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Comparative Performance based on Components of Technical Efficiency of Commercial Banks in India

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Abstract:

This paper aims to measure and compare the Technical Efficiency (TE) of major public sector and private sector banks operating in India from 2013 to 2024. The paper evaluates the technical efficiency, Pure Technical Efficiency (PTE), and Scale Efficiency (SE) of ten public sector banks and ten private sector banks operating in India within the period. Data envelopment analysis (DEA) has been used to calculate the TE. BCC Input Oriented approach has been used to measure the PTE and SE. It is revealed from the DEA results that during the covered years the mean efficiency of overall banks under study was 0.864. The most efficient bank with a maximum mean efficiency score of 0.950 was Bank of India and the bank with a minimum mean efficiency score of 0.70 was Indus Ind Bank. Further when we compared the mean efficiency score of public sector banks (0.901) and private sector banks (0.826). It reveals that the public sector banks were more efficient than the private sector banks under the study. The results suggest that the overall low efficiency of banks under study is due to pure technical efficiency rather than scale efficiency.

Keywords: *Technical Efficiency, Data Envelopment Analysis, Comparative Analysis*

Introduction

Commercial banks are an integral part of Indian financial system. The basic function of commercial banks is to accept deposits from people who have surplus money and provide loans to the needy people. Commercial banks play a vital role in strengthening the economy of a nation. A healthy financial system is the need for a healthy economy. The health of the financial system of an economy depends on the health of the commercial banks operating within it. The performance of the commercial banks has to be paid attention to for a healthy financial system and so for a healthy economy. Evaluating the efficiencies of banks can give useful information based on which the banks form their future strategies which in turn paves way to economic development of a country. Efficiency and productivity measurement are the major performance indicators of financial institutions. Efficiency measurement is a very important concept for the shareholders, regulators, managers and customers. Inefficient banks are riskier and have a higher risk of failure. Efficient banking system directly contributes to the productivity of the economy. Without a sound and efficiently functioning banking system, the economy cannot function smoothly and efficiently (Kumar and Gulati, 2008). In a dynamic and competitive market environment, only efficient banks will survive and maintain their profitability and inefficient ones will not be able to compete and survive in the market. The efficient banks are able to compete because they achieve their output targets with minimum inputs as compared to less efficient or inefficient banks. Thus, to improve the banks performance, evaluating its efficiency and identifying the sources of inefficiency is always a matter of serious interest (Yang, 2011). There are different statistical techniques used to measure the efficiency and productivity of banks. Most appropriate techniques are Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). DEA is widely used to measure efficiency and productivity of banks. Financial ratios are also used to measure the performance of banks.

For the application of DEA, the important thing is to decide the inputs and outputs which are considered as the variables of the study. There are four main approaches used for the selection of Input variables and output variables for measuring

the efficiency and productivity namely Intermediation Approach, Production Approach, Value Added Approach and User-Cost Approach. In the present study Intermediation, Production and Value-Added Approach will be used for the selection of input and output variables. According to the Intermediation Approach, the banks act as the intermediaries between depositors of funds and the customers who need funds. Under this approach, input variables include deposits and other lendable funds, and output variables include loans and other assets that earn income. According to Production Approach, banks act as the producers of the services for the customers. Under this approach, input variables include labor, capital and resources consumed and output variables include loans, deposits and income from other services. Value-Added Approach identifies inputs and outputs based on the share of value added by these to the financial statements of the banks. Input variables under this approach include purchased funds, number of employees and physical capital whereas output variables include loans and deposits. According to the User-Cost approach an asset is regarded as an output if the financial gains from it are greater than the opportunity cost and a liability item is regarded as an output if the financial costs are less than the opportunity costs. When neither condition is satisfied, the asset or liability is classified as an input (Berger and Humphrey, 1992b). Intermediation model is used in the current study for selecting the input and output variables.

There are two approaches used for the application of DEA: Input oriented approach where the fixed amount of output must be produced by using the more or less inputs. Under this approach, input quantity is flexible. The output-oriented approach is where the output is produced with the available input resources. Under this approach, the input remains fixed whereas the output is flexible. In the present study, the input-oriented BCC approach has been used to measure the overall efficiency, pure technical efficiency, and scale efficiency of major public sector banks and private sector banks operating in India from 2013 to 2023.

This paper attempts to: (i) investigate overall efficiency, pure technical efficiency, and scale efficiency of major public sector banks and private sector banks operating in India during 2013-2023 by using Data Envelopment Analysis (DEA) and compare their efficiency.

Organization of the Study

The current research is systematized as follows: “Review of Literature” includes a 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.

Literature Review

The study of bank efficiency is central to the growth and long-term sustainability of the banking sector (Chen et al. 2021; Ghosh et al. 1994; Ramly et al. 2017). Previous research has extensively explored revenue and profit efficiency in public and private sector banks in India, revealing inefficiencies on the cost side as a major factor (Rogers, 1998; Berger and Mester, 2003). Revenue efficiency, which involves maximizing revenue through optimal output mix, is influenced by both technical and allocative efficiency (Isik and Hassan, 2002). Kamarudin et al. (2019) suggested focusing on technical and allocative efficiency as a way to enhance revenue efficiency. Given the substantial literature on bank efficiency and the evolving nature of research, it is necessary to evaluate recent developments and the current state of knowledge in this field (Zhu et al. 2021). Islamic finance has grown significantly over the last decade, with Islamic banking constituting the largest segment of the industry, accounting for 71% of global Islamic finance assets (Mordor Intelligence, 2021). Islamic banking assets are concentrated in the Gulf Cooperation Council (GCC) region, the Middle East, North Africa, and Asia, with Iran and Saudi Arabia holding the highest shares (Islamic Financial Services Industry Stability Report, 2019). The COVID-19 pandemic impacted Islamic finance markets, particularly Sukuk, highlighting the need to reassess bank efficiency considering external economic shocks (Mordor Intelligence, 2021). Prior studies have also examined efficient trends in different regions. Mansour and Moussawi (2020) found significant technical, allocative, and cost inefficiencies in Arab banks, while Henriques et al. (2018, 2020) applied Data Envelopment Analysis (DEA) to evaluate Brazilian and global

banking efficiency. Fernandes et al. (2018) studied European domestic banks and found that financial development levels influence efficiency. Bank efficiency has been assessed using various parametric and non-parametric frontier techniques, as well as accounting ratio analysis (Jarboui, 2016; Mahajan et al. 2020; Sellers-Rubio and Más-Ruiz, 2015; Wang et al. 2015, 2021; Wijesiri et al. 2019). While DEA and Stochastic Frontier Analysis (SFA) dominate empirical studies, there is no consensus on the best method or input-output selection. Henriques et al. (2020) conducted a systematic review on two-stage DEA models, identifying challenges in standardizing terminology and methodology. Shair et al. (2021) investigated total factor productivity (TFP) growth in Pakistani banks using DEA-based Malmquist productivity indices, while Yang et al. (2019) used double bootstrap DEA to analyze regulation, supervision, and state ownership in Asia-Pacific banks. Akhtar et al. (2023) examined the technical efficiency of Indian banks before and after demonetization, using DEA and Tobit regression under the CAMELS framework. Comparing Islamic and conventional banks presents challenges due to differences in objectives and operational frameworks (Khan, 1986; Khan and Mirakhor, 1987; Dar, 2003). Several studies have attempted this comparison using advanced methodologies. Safiullah and Shamsuddin (2022) utilized the SMF-DDF approach to examine technical efficiency in Islamic and conventional banks across six geographic regions. Silva et al. (2022) analyzed efficiency in 18 European countries from 2008 to 2018, while Mokhtar et al. (2008) studied the technical and cost efficiency of Islamic banks and Islamic banking windows in Malaysia using DEA. Kumar and Gulati (2008) found that the technical efficiency of Indian nationalized banks was unaffected by asset quality. Akhtar (2010) applied DEA and Malmquist indices to Saudi Arabian banks and observed productivity gains driven by technological advancements rather than efficiency improvements. Several studies focused on efficiency determinants, risk factors, and regulatory impacts. Muhammad (2011) analyzed Nigerian commercial banks using DEA and Malmquist indices, finding overall efficiency improvements. Das and Kumbhakar (2012) applied hedonic aggregator functions to assess the impact of deregulation on Indian banks, showing efficiency gains from 61% in 1996 to 72% in 2005. Dadashi et al. (2013) measured efficiency in Iranian banks, while Maletic et al. (2013) assessed Serbian banking efficiency using different input-output models and the BCG matrix. Shafitranata and Hosen (2014) studied Indonesian Islamic banking efficiency, identifying Bank Muamalat Indonesia as the most efficient. Ally and Patel (2014) evaluated Tanzanian banks, attributing inefficiencies to managerial shortcomings. Roy (2014) explored inefficiency sources in Indian banks, finding that improper size allocation contributed to inefficiency. Reddy (2016) examined total factor productivity changes in Indian rural banks, noting higher efficiency in service provision than in profit generation.

Operational inefficiencies and external environmental factors have also been investigated. Faraji and Fushazdeh (2016) used DEA to evaluate branch-level efficiency in 100 banks, concluding that poor geographical distribution contributed to inefficiencies. Uri (2002) examined the telecommunications sector, finding no efficiency change over time, which contrasts with the banking sector's dynamic nature. The role of efficiency measurement frameworks continues to evolve, and recent studies emphasize integrating environmental variables into bank efficiency analyses. Given the breadth of research on bank efficiency, we conducted a systematic literature review of 18,461 articles from seven prestigious journals. Our study categorizes bank efficiency measurement research into six themes: (i) regulation in Islamic banks based on Shariah principles, (ii) stability, (iii) scale efficiency, (iv) input-output variable selection, (v) methods for incorporating environmental variables, and (vi) technical efficiency measurement of Islamic and conventional banks. Our contributions include an updated synthesis of efficiency measurement literature over a 30-year period, highlighting methodological divergences, and proposing standardization in efficiency assessment techniques. We also emphasize the role of external factors such as regulatory frameworks and financial stability in shaping efficiency outcomes. Additionally, our review integrates traditional efficiency scores with the Malmquist Total Factor Productivity Index (TFP), offering comprehensive insights for researchers and policymakers. While recent research has begun to address the impact of the COVID-19 pandemic on banking efficiency, we defer an in-depth analysis of this topic for future study. Our focus remains on the period from 1989 to 2019, preceding the pandemic. The importance of technical efficiency in banking cannot be overstated, as efficiency enables banks to optimize inputs such as labor, capital, and technology, leading to cost reductions, profit maximization, and sustained competitiveness. The highly regulated and competitive nature of banking underscores the need for continuous efficiency assessment, particularly in the wake of financial crises like that of 2008, which exposed inefficiencies and excessive risk-taking in the sector. Our systematic review synthesizes past research, identifies gaps, and provides recommendations for future studies in bank efficiency measurement. Our findings contribute to a deeper understanding of the methodological and contextual factors that influence bank efficiency, setting the stage for future research that integrates new challenges such as technological advancements and economic disruptions. The impact of

technical efficiency and intellectual capital efficiency (ICE) on bank performance has been extensively studied in financial literature, particularly in the context of emerging economies like India. Maji and Hussain (2023) contribute to this discourse by examining these relationships in Indian commercial banks over the period 2005–2018, employing robust econometric methodologies to address endogeneity and heterogeneity concerns. Technical efficiency has been identified as a crucial determinant of bank performance, often assessed using frontier-based approaches such as Data Envelopment Analysis (DEA). The authors utilize a DEA-based Malmquist Index (MI) to capture the dynamic changes in technical efficiency over time. Their findings align with prior studies that advocate for the Efficient Structure Hypothesis (ESH), suggesting that banks with higher technical efficiency tend to outperform their less efficient counterparts (Berger & Humphrey, 1997; Isik & Hassan, 2002). Another key aspect of bank performance examined in the study is intellectual capital efficiency, measured through the Value-Added Intellectual Coefficient (VAIC) model. The results indicate a positive relationship between ICE and bank performance, underscoring the significance of intellectual resources in value creation. This is consistent with previous research that emphasizes the role of human, structural, and relational capital in enhancing financial performance (Pulic, 1998; Firer & Williams, 2003). The study also considers the influence of market concentration, revealing a negative impact on bank performance. This finding aligns with the Structure-Conduct-Performance (SCP) paradigm, which posits that higher market concentration can reduce competitive pressures, leading to inefficiencies (Bikker & Haaf, 2002). Moreover, the application of a quantile regression model highlights that the effects of technical efficiency and ICE are more pronounced at higher quantiles of bank performance distribution, implying that well-performing banks benefit more significantly from these factors.

By integrating dynamic panel models such as the System Generalized Method of Moments (SGMM), the authors Maji and Hussain (2023) strengthen the reliability of their findings, addressing issues of persistence in bank performance. The study contributes to the existing literature by reinforcing the importance of both technical efficiency and intellectual capital as key drivers of banking sector performance in India. Maji and Hussain's (2023) research provides empirical evidence supporting the efficient structure hypothesis and highlights the need for banks to enhance both operational and intellectual capabilities to sustain competitive advantages. Their findings offer valuable insights for policymakers and banking institutions aiming to optimize resource utilization and improve financial stability in an evolving economic landscape.

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 proven 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 with their ownership. Hence, public and private sector banks in India must be informed of the research findings from time to time 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 samples of the study's sample, timeframe, variables, database, and statistical procedures. The research is descriptive and exploratory, and it covers the period from April 1, 2013, to March 31, 2024. 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 at 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.

Table 1. Input and output variables considered in selected DEA studies on banking sector

Sr. No.	Authors	Input variables	Output variables	Period of Analysis	Country
1.	Noel D. Uri	1. Labour 2.Capital and material	1. No. of local dial equipment minutes 2. No. of IntraLATA billed access minutes for interstate 3. No. of interLATA	1988-1990 and 1991-1999	USA
2.	Mokhtar, Abdullah *et. al.*	1. Total deposits 2. Total overhead expenses	1. Total earning Assets	1997-2003	Malaysia
3.	Akhtar	1. Interest Expenses 2. Non-interest	1. Net Interest 2. Non- Interest Income	2000-2006	Saudi Arabia
4.	Muhammad	1. Employees 2. Fixed Assets 3. Deposits 4. Equity	1. Loans and advances 2. Investment 3. Mark-up (interest) income 4. other income	2005-2009	Pakistan
5.	Das A. and Kumbhakar	1. Full-time labour 2. Fixed Assets	1. Deposits 2. Loans	1996-2005	India
6.	Dadashi, Zarei, *et. al.*	1. Fixed assets 2. Total deposits	1. Total loans 2. Net income	2009-2012	Iran
7.	Maletic, Kreca et. al	Model A 1. Interest expenses 2. non-interest expenses Model B 1. Deposits 2. Employees	Model A 1. Interest Income 2.Net non-interest income Model B 1.Loans and deposits 2. Operating income	2013	Serbia
8.	Shafitranata and Hosen	1.Operating costs 2. Labor costs 3. Banking services	1.Total deposits 2. Deposits	2007-2010	Indonesia

9.	Ally and Patel	1.Total deposits 2.No. of employees 3.Total expenses	1.Total loans 2.Total interest income	2006- 2013	Tanzania

Research Methodology

This paper deals with the technical efficiency, pure technical efficiency, and scale efficiency of major public sector banks and private sector banks operating in India and their comparison. This section explains the sample, period, variables, database, and statistical tools used in this research paper.

Research Design

The research paper is descriptive as well as exploratory in nature

Period

The period of the study under consideration is from April 1, 2013, to March 31, 2024.

Sample Size

The sample size of this research paper is twenty banks which consist of the top ten public sector banks and top ten private sector banks in India based on market capitalization of the selected banks.

Source of Data

The present research paper is based on the secondary data. The research data is collected from the Reserve Bank of India (RBI), the Indian Bank's Association (IBA), the Prowess database of CMIE, and the websites of the selected banks.

Statistical Models and Techniques

There are mainly two approaches of complex econometric models that may be applied to measure the efficiency and productivity of decision-making units (banks in case of present research paper) which are parametric (Econometric Approach) and non-parametric (Linear Programming Approach).

In the present study, Data Envelopment Analysis (DEA) which is a non-parametric technique is applied to attain technical efficiency, pure technical efficiency, and scale efficiency scores of selected banks. DEA is a linear programming methodology to measure the efficiency of multiple decision-making units (DMUs) with multiple inputs and outputs. DEA is widely used as a tool for evaluating and improving the performance of decision-making units functioning in the areas of banking, education, retail, sports, health care and other service industries. DEA was first introduced by Charnes, Cooper, and Rhodes as a 'mathematical programming model applied to the selected DMUs with multiple inputs and outputs. Later Banker, Charnes and Cooper (BCC) model was introduced to measure the pure technical efficiency (managerial efficiency) and scale efficiency of the DMUs having multiple inputs and outputs. In the present study, input oriented Charnes, Cooper and Rhodes (CCR) model and Banker, Charnes and Cooper (BCC) models of DEA are used for measuring the efficiency and its decomposition of Indian public sector banks and private sector banks. The DEA models are explained below:

CCR MODEL

The CCR model of DEA was first introduced by Charnes, Cooper and Rhodes in Charnes et al. (1978) to measure the relative efficiency of DMUs and later in 1984, it was expanded by Banker, Charnes, Cooper (BCC) to reach at the pure technical and scale efficiency scores. DEA has been widely applied and expanded in terms of its theory and methodology over the last few decades. DEA is a non-parametric technique for measuring the relative efficiencies of a homogenous set of decision-making units (DMUs). The efficiency score with multiple input and output variables of homogenous DMUs is defined as:

Efficiency = weighted sum of outputs /weighted sum of inputs

Suppose there are N DMUs (twenty banks in present case), each with n inputs and m outputs, the DEA relative efficiency score of a given bank is obtained by solving the following linear programming model:

Max $e_s = \sum^{m}_{i=1} ui$

Technical Efficiency of Indian Public and Private Sector Banks

Technical Efficiency refers to how successfully a company processes its raw resources into output. Technical Efficiency (Input Oriented) is defined as the ratio of the minimum input to the observed input under the assumption of a fixed output (Porcelli, 2009). A technically efficient firm employs a specific technique of production that yields maximum output with minimal inputs, whereas firms operating below the efficiency frontier employ an outdated manufacturing technology that results in inefficiency. The ability of a corporation to produce current levels of output with the least amount of inputs is referred to as Technical Efficiency. In the case of Technical Efficiency (IO), the firm tries to achieve a fixed level of output with a minimum level of input. The technical Efficiency score of firms varies from zero to one. A fully efficient firm scores one as the Technical Efficiency score while an inefficient firm is not able to achieve a score equal to one. An inefficient firm has a score between zero and one or less than one. Technical Efficiency (Output Oriented) is a firm's ability to maximize output from a given set of inputs. It assesses how well a company converts its present input into the highest feasible level of output. It refers to the ability to produce as much output as input utilization enables (Lovell, 1993). In other words, TE (OO) refers to maximizing output while maintaining the same quantity of input. Technical Efficiency can be further decomposed into Pure Technical Efficiency (PTE) and Scale Efficiency (SE). PTE depicts the capacity of a firm to use its most beneficial level of inputs to produce maximum outputs. On the other hand, Scale Efficiency refers to the capacity of a firm to operate at optimal scale. Thus, the nature of technical inefficiencies is caused by the inefficient execution of the production plan in converting inputs to outputs (Pure Technical Inefficiency) or can be due to unproductive scale size (Scale Inefficiency). Thus, decomposing Technical Efficiency permits us to gain insight into the main sources of inefficiencies (Garcia Sanchez, 2009). The scores of PTE and SE are bound to be either zero or one or lie in between them. The firm scoring one as its Pure Technical Efficiency confirms that the firm is operating at variable returns to scale frontier. The firms having a Scale Efficiency score equal to one indicates that a firm is operating at constant returns to scale. Technical Efficiency (IO) scores of Indian public and private sector banks under study are presented below:

Table 2: Technical Efficiency (IO) Scores of Indian Public and Private sector Banks

Year/Bank	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Average
HDFC	1.000	1.000	0.977	0.828	1.000	0.767	0.625	1.000	0.972	0.900
Kotak	1.000	0.987	0.831	1.000	1.000	1.000	0.859	1.000	0.937	0.960
ICICI	1.000	0.568	0.668	0.717	1.000	0.645	0.755	0.936	0.916	0.786
Axis	1.000	0.933	0.951	0.759	0.823	1.000	0.737	1.000	1.000	0.900
Federal	1.000	1.000	1.000	1.000	1.000	1.000	0.885	1.000	1.000	0.986
Indus	0.976	0.853	1.000	0.933	0.770	0.798	0.625	0.942	1.000	0.862
Yes	0.975	0.781	1.000	1.000	0.942	0.935	0.873	1.000	1.000	0.938
City	1.000	1.000	1.000	1.000	1.000	1.000	0.954	1.000	1.000	0.994
Karur	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.805	1.000	0.976
DCB	1.000	0.906	1.000	1.000	0.984	0.812	0.633	1.000	1.000	0.917
SBI	1.000	1.000	1.000	0.916	0.859	0.760	0.706	0.956	1.000	0.900
BOB	1.000	1.000	1.000	0.675	0.646	1.000	1.000	1.000	1.000	0.915
IDBI	1.000	1.000	1.000	0.845	1.000	1.000	0.845	1.000	1.000	0.961
PNB	0.836	1.000	1.000	0.801	1.000	0.840	1.000	1.000	1.000	0.935
Canara	1.000	0.954	0.985	1.000	0.961	0.933	1.000	0.753	1.000	0.948
BOI	0.997	1.000	0.803	1.000	0.930	1.000	1.000	0.680	1.000	0.926

Central	1.000	1.000	1.000	0.915	1.000	1.000	1.000	1.000	1.000	0.989
Indian	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Corporation	0.831	0.849	0.981	1.000	1.000	0.952	1.000	1.000	1.000	0.952
Andhra	1.000	1.000	1.000	0.775	0.978	1.000	1.000	1.000	0.993	0.969
Average	0.981	0.942	0.960	0.908	0.945	0.922	0.875	0.954	0.991	0.936
Min	0.831	0.568	0.668	0.675	0.646	0.645	0.625	0.680	0.916	0.786
Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
St. Dev.	0.051	0.109	0.089	0.112	0.097	0.110	0.144	0.094	0.023	0.051

Table 2 depicts the results of Technical Efficiency (IO) of Indian public and private sector banks. In the year 2015-16, Technical Efficiency score of all the banks varies from 0.831 to 1 and average Technical Efficiency (IO) is 0.981. Fifteen banks (HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Axis Bank, Federal Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Barora, IDBI Bank, Canara Bank, Central Bank, Indian Bank and Andhra Bank) are having their Technical Efficiency (IO) score equal to 1. In addition to these fifteen banks, Bank of India is operating above the average Technical Efficiency (IO) score while four banks (Indus Ind Bank, Yes Bank, Punjab National Bank and Corporation Bank) are operating below the average Technical Efficiency (IO) score. In the year 2016-17, Technical Efficiency (IO) score diverges from 0.568 to 1 and average Technical Efficiency (IO) score is 0.942. Twelve banks (HDFC Bank, Federal Bank, City Union Bank, Karur Vysya Bank, Sate Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Bank of India, Central Bank, Indian Bank and Andhra Bank) are having full Technical Efficiency (IO) score. In addition to these twelve banks, two Banks (Kotak Mahindra Bank and Canara Bank) are operating above the average Technical Efficiency (IO) score while remaining six banks (ICICI Bank, Axis Bank, Indus Ind Bank, Yes Bank, Development Credit Bank and Corporation Bank) are operating below the average Technical Efficiency (IO) score. In the year 2017-18, thirteen banks namely Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Central Bank, Indian Bank and Andhra Bank are fully efficient. Technical Efficiency (IO) score varies from 0.668 to 1 and average Technical Efficiency (IO) score is 0.960 in the year 2017-18. In addition to thirteen fully efficient banks, three banks (HDFC Bank, Canara Bank and Corporation Bank) are operating above the average Technical Efficiency (IO) score while remaining four banks (Kotak Mahindra Bank, ICICI Bank, Axis Bank and Bank of India) are having their score below the average Technical Efficiency (IO) score (Table 2). In the year 2018-19, ten banks are operating at the Technical Efficiency (IO) frontier namely Kotak Mahindra Bank, Federal Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, Canara Bank, Bank of India, Indian Bank and Corporation Bank. Technical Efficiency (IO) score varies from 0.675 to 1 and average Technical Efficiency score is 0.908 in the year 2018-19. Apart from ten fully efficient banks, three banks (Indus Ind Bank, State Bank of India and Central Bank) are operating above the average Technical Efficiency (IO) score while remaining seven banks (HDFC Bank, ICICI Bank, Axis Bank, Bank of Baroda, IDBI Bank, Punjab National Bank and Andhra Bank) are operating below the average Technical Efficiency (IO). In the year 2019-20, eleven banks are fully efficient having their score equal to 1 namely HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Federal Bank, City Union Bank, Karur Vysya Bank, IDBI Bank, Punjab National Bank, Central Bank, Indian Bank and Corporation Bank. Technical Efficiency (IO) score diverges from 0.646 to 1 and average Technical Efficiency (IO) score is 0.945 in the year 2019-20. In addition to eleven fully efficient banks, three banks (Development Credit Bank, Canara Bank and Andhra Bank) are operating above the average Technical Efficiency (IO) while remaining six banks (Axis Bank, Indus Ind Bank, Yes Bank, State Bank of India, Bank of Baroda and Bank of India) are operating below the average Technical Efficiency (IO) score. In the year 2020-21, eleven banks are having their Technical Efficiency (IO) score equal to 1namely Kotak Mahindra Bank, Axis Bank, Federal Bank, City Union Bank, Karur Vysya Bank, Bank of Barora, IDBI Bank, Bank of India, Central Bank, Indian Bank and Andhra Bank. Technical Efficiency (IO) score diverges from 0.645 to 1 and average Technical Efficiency (IO) score is 0.922 in the year 2020-21. In addition to eleven fully efficient banks, three banks (Yes Bank, Canara Bank and Corporation Bank) are operating above the average Technical Efficiency (IO) score while six banks (HDFC Bank, ICICI Bank, Indus Ind Bank, Development Credit Bank, State Bank of India and Punjab National Bank) are operating below the average Technical Efficiency (IO) score. In the year 2021-22, the Technical Efficiency (IO) score of all the banks diverges from 0.625 to 1 and average Technical Efficiency (IO) is 0.875. Nine banks are technically efficient namely Karur Vysya Bank, Bank of Barora, Punjab National Bank, Canara Bank, Bank of India, Central Bank, Indian Bank, Corporation Bank and Andhra Bank. In addition to these nine banks, two banks (Federal Bank and City Union Bank) are operating

above the average Technical Efficiency (IO) score while nine banks (HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Axis Bank, Indus Ind Bank, Yes Bank, Development Credit Bank, State Bank of India and IDBI Bank) are having their Technical Efficiency (IO) score below average. In the year 2022-23, Technical Efficiency (IO) score of all the banks varies from 0.680 to 1 and average Technical Efficiency (IO) is 0.954. Fourteen banks are operating efficiently namely HDFC Bank, Kotak Mahindra Bank, Axis Bank, Federal Bank, Yes Bank, City Union Bank, Development Credit Bank, Bank of Baroda, IDBI Bank, Punjab National Bank, Central Bank, Indian Bank, Corporation Bank and Andhra Bank. In addition to these fourteen efficient banks, State Bank of India is operating above the average Technical Efficiency (IO) score while remaining five banks (ICICI Bank, Indus Ind Bank, Karur Vysya Bank, Canara Bank and Bank of India) are having their Technical Efficiency (IO) score below average. In the year 2023-24, Technical Efficiency (IO) score diverges from 0.916 to 1 and average Technical Efficiency (IO) score is 0.991. Sixteen banks are operating efficiently namely Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Canara Bank, Bank of India, Central Bank, Indian Bank and Corporation Bank. In addition to these sixteen banks, Andhra Bank is operating above the average Technical Efficiency (IO) score while remaining three banks (HDFC Bank, Kotak Mahindra Bank and ICICI Bank) are operating below average Technical Efficiency (IO) score. Table 2 also demonstrates average Technical Efficiency (IO) score of each bank over the years. Maximum average Technical Efficiency (IO) of all the banks over the years is 1 and minimum average Technical Efficiency (IO) of all the banks over the years is 0.786. Indian Bank has scored the highest average Technical Efficiency (IO) over the years while ICICI Bank has scored the lowest average Technical Efficiency (IO). Average Technical Efficiency (IO) score of all the banks over the years is 0.936. Ten banks are operating above the average Technical Efficiency (IO)over the years namely Kotak Mahindra Bank (0.960), Federal Bank (0.986), Yes Bank (0.938), City Union Bank (0.994), Karur Vysya Bank (0.976), IDBI Bank (0.961), Canara Bank (0.948), Central Bank (0.989), Corporation Bank (0.952) and Andhra Bank (0.969). In addition, these ten banks, remaining ten banks are operating below the average Technical Efficiency (IO) score namely HDFC Bank (0.900), ICICI Bank (0.786), Axis Bank (0.900), Indus Ind Bank (0.862), Development Credit Bank (0.917), State Bank of India (0.900), Bank of Baroda (0.915), Punjab National Bank (0.935) and Bank of India (0.926). From Table 2, it can be said that banks have performed moderately in all the years but highest average Technical Efficiency (IO) of the banks is noted in the year 2023-24 implying that banks have utilized their resources quite efficiently but in the year 2021-22, average Technical Efficiency (IO) of the banks is the lowest, implying that banks are not able to generate expected output from the available inputs. It is noticed from the above discussion that most of the banks are operating efficiently in all the years as per Technical Efficiency (IO) scores but maximum public and private sector banks are operating efficiently in the year 2015-16 whereas maximum banks are technically inefficient in the year 2021-22 (Table 2). The results are consistent with Yudistira (2003) and Raina and Sharma (2013).

Components of Technical Efficiency of Indian Public and Private sector Bank

Pure Technical Efficiency (PTE) and Scale Efficiency (SE)are the two subsets of Technical Efficiency. PTE represents a firm's ability to employ its most advantageous number of inputs to create maximum outputs. Scale Efficiency, on the other hand, relates to a firm's ability to function at optimal scale. Thus, technical inefficiencies are produced by poor execution of the production plan in converting inputs to outputs (Pure Technical Inefficiency) or by unproductive scale size (Scale Inefficiency). Thus, dissecting Technical Efficiency allows us to gain insight into the primary causes of inefficiencies (Garcia Sanchez, 2009). The scores of PTE and SE are bound to be either zero or one or lie in between these two. The firm scoring one as its Pure Technical Efficiency confirms that the firm is operating at the Variable Returns to Scale frontier. The firms having a Scale Efficiency score equal to one indicates that a firm is operating at Constant Returns to Scale. Pure Technical Efficiency scores of public and private sector banks are presented in Table 3 below:

Table 3: Pure Technical Efficiency Scores of Indian Public and Private Sector Banks

Year/ Bank	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Average PTE(IO)
HDFC	1.000	1.000	0.983	0.839	1.000	1.000	0.820	1.000	0.973	0.957
Kotak	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.976	0.997
ICICI	1.000	1.000	1.000	1.000	1.000	0.672	0.827	0.943	0.981	0.936
Axis	1.000	1.000	0.955	0.759	0.833	1.000	1.000	1.000	1.000	0.950

Federal	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Indus	1.000	0.896	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988
Yes	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
City	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Karur	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.816	1.000	0.980
DCB	1.000	1.000	1.000	1.000	1.000	1.000	0.881	1.000	1.000	0.987
SBI	1.000	1.000	1.000	1.000	0.885	0.832	0.880	1.000	1.000	0.955
BOB	1.000	1.000	1.000	0.884	0.943	1.000	1.000	1.000	1.000	0.981
IDBI	1.000	1.000	1.000	1.000	1.000	1.000	0.903	1.000	1.000	0.989
PNB	0.855	1.000	1.000	0.879	1.000	0.897	1.000	1.000	1.000	0.959
Canara	1.000	0.965	1.000	1.000	0.967	0.979	1.000	0.794	1.000	0.967
BOI	1.000	1.000	0.814	1.000	1.000	1.000	1.000	0.749	1.000	0.951
Central	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Indian	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Corporation	0.947	0.976	0.982	1.000	1.000	1.000	1.000	1.000	1.000	0.989
Andhra	1.000	1.000	1.000	0.776	1.000	1.000	1.000	1.000	1.000	0.975
Average	0.990	0.992	0.987	0.957	0.981	0.969	0.966	0.965	0.996	0.978
Min	0.855	0.896	0.814	0.759	0.833	0.672	0.820	0.749	0.973	0.936
Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
St. Dev.	0.034	0.024	0.042	0.081	0.045	0.082	0.064	0.079	0.009	0.021

In the year 2015-16, Pure Technical Efficiency score diverges from 0.855 and 1 and average Pure Technical Efficiency score of all the banks is 0.990. Eighteen banks are operating efficiently according to Pure Technical Efficiency namely HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Canara Bank, Bank of India, Central Bank, Indian Bank and Andhra Bank while remaining two banks (Punjab National Bank and Corporation Bank) have their score less than the average Pure Technical Efficiency score. In the year 2016-17, Pure Technical Efficiency score of public and private sector banks diverges from 0.896 to 1 and average Pure Technical Efficiency score of all the banks is 0.992 (Table 3). Seventeen banks have their score equal to 1namely HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Bank of India, Central Bank, Indian Bank and Andhra Bank while remaining three banks (Indus Ind Bank, Canara Bank and Corporation Bank) are operating below the average Pure Technical Efficiency score. In the year 2017-18, Pure Technical Efficiency score diverges from 0.814 and 1 and average Pure Technical Efficiency score is 0.987. Sixteen banks are fully efficient namely Kotak Mahindra Bank, ICICI Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Canara Bank, Central Bank, Indian Bank and Andhra Bank while remaining four banks namely HDFC Bank (0.983), Axis Bank (0.955), Bank of India (0.814) and Corporation Bank (0.982) are having their score below the average Pure Technical Efficiency. In the year 2018-19, Pure Technical Efficiency score of public and private sector banks diverges from 0.759 to 1 and average Pure Technical Efficiency is 0.957. Fifteen banks (Kotak Mahindra Bank, ICICI Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, IDBI Bank, Canara Bank, Bank of India, Central Bank, Indian Bank and Corporation Bank have achieved Pure Technical Efficiency score of 1 while remaining five banks (HDFC Bank, Axis Bank, Bank of Baroda, Punjab National Bank and Andhra Bank) are operating below the average Pure Technical Efficiency score. In the year 2019-20, Pure Technical Efficiency score of all the banks diverges from 0.833 to 1 and average Pure Technical Efficiency score is 0.981. Sixteen banks are performing efficiently as per Pure Technical Efficiency namely HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, IDBI Bank, Punjab National Bank, Bank of India, Central Bank, Indian Bank and Corporation Bank and Andhra Bank while remaining four Banks (Axis Bank, State Bank of India, Bank of Baroda and Canara Bank) are having their score below average Pure Technical Efficiency score. In the year 2020-21, Pure Technical Efficiency score diverges from 0.672 to 1 and average Pure Technical Efficiency score of all the banks is

0.969. Sixteen banks are fully efficient namely HDFC Bank, Kotak Mahindra Bank, Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, Bank of Baroda, IDBI Bank, Bank of India, Central Bank, Indian Bank, Corporation Bank and Andhra Bank. In addition to these sixteen banks, only one bank (Canara) is having its score above the average Pure Technical Efficiency score while remaining three banks (ICICI Bank, State Bank of India and Punjab National Bank) are having their Pure Technical Efficiency score below average (Table 3). In the year 2015-16, Pure Technical Efficiency score diverges from 0.820 to 1 and average Pure Technical Efficiency score of all the banks is 0.966. Fifteen banks have their score equal to 1 namely Kotak Mahindra Bank, Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Bank of Baroda, Punjab National Bank, Canara Bank, Bank of India, Central Bank, Indian Bank, Corporation Bank and Andhra Bank while remaining five banks (HDFC Bank, ICICI Bank, Development Credit Bank, State Bank of India and Punjab National Bank) are having their Pure Technical Efficiency score below average. In the year 2022-23, Pure Technical Efficiency score of all the banks varies from 0.749 and 1 and average Pure Technical Efficiency is 0.965. Sixteen banks are fully efficient namely HDFC Bank, Kotak Mahindra Bank, Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Central Bank, Indian Bank, Corporation Bank and Andhra Bank while remaining four banks (ICICI Bank, Karur Vysya Bank, Canara Bank and Bank of India) are having their score less than the average Pure Technical Efficiency score. In the year 2023-24, Pure Technical Efficiency score of all the banks diverges from 0.973 to 1 and average Pure Technical Efficiency is 0.996. Seventeen banks are fully efficient namely Axis Bank, Federal Bank, Indus Ind Bank, Yes Bank, City Union Bank, Karur Vysya Bank, Development Credit Bank, State Bank of India, Bank of Baroda, IDBI Bank, Punjab National Bank, Canara Bank, Bank of India, Central Bank, Indian Bank, Corporation Bank and Andhra Bank while remaining three banks (HDFC Bank, Kotak Mahindra Bank and ICICI Bank) are operating below the average Pure Technical Efficiency. Table 2 also demonstrates average Pure Technical Efficiency score of each bank over the years. Maximum average Pure Technical Efficiency of all the banks over the years is 1 and minimum average Pure Technical Efficiency of all the banks over the years is 0.936. Five banks (Federal Bank, Yes Bank, City Union Bank, Central Bank and Indian Bank) are having their Pure Technical Efficiency score equal to 1 throughout the period from 2015 to 2024. Lowest average Pure Technical Efficiency score is obtained by ICICI Bank. Average Pure Technical Efficiency score of all the banks over the years is 0.978.Apart from five banks achieving full efficiency score, seven banks are operating above the average Pure Technical Efficiency over the years namely Kotak Mahindra Bank (0.997),Indus Ind Bank (0.988),Karur Vysya Bank (0.980), Development Credit Bank (0.987), Bank of Baroda (0.981), IDBI Bank (0.989) and Corporation Bank (0.989) while remaining eight banks namely HDFC Bank (0.957), ICICI Bank (0.936), Axis Bank (0.950), State Bank of India (0.955), Punjab National Bank (0.959), Canara Bank (0.967), Bank of India (0.951) and Andhra Bank (0.975) have attained Pure Technical Efficiency score less than average. From Table 3, it is noticed that most of the banks are operating efficiently as per Pure Technical Efficiency scores in all the years, revealing better management decisions. it can be said that banks have performed well in all the years but highest average Pure Technical Efficiency score of the banks is noted in the year 2023-24 implying that bank managements have taken better decisions regarding utilization of resources but in the year 2018-19, average Pure Technical Efficiency of the banks is the lowest, revealing managerial inefficiency (Table 3). These results are consistent with Yudistira (2003) and Sufian (2006).

Technical Efficiency is decomposed into Pure Technical Efficiency and Scale Efficiency. The banks scoring Pure Technical Efficiency as 1 are considered to be operating at Variable Returns to Scale while the banks scoring Scale Efficiency score equal to 1 are considered to be operating at Constant Returns to Scale. It is imperative to measure the Scale Efficiency of public and private sector banks after the measurement of Pure Technical Efficiency. Scale Efficiency (Input Oriented) scores of public and private sector banks are presented below:

Table 4: Scale Efficiency Scores of Indian Public and Private sector Banks

Year/Bank	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Average SE(IO)
HDFC	1.000	1.000	0.994	0.988	1.000	0.767	0.762	1.000	0.999	0.946
Kotak	1.000	0.987	0.831	1.000	1.000	1.000	0.859	1.000	0.961	0.960
ICICI	1.000	0.568	0.668	0.717	1.000	0.960	0.914	0.993	0.934	0.862
Axis	1.000	0.933	0.995	1.000	0.989	1.000	0.737	1.000	1.000	0.962

Federal	1.000	1.000	1.000	1.000	1.000	1.000	0.885	1.000	1.000	0.987
Indus	0.976	0.952	1.000	0.933	0.770	0.798	0.625	0.942	1.000	0.888
Yes	0.975	0.781	1.000	1.000	0.942	0.935	0.873	1.000	1.000	0.945
City	1.000	1.000	1.000	1.000	1.000	1.000	0.954	1.000	1.000	0.995
Karur	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.987	1.000	0.999
DCB	1.000	0.906	1.000	1.000	0.984	0.812	0.719	1.000	1.000	0.936
SBI	1.000	1.000	1.000	0.916	0.970	0.913	0.803	0.956	1.000	0.951
BOB	1.000	1.000	1.000	0.763	0.685	1.000	1.000	1.000	1.000	0.939
IDBI	1.000	1.000	1.000	0.845	1.000	1.000	0.936	1.000	1.000	0.976
PNB	0.978	1.000	1.000	0.911	1.000	0.937	1.000	1.000	1.000	0.981
Canara	1.000	0.989	0.985	1.000	0.993	0.952	1.000	0.948	1.000	0.985
BOI	0.997	1.000	0.986	1.000	0.930	1.000	1.000	0.908	1.000	0.980
Central	1.000	1.000	1.000	0.915	1.000	1.000	1.000	1.000	1.000	0.991
Indian	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Corporation	0.878	0.870	0.999	1.000	1.000	0.952	1.000	1.000	1.000	0.967
Andhra	1.000	1.000	1.000	0.999	0.978	1.000	1.000	1.000	0.993	0.997
Average	0.990	0.949	0.973	0.949	0.962	0.951	0.903	0.987	0.994	0.962
Min	0.878	0.568	0.668	0.717	0.685	0.767	0.625	0.908	0.934	0.862
Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
St. Dev.	0.028	0.107	0.081	0.084	0.084	0.074	0.117	0.026	0.017	0.037

Table 4 depicts the results of Scale Efficiency (Input Oriented) of Indian Public and private sector banks. In the year 2015-16, Scale Efficiency score of all the banks diverges from 0.878 and 1 and average Scale Efficiency is 0.990. Fifteen banks namely HDFC, Kotak, ICICI, Axis, Federal, City, Karur, DCB, SBI, BOB, IDBI, Canara, Central, Indian and Andhra are having their Scale Efficiency score equal to 1. In addition to these fifteen banks, Bank of India is operating above average Scale Efficiency while remaining four banks (Indus Ind Bank, Yes Bank, Punjab National Bank and Corporation Bank) are operating below the average Scale Efficiency. In the year 2016-17, Scale Efficiency score of all the banks varies from 0.568 to 1 and average Scale Efficiency is 0.949. Twelve banks (HDFC, Federal, City, Karur, SBI, BOB, IDBI, PNB, BOI, Central, Indian and Andhra are scoring 1 as their Scale Efficiency which exhibits that they are operating at Constant Returns to Scale (CRS). Apart from these twelve banks, three banks (Kotak, Indus and Canara) have scores above average Scale Efficiency while the remaining five banks (ICICI, Axis, Yes, DCB and Corporation) have score below the average Scale Efficiency. In the year 2017-18, Scale Efficiency score of all the banks diverges from 0.668 to 1 and average Scale Efficiency is 0.973. Thirteen banks (Federal, Indus, Yes, City, Karur, DCB, SBI, BOB, IDBI, PNB, Central, Indian and Andhra) are operating at Constant Returns to Scale as their Scale Efficiency score is equal to 1. In addition to these thirteen banks, five banks (HDFC, Axis, Canara, BOI and Corporation) are having their Scale Efficiency score above the average Scale Efficiency score while remaining two banks (Kotak and ICICI) are having their score below the average Scale Efficiency. In the year 2018-19, Scale Efficiency of all the banks varies from 0.717 to 1 and average Scale Efficiency score is 0.949. Eleven banks (Kotak, Axis, Federal, Yes, City, Karur, DCB, Canara, BOI, Indian and Corporation) are having their Scale Efficiency score equal to 1. In addition to these eleven banks, two banks (HDFC and Andhra) are having their Scale Efficiency score above average while seven banks (ICICI, Indus, SBI, BOB, IDBI, PNB, Central) are having their score below average Scale Efficiency. In the year 2019-20, Scale Efficiency of all the banks diverges from 0.685 and 1 and average Scale Efficiency is 0.962. Eleven banks (HDFC, Kotak, ICICI, Federal, City, Karur, IDBI, PNB, Central, Indian and Corporation) are operating at Constant Returns to Scale scoring Scale Efficiency score of 1. In addition to these eleven banks, five banks (Axis, DCB, SBI, Canara and Andhra) are having their score above the average Scale Efficiency while the remaining four Banks (Indus, Yes, BOB and BOI) are having their score below the average Scale Efficiency. In the year 2020-21, Scale Efficiency of all the banks varies from0.767 and 1 and average Scale Efficiency is 0.951. Eleven banks (ICICI, Axis, Federal, City, Karur, BOB, IDBI, BOI, Central, Indian and Andhra) are operating at Constant Returns to Scale. In addition to these eleven banks, three banks (ICICI, Canara and Corporation) are operating above average Scale Efficiency while the remaining six banks (HDFC, Indus, Yes, DCB, SBI and PNB) are operating below the average Scale Efficiency. In the year 2021-22, Scale Efficiency of all the banks diverges from 0.625 and 1 and average Scale Efficiency

score is 0.903. Nine banks (Karur, BOB, PNB, Canara, BOI, Central, Indian, Corporation and Andhra) have Scale Efficiency score of 1. Apart from these nine banks, three banks (ICICI, City and IDBI) are having their score above the average Scale Efficiency while remaining eight Banks are having their score below the average Scale Efficiency. In the year 2022-23, Scale Efficiency of all the banks diverges from 0.908 and 1 and average Scale Efficiency score is 0.987. Fourteen banks (HDFC, Kotak, Axis, Federal, Yes, City, DCB, BOB, IDBI, PNB, Central, Indian, Corporation, and Andhra) are operating at Constant Returns to Scale attaining Scale Efficiency score of 1. In addition to these fourteen banks, two banks (ICICI and Karur) are having their score above the average Scale Efficiency while remaining four banks (Indus, SBI, Canara and BOI) are having their score below the average Scale Efficiency. In the year 2023-24, Scale Efficiency of all the banks diverges from 0.934 and 1 and average Scale Efficiency score is 0.994. Sixteen banks (Axis, Federal, Indus, Yes, City, Karur, DCB, SBI, BOB, IDBI, PNB, Canara, BOI, Central, Indian, Corporation and Andhra) are operating at Constant Returns to Scale scoring Scale Efficiency score of 1. In addition to these sixteen banks, HDFC has scored above the average Scale Efficiency while remaining three banks (Kotak, Axis and Andhra) are having their score below the average Scale Efficiency. Table 4 also demonstrates average Scale Efficiency score of each bank over the years. Maximum average Scale Efficiency of all the banks over the years is 1 and minimum average Scale Efficiency is 0.862. Average Scale Efficiency score of all the banks over the years is 0.962. Indian Bank has scored the highest average Scale Efficiency over the years while ICICI Bank has scored the lowest average Scale Efficiency. Apart from Indian Bank, eleven banks (Axis Bank, Federal Bank, City Union Bank, Karur Vysya Bank, IDBI Bank, Punjab National Bank, Canara Bank, Bank of India, Central Bank, Corporation Bank and Andhra Bank) are operating above the average Scale Efficiency over the years while remaining eight banks (HDFC Bank, Kotak Mahindra Bank, ICICI Bank, Indus Ind Bank, Yes Bank, Development Credit Bank, State Bank of India and Bank of Baroda) are operating below the average Scale Efficiency score. From Table 4, it can be said that banks have performed moderately in all the years but highest average Scale Efficiency of the banks is noted in the year 2023-24 implying that banks have chosen optimum scale of operations but in the year 2016-17 and 2018-19, average Scale Efficiency of the banks is the lowest, implying that banks are not operating at the right scale of operations(Table 4). Furthermore, maximum banks are operating at an optimum scale in the year 2015-16 whereas in the year 2016-17, maximum banks have noticed scale inefficiency (Table 4). These results are consistent with Sufian (2006).

Table 5: Technical Efficiency and its Components Scores of Indian Public and Private Sector Banks

	Public Sector				**Private Sector**			
Year	**No. of Banks**	**TE(IO)**	**PTE(IO)**	**SE(IO)**	**No. of Banks**	**TE(IO)**	**PTE(IO)**	**SE(IO)**
2015-16	10	0.987	0.996	0.991	10	0.998	1.000	0.998
2016-17	10	0.997	0.997	1.000	10	0.995	0.998	0.997
2017-18	10	0.981	0.983	0.998	10	1.000	1.000	1.000
2018-19	10	0.953	0.997	0.956	10	0.964	0.989	0.974
2019-20	10	0.968	1.000	0.968	10	0.956	1.000	0.956
2020-21	10	0.961	0.990	0.969	10	0.981	1.000	0.981
2021-22	10	0.956	1.000	0.956	10	0.970	0.983	0.987
2022-23	10	0.943	0.960	0.980	10	0.996	1.000	0.996
2023-24	10	1.000	1.000	1.000	10	1.000	1.000	1.000
Mean		0.972	0.992	0.980		0.984	0.997	0.988
St. Dev.		0.020	0.013	0.018		0.017	0.006	0.015
Minimum		0.943	0.960	0.956		0.956	0.983	0.956
Maximum		1.000	1.000	1.000		1.000	1.000	1.000

As depicted from Table 5, Technical Efficiency (IO) of public sector banks varies from 0.943 to 1 and average Technical Efficiency (IO) score of Indian public sector banks is 0.972. Technical Efficiency (IO) of public sector banks is 0.987 in the year 2015-16 which increases for next two years up to the year 2017-18 (0.981). The efficiency score declines to 0.953 in the year 2018-19 but increases to 0.968 in the year 2019-20. Further, a decreasing trend is

noticed from (0.961) the year 2020-21 to (0.943) the year 2022-23. Public sector banks have scored lowest Technical Efficiency (IO) score (0.981) in the year 2017-18 and highest score of 1 in the year 2023-24. Pure Technical Efficiency of public sector banks varies from 0.960 to 1 and average Pure Technical Efficiency of public sector banks is 0.992. In the year 2015-16, Pure Technical Efficiency score of public sector banks is 0.996 which increases to 0.997 in the year 2016-17. Further it declined to 0.983 in the year 2017-18. In the year 2018-19 Pure Technical Efficiency score is 0.997 which increases to one (highest Pure Technical Efficiency score) in the year 2019-20. Lowest Pure Technical Efficiency score (0.960) is observed in the year 2022-23. All the components of Technical Efficiency demonstrate an inconsistent pattern over the years. Scale Efficiency of public sector banks varies from 0.956 to 1. In the year 2015-16, Scale Efficiency score is 0.991 which increases to 1 in the year 2016-17. In the year 2017-18, Scale Efficiency score remains 0.998 which declines to 0.956 in the year 2018-19. Further, it increases to 0.968 in the year 2019-20. Scale Efficiency scores of public sector banks follow a declining trend for next two years up to the year 2021-22 (0.956) which is the lowest of all the years. In the year 2021-22, Scale Efficiency score of public sector banks is 0.980 which increases to 1 in the year 2023-24. (Table 5)

Further it is revealed from the Table 5 that during 2015-16 to 2023-24, Technical Efficiency (IO) of private sector banks diverge from 0.956 to 1. Technical Efficiency (IO) score is 0.998 in the year 2015-16 which decreased to 0.995 in the year 2016-17. Further it increases to 1 in the year 2017-18. It decreases for next five years and remains at 0.996 in the year 2022-23. In the year 2023-24, Technical Efficiency (IO) of private sector banks is 1 which indicates full efficiency. The Pure Technical Efficiency score of private sector banks varies from 0.983 to 1. In the year 2015-16, Pure Technical Efficiency score of private sector banks is one. Further it demonstrates a rising trend for next two years and the score remains 1 in the year 2020-21 which is the highest of all the years. It decreases to 0.983 (lowest Technical Efficiency score) in the year 2021-22. In the year 2021-22 and 2023-24, Pure Technical Efficiency score is one. Scale Efficiency of private sector banks varies from 0.956 to 1. In the year 2015-16, it is 0.998 which declines to 0.997 in the year 2016-17. Further, in the year 2017-18, Scale Efficiency score increases to 1 (highest of all the years). In the year 2018-19, Scale Efficiency score of private sector banks is 0.974 which declines to 0.956 in the year 2019-20. An increasing trend is noticed in Scale Efficiency score of private sector banks for the following four years. In the year 2023-24, private sector banks have achieved full Scale Efficiency. (Table 5)

It is noticed from the above results that public sector banks and private sector banks have lower Technical Efficiency (IO) and its components scores to the ideal efficiency score of 1 in all the years, thus bringing the average of Technical Efficiency (IO) to less than the standard score. In other words, Indian public and private sector banks are not able to utilize its inputs efficiently to produce the maximum outputs. It indicates their poor selection of scale of production and managerial efficiency. Average Technical Efficiency (IO), Pure Technical Efficiency and Scale Efficiency scores of private sector banks are higher than the public sector banks. Main source of Technical Inefficiency among all the banks are attributed to Scale Inefficiency as it is higher than Pure Technical Inefficiency. Scale Inefficiency exhibits that the public and private sector banks are not performing at the optimum scale. Hence, the scale of operations of these banks has to be checked to utilize their resources to the fullest. Technical Efficiency (IO) score of private sector banks is lower than the public sector banks. Pure Technical Efficiency score of public sector banks is lower than the private sector banks. Scale Efficiency scores are also higher in case of public sector banks than those of private sector banks score. (Table 5)

Limitations and Future Directions

This research relies on secondary data sources, and the study acknowledges the inherent limitations of using secondary data as the sole basis for analysis. While secondary data provides valuable insights, it may not capture the most recent developments or specific factors influencing the efficiency of banks. To enhance the accuracy and depth of future research, alternative methods such as surveys and interviews with key bank stakeholders could be utilized. These primary data collection techniques would offer firsthand perspectives on bank efficiency, providing a more comprehensive understanding of the factors driving super efficiency.

Moreover, future research could investigate the impact of both industry-specific and bank-specific factors on the super efficiency of Indian banks. Factors such as regulatory changes, technological advancements, competitive dynamics, and macroeconomic conditions may significantly influence bank efficiency. A more comprehensive analysis incorporating

these variables could yield valuable insights for policymakers, financial institutions, and researchers seeking to enhance banking sector performance.

By addressing these aspects, future studies can build on the current research, offering a more nuanced and in-depth understanding of bank efficiency while mitigating the limitations of relying solely on secondary data.

Conclusion

The analysis of Technical Efficiency (IO) scores for Indian public and private sector banks indicates that while most banks have demonstrated operational efficiency across the years, the highest efficiency levels were recorded in 2015-16. Conversely, the majority of banks exhibited technical inefficiency in 2021-22. An evaluation of the components of Technical Efficiency reveals that banks have consistently maintained strong Pure Technical Efficiency scores, suggesting effective management decisions regarding resource utilization. The highest average Pure Technical Efficiency was observed in 2023-24, signifying improved managerial decision-making. However, 2018-19 recorded the lowest average Pure Technical Efficiency, highlighting inefficiencies in management practices during that period. Similarly, an assessment of Scale Efficiency scores indicates that banks have performed moderately across different years. The highest Scale Efficiency was observed in 2023-24, reflecting an optimal scale of operations. However, banks faced significant scale inefficiencies in 2016-17 and 2018-19, suggesting that they were not operating at an ideal scale. Additionally, while the maximum number of banks achieved an optimal scale in 2015-16, scale inefficiencies were most prominent in 2016-17.

The overall findings suggest that both public and private sector banks in India have not achieved the ideal Technical Efficiency (IO) score of 1, indicating inefficiencies in resource utilization to maximize output. This inefficiency primarily stems from Scale Inefficiency, which exceeds Pure Technical Inefficiency, demonstrating that banks are not operating at an optimal scale. Consequently, banks must reassess their operational scales to enhance resource utilization and overall efficiency.

Comparative analysis reveals that private sector banks generally exhibit higher Technical Efficiency (IO), Pure Technical Efficiency, and Scale Efficiency scores than public sector banks. However, the Scale Efficiency score of public sector banks surpasses that of private sector banks, while public sector banks lag in Pure Technical Efficiency compared to their private counterparts. These insights underscore the need for strategic interventions to improve efficiency, particularly in scale management, to optimize banking operations.

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