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Efficiency of Indian Public and Private Sector Banks: A Two-Decade Analysis (2001-2021) Using Data Envelopment Analysis

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Abstract

The paper assesses India's public and private sector banks' technical Efficiency (T.E.) over the two-decade period from 2001 to 2021. The relative efficiency of twenty-five banks comprising twelve public and thirteen private sector institutions was studied using efficiency data envelope analysis (DEA) under constant and variable return to scale (CRS and VRS) assumptions. The research uncovers interesting findings about the efficiency rankings of these banks and provides valuable insights into the Indian banking sector landscape. The study identifies three banks, Indian Bank, ICICI Bank Ltd., and City Union Bank Ltd., that consistently emerge as the top-performing decision-making units (DMUs) across all three efficiency measures, boasting perfect scores of 1. Indicates their optimal utilization of inputs to generate outputs throughout the study period. These banks have demonstrated exceptional efficiency in the Indian banking sector. Furthermore, the paper scrutinizes scale efficiency (S.E.) scores and highlights Indian Bank's sustained excellence among public sector banks, while ICICI Bank Ltd. and City Union Bank Ltd. shine brightly among their private sector peers in terms of S.E. These findings underscore the importance of scale efficiency in enhancing overall bank performance.

Interestingly, the comprehensive analysis shows that public-sector banks tend to outperform private-sector banks in terms of efficiency. Several reasons contribute to this phenomenon, such as the extensive reach of public-sector banks, their extensive customer base, and their substantial share of financial assets in the Indian market. On the other hand, private sector banks need to focus on areas where they lag to enhance their performance. This study not only advances the knowledge of the Efficiency of Indian banks but also opens avenues for future research. Subsequent investigations may delve into the factors driving inefficiency and conduct sensitivity analyses to explore this crucial area further. Overall, this research adds valuable insights to the discourse of Indian banks' efficiency and paves the way for further exploration in this field.

Keywords: Technical Efficiency, Scale Efficiency, Data Envelopment Analysis (DEA), Constant Return to Scale (CRS), Variable Return to Scale (VRS), Performance Evaluation, Decision-Making Units (DMUs), Scale Efficiency Analysis

INTRODUCTION

Following over three decades of banking sector reform in India, there has been a profound transformation in the Indian banking landscape. With the implementation of liberalization and deregulation programs, Indian banks have transitioned from a highly regulated system to a dynamic and fiercely competitive market-driven model. This shift has been characterized by the extensive adoption of innovative technology in the banking sector, evolving consumer preferences, tightening legislative regulations, and restructuring the banking landscape. Over recent years, several Indian public sector banks have undergone mergers, while new private sector banks have entered the scene. Consequently, banks now face escalating competitive pressures from foreign financial institutions and non-banking entities. Consequently, they must enhance their competitiveness and ensure sustainable growth by consistently assessing the Efficiency of Indian banks.

The central element of firm performance hinges on the evaluation of efficiency. Efficiency is gauged by considering the firm's primary objectives, such as profit maximization, cost reduction, market share expansion, and customer satisfaction. In the banking sector, efficiency is assessed regarding the business's profitability and how effectively a bank deploys its resources, including human capital, investments, and various expenditures, to generate outputs like loans or overall income. Moreover, in this era of intense competition, banks must prioritize enhancing their efficiency to attain their goals.

In everyday language, efficiency is commonly understood as the ability to work without wasting time or resources. It encompasses a broad spectrum; different disciplines perceive efficiency in distinct ways. Within a service-oriented industry like banking, Efficiency Assesses how effectively a firm can convert its inputs into outputs in alignment with its objectives. According to the definition provided by the Extended Parteo-Koopmans framework, a firm is considered 100 per cent efficient when no improvements can be made to its inputs and outputs without compromising some other aspect of its inputs or outputs.

Efficiency is a term often confused with other specific concepts, such as productivity and effectiveness, even though these terms are interconnected and possess distinct meanings. Various authors have provided specific definitions for these concepts: According to Pritchard (1995), productivity is defined as the ratio of output to input, essentially serving as a measure of efficiency from a techno-economic perspective. Rantanen (1995) presents productivity as a combination of efficiency effectiveness, with productivity equaling the sum of efficiency effectiveness. Productivity encompasses a broader scope, measuring the output-to-input ratio, while EEfficiencyfocuses on maximizing output with minimal input utilization. Drucker (1963) distinguishes between EEfficiency, which entails doing things

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correctly, and effectiveness, which pertains to doing the right things. Efficiency measures an organization's ability to achieve output using the minor input, while effectiveness evaluates an organization's capacity to attain predefined objectives and goals. Effectiveness measures output by comparing actual output to desired output, emphasizing results, whereas efficiency concentrates on achieving these outcomes. Thus, the relationship between these terms can be summarized as follows:

Productivity = Efficiency + Effectiveness

From a bank's perspective on efficiency measurement, efficiency can be divided into three parts: Technical Efficiency, Allocative Efficiency, and Cost Efficiency. Technical Efficiency is utilizing resources (such as labour, capital, and machinery) as inputs to produce output, benchmarked against the best-performing decision-making unit within a given set of firms. Allocative EEfficiencyminimizes production costs through the judicious input selection for a given input level and at a given input price, assuming the organization is fully technically efficient. Cost Efficiency combines technical and allocative efficiency, meaning an organization can be considered cost-efficient only when it achieves both technical and allocative efficiencies."

Data Envelopment Analysis (DEA), a nonparametric method, assesses the efficiency scores of each Decision-Making Unit (DMU) by comparing them against similar units (Sreekumar and Mahapatra (2011)). DMUs refer to organizations, departments, or entities with similar objectives or standards (Min et al. (2008)). The foundational model in DEA is the CCR model, introduced by Charnes et al. (1978), which operates under the assumption of constant returns to scale (CRS) and does not consider a significant relationship between efficiency and the scale of operations. This model provides an overall measure of technical efficiency. However, it is essential to note that the CRS assumption holds only when all firms within the DMUs operate optimally.

Subsequently, the CCR model was adapted by Banker et al. (1984) into the BCC model, which is based on the variable returns to scale (VRS) assumption. The VRS assumption allows for the pure technical Efficiency (PTE) measurement, which assesses technical efficiency excluding scale efficiency's influence, as Sufian (2007) outlined. DMU efficiency scores are calculated by dividing the sum of weighted inputs by the sum of weighted outputs. In cases where the production function is known or unknown, a unit receiving an efficiency score of 1 is considered relatively efficient or a best-practice unit. In contrast, a score between 0 and 1 indicates a relatively less efficient unit (Hadad et al., 2011**).**

More academic journal publications that simultaneously assess the technical efficiency of both public and private sector banks in India need to be published. Furthermore, this study evaluates Technical Efficiency (T.E.) under both the Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) assumptions, extending over a substantial study period spanning from 2001 to 2021. Individual banks are then ranked based on their efficiency scores, offering valuable insights to banks as they gauge their performance against benchmark institutions. This ranking system informs banks of their standing and highlights areas for improvement.

Additionally, the findings from this study are likely to be of considerable benefit to policymakers and regulators in crafting strategies and plans to adapt to the evolving needs of the banking sector. To sum it up, the objectives of this paper are threefold:

i. To derive technical efficiency scores for individual public and private sector banks under the assumptions of Constant Returns to Scale (technical EEfficiency and Variable Returns to Scale (pure technical EEfficiency.
ii. To compute Scale Efficiency scores based on the CRS and VRS scores.

iii. To rank public and private sector banks according to their Scale Efficiency scores and compare their performance based on these scores.

The remainder of this paper is structured as follows: The next section delves into the Data Envelope Analysis (DEA) models employed in this study. The subsequent part covers the data description and outlines the specification of input and output variables. Findings are discussed in the following section, and the empirical results are presented in the penultimate section. The final section summarizes the most relevant conclusions and identifies potential avenues for future research.

METHODOLOGICAL FRAMEWORK

Data Envelopment Analysis (DEA)

Data Envelope Analysis (DEA) is a nonparametric method for assessing the relative efficiency of a group of decision-making units (DMUs) that employ multiple inputs to generate multiple outputs. Over the years, DEA has seen significant advancements in its application across various contexts, including educational institutions (such as schools, colleges, and universities), financial institutions (such as banks and insurance companies), hospitals, courts, and more.

Efficiency measurement in DEA requires that decision-making units (DMUs) use similar inputs to produce their respective outputs. Inputs represent the resources employed within DMUs to generate the desired outcomes, referred to as outputs. According to Charnes and Cooper's definition, a DMU is considered 100% relatively efficient if its performance of other DMUs does not allow for improvements in its inputs or outputs without compromising some of its other inputs or outputs. In DEA, efficiency scores for all DMUs are either 1 or less than 1. An efficiency score of 1 indicates the most efficient unit compared to other DMUs, while a score of less than 1 designates an inefficient unit. DEA also identifies the sources of inefficiency in each input and output of inefficient units and their levels of inefficiency.

DEA's ability to measure efficiency in DMUs without requiring specific information about the products or outputs is referred to as technical efficiency in DEA literature terminology (Bhattacharjee, 2012). A DMU is considered technically efficient when it can minimize its input while maintaining a given output level or maximize its output using a fixed input level. DEA can be approached from either an input-oriented or output-oriented perspective. The input-oriented DEA approach focuses on minimizing input at a given output level, while the output-oriented DEA approach focuses on maximizing output at a given level of input (Sreekumar & Mahapatra, 2011).

The primary implication of DEA is its capacity to measure DMUs' efficiency relative to others, pinpoint the causes of inefficiencies, and suggest ways for DMUs to enhance their efficiency.

DEA was initially developed by Charnes (1978), building upon the work of Farrell (1957). The fundamental CCR model is based on the constant return to scale assumption. Subsequently, it was further refined by Banker et al. (1985) into the BCC model, which is grounded in the variable return to scale assumption.

CCR DEA Model: The CCR model was formulated by Charnes et al. (1978), drawing inspiration from Farrell's (1957) earlier work on efficiency measurements, which focused solely on single-input considerations. This model employs linear programming as an optimization approach, assessing the efficiency of decision-making units (DMUs) concerning homogeneous DMUs to establish the best-practice frontier that transforms multiple inputs into multiple outputs. The CCR model evaluates the overall efficiency entities based on the assumption of constant returns to scale. It needs to differentiate between technical and scale efficiency.

Under the assumption of CRS, a mathematical formulation of DEA was given by Charnes et al. (1978). Let us assume n DMUs to be evaluated, DMU_j consumes x x amount of input I, where $i = 1,2,3, \ldots .m$ to produce y_{rj} amount of output r, where $r = 1,2,3, \ldots .s$ and $j = 1,2,3, \ldots .n$. Also, it assumed that $x_{ij} \geq o$ and $y_{rj} \geq 0$. The CCR efficiency of $p\ th$ - DMU (particular DMU under evaluation) is symbolically defined as:

$$Maxh_p(u,v) = \frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}}$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rp}}{\sum_{i=1}^{m} v_i x_{ip}} \leq 1; j = 1,2,3, \ldots, n. \quad (1.1)$$

$$u_r, v_j \geq 0 \ for\ all\ i\ \&\ r$$

The above-mentioned fractional form of the model can have an unlimited solution. So, to get out of this problem, Charnes-Cooper has suggested transforming this mathematical formulation into linear programming. It is described as:

$$Maxh_p(u,v) = \sum_{r=1}^{s} \mu_r y_{rp}$$

Subject to

$$\sum_{i=1}^{s} \mu_r y_{rj} - \sum_{i}^{m} v_i x_{ij} \leq 0 \quad (1.2)$$

$$\sum_{i=1}^{m} v_i x_{ip} = 1 \ \ i = 1,2,3, \ldots .m$$

$$\mu_r, v_i \geq \in \geq 0 \ \ j = 1,2,3, \ldots .n \ \ r = 1,2,3, \ldots .s$$

The model mentioned above (1.2) cannot be solved using the DMU technique, for which linear programming under dual principle is used in the study. The envelopment model standard form is:

$$\theta^* = min\theta$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} \lambda_j + s_i^- = x_{ip} \ \ i = 1,2,3,.,m; \quad (1.3)$$

$$\sum_{j=1}^{n} y_{rj} \lambda_j + s_r^+ = \emptyset y_{ro} \ \ r = 1,2,3 \ldots, s;$$

$$s_i^- \ \&\ s_r^+ \geq 0 \ for\ all\ r, s$$

$$\lambda_j \geq 0; j = 1,2,3, \ldots .n.$$

The DMU_p performance is said to be fully efficient if both input and output slacks are zero,

$$s_i^- = s_r^+ = 0$$

$$\theta^* = 1$$

The DMU_p performance is inefficient when both conditions are not fulfilled—first, $s_i \ - o\ or\ s_r^+ \neq 0$, and second $^{,\theta,*} \neq 0$.

BCC DEA MODEL

The CCR model assumes that the scale of operations and efficiencies have no significant relation based on the constant return to scale (CRS) assumption. This CRS assumption is only suitable where all the DMUs are operating at the optimal level. Also, the CCR model measures the overall technical efficiencies. Further extension in the CCR model was presented by Banker et al. (1984) by adding the

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variable return to scale (VRS) assumption at a constant return to scale. The VRS assumption measures the pure technical Efficiency (PTE) of DMUs, which measures T.E. by avoiding S.E. effects. The input-oriented Envelopment model presented by Banker et al. (1984) based on VRS assumption is as follows:

$$min\theta_p - \varepsilon\left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right] \qquad (1.4)$$

Subject to:

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- = \theta_p x_{ip} \; ; i = 1,2 \dots, m$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - s_r^+ = y_{rp} \; ; r = 1,2 \dots, s$$

$$\sum_{j=1}^{n} \lambda_j = 1 \; ; j = 1,2 \dots, n$$

$$s_j^- \; and \; s_r^+ \geq 0 \, , \lambda_j = 0 \, , i = 1,2 \dots n$$

Where,

$$s_r^+ = input\ slack, s_i^- = output\ slacks,$$

$$\theta_k = efficiency\ score\ pth\ DMU\ that\ lies\ between\ 0\ and\ \ 1$$

Data and Selection of Variables

The data utilized in this study for analysis was sourced from various reputable publications, including online databases such as Emerald, JSTOR, Google Scholar, SAGE, and the Social Science Research Network (SSRN). Additionally, annual financial data related to banks spanning the period from 2001 to 2021 were gathered from PROWESS and the official websites of the respective banks. Our analysis exclusively focuses on public and private sector banks operating in India during this timeframe. Specifically, we have included 13 private and 12 public sector banks listed on the Bombay Stock Exchange (BSE) and the National Stock Exchange (NSE) from 2001 to 2021.

Defining the inputs and outputs is imperative to calculate efficiency scores using Data Envelopment Analysis (DEA). In the context of banking efficiency measurement, one of the primary challenges lies in the selection of variables, whether they are inputs or outputs. This complexity arises due to various factors, including the scarcity of data about relevant variables, the intricacies of measuring banks' costs and outputs given that many services are jointly produced, and the common practice of assigning prices to bundles of financial services (Sufian, 2011). Another often-debated issue revolves around the treatment of deposits, with some studies regarding them as inputs and others as outputs (Ahn & Le, 2014). It has been empirically demonstrated that the choice of variables significantly impacts the efficiency scores of decision-making units (DMUs) (Favero & Papi, 1995) (Sufian, 2011). In bank efficiency studies, the leading DEA approaches that predominate the literature for variable specification include intermediation, production, operating, asset, and value-added.

A review of the literature reveals that the intermediation approach is the most widely adopted method for variable selection in efficiency measurement studies of banks (Rangan et al., (1988), Charnes et al., (1990), Elyasiani & Mehdian,(1990), Berger & Humphrey, (1991), Bhattacharyya et al., (1997), Barr et al., (2002), Ataullah & Le, (2006), Kumar & Gulati, (2008), Kumar,(2008), Hanif Akhtar, (2010), Hon et al., (2011), Karimzadeh, (2012), Titko et al., (2014), Kaur & Gupta, (2015), Sufian et al., (2016b), Mahendru & Bhatia, (2017), Eyceyurt Batir et al., (2017), Chaluvadi et al., (2018), Goyal et al., (2019), Davidovic et al., (2019), Phung et al.,(2020)). In most of these studies, labour and capital are selected as input variables, while loans are designated as output variables. However, there exists a divergence of views regarding the treatment of deposits, with some studies considering deposits as inputs (Elyasiani & Mehdian, (1990), Barr et al., (2002), Kumar & Gulati, (2008), Sufian & Habibullah, (2009), Karimzadeh, (2012), Titko et al., (2014), Sufian et al., (2016b), Mahendru & Bhatia, (2017), Chaluvadi et al., (2018)) and others as outputs (Berger & Humphrey, (1991), Bhattacharyya et al., (1997)). This divergence arises from differing viewpoints, as some researchers view deposits as a variable that generates revenue for banks (hence treating it as an input). In contrast, others regard it as a by-product resulting from the inputs employed by banks to generate deposits.

Based on a comprehensive literature review and considering that the primary role of banks is to gather deposits and convert them into loans through labour utilization, the study chose to employ the Intermediation approach within the DEA framework for variable selection. In this approach, the input and output variables for study are:

Inputs	Outputs
Deposits Interest expenses Operating expenses	Investments Advances Interest income Non-interest income

To assess the relative efficiency of individual banks from 2001 to 2021 and calculate the efficiency scores, DEA Frontier, an Add-In developed by Professor Joe Zhu and designed explicitly for solving Data Envelope Analysis (DEA) models, was used.

RESULTS AND FINDINGS

This section assesses the technical efficiency of the Constant Return to Scale (CRS) and Variable Return to Scale (VRS) models. Following this, we gauge scale efficiency based on these scores and rank the banks accordingly. Under the CRS assumption, DEA provides an overall measure of technical efficiency. In contrast, the VRS assumption allows us to calculate pure technical efficiency (PTE), representing technical efficiency independent of scale efficiency (Sufian, 2007). The efficiency scores for the decision-making units (DMUs) are determined by dividing the sum of weighted inputs by the sum of weighted outputs. In cases where a unit receives an efficiency score of 1, it is considered relatively efficient or a best practice unit, while a score below 1 indicates relatively lower Efficiency (Hadad et al., 2011).

I. Technical Efficiency under the Constant Returns to Scale Assumptions

Table 1 presents the technical efficiency of twelve public and thirteen private sector Indian banks throughout the study period, assuming constant returns to scale. The banks have been ranked based on their average scores over the years. Notably, three banks have achieved the top rank, one being a public sector bank, Indian Bank, and the other representing the private sector: ICICI Bank Ltd. and City Union Bank Ltd. These banks consistently maintained 100 per cent efficiency, receiving an efficiency score of 1 every year. The top five banks, in descending order of efficiency, are Indian Bank (1), ICICI Bank Ltd. (1), City Union Bank Ltd. (1), the Central Bank of India (0.999), and Union Bank of India (0.998). Among these top-ranking banks, three are from the public sector, while the remaining two belong to the private sector.

Conversely, among the five least efficient banks, we find Karnataka Bank Ltd. (0.949) ranking 21st, South Indian Bank Ltd. (0.943) ranking 22nd, Federal Bank Ltd. (0.930) ranking 23rd, Karur Vysya Bank Ltd. (.924) ranking 24th, and IndusInd Bank Ltd. (.904) occupying the 25th position. Notably, the State Bank of India maintains a consistent 100 per cent efficiency across all years, except for 2007-08. Similarly, HDFC Bank Ltd. has demonstrated total Efficiency efficiency across all years except for 2018-19.

Among the public sector banks, the Central Bank of India and Union Bank of India exhibited inefficiency in two financial years: Central Bank of India in 2001-02 and 2010-11, and Union Bank of India in 2017-18 and 2018-19. However, aside from these specific years, they maintain full EEfficiencythroughout the study period. In contrast, IndusInd Bank Ltd., a private sector bank, consistently demonstrates inefficiency across all years, except for 2004-05, 2015-16, and 2016-17.

II. Technical Efficiency under the Variable Returns to Scale Assumption

Table 2 provides an overview of the technical EEfficiencycalculated under variable returns to scale for the twenty-five banks, encompassing both public and private sectors, over the study period. It also presents the banks' rankings based on the average efficiency scores computed across individual years. Impressively, nine banks, comprising six public and three private sector banks, clinched the top rank. These banks are Bank of Baroda, Canara Bank, Punjab & Sind Bank, State Bank of India, Union Bank of India, Indian Bank, ICICI Bank Ltd., HDFC Bank Ltd., and City Union Bank Ltd., all of which achieved a remarkable 100 per cent efficiency score, denoted by a perfect score of 1. This outcome reveals that six public sector banks have attained full EEfficiency while the remaining six exhibit varying degrees of inefficiency. Specifically, Bank of India (0.99) secures the 16th rank, Bank of Maharashtra (0.996) is positioned at the 13th rank, Central Bank of India (0.999) claims the 11th spot, Indian Overseas Bank (0.997) holds the 12th rank, Punjab National Bank (0.999) ranks 10th, and UCO Bank (.980) lands at the 18th position.

Conversely, the bottom five banks ranked from 21st to 25th, are all from the private sector. South Indian Bank Ltd. (.976), Dhanlaxmi Bank Ltd. (0.962), IndusInd Bank Ltd. (0.951), Karnataka Bank Ltd. (0.959), Federal Bank Ltd. (0.949), and Karur Vysya Bank Ltd. (0.93) are the banks with the least efficient scores, with Karur Vysya Bank Ltd. claiming the last position. Interestingly, Punjab National Bank (0.976) maintains 100 per cent efficiency across all years, except 2018-19, similar to the Central Bank of India, which exhibits efficiency in all years except for 2001-02 and 2010-11.

III. Scale Efficiency for the year 2001-2021

Table 3 provides an overview of the scale efficiency scores for twelve public-sector and thirteen private-sector Indian banks from 2001 to 2021. The analysis reveals that only three banks maintained 100 per cent scale efficiency throughout the period. Among these top-performing banks, one hails from the public sector, Indian Bank, while the other two represent the private sector, namely ICICI Bank Ltd. and City Union Bank Ltd. Intriguingly, three additional banks consistently maintain scale efficiency across all years except for a single year. Specifically, the State Bank of India experienced inefficiency in 2007, HDFC Ltd. in 2018, and Dhanlaxmi Bank Ltd. in 2002. Union Bank of India, a prominent public sector bank, exhibits scale efficiency for all years except 2017 and 2018. When we consider the ranking of these banks based on their scale efficiency scores, Karnataka Bank Ltd. emerges as the least efficient bank, boasting an S.E. (Scale Efficiency) score of 0.948.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This paper has comprehensively analyzed the technical Efficiency (T.E.) of Indian public and private sector banks over a substantial study period. The findings have unveiled noteworthy insights into the

efficiency landscape of these financial institutions, yielding some intriguing observations. Foremost among our findings are the three banks, including one public sector bank and two private sector banks, which have consistently outperformed their peers. Indian Bank, ICICI Bank Ltd., and City Union Bank Ltd. have achieved the coveted status of being 100 per cent efficient across all efficiency measures, showcasing their exceptional ability to optimize inputs and outputs throughout the entire study period.
Our study has revealed that several banks stand out when considering average T.E. scores under constant return to scale (CRS) and variable return to scale (VRS) assumptions. Regarding average T.E. (CRS) scores, Indian Bank and private sector banks, ICICI Bank Ltd. and City Union Bank Ltd., have secured the highest efficiency rankings. Meanwhile, average T.E. (VRS) scores have highlighted nine banks, including six public sector banks (Bank of Baroda, Canara Bank, Indian Bank, Punjab & Sind Bank, State Bank of India, Union Bank of India) and three private sector banks (ICICI Bank Ltd., HDFC Bank Ltd., City Union Bank Ltd.), all demonstrating 100 per cent efficiency. Moreover, in assessing scale efficiency (S.E.) scores, the Indian Bank, representing the public sector, has consistently demonstrated outstanding performance. Similarly, ICICI Bank Ltd. and City Union Bank Ltd., representing the private sector, have consistently showcased remarkable efficiency.
In the broader context, our analysis has identified the top-performing banks across all three efficiency measures, with a balanced representation of public and private sector banks. Notably, public sector banks exhibit strong efficiency on the board, contributing to their dominant presence among the top-ranking institutions. These findings align with studies by Bhattacharya et al. (1997) and Ketkar (2003), which similarly observed public sector banks' superior efficiency. Several factors may account for the public sector banks' better performance, including their extensive customer base, wide-reaching network in rural areas, and substantial financial assets. However, while granting more loans, private sector banks grapple with more Non-Performing Assets (NPAs), indicating areas where they need improvement.
In light of these findings, future research avenues beckon. One avenue is to delve into an in-depth analysis of the factors driving bank inefficiency. Additionally, conducting sensitivity analyses to assess the robustness of our findings and exploring the impact of external factors on banking efficiency could enrich our understanding of this critical sector. Overall, this study sets the stage for continued exploration, offering a wealth of possibilities to deepen our insights into banking efficiency and drive improvements within the industry.

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Table1. Technical Efficiency under Constant Return to Scale for the Year 2001 To 2021

DMU	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	AVERAGE	RANK
BOD	1.00	1.00	1.00	1.00	1.00	0.92	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	0.99	1.00	0.99	13
BOI	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.96	0.96	0.89	0.97	1.00	0.94	0.98	16
BOM	1.00	1.00	1.00	1.00	0.97	1.00	0.94	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	0.99	12
CAN	1.00	1.00	1.00	1.00	0.98	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	8
CBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4
IB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
IOB	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11
P&S	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00	8
PNB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.97	1.00	1.00	0.99	10
SBI	1.00	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	5
UCO	1.00	1.00	0.95	0.96	0.99	0.86	0.94	0.91	0.91	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	17
UBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	1.00	1.00	1.00	1.00	5

SIB	0.96	0.82	0.90	0.86	0.90	0.97	0.94	0.93	0.98	0.92	0.94	0.94	0.95	0.95	1.00	1.00	1.00	0.98	0.95	0.91	1.00	0.94	22
KMB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.96	0.94	0.97	1.00	0.99	14
KVB	1.00	0.74	0.99	1.00	0.97	0.96	0.95	0.95	0.88	0.92	0.94	0.95	0.97	0.92	1.00	1.00	0.92	0.87	0.89	0.84	0.76	0.92	24
KB	0.90	0.86	0.95	0.96	0.98	1.00	0.92	0.97	1.00	0.94	0.91	0.92	0.94	0.99	1.00	1.00	0.99	0.88	0.92	0.80	1.00	0.95	21
J& K	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.88	0.92	0.87	0.92	0.97	18
Indus	0.99	0.63	1.00	1.00	0.99	0.86	0.94	0.90	0.85	0.88	0.94	0.94	0.94	0.96	1.00	1.00	0.83	0.83	0.86	0.86	0.81	0.90	25
I D B I	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	0.99	1.00	0.98	0.99	1.00	1.00	1.00	0.90	0.86	1.00	1.00	0.99	0.99	15
I C I C I	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
H D F C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	5
FB	0.96	0.81	0.76	0.82	0.93	0.96	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.91	0.85	0.91	0.85	0.81	0.93	23
DB	0.90	0.85	0.93	0.96	0.89	1.00	1.00	0.87	1.00	0.87	1.00	1.00	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	19
CUB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
AB	0.89	0.64	0.88	0.88	1.00	1.00	0.96	0.96	1.00	1.00	0.96	0.96	0.98	0.99	1.00	1.00	0.97	0.96	0.97	1.00	1.00	0.95	20

Table 2 Technical efficiency under Variable Return to Scale for the year 2001 to 2021

DMU	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	AVERAGE	RANK
BOB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
BOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.96	0.95	0.98	1.00	0.94	0.99	16
BOM	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	13
CAN	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
CBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11
IB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
IOB	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12
P&S	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
PNB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	10
SBI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
UCO	1.00	1.00	0.97	0.98	1.00	0.86	0.95	0.91	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	18
UBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1

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SIB	0.98	1.00	0.90	0.86	1.00	1.00	1.00	1.00	1.00	0.93	0.95	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00	0.98	20
KMB	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.97	1.00	1.00	14
KVB	1.00	1.00	1.00	1.00	0.97	0.98	0.89	0.95	0.88	0.92	0.94	0.95	0.97	0.92	1.00	1.00	0.93	0.88	0.89	0.85	0.77	0.94	25
KB	0.90	1.00	0.95	0.96	0.98	1.00	0.93	0.97	1.00	0.94	0.91	0.92	0.94	0.99	1.00	1.00	1.00	0.92	0.93	0.90	1.00	0.96	23
J& K	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.92	1.00	0.88	0.92	0.98	17
Indus	0.99	0.91	1.00	1.00	1.00	0.88	0.93	0.90	0.85	0.88	0.97	0.94	0.94	0.96	1.00	1.00	0.94	0.98	0.93	1.00	0.99	0.95	22
I D B I	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.90	1.00	1.00	1.00	0.99	15
I C I C I	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
H D F C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
FB	0.99	1.00	0.78	0.86	0.99	1.00	0.91	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.93	0.89	0.91	0.86	0.81	0.95	24
DB	0.91	0.86	0.93	0.95	0.89	1.00	1.00	0.87	1.00	0.87	1.00	1.00	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	21
CUB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
AB	0.87	0.84	0.88	0.90	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.97	19

Table 3 Scale Efficiency for the Year 2001 To 2021

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DMU	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	AVERAGE	RANK
BOB	1.00	1.00	1.00	1.00	1.00	0.92	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	0.99	18
BOI	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.99	1.00	0.94	0.99	1.00	1.00	0.99	17
BOM	1.00	1.00	1.00	1.00	0.97	1.00	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	11
CAN.	1.00	1.00	1.00	1.00	0.98	1.00	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	11
CBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4
IB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
IOB	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4
P&S	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	1.00	11
PNB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.97	1.00	1.00	1.00	14
SBI	1.00	1.00	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	7
UCO	1.00	1.00	0.98	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10
UBOI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	1.00	1.00	1.00	1.00	7

SIB	0.98	0.82	0.99	1.00	0.90	0.97	0.94	0.93	0.98	0.99	0.99	0.97	0.95	0.95	1.00	1.00	1.00	0.98	0.95	1.00	1.00	0.97	23
KMB	1.00	1.00	1.00	1.00	1.00	1.00	1.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.96	0.97	1.00	1.00	0.99	15
KVB	1.00	0.74	0.99	1.00	1.00	0.97	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	0.99	0.98	0.99	21
KB	1.00	..861	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.95	0.99	1.00	1.00	0.95	25
J& K	1.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.95	0.92	0.99	1.00	0.99	19
Indus.	1.00	0.69	1.00	1.00	0.99	0.98	1.01	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00	0.89	0.85	0.93	0.86	0.81	0.95	24
I D B I	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	0.99	1.00	0.98	0.99	1.00	1.00	1.00	0.97	0.95	1.00	1.00	0.99	0.99	15
I C I C I	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
H D F C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	7
FB	0.97	0.81	0.97	0.95	0.93	0.96	1.10	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.98	0.96	0.99	0.99	0.99	0.98	20
DB	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	4
CUB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1
AB.	1.02	0.76	1.00	0.98	1.00	1.00	0.96	1.00	1.00	1.00	0.96	0.97	0.98	0.99	1.00	1.00	0.98	0.96	0.97	1.00	1.00	0.98	22