved by Corporation. In the year 2014-15, Super efficiency (IO) score of all the banks varies from 0.568 to 2.212 and average Super efficiency score is 1.179. Twelve banks are operating efficiently as per Super efficiency (IO) namely HDFC, Federal, City, Karur, State Bank India, BOB, IDBI, PNB, BOI, Central, Indian and Andhra while remaining eight banks are operating inefficiently as per Super efficiency (IO). Karur has achieved the highest Super efficiency (IO) score while lowest score has been achieved by ICICI. In the year 2015-16, Super efficiency (IO) score of all the banks diverges from 0.668 to 3.971 and average Super efficiency score is 1.341. Thirteen public and private sector banks have scored Super efficiency (IO) more than one namely Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, PNB, Central, Indian and Andhra and remaining seven banks are operating inefficiently. In the year 2017-18, Super efficiency (IO) score of all the banks varies from 0.646 to 3.116 and average Super efficiency score is 1.192. Eleven banks namely HDFC, Kotak, ICICI, Federal, City, Karur, IDBI, PNB, Central, Indian and Corporation are super-efficient while remaining nine banks are inefficient (Table 1). Maximum Super efficiency score is achieved by Indian and minimum score is achieved by BOB. In the year 2018-19, Super efficiency (IO) score of all the banks diverges from 0.645 to 6.396 and average Super efficiency (IO) score is 1.471. Eleven banks are operating efficiently as per Super efficiency (IO) scores namely Kotak, Axis, Federal, City, Karur, BOB, IDBI, BOI, Central, Indian and Andhra while remaining nine banks are operating inefficiently. Indian Bank has achieved the highest Super efficiency (IO) score while ICICI has scored the lowest. In the year 2019-20, Super efficiency (IO) score of all the banks varies from 0.625 to 8.579 and average Super efficiency

(IO) score is 1.453. Nine banks are super-efficient namely Karur, BOB, PNB, Canara, BOI, Central, Indian Bank, Corporation and Andhra while remaining eleven banks are inefficient. Highest Super efficiency (IO) score is achieved by Central while lowest score is obtained by HDFC. In the year 2020-21, Super efficiency (IO) score of all the banks diverges from 0.680 to 5.212 and average Super efficiency (IO) score is 1.645. Corporation has achieved the highest Super efficiency (IO) score while BOI has obtained

Table 1
Super Efficiency (IO) Scores of Indian Public and Private Sector Banks (CRS)

Bank Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Average
HDFC	2.100	1.028	0.977	0.828	1.322	0.767	0.625	1.278	0.972	1.100
Kotak	1.762	0.987	0.831	1.365	1.362	1.305	0.858	1.287	0.937	1.188
ICICI	1.476	0.568	0.668	0.717	1.634	0.645	0.755	0.936	0.916	0.924
Axis	1.022	0.933	0.950	0.759	0.823	1.047	0.737	1.156	1.111	0.949
Federal	1.157	1.506	2.036	1.057	1.196	1.221	0.885	1.261	1.197	1.280
Indus	0.976	0.853	1.081	0.933	0.770	0.798	0.625	0.942	1.060	0.893
Yes	0.975	0.781	1.251	1.730	0.942	0.935	0.873	1.323	1.477	1.143
City	1.524	1.337	1.076	1.511	1.283	1.782	0.954	2.371	2.089	1.547
Karur	1.141	2.212	1.007	1.159	1.188	1.331	2.012	0.805	1.057	1.324
DCB	1.072	0.906	1.045	3.046	0.984	0.812	0.633	1.037	1.207	1.194
SBI	1.343	1.341	1.356	0.916	0.859	0.760	0.706	0.956	1.724	1.107
BOB	1.200	1.403	1.445	0.675	0.646	1.934	1.860	1.226	1.060	1.272
IDBI	1.204	1.204	1.227	0.845	1.064	1.644	0.845	2.021	2.602	1.406
PNB	0.836	1.015	1.067	0.801	1.144	0.840	1.003	1.403	3.573	1.298
Canara	1.020	0.954	0.985	1.105	0.961	0.933	1.053	0.753	1.968	1.081
BOI	0.997	1.045	0.803	1.761	0.930	1.603	1.480	0.680	6.148	1.716
Central	1.012	1.537	3.063	0.915	1.427	1.492	8.579	3.006	2.042	2.564
Indian	1.711	2.114	3.971	2.861	3.116	6.396	1.629	4.091	1.230	3.013
Corporation	0.831	0.849	0.981	1.033	1.207	0.952	1.246	5.212	1.519	1.537
Andhra	1.181	1.008	1.004	0.775	0.978	2.229	1.705	1.150	0.993	1.225
Average	1.227	1.179	1.341	1.240	1.192	1.471	1.453	1.645	1.744	1.388
Min	0.831	0.568	0.668	0.675	0.646	0.645	0.625	0.680	0.916	0.893
Max	2.100	2.212	3.971	3.046	3.116	6.396	8.579	5.212	6.148	3.013
St. Dev.	0.333	0.420	0.810	0.667	0.514	1.242	1.732	1.186	1.236	0.528

Source: Author's calculations

the lowest score. In the year 2021-22, Super efficiency (IO) of all the banks varies from 0.916 to 6.148 and average Super efficiency (IO) is 1.744. Sixteen banks are operating efficiently as per Super efficiency (IO) score namely Axis, Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, PNB, Canara, BOI, Central, Indian and Corporation.

Maximum Super efficiency (IO) score is achieved by BOI while minimum score is obtained by ICICI. It is concluded from the above discussion that most of the banks are operating efficiently as per Super efficiency (IO) score in all the years but maximum banks are super-efficient in the year 2021-22 while minimum banks are super-efficient in the year 2019-20 (Table 1). These results are consistent with Sengupta and De [24].

It is imperative to measure the Super efficiency (IO) as per Variable Returns to Scale in order to have the complete evaluation of banks. In the year 2013-14, Super efficiency (IO) score of all the banks diverges from 0.855 to 2.137 and average Super efficiency (IO) score of is 1.320. Eighteen banks have Super efficiency (IO) scores more than one namely HDFC, Kotak, ICICI, Axis, Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, Canara, BOI, Central, Indian Bank, and Andhra while remaining three banks are scoring less than one. DCB has scored the maximum Super efficiency (IO) while minimum score is attained by PNB. In the year 2014-15, Super efficiency score of all the banks varies from 0.896 to 3.736 and average Super efficiency score is 1.418.

Table 2
Super Efficiency (IO) Scores of Indian Public and Private Sector Banks (VRS)

Bank Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Average
HDFC	1.000	1.147	0.983	0.839	1.325	1.167	0.820	1.439	0.973	1.077
Kotak	1.766	1.205	1.105	1.530	1.376	1.386	2.262	1.673	0.976	1.476
ICICI	1.000	1.000	4.704	1.000	1.000	0.672	0.827	0.943	0.980	1.347
Axis	1.236	1.071	0.955	0.759	0.833	1.065	1.124	1.422	1.000	1.051
Federal	1.494	1.000	1.000	1.277	1.212	1.234	1.354	1.435	1.209	1.246
Indus	1.089	0.896	1.157	1.016	1.013	1.395	1.065	1.121	1.062	1.090
Yes	1.480	1.624	1.255	1.757	1.226	1.289	1.288	2.069	2.216	1.578
City	1.525	1.535	1.135	1.520	1.323	1.871	1.078	1.000	3.518	1.612
Karur	1.142	3.736	1.186	1.622	1.283	1.000	1.000	0.816	1.000	1.421
DCB	2.137	1.866	1.048	3.140	1.352	1.135	0.881	1.073	1.250	1.542

Contd...

SBI	1.346	1.000	1.000	2.699	0.885	0.832	0.880	1.011	1.000	1.184
BOB	1.290	1.759	1.477	0.884	0.943	1.000	2.579	1.233	1.069	1.359
IDBI	1.300	1.210	1.000	1.134	1.000	1.000	0.903	1.000	6.247	1.644
PNB	0.855	1.059	1.156	0.879	2.927	0.897	1.087	1.523	1.000	1.265
Canara	1.022	0.965	1.324	1.000	0.967	0.979	1.115	0.794	1.000	1.018
BOI	1.001	1.047	0.814	1.000	1.021	1.618	1.495	0.749	11.046	2.199
Central	1.424	1.757	8.274	1.880	1.700	2.532	1.000	3.267	3.093	2.770
Indian	2.097	2.431	4.180	1.000	10.076	1.000	1.000	1.000	1.351	2.682
Corporation	0.947	0.976	0.982	1.036	1.310	2.521	1.000	1.000	1.544	1.257
Andhra	1.245	1.072	1.006	0.776	1.024	2.245	2.289	1.156	1.000	1.313
Average	1.320	1.418	1.787	1.337	1.690	1.342	1.252	1.286	2.127	1.507
Min	0.855	0.896	0.814	0.759	0.833	0.672	0.820	0.749	0.973	1.018
Max	2.137	3.736	8.274	3.140	10.076	2.532	2.579	3.267	11.046	2.770
St. Dev.	0.358	0.679	1.848	0.638	2.024	0.545	0.517	0.570	2.469	0.496

Source: Author's calculations

Seventeen banks are operating efficiently namely HDFC, Kotak, ICICI, Axis, Federal, Yes Bank, City, Karur, DCB, State Bank India, BOB, IDBI, PNB, BOI, Central, Indian and Andhra and remaining three banks are operating inefficiently as per Super efficiency (IO). Karur has achieved the highest Super efficiency (IO) score while lowest score has been attained by Indus. In the year 2015-16, Super efficiency score of all the banks varies from 0.814 to 8.274 and average Super efficiency score of all the banks is 1.787. Sixteen banks have scored Super efficiency (IO) score more than one namely Kotak, ICICI, Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, PNB, Canara, Central, Indian and Andhra and remaining four banks are operating inefficiently. Central has achieved the highest Super efficiency (IO) score while lowest score has been attained by BOI (Table 2). In the year 2016-17, Super efficiency score of all the banks diverges from 0.759 to 3.140 and average Super efficiency (IO) score is 1.337. Fifteen banks are superefficient namely Kotak, ICICI, Federal, Indus, Yes Bank, City Bank, Karur, DCB, SBI, IDBI, Canara, BOI, Central, Indian and Corporation and remaining five banks are having their Super efficiency (IO) score less than one. DCB has achieved the highest Super efficiency (IO) score while Axis has achieved the lowest score. In the year 2017-20, Super efficiency score of all the banks diverges from 0.833 to 10.076 and average Super efficiency (IO) score is 1.690. Sixteen banks are performing efficiently namely HDFC, Kotak, ICICI, Federal, Indus, Yes Bank, City,

Karur, DCB, IDBI, PNB, BOI, Central, Indian and Corporation and Andhra while remaining four banks have their Super efficiency (IO) score less than 1. Maximum score is achieved by Indian and minimum score is attained by Axis. In the year 2018-19, Super efficiency (IO) score of all the banks diverges from 0.672 to 2.532 and average Super efficiency (IO) score is 1.342. Sixteen banks are operating efficiently as per Super efficiency (IO) scores namely HDFC, Kotak, Axis, Federal, Indus, Yes Bank, City, Karur, DCB, BOB, IDBI, BOI, Central, Indian Bank, Corporation and Andhra while remaining four banks are operating inefficiently. Central has achieved the highest Super efficiency (IO) score while ICICI has attained the lowest (Table 2). In the year 2019-20, Super efficiency (IO) score of all the banks varies from 0.820 to 2.579 and average Super efficiency (IO) score of all the banks is 1.252. Fifteen banks are superefficient namely Kotak, Axis, Federal, Indus, Yes Bank, City, Karur, BOB, PNB, Canara, BOI, Central, Indian Bank, Corporation and Andhra while remaining five banks are inefficient in the year 2019-20. Highest Super efficiency (IO) score is achieved by BOB while lowest score is obtained by HDFC. In the year 2020-21, Super efficiency (IO) score of all the banks diverges from 0.749 to 3.267 and average Super efficiency (IO) score is 1.286. Sixteen banks have scored Super efficiency (IO) score more than one. while remaining four banks are operating inefficiently. Central has achieved the highest Super efficiency (IO) score while BOI has obtained the lowest score in the year 2020-21. In the year 2021-22, Super efficiency (IO) of all the banks varies from 0.973 to 11.046 and average Super efficiency (IO) is 2.127. Seventeen banks are operating efficiently as per Super efficiency (IO) score namely Axis, Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, PNB, Canara, BOI, Central, Indian and Corporation and Andhra. Maximum Super efficiency (IO) score is achieved by BOI while minimum score is obtained by HDFC. It is revealed from Table 2 that most of the banks are operating efficiently as per Super efficiency (IO) scores but maximum banks are superefficient in the year 2013-14 while minimum banks are superefficient in the year 2016-20.

Super efficiency (IO) of public and private sector banks are measured and analyzed and Table 3 depicts the Super efficiency (IO) score of Indian public sector banks. In the year 2013-14, Super efficiency (IO) of public sector banks varies from 0.916 to 2.536 and average Super efficiency (IO) is 1.451. Eight banks are operating efficiently namely SBI, BOB, IDBI, Canara, BOI, Central, Indian and Andhra. Andhra has achieved the highest Super efficiency (IO) while Corporation has scored the lowest. In the year 2014-15, Super efficiency (IO) score of all the public sector banks diverges from

0.965 to 2.250 and average Super efficiency (IO) is 1.364 (lowest among all the years under reference). Nine banks are operating efficiently namely SBI, BOB, IDBI, PNB, BOI, Central, Indian Bank, Corporation and Andhra. Indian Bank has achieved the highest Super efficiency (IO) while Canara has obtained the lowest. In the year 2014-15, Super efficiency (IO) score of all the public sector banks varies from 0.814 to 9.266 and average Super efficiency (IO) is 2.209. All the banks except BOI are operating efficiently.

Table 3
Super Efficiency (IO) Scores of Indian Public Sector Banks

Bank Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Average
SBI	1.922	1.374	1.398	1.947	1.017	0.792	0.712	1.234	1.724	1.347
BOB	1.292	1.407	1.478	0.680	0.724	2.797	1.860	1.226	1.168	1.404
IDBI	1.379	1.204	1.440	1.157	1.324	1.644	0.845	2.798	4.188	1.775
PNB	0.951	1.015	1.099	1.059	1.344	0.864	1.155	1.442	3.573	1.389
Canara	1.033	0.965	1.196	1.603	0.961	0.990	1.053	0.753	2.140	1.188
BOI	1.203	1.079	0.814	1.963	1.021	1.603	1.480	0.680	6.148	1.777
Central	1.569	1.537	3.330	1.693	1.489	2.495	9.911	3.036	2.752	3.090
Indian	1.712	2.250	9.266	4.034	4.304	6.396	1.629	4.200	1.971	3.973
Corporation	0.916	1.802	1.032	1.185	1.218	0.959	1.246	6.405	1.612	1.819
Andhra	2.536	1.008	1.039	0.854	1.038	2.455	1.705	1.183	1.048	1.430
Mean	1.451	1.364	2.209	1.617	1.444	2.099	2.160	2.296	2.632	1.919
St. Dev.	0.504	0.411	2.578	0.957	1.029	1.682	2.749	1.842	1.594	0.900
Minimum	0.916	0.965	0.814	0.680	0.724	0.792	0.712	0.680	1.048	1.188
Maximum	2.536	2.250	9.266	4.034	4.304	6.396	9.911	6.405	6.148	3.973

Source: Author's calculations

Maximum score is achieved by Indian while minimum score is obtained by BOI. In the year 2016-17, Super efficiency (IO) score of all the public sector banks diverges from 0.680 to 4.034 and average Super efficiency (IO) is 1.617. Eight banks are operating efficiently namely SBI, IDBI, PNB, Canara, BOI, Central, Indian Bank, and Corporation (Table 4). Indian Bank has achieved the highest score while the lowest score is obtained by BOB. In the year 2017-18, Super efficiency (IO) score of public sector banks varies from 0.724 to 4.304 and average Super efficiency (IO) of public sector banks is 1.444. Eight banks are super-efficient namely SBI, IDBI, PNB, BOI, Central, Indian Bank, Corporation and Andhra while

remaining two banks (BOB and Canara) are inefficient. Indian Bank has achieved the highest Super efficiency (IO) while the lowest is score by BOB in the year 2017-18. In the year 2017-18, Super efficiency (IO) score of public sector banks varies from 0.792 to 6.396 and average Super efficiency (IO) is 2.099. Six banks are operating efficiently namely BOB, IDBI, BOI, Central, Indian and Andhra. Highest score is achieved by Indian Bank while the lowest score is obtained by SBI. In the year 2019-20, Super efficiency (IO) score of public sector banks diverges from 0.712 to 9.911 and average Super efficiency (IO) is 2.160. Eight banks are operating efficiently namely BOB, PNB, Canara, BOI, Central, Indian Bank, Corporation and Andhra. Highest score is achieved by Central while the lowest score is obtained by SBI. In the year 2020-2021, Super efficiency (IO) score of public sector banks varies from 0.680 to 6.405 and average Super efficiency (IO) is 2.296. Eight banks are super-efficient namely SBI, BOB, IDBI, PNB, Central, Indian Bank, Corporation and Andhra. Corporation has achieved the highest Super efficiency (IO) score while BOI has obtained the lowest score. In the year 2021-22, Super efficiency (IO) score of public sector banks diverges from 1.048 to 6.148 and average Super efficiency (IO) is 2.632. All the public sector banks are operating efficiently in the year 2021-22. BOI has achieved the highest Super efficiency (IO) score while Andhra has obtained the lowest score. Table 3 demonstrates the Super efficiency (IO) scores of private sector banks. In the year 2013-14, Super efficiency (IO) of private sector banks varies from 0.976 to 3.050 and average Super efficiency (IO) is 1.522. Nine banks are operating efficiently namely HDFC, Kotak, ICICI, Axis, Federal, Yes Bank, City, Karur and DCB. HDFC has achieved the highest Super efficiency (IO) while Indus has scored the lowest. In the year 2014-15, Super efficiency (IO) score of all the private sector banks diverges from 0.947 to 3.532 and average Super efficiency (IO) is 1.596 (lowest among all the years under reference). Nine banks are operating efficiently namely HDFC, Kotak, ICICI, Axis, Federal, Yes Bank, City, Karur and DCB while Indus is the only one operating below the standard efficiency level. Karur has achieved the highest Super efficiency (IO) while Indus has obtained the lowest. In the year 2015-16, Super efficiency (IO) score of all the private sector banks varies from 0.997 to 6.276 and average Super efficiency (IO) is 1.719. In the year 2016-17, Super efficiency score of all the private sector banks diverges from 0.838 to 5.848 and average Super efficiency (IO) is 1.670. Six banks are operating efficiently namely Kotak, Federal, Yes Bank, City, Karur and DCB (Table 4). DCB has achieved the highest score while the lowest score is obtained by Axis. In the year 2017-18, Super efficiency (IO) score of all the private

sector banks varies from 0.793 to 2.087 and average Super efficiency (IO) is 1.306. Seven banks are superefficient namely HDFC, Kotak, ICICI, Federal, City, Karur and DCB while remaining four banks are operating inefficiently. Kotak has achieved the highest Super efficiency (IO) while the lowest is scored by Indus. In the year 2018-19, Super efficiency (IO) score of private sector banks diverges from 0.874 to 2.943 and average Super efficiency (IO) is 1.437.

Table 4
Super Efficiency Scores of Indian Private Sector Banks

Bank Year	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	Average
HDFC	3.050	1.550	1.137	0.883	1.560	1.439	1.129	1.281	1.085	1.457
Kotak	1.762	1.156	0.997	1.657	2.087	1.648	1.687	1.289	1.219	1.500
ICICI	1.803	1.336	1.278	0.972	1.801	0.874	0.915	1.596	1.944	1.391
Axis	1.022	1.653	1.210	0.838	0.830	1.229	1.825	1.310	1.141	1.229
Federal	1.207	1.506	6.276	1.102	1.271	1.305	1.627	1.434	1.302	1.892
Indus	0.976	0.947	1.115	0.944	0.793	0.940	0.956	0.955	1.060	0.965
Yes	1.204	1.045	1.273	1.730	0.942	1.276	1.128	2.558	1.670	1.425
City	1.958	1.708	1.212	1.562	1.448	2.943	0.994	2.669	2.389	1.876
Karur	1.155	3.532	1.170	1.167	1.201	1.630	2.179	1.668	2.154	1.762
DCB	1.084	1.524	1.519	5.848	1.124	1.086	0.839	1.106	1.207	1.704
Mean	1.522	1.596	1.719	1.670	1.306	1.437	1.328	1.587	1.517	1.520
St. Dev.	0.644	0.728	1.607	1.504	0.423	0.589	0.463	0.581	0.487	0.294
Minimum	0.976	0.947	0.997	0.838	0.793	0.874	0.839	0.955	1.060	0.965
Maximum	3.050	3.532	6.276	5.848	2.087	2.943	2.179	2.669	2.389	1.892

Source: Author's calculations

Eight banks are operating efficiently namely HDFC, Kotak, Axis, Federal, Yes Bank, Karur and DCB while remaining two banks are operating inefficiently. Highest score is achieved by City while the lowest score is obtained by ICICI. In the year 2019-20, Super efficiency (IO) score of private sector banks diverges from 0.839 to 2.179 and average Super efficiency (IO) is 1.328. Six banks are operating efficiently namely HDFC, Kotak, Axis, Federal, Yes Bank and Karur while remaining four banks (ICICI, Indus, City and DCB) have their Super efficiency (IO) score less than one. Highest score is achieved by Karur while the lowest score is obtained by Indus. In the year 2020-2021, Super efficiency (IO) score of

private sector banks varies from 0.955 to 2.669 and average Super efficiency (IO) is 1.587. Nine banks are superefficient namely HDFC, Kotak, ICICI, Axis, Federal, Yes Bank, City, Karur and DCB and remaining one bank (Indus) is operating inefficiently. Corporation has achieved the highest Super efficiency (IO) score while BOI has obtained the lowest score. In the year 2021-22, Super efficiency (IO) score of private sector banks diverges from 1.060 to 2.389 and average Super efficiency (IO) is 1.517. All the private sector banks are operating efficiently in the year 2017-18. BOI has achieved the highest Super efficiency (IO) score while Andhra has obtained the lowest score.

Ranking of Indian Public and Private Sector Banks as per Super efficiency (IO) Scores

Ranking of Indian public and private sector banks under study is done based on the ranking method observed by Soleimani *et al.*, (2009) and Charles and Kumar, (2012) to recognize the efficiency efficient and the followers.

The banks attaining 1st rank are the efficient and the others are the followers. The follower banks improve their efficiency scores as per the strategies of the efficient. Banks under reference are ranked according to their Super efficiency (IO) Scores. Table 5 depicts the ranking of public and private sector banks according to Super efficiency (IO) Scores obtained in different years.

Results and Discussions

Super efficiency (IO) scores of twenty banks including ten public sector banks and ten private sector banks operating in India are calculated. Super efficiency (IO) scores of Indian public and private sector banks under reference are calculated based on CRS and VRS approaches. In addition, comparison of Indian public and private sector banks on the basis of Super efficiency (IO) ratings is also done. Furthermore, super-efficient banks are more under Super efficiency (IO) VRS approach as compared with Super efficiency (IO) CRS approach (Table 2). These results are consistent with Spaho, Mitre, and Shehu, [27] and inconsistent with Charles and Kumar (2013). To compare the performance of efficient banks of both the ownerships, Super efficiency (IO) scores of banks of both the ownerships have been measured separately. Super efficiency (IO) scores have been calculated through DEA. It is noticed that private sector banks

Table 5
Rank Wise Super efficiency (IO) Scores of Indian Private Sector Banks

Bank \ Year	2013-14		2014-15		2015-16		2016-17		2017-18		2018-19		2019-20		2020-21		2021-22	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
HDFC	2.100	1	1.028	10	0.977	16	0.828	15	1.322	5	0.767	18	0.625	20	1.278	9	0.972	18
Kotak	1.762	2	0.987	13	0.831	18	1.365	6	1.362	4	1.305	9	0.858	13	1.287	8	0.937	19
ICICI	1.476	5	0.568	20	0.668	20	0.717	19	1.634	2	0.645	20	0.755	15	0.936	17	0.916	20
Axis	1.022	13	0.933	15	0.950	17	0.759	18	0.823	18	1.047	11	0.737	16	1.156	12	1.111	13
Federal	1.157	10	1.506	4	2.036	3	1.057	9	1.196	8	1.221	10	0.885	11	1.261	10	1.197	12
Indus	0.976	17	0.853	17	1.081	8	0.933	11	0.770	19	0.798	17	0.625	19	0.942	16	1.060	14
Yes	0.975	18	0.781	19	1.251	6	1.730	4	0.942	15	0.935	13	0.873	12	1.323	7	1.477	9
City	1.524	4	1.337	7	1.076	9	1.511	5	1.283	6	1.782	4	0.954	10	2.371	4	2.089	4
Karur	1.141	11	2.212	1	1.007	12	1.159	7	1.188	9	1.331	8	2.012	2	0.805	18	1.057	16
DCB	1.072	12	0.906	16	1.045	11	3.046	1	0.984	12	0.812	16	0.633	18	1.037	14	1.207	11
SBI	1.343	6	1.341	6	1.356	5	0.916	12	0.859	17	0.760	19	0.706	17	0.956	15	1.724	7
BOB	1.200	8	1.403	5	1.445	4	0.675	20	0.646	20	1.934	3	1.860	3	1.226	11	1.060	15
IDBI	1.204	7	1.204	8	1.227	7	0.845	14	1.064	11	1.644	5	0.845	14	2.021	5	2.602	3
PNB	0.836	19	1.015	11	1.067	10	0.801	16	1.144	10	0.840	15	1.003	9	1.403	6	3.573	2
Canara	1.020	14	0.954	14	0.985	14	1.105	8	0.961	14	0.933	14	1.053	8	0.753	19	1.968	6
BOI	0.997	16	1.045	9	0.803	19	1.761	3	0.930	16	1.603	6	1.480	6	0.680	20	6.148	1
Central	1.012	15	1.537	3	3.063	2	0.915	13	1.427	3	1.492	7	8.579	1	3.006	3	2.042	5
Indian	1.711	3	2.114	2	3.971	1	2.861	2	3.116	1	6.396	1	1.629	5	4.091	2	1.230	10
Corporation	0.831	20	0.849	18	0.981	15	1.033	10	1.207	7	0.952	12	1.246	7	5.212	1	1.519	8
Andhra	1.181	9	1.008	12	1.004	13	0.775	17	0.978	13	2.229	2	1.705	4	1.150	13	0.993	17

Source: Author's calculations

are performing well in all the years but in the year 2019 -20, four private sector banks (maximum of all the years) are performing inefficiently. In the year 2021-22, all the private sector banks have achieved the Super efficiency (IO) score more than 1 (Table 4). These results are inconsistent with Minh *et al.*, [22]. It is noticed from the Table 3 that public sector banks are performing well in all the years but performance of public sector banks have been outstanding in the year 2021-22 as all the banks are super-efficient in this year. The performance of public sector banks is lowest in the year 2018-19 as four banks are inefficient in this year. These results are consistent with Spaho, Mitre, and Shehu, [27] inconsistent with Zimkova, [32]. It is concluded that in the year 2013-14, 2014-15 and 2016-17 maximum private sector banks have achieved the 1st rank. In the remaining years, 1st rank is mostly achieved by public sector banks, thus performance of public sector banks in these years has been comparatively better than the private sector banks.

Conclusion and implications

Super Efficiency of Decision Making Units is measured in order to rank the banks which are found efficient on the foundation of TE evaluation. The Super Efficiency Model allows efficiency scores to exceed one by excluding each observation from its own reference set [32]. A Super Efficiency model differs from a typical efficiency model in that the DMU being evaluated is not included in the study. Andersen and Petersen [3] established the Super Efficiency Model, which assigns a rigid standing to all DMUs in the sample [27]. By computing their Super Efficiency scores, the Super Efficiency model is used to rank the efficient banks identified in the first stage [20]. Super Efficiency (IO) scores of ten public sector banks and ten private sector banks operating in India are calculated. Super Efficiency (IO) scores of Indian public and private sector banks under reference are calculated based on CRS and VRS approaches. In addition, comparison of Indian public and private sector banks on the basis of Super Efficiency (IO) ratings is also done. In the year 2009-10, Super Efficiency score of all the banks varies from 0.831 to 2.100 and average Super Efficiency score of all the banks is 1.227. Number of Efficient banks scoring Super Efficiency scores more than one is fifteen which includes HDFC, Kotak, ICICI, Axis, Federal, City, Karur, DCB, SBI, BOB, IDBI, Canara, Central, Indian and Andhra while remaining five banks have scored less than one. HDFC has scored the maximum Super Efficiency (IO) while minimum score is achieved by Corporation. Thirteen public and private

sector banks have scored Super Efficiency (IO) more than one namely Federal, Indus, Yes Bank, City, Karur, DCB, SBI, BOB, IDBI, PNB, Central, Indian and Andhra and remaining seven banks are operating inefficiently. Super efficiency of Indian banks have been analysed in the present study, and future research can be conducted on measuring and comparing the efficiency of foreign banks. Indian banks, both public and private, ought to implement customer-friendly practices to boost interest revenue and decrease bad loans.

Indian banks, both public and private, must prioritize implementing corrective actions pertaining to non-performing assets (NPAs). The most crucial requirement for raising bank productivity and efficiency is this. Indian banks should prioritize credit risk management. Loans and advances need to be diligently and frequently followed up on. Every quarter, banks should conduct investigations for financial theft. Bank employees need to be knowledgeable about the proper paperwork when it comes to lending money to clients. To ascertain credit ratings, borrowers' periodic statements should be thoroughly examined through appropriate monitoring.

Limitations and Future Directions

The data used in this research originates from secondary sources. The limitations of employing secondary data as the only information source are acknowledged in this study. Future approaches, such as surveys or interviews with bank stakeholders, may be used to determine the super efficiency of the banks in place of current implementation of Data Envelopment Analysis. To reevaluate and broaden the study's conclusions, super efficiency analysis of banks could be measured using an additional set of data over a longer time period. Additionally, the study might be extended to look into how industry- and bank-specific factors affect the super efficiency of Indian banks.

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