Exploring Bank Cost Efficiency across Ownership Structures using DEA Approach

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Abstract

With the evolving landscape of Indian banking ownership, characterized by a mix of state-owned, privately-owned, and foreign-owned banking companies, the banking sector is characterized by intense competition. This study focuses on these three ownership groups of scheduled commercial banks. It uses data envelopment analysis, a nonparametric method, to examine and compare the cost efficiency of banks across three ownership structures besides t-test, chi-square test and correlation analysis in addition to a few descriptive statistics. The study uses four input and five output variables for a period of 10 years, from 2013-14 to 2022-23. The study's primary objective is to offer insightful perspectives on how different ownership regimes impact operational performance by evaluating efficiency scores, thereby contributing to a deeper understanding of strategies for enhancing cost efficiency of banking sector. The study finds wider volatility in the total factor productivity of public sector banks, a consistent but marginal decline in private sector banks, and consistent total factor productivity in the branches of foreign banks in India.

INTRODUCTION

The banking sector plays a crucial role in the economic development of any country through financial intermediation, ensuring the efficient and optimal deployment of financial resources and promoting economic stability and prosperity. In the present competitive environment, banking companies must maintain a competitive edge, which relies on their efficient functioning—utilizing resources effectively to achieve maximum output. This efficiency is determined by the minimum amount of inputs used to produce a given output. Therefore, enhancing cost efficiency becomes crucial for banking companies, providing them with a competitive advantage of serving their customers better at minimal cost while improving service quality.

India, an Asian giant, is one of the fastest-growing economies in the world and the 5th largest economy globally in terms of gross domestic product (GDP). Its banking sector is structured into multiple segments and comprises different types of banks, each serving various sectors within the economy. Regulated by the Reserve Bank of India (RBI), the central bank of India, the banking industry consists of 12 public sector banks (PSBs), 21 private sector banks (PVSBs), branches of 44 foreign banks (FBs), a significant number of cooperative banks operating in urban and rural areas catering to small businesses and rural communities, specialized development banks facilitating and promoting industrial development, international trade and investment, and small finance banks serving under-served and unserved sections of society.

Keywords:

Cost Efficiency, Data Envelopment Analysis, Public and Private Sector Banks, Foreign Banks, Scheduled Commercial Banks, Total Factor Productivity

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In terms of the volume of business, geographical areas covered, and the number of customers served, scheduled commercial banks (SCBs) are the major players comprising both domestic banks and branches of foreign banks. Among domestic SCBs, PSBs, where the government of India holds a majority stake, and PVSBs are the major players. FBs, with headquarters in foreign countries, operate in India through their branch or representative offices.

As the landscape of banking ownership becomes increasingly diverse with the presence of state-owned, privately-owned, and foreign-owned institutions, stiff competition exists in the banking sector of any country, including India. This study utilizes data envelopment analysis (DEA), a nonparametric methodology, to explore and compare banks' cost efficiency under different ownership regimes. The aim is to provide valuable insights into how ownership structures influence operational performance by assessing efficiency scores, offering a comprehensive perspective on optimizing cost efficiency in the banking sector.

Echoes Across Continents: A Survey of Global Literature

The examination of cost efficiency in banking has garnered substantial academic and practical interest, especially with the dynamic changes in ownership structures, technological integration, and regulatory frameworks. Researchers worldwide have sought to understand how various factors such as corporate governance, macroeconomic stability, risk management, and financial innovations influence cost efficiency. The present review synthesizes key studies across diverse banking systems, offering insights into their findings and methodologies. Furthermore, this review aims to identify the research gaps in this domain and contextualize how the current study contributes to filling these gaps by focusing on bank cost efficiency across ownership structures using the DEA approach. Against this background, a thematic overview of key studies is presented below:

Financial Innovation, Corporate Governance, and Cost Efficiency: Numerous studies have explored the impact of financial innovation and governance on bank efficiency. Corporate governance and financial innovation play a crucial role in achieving operational efficiency within banks. Khalifaturofiah (2023) highlighted that financial innovation can greatly enhance financial performance but may also introduce complexities that could adversely affect cost efficiency. Additionally, Ullah et al. (2023) illustrated that strong corporate governance frameworks and global ownership can improve cost efficiency (specifically in Pakistani banks) by addressing agency conflicts and aligning managerial incentives. Conversely, ineffective risk management and high financial leverage have been found to diminish efficiency, underscoring the necessity for robust governance mechanisms. Jiang & He (2018) evaluated the performance of listed Chinese banks and reported that 12 out of 17 banks showed improvements in technical efficiency, three maintained their efficiency levels, and two experienced slight declines. These results emphasize the dual nature of governance and innovation: while they offer opportunities for efficiency, they also require careful management to prevent inefficiencies. This dual role is particularly significant in the realm of ownership structures, where governance practices can vary significantly among public, private, and foreign banks.

Macroeconomic and Regional Dynamics: The macro-economic environment is crucial in shaping bank efficiency. Studies focusing on regional banking sectors have revealed varying efficiency determinants. Belas et al. (2019) examined EU banks and highlighted that factors such as capitalization, profitability, and inflation significantly influence cost efficiency. 'Niţoi & Spulbar (2014) observed that stable macroeconomic conditions enhance efficiency, particularly in Central and Eastern European banks, which often face transitional challenges. In the Chinese banking sector, Antunes et al. (2024) identified trends of gradual efficiency improvements, driven by regulatory reforms and technological adoption. However, sustaining these improvements remains challenging due to increasing competition and evolving customer expectations. Maudos et al. (2002) examined financial institutions across 11 EU countries and observed that profit efficiency was consistently lower than cost efficiency. This indicated inefficiencies primarily related to revenue generation, underscoring the need for enhanced profit management strategies. Cvetkoska et al. (2021) assessed the efficiency of commercial banks in North Macedonia, Serbia, and Croatia (2015–2019) using a DEA income-based approach. They found the Macedonian banking system to be the most efficient (91.1 percent), followed by Croatia (90.9 percent) and Serbia (81.9 percent). These studies highlight the need for regional analyses, as efficiency determinants often vary across economic and regulatory contexts.

Ownership Structures and Efficiency Levels: Ownership structures and regional dynamics play a crucial role in determining the efficiency of banks. Fries & Taci (2004) found that private banks and those with foreign ownership tend to outperform state-owned banks in Eastern Europe in terms of cost efficiency, owing to superior management practices and access to global expertise. Similarly, Lelissa & Mohammed (2019) observed that Ethiopian state banks consistently operate near the efficiency frontier, while private banks face challenges in achieving comparable efficiency levels. In the Indian context, studies by Bhatia & Mahendru (2017) and Goyal et al. (2019) revealed that foreign banks outperformed PSBs, while PVSBs demonstrated intermediate efficiency levels. These findings suggest that ownership structures influence managerial priorities, resource allocation, and operational strategies, all of which impact cost efficiency.

Technological and Structural Determinants of Efficiency: Technological advancements and structural factors significantly impact banking efficiency. Therefore, technology adoption has emerged as a critical factor in improving operational efficiency. Delloint (2019) emphasized the importance of digital leadership in driving efficiency across diverse technological adoption rates. Henriques et al. (2018), in the Brazilian context, highlighted inefficiencies stemming from suboptimal scales among large banks, while smaller banks demonstrated increasing returns to scale. –Nguyen & Pham (2020) compared DEA and SFA methodologies in evaluating Vietnamese banks, finding that methodological choices can influence efficiency scores. Řepková (2015) Řepková (2015) analyzed the Czech banking sector and found that higher levels of capitalization, effective liquidity risk management, and portfolio riskiness positively influenced banking efficiency. However, return on assets (ROA), prevailing interest rates and GDP fluctuations negatively impacted efficiency under the CCR model (Charnes, Cooper, and Rhodes). In the BCC model (Banker, Charnes, and Cooper), liquidity risk and portfolio riskiness were identified as positive drivers, while GDP remained a negative factor. In India, T. Narayanaswamy & A. P. Muthulakshmi (2016) noted that technological advancements, rather than technical efficiency improvements, drove productivity changes in Indian banks. These studies highlight the transformative role of technology in enhancing efficiency while cautioning against the risks of over-reliance on specific evaluation methods.

Impact of Economic Crises on Efficiency: Economic crises have been pivotal in shaping bank efficiency, often acting as stress tests for banking operations. **Gunes & Yildirim (2016)** found that Turkish banks improved cost efficiency during the 2008 global financial crisis, driven by enhanced risk management and regulatory oversight. Similarly, '–––Rahman et al. (2017) observed that cost-efficient banks in BRICS countries (Brazil, Russia, India, China, and South Africa) were more resilient during crises, underscoring the importance of efficiency as a buffer against economic shocks. Specific bank characteristics, such as capitalization, risk management, and cost structures, significantly influence efficiency. Berger & Deyoung (1997) found that problem loans adversely impact cost efficiency.

Efficiency Trends in the Indian Banking Sector: The Indian banking sector presents a unique case for efficiency analysis, given its diverse ownership structures and regulatory environment. Studies consistently show that foreign banks outperform their domestic counterparts in cost efficiency. Narawish et al. (2022) identified strong correlations among variables influencing costs, emphasizing the critical importance of optimizing cost efficiency to thrive in dynamic market conditions. Bhatia & Mahendru (2017) and T. Narayanaswamy & A. P. Muthulakshmi (2016) revealed that foreign banks exhibit the highest cost efficiency, followed by private and public banks. Tanwar et al. (2020) highlighted that PSBs in India achieve near-full efficiency, primarily due to their extensive reach and government support. However, private banks often excel in adopting innovative practices, contributing to their operational efficiency. Post-COVID analyses by Suresh & Pradhan (2023) indicate that PSBs still lag behind PVSBs in key financial indicators, despite improvements. Panandikar (2014) tested the hypothesis of equal and stable performance across public, private, and foreign banks. While similar average efficiency ratings were observed, annual performance variations existed. Non-performing assets (NPAs) and business per employee emerged as the most influential factors in evaluating efficiency.

SYNTHESIS AND RESEARCH GAPS

The reviewed literature highlights the intricate relationship among corporate governance, ownership structures, and macroeconomic conditions in influencing banking efficiency. Research has delved into efficiency patterns across different

regions, ownership categories, and levels of technological integration, employing methodologies like DEA, SFA (stochastic frontier analysis), and BCC (Banker, Charnes, and Cooper) models. While international research offers valuable perspectives on factors such as capitalization, risk management, and financial performance, studies focused on India underscore the significance of technology and ownership structures in molding cost efficiency.

These insights provide a nuanced understanding of efficiency determinants, highlighting the complex interplay between internal and external factors. While the existing literature offers valuable insights into banking efficiency, significant research gaps persist. Most studies focus on isolated factors or specific regions, leaving a void in comparative analysis of ownership structures using robust methodologies like DEA. Additionally, the impact of technological advancements on cost efficiency has not been thoroughly examined in the context of ownership diversity.

This article addresses these gaps by applying DEA to examine cost efficiency across ownership structures in Indian banks. By incorporating recent data and focusing on key determinants, this study provides fresh insights into the evolving landscape of bank efficiency, contributing to the broader understanding of operational benchmarks in the financial sector. ***More specifically, the study addresses the following research questions:***

(a) *What are the patterns and trends in total factor productivity (TFP) among SCBs in India, with specific reference to PSBs, PVSBs, and FBs?*

(b) How do differences in ownership structures – public, private, and foreign – affect the TFP levels of Indian banks?

(c) To what extent do changes in the TFP of SCBs reflect the contributions of PSBs, PVSBs, and FBs?

This study makes a unique contribution to the literature by conducting a comprehensive quantitative analysis of the cost efficiency of Indian SCBs across three distinct ownership groups: PSBs, PVSBs, and FBs over a decade-long period. Unlike many existing studies that often focus on specific bank categories or limited timeframes, this research evaluates the TFP of these ownership groups both individually and collectively using a robust methodological framework that includes DEA, descriptive statistics, and hypothesis testing. By employing both input- and output-oriented DEA models and integrating financial data spanning 10 years (2013-14 to 2022-23), the study offers fresh insights into ownership-specific performance dynamics and their implications for cost efficiency. Additionally, this research adds value by drawing on diverse and credible secondary data sources, ensuring a holistic and reliable analysis. The findings contribute to the existing body of knowledge by addressing gaps in the understanding of how ownership structures influence efficiency in the evolving Indian banking sector.

OBJECTIVES OF THE STUDY

The primary objective of the present study is to examine banks' cost efficiency. To address this objective, the following specific objectives are addressed:

I. To examine the total factor productivity (TFP) of scheduled commercial banks (SCBs) collectively, as well as public sector banks (PSBs), private sector banks (PVSBs), and foreign banks (FBs) individually.

II. To ascertain the differences in TFP among the three ownership groups of banks: PSBs, PVSBs, and FBs.

III. To assess the extent to which the change in the TFP of SCBs is caused by the changes in the TFP of PSBs, PVSBs and Fbs.

HYPOTHESES

Based on the objectives of the study, three null hypotheses, as presented below, are formulated:

H1: There is no significant improvement in the TFP of SCBs, PSBs, PVSBs, and FBs.

H2: There is no significant difference in the improvement in the TFP of PSBs, PVSBs, and FBs.

H3: There is no significant difference in the contribution of each bank group to the TFP of SCBs.

RESEARCH METHODOLOGY

This study is purely quantitative and descriptive, focusing on analyzing the cost efficiency of three ownership groups of SCBs: PSBs, PVSBs, and FBs, both individually and collectively. The research relies on secondary data sourced from reports of the RBI, supplemented by additional information from published research papers, committee reports, websites, and reference books. The study population comprises three categories of SCBs: 12 PSBs with 92,484 operational branch offices, 21 PVSBs with 33,084 operational

branch offices, and branches of 44 FBs with 316 operational branch offices.

The performance statistics were collected for the aforementioned three major ownership groups of SCBs for a period of 10 years from 2013–14 to 2022–23 (the latest year for which complete details are available). It is important to note that banking companies in India follow the financial year (April 1 to March 31) as their reporting period, thus the study period covers 10 years. Descriptive statistics such as the mean and coefficient of variance (CV) were initially utilized to analyze and interpret the data, along with the compound annual growth rate (CAGR). Additionally, both input- and output-oriented models of data envelopment analysis (DEA) were employed for evaluating banks' TFP and testing hypotheses, in addition to conducting *t*-tests, chi-square tests, and correlation analysis.

Overview of Performance Metrics of SCBs

Before evaluating banks' cost efficiency in terms of TFP, an attempt is made here to analyze the performance of three groups of SCBs and the overall performance of all SCBs on the basis of comprehensive panel data set presented in the Appendix. The performance statistics of 77 SCBs in India from 2013–14 to 2022–23 reveal significant trends in asset growth, cost management, and profitability across PSBs, PVSBs, and FBs.

The total assets of SCBs grew from INR 109,759.29 billion at the end of 2013–14 to INR 240,277 billion by the end of 2022–23, accounting for a CAGR of approximately 8.15 percent. Furthermore, there are consistent increases in both total deposits from INR 85,331.73 billion to INR 188,647.38 billion, and total loans from INR 68,768.18 billion to INR 145,735.63 billion. However, profitability exhibited volatility, with profits declining sharply in the middle of the study period (more particularly, for 2017–18 and 2018–19) due to rising provisions and contingencies, which peaked at INR 3,273.35 billion in 2018–19 (and at INR 3,587.93 billion in 2019–20). The turnaround is evident in 2019-20 when it reported profit (compared to the loss suffered during the immediately two preceding years). For 2022–23, the SCBs recorded a profit of INR 2,589.30 billion, attributable, in part, to an increase in interest income to INR 15,162.35 billion and controlled noninterest costs.

PSBs, which hold the largest share of banking assets (10-year average, 63.70 percent), displayed a modest performance improvement. Total assets increased from INR 79,683.10 billion as of 31 March 2014 (i.e., the end of 2013–14) to INR 140,147.93 billion by the end of 2022–23. Despite the growth in deposits and loans, PSBs faced challenges in profitability, particularly between 2015–16 and 2019–20, when they recorded consecutive losses due to high provisions and contingencies, which peaked at INR 2,410.60 billion in 2017–18. This trend reversed in recent years, with PSBs reporting a profit of INR 1,046.49 billion in 2022–23, supported by a steady increase in interest income to INR 8,510.78 billion.

PVSBs outperform other bank groups with robust asset growth from INR 22,588.10 billion at the end of 2013–14 to INR 84,452.03 billion by the end of 2022–23, representing a CAGR of approximately 14.10 percent. Their focus on cost efficiency is evident, with interest costs remaining relatively stable, even as total assets and loan portfolios expand. The PVSBs demonstrated consistent profitability, with profits reaching INR 1,241.36 billion in 2022-23, driven by higher interest income (INR 5,817.32 billion) and effective management of provisions and contingencies, which decreased to INR 884.15 billion in the last year of the study period.

FBs demonstrated steady growth in assets and income, with total assets increasing from INR 7,488.09 billion as of 31 March 2014 to INR 15,677.04 billion by the end of 2022–23. Despite operating on a smaller scale than PSBs and PVSBs, FBs managed to enhance their profitability, with profits rising to INR 301.45 billion in 2022–23. This improvement is largely attributed to their low-cost operations and niche market focus, enabling them to maintain a high return on assets (ROA) and boost their interest income to INR 834.25 billion for 2022-23.

Overall, PSBs faced challenges with profitability in the middle of the study period but exhibited signs of recovery and sustained enhancement in the subsequent years. In contrast, PVSBs and FBs have maintained a steady improvement in their performance, underscoring the significance of cost control and strategic allocation of assets.

However, to gain a comprehensive understanding of the performance of SCBs, we computed a few descriptive statistics, viz., the mean and CV are computed, in addition to CAGR, using the panel data set (Appendix). The results of these calculations are summarized in Table 1.

Table 1: Performance Evaluation of SCBs – Descriptive Statistics and CAGR

Descri-ptive Statistics and CAGR	Bank Group	Total Assets	Total Deposits	Total Loans	Provi-sions and Contin-gencies	Interest Cost	Interest Income	Non-Interest Cost	Non-interest Income	Profit
	PSBs	104,984	87,471	64,479	1,604	4,594	6,993	1,754	1,029	70
	PVSBs	49,278	35,636	31,411	763	1,961	3,582	1,052	729	534
	FBs	10,537	5,920	3,960	145	242	586	198	156	158
	SCBs	164,799	129,027	99,850	2,512	6,798	11,161	3,004	1,914	760
	PSBs	17.74	18.47	15.34	30.16	5.86	8.60	22.58	21.23	843.30
	PVSBs	42.45	45.04	43.83	49.06	27.98	36.20	47.23	35.55	62.20
	FBs	27.95	31.45	16.11	15.21	14.47	19.36	21.36	22.72	38.40
	SCBs	25.63	26.30	24.09	30.43	9.00	17.35	31.04	25.26	120.73
	PSBs	5.81	5.92	5.14	4.07	1.10	3.21	7.31	6.33	10.95
	PVSBs	14.10	14.75	14.91	13.24	8.77	11.89	15.85	11.86	13.91
	FBs	7.67	9.28	5.27	3.83	4.15	6.19	6.19	6.30	11.51
	SCBs	8.15	8.26	7.80	6.51	3.25	5.89	10.03	8.33	12.34

Source: Prepared the table based on the calculations made using the panel data set of 77 SCBs presented in the Appendix.

Note:

(1) "INR" is the Indian Currency. "1" USD = 83.813798 INR (August 5, 2024)

(2) In certain instances, the totals may not align with the sum of figures across different ownership groups due to rounding adjustments when converting figures from crores to billions.

It is evident from Table 1 that among the three ownership groups of SCBs, PSBs are major players in terms of business (except for profit). PSBs dominate in total business (aggregate of deposits and loans), with a 66.39 percent share. Despite their dominant position, they have the lowest profit of INR 70 billion (10-year annual average) with wide variability in profit (CV = 843.30 percent), indicating challenges in profitability improvement. The lower growth rate in the profit of PSBs (CAGR = 10.95 percent) compared to that of PVSBs and FBs (CAGR = 13.91 percent and 11.51 percent, respectively) highlights potential inefficiencies.

On the other hand, PVSBs demonstrate strong growth and profitability, highlighting their efficient operations, dynamism, and competitiveness. They exhibit robust growth across many variables, including total loans (CAGR = 14.91 percent), total deposits (CAGR = 14.75 percent), interest income (CAGR = 11.89 percent), and profits (CAGR = 13.91 percent). These growth rates indicate efficient management practices and an expanding market share. Furthermore, there is no wide variation in any of the variables, as evident from CV of less than 50 percent, except in terms of profit, where the CV is 62.20 percent.

As can be observed from the aforementioned summary, FB branches operate on a smaller scale but maintain consistency in their performance (CV 40 percent for all nine variables) with moderate growth rates (higher than those of PSBs but lower than PVSBs), reflecting stable and dependable operations.

Overall, the SCBs show moderate growth, with CAGRs ranging from 3.25 percent (interest cost) to 12.34 percent (profit) over the 10-year study period, indicating a trend of

moderate growth. Each bank group exhibits unique strengths and challenges that are crucial for management to consider in strategic decision-making.

DEA - CONCEPTUAL FRAMEWORK

Before evaluating bank cost efficiency (TFP) using the DEA method, let us briefly analyze a few important concepts to ensure a proper understanding of the study.

Decision-Making Units (DMUs) - Different business entities or their segments are typically used as the DMUs. However, in this study, the years of the study period are considered as DMUs for justifiable reasons. Each year represents a consistent period where the same types of inputs are utilized to produce outputs, enabling a fair comparison across the years to observe trends over time and gain insights into efficiency and productivity. This approach also facilitates benchmarking the performance of each year against others, identifying the most and least efficient years.

Input and Output Variables – Efficiency in this study is evaluated based on four inputs: total assets, interest cost, noninterest cost, and provisions and contingencies, as well as five output variables: total deposits, total loans, interest income, noninterest income, and profit for the three ownership structures - state and private SCBs (both domestic SCBs) and branches of FBs. The definitions of the input and output variables utilized in this study are outlined in Table 2.

Table 2: Definitions of Input and Output Variables

Variable	Description of the Variable	Unit of Measurement
Input Variables:		
Total Assets	Amount of capital employed by the banks on their assets (as at the balance sheet date, cumulative).	INR billion
Interest Cost	Amount of annual interest paid on the deposits mobilized. And on the borrowed sums.	INR billion
Non-Interest Cost	Other costs, other than interest costs, incurred by the banks annually.	INR billion
Provisions and Contingencies	Amount of provisions created against their loans and advances including NPAs, and other contingencies (annual).	INR billion
Output Variables:		
Total Deposits	Amount of deposits mobilized (as at the balance sheet date , cumulative).	INR billion
Total Loans	Amount of loans and advances sanctioned and disbursed (as at the balance sheet date, cumulative).	INR billion
Interest Income	Amount of annual interest earned on the loans and advances disbursed.	INR billion
Noninterest Income	Other incomes, other than interest income, earned by the banks annually.	INR billion
Profit	Amount of profit earned annually (after meeting all expenses including provisions and contingencies).	INR billion

Input and Output-Oriented Models – In the case of the input-oriented model, the focus is on minimizing input quantities while maintaining the same level of output. This model evaluates the efficiency of a DMU by determining how much input can be proportionally reduced without decreasing output levels. An efficiency score of "1" (i.e., 100 percent) indicates that the DMU is efficient, meaning that further input reduction without affecting output is not possible. Conversely, a score below "1" indicates inefficiency, implying potential for input reduction. On the other hand, the output-oriented model emphasizes maximizing output quantities while keeping input levels constant. This model assesses the efficiency of a DMU by determining how much output can be increased without increasing inputs. An efficiency score of "1" indicates that the DMU is efficient, and further increase in output without increasing inputs is not possible. Conversely, a score below "1" indicates inefficiency, suggesting room for output improvement.

Efficient Frontier – In DEA, the term "efficient frontier" refers to a group of DMUs that are considered efficient compared to other entities. These DMUs operate at optimal levels, either producing the maximum achievable outputs from a given quantity of inputs or using the minimum required inputs to attain a specific quantity of outputs. Therefore, the efficient frontier serves as a benchmark for assessing the performance of other DMUs. DMUs that are not on the frontier are labeled as inefficient, and the degree of their inefficiency can be measured relative to this benchmark.

CRS efficiency (Constant Returns to Scale), also known as the CCR Model (Charnes, Cooper, and Rhodes), posits that production technology demonstrates constant returns to scale, signifying that scaling up all inputs proportionally leads to a corresponding increase in outputs. The CRS score varies from "0" to "1", with a score of "1" denoting that the DMU is positioned on the efficient frontier.

VRS efficiency (Variable Returns to Scale), also known as the BCC Model (Banker, Charnes, and Cooper), assumes that production technology results in variable returns to scale, allowing for increasing, constant, or decreasing returns to scale. Under VRS, a DMU is considered efficient if it is producing the maximum output possible given the input levels. VRS efficiency accounts for the fact that DMUs may operate at different scales and adjust for this. The VRS efficiency score also ranges between "0" and "1".

Scale efficiency (SE) is a metric that evaluates how effectively a DMU is utilizing its scale of operation. It is determined by the ratio of CRS efficiency to VRS efficiency. A scale efficiency score of "1" suggests that the DMU is operating at its optimal scale, maximizing productivity. A score below "1" signifies inefficiency stemming from scale issues, implying that the DMU has room for improvement by adjusting its operational scale.

Returns to Scale (RTS) refers to how the output responds to a proportional change in all inputs. Therefore, three possibilities exist: (i) increasing returns to scale (IRS) exist when the output increases more than proportionally to the increase in inputs, suggesting that the DMU could improve efficiency by expanding its scale; (ii) constant returns to scale (CRS) occur when output increases proportionally to the increase in inputs, indicating that the DMU is operating at the optimal scale; and (iii) decreasing returns to scale (DRS) take place when output increases less than proportion-ally to the increase in inputs, suggesting that the DMU could improve efficiency by reducing its scale.

In light of the above conceptual framework, we will examine bank cost efficiency using the DEA method.

Evaluation of The Bank Group-wise Cost Efficiency Of SCBs (Input-oriented Model)

Based on the data presented in the panel dataset (Appendix) and utilizing the input-oriented model of DEA, cost efficiency scores are calculated for all SCBs — both individual groups and collectively — and the summary of the test results is tabulated below (Table 3).

Table 3: Cost Efficiency – PSBs, PVSBs, FBs and SCBs

	Public Sector Banks				Private Sector Banks			
	Input				Input			
	CRS Efficiency (CCR Model)	VRS Efficiency (BCC Model)			CRS Efficiency (CCR Model)	VRS Efficiency (BCC Model)		
2014-15	0.00000	1.00000		Increasing	0.00000	1.00000		Increasing
2015-16	0.00000	0.95574		Increasing	0.00000	0.89856		Increasing
2016-17	0.00000	1.00000		Increasing	0.00000	0.81040		Increasing
2017-18	0.00000	0.95600		Increasing	0.00000	0.77658		Increasing
2018-19	0.00000	1.00000		Increasing	0.00000	0.76951		Increasing
2019-20	0.00000	1.00000		Increasing	0.00000	0.93670		Increasing
2020-21	0.00000	0.94534		Increasing	0.00000	1.00000		Increasing
2021-22	0.00000	0.98623		Increasing	0.00000	0.51140		Increasing
2022-23	0.00000	1.00000		Increasing	0.00000	0.52996		Increasing
	Branches of Foreign Banks				Scheduled Commercial Banks			
	Input				Input			
	CRS Efficiency (CCR Model)	VRS Efficiency (BCC Model)			CRS Efficiency (CCR Model)	VRS Efficiency (BCC Model)		
2014-15	0.00000	1.00000		Increasing	0.00000	1.00000		Increasing
2015-16	0.00000	1.00000		Increasing	0.00000	0.93463		Increasing
2016-17	0.00000	1.00000		Increasing	0.00000	1.00000		Increasing
2017-18	0.00000	0.92167		Increasing	0.00000	0.92664		Increasing
2018-19	0.00000	1.00000		Increasing	0.00000	1.00000		Increasing
2019-20	0.00000	1.00000		Increasing	0.00000	1.00000		Increasing
2020-21	0.00000	0.78792		Increasing	0.00000	0.83980		Increasing
2021-22	0.00000	0.98294		Increasing	0.00000	0.84189		Increasing
2022-23	0.00000	0.98723		Increasing	0.00000	0.87863		Increasing

Source: Compiled the table using the calculations made based on the relevant data in the panel data set (Appendix).

Note:

(1) Regarding the CRS efficiency (CCR Model), the result obtained was 0.00000, with potential values greater than zero beyond this precision.

(2) Given that the CRS efficiency is negligible, the Scale Efficiency is significantly lower, with potential values greater than zero beyond the precision of 0.00000. As a result, the "Scale Efficiency" columns have been left blank.

The results of the input-oriented DEA analysis for PSBs over the period from 2014–15 to 2022–23 provide valuable insights into the cost efficiency and scale dynamics of these banking institutions. According to the VRS efficiency scores based on the BCC model, most examined years (2014–15, 2016–17, 2018–19, 2019–20, and 2022–23) show that PSBs achieved full cost efficiency, with a score of 1.00000. This indicates that during these years, PSBs operated efficiently by minimizing costs relative to output levels. However, in 2015–16, 2017–18, 2020–21, and 2021–22, the efficiency scores slightly decreased to below "1", suggesting some minor inefficiencies in cost management. The consistent scale efficiency (SC) of 0.00000 across all years indicates that the inefficiencies observed were not due to scale issues but other factors related to resource utilization. Additionally, the returns to scale (RTS) for all years show an increasing trend, implying that PSBs operated at suboptimal scales and could potentially reduce average costs by expanding their operations. This highlights the presence of untapped economies of scale within these banks and suggests opportunities for enhancing cost efficiency through operational optimization.

The results for the PVSBs reveal a fluctuating pattern in cost efficiency. The CRS efficiency scores, reflecting overall technical efficiency under the assumption of constant returns to scale, consistently register at zero, indicating no cost efficiency in terms of input usage relative to the best-performing DMU/year. However, the VRS efficiency scores, which account for varying returns to scale, present a more nuanced picture. These scores exhibit a general decline from 0.89856 in 2015–16 to a low value of 0.51140 in 2021–22, before slightly improving to 0.52996 in 2022–23. This trend suggests that PVSBs experienced increasing returns to scale throughout the period, indicating potential benefits from scaling up operations, but struggled to optimize their input mix effectively, particularly in the latter years. The observed inefficiencies highlight the need for strategic interventions to increase the operational efficiency of these banks.

The CRS efficiency (CCR model), consistently at zero for FBs, indicates a lack of cost efficiency under the assumption of constant returns to scale. However, the VRS efficiency (BCC model) reveals varying degrees of efficiency under variable returns to scale, with scores ranging from 0.78792 (2020–21) to 1.00000 (2014–17 and 2018–20). The RTS for all years displays an increasing trend, suggesting that these banks operate under increasing returns to scale, implying that they could reduce their average costs by scaling up their operations. This persistent scale inefficiency, combined with fluctuating VRS efficiency, underscores that while some FBs may efficiently manage their resources compared to others in the sample, they are not optimizing their scale of operations effectively.

The results of the input-oriented DEA for SCBs over the period from 2014–15 to 2022–23 reveal notable insights into their cost efficiency. The CRS efficiency, as measured by the CCR model, consistently registers at 0.00000 across all years. This suggests that under the assumption of constant returns to scale, banks are not operating efficiently with respect to cost. In other words, banks have not been able to fully optimize their input usage relative to their output under the CRS assumption, indicating potential inefficiencies at a constant scale of operation. On the other hand, the VRS efficiency, as measured by the BCC model, shows variability, with scores ranging from 0.83980 (2020–21) to 1.00000 (2014–15, 2016–17, and 2018–20). This variation suggests that while some banks are operating efficiently under variable returns to scale, others are not fully utilizing their inputs effectively. The occurrence of perfect VRS efficiency in some years (e.g., 2014–15, 2016–17, 2018–19, and 2019–20) suggests that while banks may not be cost-efficient under the assumption of constant returns to scale, they are efficient when we allow for variable returns to scale. This finding indicates that banks might be better suited to operate at a different scale, as reflected in the scale efficiency (SC) values, which are implied but not explicitly provided. Additionally, the consistent "increasing" nature of RTS across the period indicates that banks have the potential to achieve greater efficiency if they scale up their operations. This pattern suggests that expansion could be a viable strategy for improving overall cost efficiency.

Total Factor Productivity of SCBs – Malmquist Production Index

The results of input-oriented DEA analysis revealed that, under the CCR model (which is based on the assumption of CRS), the efficiency score remained zero. This indicates that an increase in input does not lead to an increase in output. Therefore, the scale efficiency for PSBs, PVSBs, FBs, and SCBs cannot be computed, as CRS stands at zero. Consequently, the analysis is performed based on the Malmquist production index (MPI).

DEA measures the relative efficiency of DMUs with multiple inputs and multiple outputs. Total factor productivity (TFP) is a crucial metric for evaluating the overall efficiency of banks, especially when the DEA method is used. TFP assesses how effectively a bank converts its inputs into outputs. In the

context of DEA, TFP is often evaluated using the MPI, which enables the assessment of productivity changes over time. TFP is essential as it encompasses both technical efficiency (how well a bank utilizes its resources) and technological change (advancements in methods or technologies used, indicating shifts in the production frontier and showing advancements or regressions in technology), providing a holistic view of a bank's performance.

The significance of TFP in assessing bank cost efficiency is its capability to emphasize productivity growth and recognize the fundamental drivers of efficiency. Through TFP analysis, banks can ascertain whether enhancements result from improved resource management or technological progress. This understanding is crucial for formulating strategies to boost productivity and competitiveness. Furthermore, TFP enables benchmarking, assisting banks in pinpointing best practices and areas necessitating enhancement. Ultimately, comprehending and enhancing TFP can result in improved cost management, optimal resource employment, and heightened profitability for banks.

In light of the theoretical framework presented above and utilizing the input and output variables outlined in the panel dataset (Appendix), we calculate TFP and present a summary of the results of calculations in Table 4.

Table 4: Total Factor Productivity (Malmquist Index Summary) of PSBs, PVSBs, FBs, and SCBs (Output-Oriented)

Year	PSBs	PVSBs	FBs	SCBs
Malmquist Index:				
2014-15	1.014	1.046	1.253	1.258
2015-16	1.331	1.065	1.288	1.147
2016-17	0.879	0.993	1.017	0.996
2017-18	4.147	1.036	1.185	1.096
2018-19	0.509	1.026	0.908	1.089
2019-20	0.735	1.051	0.935	0.924
2020-21	0.793	0.577	1.129	1.072
2021-22	0.954	0.938	1.124	1.031
2022-23	1.036	0.990	0.767	0.979
Mean:	1.2664	0.9691	1.0673	1.0658
t-value:	3.442	19.106	18.500	32.227
	(0.009)	(0.001)	(0.001)	(0.001)
Chi-square:	$X^2 = 2.942$; $p = 0.99$; and $df = 16$ (X^2 critical value = 26.296)			
Correlation, '*r*'	• PSBs with SCBs: 0.179 (0.646), • PVSBs with SCBs: 0.078 (0.841), and • FBs with SCBs: 0.730 (0.026).			

Source: Compiled the table using the calculations made based on the relevant data in the Panel Dataset.

Note:

(1) Table value of '*r*' at 0.05 level of significance = 0.602.

(2) Figures in parentheses indicate '*p*' values.

(3) To perform the Malmquist Productivity Index, the profit of PSBs and SCBs which were negative (for a few years) were converted into positive values by adding INR 900 billion to all years of the study period.

Improvement in TFP

The Malmquist Index Summary for TFP across different ownership groups of SCBs in India reveals significant insights into their performance from 2014–15 to 2022–23.

PSBs exhibited significant volatility, with TFP fluctuating widely—highlighted by a dramatic peak in 2017–18 and a sharp decline in subsequent years. These findings suggest that PSBs are highly sensitive to external factors, possibly due to regulatory or internal challenges. Despite these fluctuations, PSBs maintained an average TFP of 1.2664, primarily fueled by exceptional performance in specific years. It is evident (as shown in Table 4) that the TFP of PSBs experienced modest increases of 1.4 percent and 3.6 percent in 2014–15 and 2022–23, respectively, compared with the previous years, with a substantial 33.1 percent surge in 2015–16 compared to 2014–15. The remarkable 314.7 percent spike in TFP in 2017–18 was largely attributed to the increased adoption of technology by PSBs. In subsequent years, PSBs experienced inefficiencies, notably from 2018–19 to 2020–21, operating at 50.90 percent, 73.50 percent, and 79.30 percent of their maximum capacity during those years. However, in 2021–22, the PSBs improved their productivity substantially to 95.4 percent, which further improved in 2022-23 to 103.60 percent.

On the other hand, PVSBs exhibited relatively stable but slightly declining productivity, suggesting the necessity for strategic interventions to bolster their competitive edge and spur productivity growth. PVSBs, with an average of 0.9691, showed a marginal decrease in productivity over the period. In contrast, FBs consistently outperformed, showcasing a continuous enhancement in TFP, which reflects their resilience and adeptness in adapting to market conditions. They sustained a positive trajectory with an average of 1.0673, highlighting their superior performance.

The average TFP for SCBs (Mean = 1.0658) demonstrates an overall positive trend, signifying gradual productivity enhancements in the banking sector as a whole. However, the fluctuation in PSBs and the plateau in PVSBs imply the need for specific policies and strategies to stabilize and enhance productivity across all bank groups, ensuring a more resilient and competitive banking sector in India.

However, based on the above analysis (addressing Objective 1), it is challenging to definitively determine whether there has been an enhancement in TFP and, if so, whether it is deemed significant. To gain a clearer insight into this matter (and to test the first null hypothesis), a *t*-test is conducted. The first null hypothesis (H_{01} = *There is no significant improvement in the TFP of SCBs, PSBs, PVSBs, and FBs*) is consequently evaluated using a *t*-test. As per convention, at a 5 percent significance level with 9 degrees of freedom, the critical *t*-value is 2.262. The computed *t*-values for PSBs (3.442), PVSBs (19.106), FBs (18.5), and SCBs (32.227) surpass the critical value, along with a *p-value* of less than 0.05 (*p-value* for PSBs: 0.009; PVSBs: 0.001; FBs: 0.001 and SCBs: 0.001). Hence, the null hypothesis is rejected (*i.e., not accepted*), and the alternative hypothesis is accepted. Consequently, it can be inferred that there is a statistically significant improvement in the TFPs of PSBs, PVSBs, FBs, and SCBs.

Differences in the Improvement of TFP

The analysis of TFP across different bank ownership structures—PSBs, PVSBs, FBs, and SCBs as a whole—reveals significant differences in productivity trends from 2014–15 to 2022–23. PSBs exhibited the most volatility, with TFP values ranging from a low of 0.509 in 2018–19 to an exceptional peak of 4.147 in 2017–18. This suggests that PSBs experienced considerable fluctuations in productivity, likely influenced by major policy changes or economic factors. On average, PSBs had a TFP of 1.2664, indicating a 26.64 percent productivity improvement over the period, although this value was heavily influenced by the 2017–18 outlier.

PVSBs and FBs exhibited more consistent performances, albeit with varying outcomes. PVSBs showed minor fluctuations, with TFP values generally around '1', yet indicating an overall slight productivity decline, with a mean TFP of 0.9691. In contrast, FBs maintained a stable and positive trajectory, consistently surpassing '1' in TFP values throughout most years, resulting in a mean TFP of 1.0673. This indicates that FBs excel in adapting to market conditions and improving productivity. *The findings of this study align closely with those of earlier research. Tanwar et al. (2020), for instance, conducted an efficiency evaluation of the Indian banking industry using a BCC output-oriented DEA model. Analyzing a panel dataset of 50 Indian banks spanning the period 2009-10 to 2018-19, their study compared efficiency across six ownership structures. The results revealed that most Indian banks were either efficient or nearly fully efficient, with public sector banks (PSBs) outperforming private sector banks (PVSBs) and foreign banks (FBs) in terms of average efficiency. Similarly, Bhattacharyya et al. (1997) found that publicly owned Indian banks exhibited the highest levels of efficiency, followed by foreign-owned and privately owned banks. Of course, a few studies*

also contradicted these findings. For example, Nainggolan et al. (2022) applied stochastic frontier analysis (SFA) to a panel dataset of 38 Indonesian banks (2012–2018). Their findings revealed that larger banks exhibited lower cost efficiency, while reduced credit risk and higher capital adequacy enhanced efficiency. Smaller banks faced significant efficiency challenges, and external factors such as economic growth and inflation were deemed insignificant. Kumar Bhaumik & Dimova (2004) questioned the notion that private ownership inherently improves performance. Their study highlighted agency problems as potential obstacles to private firms outperforming state-owned firms. By 1999-2000, ownership ceased to be a significant determinant of performance, as reforms enabled public sector banks to bridge the gap with private and foreign banks. Anyhow, the overall TFP of SCBs, closely resembling FBs' trends, averaged at 1.0658, demonstrating a steady, modest productivity growth of 6.58 percent over the period.

In summary, the above analysis (addressing Objective 2) emphasizes the significant productivity variations across different bank ownership structures, with PSBs showing the most inconsistent performance, while FBs demonstrated steady and continuous improvements. The findings highlight the importance of PSBs focusing on stabilizing their productivity, PVSBs addressing the slight decline, and FBs leveraging the strengths of their most productive segments.

However, the disparity in the TFP improvement among SCBs remains unclear. Therefore, we conducted another statistical test, the chi-square test, to address this. The chi-square test compared the observed and expected TFP values of PSBs, PVSBs, and FBs simultaneously. At a 5 percent significance level and 16 degrees of freedom, the critical X^2 value is 26.296. However, the computed X2 value of 2.942, as shown in Table 4, indicates that it is lower than the critical X^2value. Additionally, the *p*-value of 0.99 exceeds the alpha value of 0.05. Consequently, the second null hypothesis (H_{02} = *There is no significant difference in the* TFP improvement of PSBs, PVSBs, and FBs) is tested and accepted (*i.e., not rejected*). This acceptance leads to the conclusion that the disparity in TFP among PSBs, PVSBs, and FBs is not statistically significant.

Relationships between the TFP of PSBS, PVSBS, and FBS, and SCBS

The analysis of the Malmquist Index Summary for the TFP of SCBs and their subcategories—PSBs, PVSBs, and FBs—over the period from 2014–15 to 2022–23 provides several insights into the dynamics of productivity changes within the Indian banking sector.

Over the study period, the average TFP change for SCBs stands at 1.0658, signifying overall positive productivity growth. Among the subcategories, PSBs show the highest mean TFP change (1.2664), indicating notable variability and some substantial positive changes, notably in 2017–18 (4.147). However, this elevated mean is partly influenced by extreme fluctuations, which are evident in other years with much lower TFP values (e.g., 0.509 for 2018–19). In contrast, PVSBs display more stable TFP performance, with a mean value of 0.9691, suggesting a slight decline in productivity over the period. FBs, boasting an average TFP change of 1.0673, exhibit more consistent and moderate growth, reflecting the steady performance of foreign banks in India.

However, based on the descriptive analysis above (addressing Objective 3), establishing the relationship between the TFP of each of the three ownership groups of banks and that of SCBs proves to be challenging. Hence, another statistical test is conducted. The third null hypothesis (H_{03} = *There is no significant difference in the contribution of each group to the TFP of SCBs*) primarily focuses on examining the correlation between the TFP of PSBs, PVSBs, and FBs and that of SCBs. Therefore, the correlation between the TFP of each of the three groups of SCBs (PSBs, PVSBs, and FBs) and that of SCBs is calculated, and a summary of the correlation results is presented in Table 4. The correlation results indicate that PSBs and PVSBs had weak positive correlations with SCBs, with correlations between PSBs and SCBs, and between PVSBs and SCBs standing at 0.179 and 0.078, respectively, with *p*-values of 0.646 and 0.841, respectively. In contrast, a strong positive correlation between FBs and SCBs is evident, with an *r*-value of 0.730 and a *p*-value of 0.026. At a 5 percent significance level, since the *p*-values for PSBs with SCBs (0.646), and for PVSBs with SCBs (0.841) are greater than the alpha value of 0.05, the null hypothesis is tested and accepted (*i.e., not rejected*). This suggests that the relationships between PSBs and SCBs, and between PVSBs and SCBs regarding TFP are statistically not significant. However, with the *p*-value for FBs with SCBs (0.026) being less than the alpha value of 0.05, the null hypothesis is tested and rejected, accepting the alternative hypothesis. This implies that the relationship between FBs and SCBs concerning TFP is statistically significant.

Overall, the findings emphasize that among the three ownership groups, foreign banks had the most consistent and significant impact on the productivity dynamics of SCBs throughout the study period.

FINDINGS AND SUGGESTIONS

The analysis of performance statistics of PSBs, PVSBs, and FBs in India reveals distinct characteristics and challenges across these ownership groups. PSBs dominate in terms of total business volume, controlling a significant 66.39 percent share of combined deposits and loans. However, despite their market dominance, PSBs reported the lowest profit, with an annual average of INR 70 billion over the last decade. The high CV of 843.30 percent in profits suggests significant instability, indicating underlying challenges in profitability management. This is further underscored by the relatively lower profit growth rate (CAGR = 10.95 percent) than that of PVSBs (13.91 percent) and FBs (11.51 percent), highlighting potential inefficiencies in resource utilization and strategic management within PSBs.

However, the consistent scale efficiency of 0.00000 across all years implies that the inefficiencies observed within PSBs are not due to scale inefficiencies but rather other factors, possibly related to resource allocation, operational strategies, or external influences. The RTS analysis indicates an "increasing" trend across the study period, suggesting that PSBs are operating below the optimal scale and have the potential to reduce average costs by expanding their operations. This highlights unexploited economies of scale within PSBs, suggesting that strategic scaling or operational optimization could significantly enhance their cost efficiency.

PVSBs exhibited a trend of increasing RTS, indicating potential gains from scaling up operations. However, inefficiencies in input mix optimization, particularly in later years, indicate that PVSBs need strategic interventions to increase their operational efficiency. These banks have shown the capacity for growth, but to capitalize fully on their potential, they need to better manage their resources and operational strategies.

For FBs, the analysis reveals a consistent trend of increasing RTS, mirroring that of PVSBs. Nonetheless, the persistent scale inefficiency and fluctuating VRS efficiency imply that while some FBs demonstrate relatively efficient resource management, they have not fully optimized their operational scale. This suggests that FBs could enhance cost efficiency by expanding their operations and rectifying operational inefficiencies.

The TFP trends reveal significant volatility, especially within PSBs. The dramatic peak in TFP during 2017–18, followed by a sharp decline, suggests that PSBs are highly sensitive to external factors, possibly including regulatory changes or internal challenges. Despite these fluctuations, PSBs maintained an average TFP of 1.2664, largely due to exceptional performance in specific year/s.

The statistical analysis, with *t*-values for PSBs (3.442), PVSBs (19.106), FBs (18.5), and SCBs (32.227), coupled with *p*-values of less than 0.05, indicates a statistically significant improvement in the TFPs across all ownership groups. However, the acceptance of the second null hypothesis suggests that the differences in TFP improvements among PSBs, PVSBs, and FBs are statistically insignificant, pointing to a convergence in productivity trends across these ownership structures.

In the light of the above, a few suggestions, as presented below, are offered for banking companies to consider:

(a) PSBs should consider strategic mergers or expansion plans to achieve optimal scale and stabilize profitability.

(b) The operational efficiency of PVSBs should be increased by focusing on resource optimization and strategic scaling.

(c) FBs could benefit from scaling up their operations while addressing any internal inefficiencies to maintain their competitive edge.

These targeted strategies could lead to improved cost efficiency and better performance outcomes across all ownership groups in the Indian banking sector.

CONCLUSION

The findings of this study underscore the critical importance of strategic scaling and operational optimization across all ownership groups of SCBs to enhance cost efficiency and maintain a competitive edge in the dynamic financial landscape. PSBs encounter significant hurdles in leveraging economies of scale and stabilizing profitability. Therefore, it is crucial for them to embrace innovative resource management strategies and streamline operational processes to enhance overall efficiency. Conversely, PVSBs demonstrate promising growth prospects but require a more refined input mix and targeted operational strategies to fully capitalize on these opportunities. Their agility and capacity for innovation

position them favorably to achieve heightened efficiency levels with appropriate adjustments.

Foreign banks (FBs), while demonstrating consistent performance, face limitations in their scale of operations, which constrain their ability to achieve optimal cost efficiency. Enhancing their market presence and expanding operational capacity without compromising their niche strengths could enable these banks to better align with the efficiency benchmarks of the sector. Collectively, these findings underscore the importance of ownership-specific strategies tailored to the distinct operational dynamics and challenges faced by each group. Policymakers and banking institutions must consider these insights to drive informed decision-making and foster sustainable growth in the Indian banking sector.

LIMITATIONS OF THE STUDY

Despite taking necessary care to make the present study as comprehensive as possible, it is not free from a few limitations, as identified below:

As the study period covers only 10 years from 2013–14 to 2022–23, the performance of selected banks before 2013–14 and after 2022–23 falls outside the scope of the present study. The study focuses on four input variables (total assets, interest cost, noninterest cost, and provisions and contingencies) and five output variables (total deposits, total loans, interest income, noninterest income, and profit). Therefore, other variables do not fall within the scope of the present study. Typically, the decision-making units (DMUs) should be three times the number of input and output variables utilized. With nine total variables in this study, the number of DMUs (years in this analysis) should be ≥ 27, yet only 10 years (i.e., 10 DMUs) are used.

While it is generally recommended that the number of decision-making units (DMUs) be at least three times the total number of input and output variables to ensure robust results in DEA, it is important to note that DEA remains a flexible and widely used tool for efficiency analysis even in cases where this guideline is not fully met. In this study, the limitation of using 10 years (10 DMUs) instead of the recommended 27 DMUs is acknowledged. However, to address this, the input and output variables were carefully selected to represent the critical dimensions of bank performance, ensuring the relevance and validity of the analysis. Additionally, robustness checks were performed to confirm the reliability of the findings despite the lower number of DMUs. The study's focus on a decade-long period provides meaningful insights into the evolving cost efficiency of banks under distinct ownership structures, capturing significant trends and developments during the selected timeframe.

However, every effort has been made to ensure the study is as comprehensive as possible. This includes selecting input and output variables that are widely recognized in the literature as critical determinants of bank performance and efficiency. Additionally, the study employs the DEA approach, which is well-suited for analyzing productivity and efficiency even with a limited number of DMUs. The choice of a 10-year period, from 2013–14 to 2022–23, reflects an effort to capture recent trends and developments in the banking sector, including regulatory changes and economic dynamics. Robustness checks and methodological consistency were applied to validate the findings, and the results were interpreted within the context of the study's scope to provide meaningful insights. While acknowledging the limitations, these measures were undertaken to enhance the reliability and relevance of the analysis.

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Appendix: Panel Dataset of 77 Indian SCBs
Scheduled Commercial Banks in India -Performance Statistics (INR Billion)

	Input Variables				Output Variables				
	Total Assets	Interest Cost	Non-Interest Cost	Provisions and Contin-gencies	Total Deposits	Total Loans	Interest Income	Non-interest Income	Profit
Scheduled Commercial Banks:									
2013-14	109,759.29	5,771.65	1,824.16	1,287.32	85,331.73	68,768.18	8,551.32	1,140.93	809.13
2014-15	120,369.92	6,370.57	2,028.03	1,442.47	94,338.38	75,619.84	9,407.76	1,324.09	890.79
2015-16	131,292.88	6,660.63	2,254.23	2,094.04	100,926.51	81,784.59	9,909.45	1,440.93	341.48
2016-17	141,626.40	6,685.92	2,478.43	2,436.72	111,071.49	84,707.03	10,108.27	1,930.61	437.80
2017-18	152,033.78	6,508.54	2,687.22	3,240.26	117,709.11	92,308.94	10,161.14	1,947.53	-327.35
2018-19	165,175.37	7,063.46	3,030.87	3,273.35	128,374.65	102,316.89	11,307.81	1,815.09	-244.79
2019-20	178,800.33	7,548.53	3,409.68	3,587.93	138,917.02	108,274.09	12,318.82	2,320.08	92.77
2020-21	194,112.66	6,855.57	3,566.40	2,902.80	154,683.10	112,880.19	12,223.29	2,304.08	1,202.60
2021-22	214,540.56	6,568.94	4,016.76	2,439.48	170,270.85	126,108.24	12,459.13	2,377.54	1,811.48
2022-23	240,277.00	7,948.94	4,746.38	2,417.84	188,647.38	145,735.63	15,162.35	2,540.12	2,589.30
Public Sector Banks:									
2013-14	79,683.10	4,371.39	1,205.66	906.33	65,890.20	52,159.20	6,202.28	651.29	370.19
2014-15	86,788.33	4,809.76	1,323.66	1,009.01	71,941.92	56,167.17	6,761.85	755.97	375.40
2015-16	91,680.96	4,920.93	1,455.14	1,529.30	74,861.78	58,274.99	6,906.44	819.00	-179.93
2016-17	97,366.05	4,798.58	1,551.86	1,704.11	80,767.82	58,663.74	6,802.76	1,137.90	-113.89
2017-18	100,349.01	4,552.21	1,642.06	2,410.60	82,623.22	61,416.98	6,603.61	1,147.56	-853.71
2018-19	101,632.26	4,506.14	1,751.14	2,162.11	84,862.15	63,824.61	6,815.75	937.55	-666.08
2019-20	107,828.31	4,680.05	1,927.20	1,996.09	90,484.20	66,151.12	7,162.03	1,181.17	-260.15
2020-21	117,287.99	4,316.27	2,038.55	1,630.45	99,007.66	67,703.63	7,072.01	1,231.44	318.18
2021-22	127,076.43	4,111.81	2,200.91	1,340.88	107,173.62	74,330.06	7,091.32	1,227.68	665.40
2022-23	140,147.93	4,876.90	2,440.64	1,350.18	117,095.81	86,101.15	8,510.78	1,203.43	1,046.49
Private Sector Banks:									
2013-14	22,588.10	1,188.34	465.20	255.03	15,916.94	13,613.23	1,891.36	354.74	337.54
2014-15	26,032.62	1,322.49	541.52	308.51	18,344.70	16,086.57	2,141.45	418.42	387.35
2015-16	31,467.34	1,498.45	637.04	427.75	21,476.73	19,742.40	2,479.84	496.54	413.14
2016-17	36,014.24	1,650.07	758.10	596.18	25,648.39	22,604.08	2,791.69	634.70	422.04
2017-18	42,989.21	1,742.11	865.05	695.81	30,136.88	27,258.91	3,052.50	668.30	417.83
2018-19	52,979.37	2,312.57	1,092.76	989.05	37,700.13	34,423.47	3,936.37	734.22	276.21
2019-20	58,321.23	2,580.38	1,266.63	1,425.35	41,590.44	37,762.31	4,490.06	973.41	191.11
2020-21	64,217.84	2,323.70	1,304.51	1,097.37	47,912.79	40,970.40	4,514.39	905.96	694.77
2021-22	73,718.01	2,242.31	1,566.14	952.16	54,642.41	47,017.33	4,709.40	1,013.44	962.23
2022-23	84,452.03	2,753.91	2,026.16	884.15	62,993.32	54,629.76	5,817.32	1,088.25	1,241.36
Branches of Foreign Banks:									
2013-14	7,488.09	211.92	153.29	125.97	3,524.59	2,995.75	457.69	134.89	101.40
2014-15	7,548.98	238,32	162.85	124.96	4,051.76	3,366.09	504.45	149.70	128.02
2015-16	8,144.58	241.25	162.05	136.99	4,588.00	3,767.20	523.18	125.39	108.27
2016-17	8,246.11	237.27	168.47	136.44	4,655.28	3,439.21	513.82	158.01	129.65
2017-18	8,695.56	214.22	180.11	133.85	4,949.01	3,633.05	505.04	131.67	108.53
2018-19	10,563.75	244.76	186.97	122.20	5,812.38	4,068.81	555.69	143.32	145.08
2019-20	12,650.79	288.10	215.84	166.48	6,842.39	4,360.66	666.73	165.50	161.80
2020-21	12,606.82	215.60	223.34	174.98	7,762.66	4,206.17	636.88	166.69	189.65
2021-22	13,746.12	214.82	249.72	146.45	8,454.82	4,760.85	658.42	136.42	183.85
2022-23	15,677.04	318.14	279.58	183.51	8,558.25	5,004.72	834.25	248.43	301.45

Source: Compiled the Annexure based on the data collected from, the Reserve Bank of India. (December 2023). Report on trend and progress of banking in India, 2022-23. Mumbai. https://www.rbi.org.in/