Assessing Efficiency of Indian Banking Sector in Merger Era: A Two Stage DEA Approach

Dibakar Sahoo, Dr. Ramesh Chandra Das, Dr. Bhagaban Das

Research Scholar, PG Department of Business Management, F.M University,
Balasore, Odisha, PIN-756019
Email id: dibakar456@gmail.com, Mob-9861216864
Asst Professor, PG Dept. of Commerce,
Bhadrak Auto. College, Bhadrak, Odisha, PIN-751014
Email id: rameshchandradas99@gmail.com Mob-9002883115
Former Professor, Head and Dean of PG Dept. of Business Management, F.M
University,Balasore, Odisha, PIN-756019
Email id: drbhagabandas@gmail.com Mob-9437131429

Abstract

Purpose

The main objective of this paper is to present a holistic approach for measuring overall bank efficiency which empirically evaluate the performance of public and private sector banks operating in India.

Design/methodology/approach

A two-stage Data Envelopment Analysis (DEA) model has been employed to assess intermediation and profitability efficiencies, along with the overall efficiency of banks. In the DEA framework, Overall Technical Efficiency (OTE), Pure Technical Efficiency (PTE), and Scale Efficiency (SE) have been estimated for all 12 Public Sector Banks (PSBs) and 12 Private Sector Banks (PVTs) using an input-oriented approach. Furthermore, Tobit regression has been applied to identify the key determinants influencing bank efficiency. The study covers the period from 2010 to 2024.

Findings

The findings from the CRS and VRS measures indicate that Indian banks have struggled to utilize their inputs efficiently and transform them into outputs, suggesting that they do not operate at an optimal level. A comparative assessment of public and private sector banks in India reveals that private banks outperform public banks in terms of profitability efficiency. However, public sector banks demonstrate higher efficiency scores overall, followed by their private counterparts. Another key observation is that none of the banks achieved full efficiency throughout the study period. Factors influencing efficiency include firm size, return on assets, market share, and ownership, while profitability efficiency is primarily determined by diversification and ownership structure.

Research limitations/implications

This study provides valuable insights for the Indian banking sector, helping institutions identify and address areas where they are lagging to enhance overall performance. Additionally, factors such as loan waivers and the disposal of non-performing assets (NPAs) were not included in the analysis due to the unavailability of relevant data in the output measures of the DEA model.

Originality/value

This paper not only offers a comprehensive performance evaluation of Indian banks but also analyses their internal efficiency using deposits as an intermediary measure.

Keywords: Data Envelopment Analysis, Tobit Regression, Bank Efficiency, Merger Era, NPA, Profitability, CCR Model, BCC Model

JEL Classification Codes- G21, G20, G34

Introduction

The banking sector serves as a cornerstone of economic development, playing a vital role in ensuring financial stability, resource mobilization, and investment facilitation (Mohan, 2006). In India, the sector has undergone significant transformations, particularly after the liberalization reforms of the 1990s. These reforms aimed to enhance competitiveness, improve operational efficiency, and expand financial inclusion (Reddy, 2005). Among the various measures introduced, mergers and acquisitions (M&As) have emerged as a strategic approach to address critical challenges such as rising non-performing assets (NPAs), inadequate capital reserves, and fragmented market structures (Kaur & Kaur, 2010).

In recent years, Indian banks have encountered multiple hurdles, including increasing NPAs, regulatory challenges, and the need for digital transformation. To mitigate these issues, policymakers and regulatory bodies have implemented various initiatives, such as bank recapitalization, the Insolvency and Bankruptcy Code (IBC), and the promotion of mergers and consolidations. These measures are intended to strengthen banking institutions, enabling them to drive economic growth and remain competitive in the global financial landscape (Yadav et al., 2018).

The ongoing "merger era" in India's banking industry has been characterized by both government-led and market-driven consolidations. These mergers aim to create stronger financial entities capable of achieving economies of scale, expanding market reach, and competing internationally (Das & Ghosh, 2006). However, the effectiveness of these mergers largely depends on their ability to enhance the operational efficiency and overall performance of the involved banks. Efficiency serves as a crucial metric for evaluating whether these consolidations have led to cost optimization, improved resource allocation, and enhanced financial performance (Berger & Humphrey, 1997).

This study examines the efficiency of Indian banks during the merger era using a two-stage Data Envelopment Analysis (DEA) approach. This dual-stage analysis provides a comprehensive perspective on bank efficiency and identifies key influencing factors (Ouenniche & Carrales, 2018; Kwon & Lee, 2015; Patra, Pradhan & Padhi, 2023; Goswami et al., 2019). DEA, a well-established non-parametric methodology, is particularly useful for evaluating banking efficiency as it accounts for multiple input-output relationships and provides insights into both operational and financial efficiency (Cooper et al., 2011). In the second stage, Tobit regression analysis is applied to identify the factors affecting financial efficiency (Xiping & Yuesheng, 2010; Liu et al., 2018; Eritrea, 2007; Kumar & Gulati, 2009; McDonald, 2009). By employing this two-stage framework, the study offers deeper insights into the factors influencing efficiency and provides a nuanced understanding of pre- and post-merger dynamics.

The findings of this research are expected to contribute significantly to the ongoing discourse on banking sector reforms in India. They will offer practical insights for policymakers, helping assess the effectiveness of consolidation strategies and identify areas requiring efficiency improvements. Moreover, the study provides valuable perspectives for banking professionals and researchers, enhancing the understanding of how mergers impact the performance and long-term sustainability of financial institutions.

DEA, originally introduced by Charnes, Cooper, and Rhodes (1978), is a widely used non-parametric approach for assessing bank efficiency. It evaluates multiple inputs and outputs, making it particularly relevant for financial institutions that utilize diverse resources to generate various forms of income. The DEA framework includes two key models: the CCR model, which assumes constant returns to scale, and the BCC model, which operates under variable returns to scale. DEA is frequently applied in operations research and economics to estimate production frontiers and assess the relative efficiency of decision-making units (Cooper et al., 2007; Vazquez-Rowe & Tyedmers, 2013; Avadi et al., 2014). It employs mathematical programming techniques to identify best practices and benchmark efficiency (Bogetoft & Otto, 2011).

The methodology has been widely utilized in diverse research areas, including economic efficiency analysis (Ferreira et al., 2021), regional economic assessments (Ibrahim et al., 2021), resource optimization (Ibrahim et al., 2019), sustainable development evaluation (Amin et al., 2022), performance measurement (Amaral et al., 2022; Cetrulo et al., 2020), and risk assessment (Hu et al., 2018). The advantages of DEA include: (1) its ability to handle multiple input and output variables while generating a single efficiency score, (2) its non-reliance on specific assumptions, (3) its flexibility in dealing with different measurement units for inputs and outputs, and (4) its capability to assess relative efficiency based on a given dataset (Cooper et al., 2007). According to Kumar and Singh (2014), one of DEA's primary strengths is its adaptability to various input-output metrics. Over time, DEA has emerged as the dominant non-parametric technique for evaluating the efficiency of decision-making units handling multiple inputs to generate multiple outputs (Pereira et al., 2021).

In light of evolving economic and financial conditions, assessing the efficiency of commercial banks has become essential for improving institutional performance and ensuring financial sustainability. A holistic approach to institutional performance integrates efficient resource utilization with enhanced service quality. Meanwhile, achieving financial sustainability remains a challenge amidst economic uncertainties and dynamic market conditions (Rasha et al., 2024).

The structure of this article as follows. Section 2 and 3 discuss the review of literature and theoretical framework, followed by research objective respectively. Section 4 outlines methodology used in this study, explaining the model approach in detail. In sections 5, result analysis and discussions are presented. Finally, Section 6 is devoted to the conclusions and future recommendations and also the limitation of the study.

Review of Literature

In the analysis of the banking sector, researchers predominantly utilize the Data Envelopment Analysis (DEA) model to assess banking efficiency. Numerous studies have focused on the application of DEA in evaluating efficiency outcomes following bank mergers. Over the last two decades, there has been a significant increase in research efforts aimed at measuring banking industry efficiency.

Regarding bank performance evaluation using DEA, Saha and Ravisankar (2000) developed a framework to assess the relative efficiency of Indian public sector banks (PSBs) from the perspectives of regulators and investors. Similarly, Bhattacharyya et al. (1997) examined the efficiency of Indian banks during the early phase of liberalization using DEA and complemented their findings with stochastic frontier analysis to explain efficiency variations.

Bank mergers are often pursued to achieve economies of scale, enhance cost efficiency, expand market share, and improve profitability. Research in banking and finance identifies mergers as a strategic response to competition, regulatory requirements, and economic challenges. Studies by Berger and Humphrey (1997) and Altunbas and Marques (2008) suggest that mergers can enhance cost efficiency by eliminating redundant operations and leveraging economies of scale. Additionally, profit efficiency improvements stem from better revenue generation and optimized resource allocation.

In the Indian banking context, financial sector liberalization in the early 1990s and subsequent regulatory reforms led to multiple mergers, including the consolidation of the State Bank of India (SBI) with its associate banks. Studies by Sathye (2005) and Das, Nag, and Ray (2005) have explored the efficiency implications of mergers among PSBs, concluding that outcomes vary depending on the banks involved. Their research indicates that private sector banks generally exhibit lower efficiency levels than public and foreign banks.

Seiford and Thrall (1990) and Coelli et al. (2005) established DEA as a standard methodology for banking efficiency analysis, enabling comparisons across banks and over time. DEA is employed in two orientations: the input-oriented model minimizes resource utilization for a given level of output (cost efficiency), while the output-oriented model maximizes outputs using existing resources (profit efficiency). Both orientations are essential in post-merger evaluations to assess cost management and profit generation capabilities.

Research by Bhattacharyya, Lovell, and Sahay (1997) highlights that mergers can reveal input redundancies, such as overlapping branches and excess staffing, particularly in PSBs, where operational efficiency is often lower. DEA models facilitate slack analysis, identifying potential areas for resource reduction post-merger. Their study also found that deregulation improved the efficiency of Indian commercial banks.

Das and Ghosh (2006) analyzed PSBs in India from 1992 to 2004, using deposits, number of employees, fixed assets, and equity as inputs, while considering investments, loans and advances, and non-interest fee-based incomes as outputs. Their findings indicated that many PSBs did not achieve anticipated cost efficiency gains post-merger due to integration expenses and regulatory constraints. However, they noted that larger banks demonstrated a higher potential for efficiency improvements post-merger due to their scale advantages.

Das et al. (2009) applied DEA to measure labor efficiency across branches of a large Indian PSB. They concluded that organizational policies and incentives could not entirely mitigate the impact of local work environments. Downsizing subordinate and clerical staff was identified as a potential strategy for reducing labor costs.

To develop a more efficient model compared to conventional DEA, researchers proposed a two-stage approach. Wang et al. (2014) utilized two-stage network DEA to measure the efficiency of Chinese banks during the third round of banking reforms. Their study revealed that the two-stage DEA model outperformed conventional DEA, with state-owned banks performing better than joint-stock commercial banks. Additionally, banking reforms contributed to improved efficiency.

Ohsato and Takahashi (2015) evaluated the management efficiency of regional banks in Japan using network DEA. Their study considered deposit interest, branches, and employees as inputs, while non-interest and interest income were treated as outputs.

Paradi et al. (2011) employed a two-stage DEA methodology to assess the operational performance of Canadian banks. They developed a modified Slacks-Based Measurement (SBM) model to generate performance indices for banking units, finding that small and medium-sized branches were more efficient in profitability and production metrics.

Sufian and Noor (2009) applied output-oriented DEA models to assess profit efficiency using outputs such as interest income, non-interest income, and total loans. Sufian and Noor (2013) analyzed the profit efficiency of Malaysian domestic Islamic banks from 2006 to 2010 using an output-oriented DEA model with deposits and labor as inputs and loans and investments as outputs. Their findings indicated that Malaysian domestic Islamic banks exhibited lower cost efficiency than foreign Islamic banks, with revenue efficiency being a key determinant of overall profit efficiency.

Kumar and Gulati (2008) examined post-liberalization efficiency in Indian banks, concluding that mergers could enhance profitability if resources were effectively utilized to expand lending, deposits, and fee-based income. Ray and Das (2010) analyzed Indian bank branches, finding significant efficiency variations across regions. Their findings are relevant to SBI's post-merger analysis, as regional disparities in efficiency may persist.

Kaur and Gupta (2010) incorporated risk-adjusted DEA models to assess Indian bank efficiency, integrating risk factors such as non-performing assets (NPAs). For SBI post-merger, evaluating profit efficiency with a risk-adjusted DEA model provides insights into how effectively the bank manages credit risks while maintaining profitability.

Bhatia and Mahendru (2015, 2017) analyzed Indian commercial banks, considering deposits, borrowings, and number of employees as inputs, with investments, advances, and non-interest income as outputs. Their findings indicated that foreign banks exhibited higher cost and profit efficiency compared to public and private sector banks.

Maity and Sahu (2017) assessed the efficiency of SBI's associate banks in the pre-merger period using DEA. The study included three output variables (deposits, advances, and total income) and four input variables (number of bank branches, ATMs, total assets, and gross NPAs), measuring overall technical efficiency (OTE), pure technical efficiency (PTE), and scale efficiency (SE).

Mittal and Kishore (2019) conducted a comparative DEA-based study on pre- and post-merger bank performance, concluding that mergers enhanced cost efficiency but required time to achieve full operational synergies.

Aggarwal and Kaur (2021) applied the Malmquist Productivity Index (MPI) to assess productivity changes in SBI post-merger. Their findings suggested that technological advancements contributed to productivity growth, while cost efficiency improvements were initially limited due to integration expenses.

Jayaraman et al. (2022) examined the impact of mergers and acquisitions on Indian bank efficiency using DEA. Their study compared efficiency scores three years before and after mergers, finding that technical efficiency declined immediately post-merger but improved from the third year onward. The study also noted that the effect of mergers on profitability and operational costs was minimal in the initial years.

Shenoy and Shailashri (2021) highlighted that financial performance evaluation is a key method for assessing operational efficiency, with ratio analysis indicating a decline in profitability, asset quality, and employee productivity post-merger.

Kumar et al. (2019) quantified the impact of mergers on Indian banks' operational efficiency using DEA. They analyzed secondary data from the Reserve Bank of India (RBI) on five major mergers between 2000 and 2005, concluding that market-driven mergers enhanced efficiency, whereas forced mergers led to declines in efficiency.

Theoretical Farmwork

The consolidation era in India's banking sector has seen significant changes, with several public sector banks (PSBs) undergoing mergers (*Table 1*). For instance, State Bank of India (SBI) merged with its associate banks, and in 2019, Bank of Baroda, Vijaya Bank, and Dena Bank were merged. From 2014 to 2024, the number of PSBs has been reduced from 24 to just 12. This trend highlights the growing importance of consolidation within the sector, prompting the author to explore the impact of these mergers.

Table 1 List of the PSBs Merger from 2017 to 2022

YEAR	BANK NAME	MERGED ENTITIES
2017	State Bank of India (SBI)	- State Bank of Bikaner & Jaipur (SBBJ)
		- State Bank of Hyderabad (SBH)
		- State Bank of Mysore (SBM)
		- State Bank of Patiala (SBP)
		- State Bank of Travancore (SBT)
		- Bharatiya Mahila Bank
2019-20	Punjab National Bank (PNB)	- Oriental Bank of Commerce (OBC)
		- United Bank of India
	Bank of Baroda	- Vijaya Bank
		- Dena Bank
	Canara Bank	- Syndicate Bank
	Union Bank of India	- Andhra Bank
		- Corporation Bank
	Indian Bank	- Allahabad Bank

Source: Authors' collection

The Narasimham Committee, recognizing the challenges of excessive fragmentation and inefficiency in India's banking sector, proposed a structured four-tier banking hierarchy. At the highest level, it suggested the presence of three to four large public sector banks with international capabilities, followed by national banks with a strong domestic footprint. Below them, regional banks would cater to specific states or areas, while rural development banks would focus on agricultural financing at the grassroots level. To enhance efficiency and achieve economies of scale, the committee advocated for the consolidation of banks within each tier. It emphasized the importance of strengthening the banking system by merging major public sector banks to enhance global trade competitiveness. However, it cautioned against merging financially strong banks with weaker ones, as this could undermine overall stability.

To improve financial health, the committee set a target for banks to reduce their Non-Performing Assets (NPAs) to 3% by 2002. Additionally, it recommended the establishment of

Asset Reconstruction Funds or Asset Reconstruction Companies to manage and recover bad loans effectively.

Objective of the Study

The study aims to analyze the efficiency scores—Overall Technical Efficiency (OTE), Pure Technical Efficiency (PTE), and Scale Efficiency (SE)—of public and private sector banks in India during the merger era from 2010 to 2024. Additionally, it seeks to explore the relationship between these efficiency scores and various key performance indicator (KPI) variables to understand their impact on banking performance.

Research Methodology

Sample Selection:

The study considers a sample of 12 Public Sector Banks (PSBs) to represent the entire public banking sector in India. Additionally, 12 leading Private Sector Banks (PVTs) have been selected based on their total assets, despite the presence of numerous private banks in the country. Since the research aims to conduct a comparative efficiency analysis of public and private sector banks, an equivalent number of banks from both sectors has been chosen to ensure a balanced evaluation.

Source of Data:

The research relies on secondary data sources, including published reports from the Reserve Bank of India (RBI) and annual reports of the selected banks. Supplementary data has been gathered from financial platforms such as Moneycontrol and other relevant websites. The input and output variables for the study have been extracted from the PROWESS database, which is maintained by the Center for Monitoring Indian Economy (CMIE). All collected data is considered on a stand-alone basis to maintain consistency.

Period of Study:

The study period plays a crucial role in achieving the research objectives. In 2014, there were 24 PSBs operating in India; however, following major banking sector reforms and mergers, this number reduced to 12 (*Table 2*). Significant consolidation occurred in 2017 and 2020, making it essential to assess both pre-merger and post-merger efficiency. Consequently, the study spans 15 financial years, from FY 2009-10 to FY 2023-24. After reviewing existing literature, the intermediation approach has been identified as the most suitable framework for this research, given the intermediary role banks play in financial systems.

Table 2 Sample composition

SL NO	Bank Name	Abbreviation	Total Assets	Type
1	State Bank of India	SBI	6,179,693.95	PSB
2	Bank of Baroda	BOB	1,585,797.09	PSB
3	Punjab and National Bank	PNB	1,561,835.01	PSB
4	Canara Bank	CANARA	1,491,540.72	PSB
5	Union Bank	UNION	1,391,957.62	PSB
6	Bank of India	BOI	912,597.92	PSB
7	Indian Bank	INDIAN	792,619.12	PSB
8	Central Bank	CENTRAL	446,672.68	PSB
9	Indian Overseas Bank	IOB	352,033.62	PSB
10	UCO Bank	UCO	323,691.45	PSB
11	Bank of Maharastra	BOM	307,137.86	PSB
12	Punjab & Sind Bank	P&SB	147,656.53	PSB
13	HDFC Bank	HDFC	3,617,623.09	PVT
14	ICICI Bank	ICICI	1,871,514.58	PVT
15	Axis Bank	AXIS	1,477,208.60	PVT
16	IndusInd Bank	INDUS	514,935.14	PVT
17	Kotak Mahindra Bank	KOTAK	600,357.05	PVT
18	Yes Bank	YES	405,492.99	PVT
19	IDBI Bank	IDBI	363,190.47	PVT
20	Federal Bank	FEDERAL	308,311.80	PVT
21	IDFC First Bank	IDFC	296,115.10	PVT
22	Bandhan Bank	BANDHAN	177,841.66	PVT
23	JK Bank	JKB	154,526.59	PVT
24	RBL Bank	RBL	138,432.21	PVT

Source: Authors collection

Selection of Model and Orientation

Data Envelopment Analysis (DEA), originally introduced by Charnes et al. (1978), was used to assess the efficiency of banks in India. This non-parametric technique is widely applied in the banking sector to evaluate how effectively financial institutions convert inputs into outputs compared to their peers. The methodology is grounded in the concept of technical efficiency, which measures how well a bank utilizes resources to achieve optimal performance (Chaluvadi, Raut, & Gardas, 2018).

There are two primary DEA models: Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS). The CRS model, formulated by Charnes et al. (1978), assumes that all Decision-Making Units (DMUs) operate at an optimal efficiency level. This requires them to function at the flat portion of the long-run average cost curve (Banker et al., 1984; Coelli, 1996). However, in practical scenarios, factors such as financial constraints, regulatory limitations, and information asymmetry may prevent DMUs from achieving optimal scale efficiency (Coelli et al., 2005).

To address these real-world inefficiencies, the VRS model, introduced by Banker et al. (1984), was employed in this study. Unlike CRS, the VRS model accounts for scale inefficiencies and assumes that not all DMUs operate at an optimal level, thus incorporating the effects of imperfect competition (Coelli, 1996). By using the VRS model, this study isolates Pure Technical Efficiency (PTE) from scale effects, providing a more accurate measure of managerial efficiency. The Scale Efficiency (SE) of a bank can then be determined by calculating the ratio of Overall Technical Efficiency (OTE) to PTE.

$$SE = \frac{OTE}{PTE}$$

Scale Efficiency (SE) plays a crucial role in helping managers determine the optimal size of operations. Since Pure Technical Efficiency (PTE) and Scale Efficiency (SE) are independent and non-additive, their interpretations must be considered separately. This study employs the input-oriented approach under both the CCR and BCC models. This choice is particularly relevant in the Indian banking sector, where institutions face narrowing profit margins and increasing pressure to optimize costs while maximizing revenue. The input-oriented model aligns with these challenges by emphasizing cost control and resource efficiency. Since bank managers typically have greater control over input factors such as operational costs, capital, and labor—rather than directly influencing output demand—the input-oriented model is more appropriate (Taylor et al., 2022). Furthermore, the VRS DEA model (BCC model) has been adopted in this study, as it accounts for scale differences among DMUs, making it a suitable choice for evaluating the efficiency of banks operating at varying scales.

All statistical analyses were conducted using R Statistical Software (v4.2.2; R Core Team, 2022). Data Envelopment Analysis (DEA) was performed utilizing the rDEA package (v1.2-7; Simm & Besstremyannaya, 2023), while Tobit regression analysis was carried out using the AER package (v1.2-10; Kleiber & Zeileis, 2008). A p-value of less than 0.05 was considered statistically significant for all tests.

Table 3 Prior authors used approaches to measure the bank efficiency

Production Approach	Berger Et Al. (1987), Hunter and Timme (1995), Berger And Deyoung (1997), Resti (1997), Saha and Ravishankar (2000), Devaney and Weber (2002), Glass Et Al. (2010), Nandy and Baidya (2012)
Intermediation Approach	Aly et al. (1990), Zaim (1995), DeYoung and Nolle (1998), Das (1997), DeYoung and Hasan (1998), Mukherjee et. al (2002), Rammohan and Ray (2004), Beccalli et al. (2006), Ray (2007), Das & Ghos(2009), Chansarn(2008) Lozano-Vivas and Pasiouras (2010), Banker et al. (2010), Hsiao et al. (2010), Nandy and Baidya (2012), Bhatia & Mahendaru (2019), Sura et.al(2023)

Source: Authors' collection

Selection of Input and Output variables

In order to estimate efficiency using the Data Envelopment Analysis (DEA) method, it is essential to carefully determine the appropriate inputs and outputs for banking institutions. However, defining these variables remains a subject of debate due to the complex nature of banking operations. A key point of contention is the classification of deposits and other liabilities—whether they should be considered inputs or outputs in the banking process.

Some researchers advocate for the production approach, arguing that deposits should be treated as outputs because banks provide deposit-related services to customers. On the other hand, the intermediation approach, introduced by Sealey and Lindley (1977), views banks as financial intermediaries that utilize deposits and liabilities to issue loans and invest in income-generating assets. According to this perspective, deposits function as inputs rather than outputs. Given the fundamental role of banks in channeling funds between depositors and borrowers, this study adopts the intermediation approach (Table 3), which is widely regarded as more suitable for evaluating banking efficiency. This approach aligns with the core function of banks in financial markets and has been extensively used in empirical research.

Impact of Non-Performing Assets (NPAs) on Efficiency

One of the significant challenges affecting banking efficiency is the presence of Non-Performing Assets (NPAs). High NPA levels negatively impact a bank's ability to operate efficiently, as they reduce the availability of funds for issuing new loans and investments. The accumulation of NPAs not only weakens the financial health of banks but also affects overall profitability and stability. Research on banking efficiency in Brazil has shown that a high volume of NPAs on bank balance sheets can significantly hinder banking operations (Takahashi, 2024). This insight further emphasizes the importance of managing NPAs to sustain banking efficiency and financial performance. The selection of input/output variables are given in Table 4

Table 4 List of Input and Output variables for Data Envelopment Analysis

NAME OF VARIABLE	SYMBOL	VARIABLE TYPE	LITERATURE REVIEW
NET NPA TO NET ADVANCE	AQ	Output	Das (1997); Das (2000); Sathye (2003); Mohan and Ray (2004) and Kumar and Gulati (2008) . Debasis(2006)
RETURN ON ASSET	ROA		Gulati (2008); Burgstaller (2013) and Sinha andSaha and Ravisankar (2000); Mukherjee et al.(2002); Sathye (2003); Das et al. (2004); Chakrabarti and Chawla (2005); Kumar and Jain (2015).
OPERATING EXPENSE	OPEX	Input	Goswami et al.(2019), Bhattacharyya et al. (1997), Mukharjee et.al(2002)
DEPOSITS	Deposit		Bhattacharyya et al. (1997); Saha and Ravisankar, (2000); Mukherjee et al. (2002); Sathye (2003); Chakrabarti and Chawla (2005) and Ordia and Bhanawat (2018).
GROSS NPA	NPA		Saha and Ravisankar (2000); Sathye (2003); Das and Ghosh (2006); Burgstaller (2013); Sinha and Jain (2015); Maity and Sahu (2017) and Sharma

Source: Authors calculation

Result Analysis and Interpretation

The analysis of bank efficiency is measured through data envelopment analysis and in the second stage impact of key determinants of bank efficiency are studied by using the Tobit regression. The descriptive statistics (Table 5) of input/output variables are presented. Operating expenses, deposits, and gross NPAs represent the inputs, with deposits showing the highest variability (SD = 623699.1) and a maximum of 4.97 million, indicating significant differences in bank sizes. Net NPA to Net Advances and Return on Assets (ROA) serve as output measures, with Net NPA to Net Advances averaging 2.46%, suggesting varying levels of asset quality across banks. ROA, a key profitability metric, has a mean of 0.63% but ranges widely from -5.15% to 4.45%, highlighting differences in financial performance and profitability among banks.

Table 5 Descriptive statistics of Input/Output variables

VARIABLE	MEAN	SD	MIN	MAX
INPUT				
Operating Expense	11671.5	18736.88	0	152269.3
Deposit	388229.6	623699.1	0	4966537
Gross NPA	18714.55	27481.01	0	223427.5
Output				
AQ	2.46308	2.84355	0	16.69101
Return on Asset	0.629806	1.139906	-5.15	4.45

Source: Authors' calculation

Data Envelopment Analysis (DEA) – 1st Stage Analysis

Table 6 presents the mean efficiency scores of 24 Indian commercial banks over the period 2010–2024, derived using the DEA model in "R" software. The sample includes 12 public sector banks (PSBs) and 12 private sector banks (PVTs). Efficiency scores were calculated using the CCR model under Constant Returns to Scale (CRS) and the BCC model under Variable Returns to Scale (VRS).

The analysis reveals notable differences in efficiency between public and private sector banks. Among PSBs, Punjab & Sind Bank demonstrates the highest efficiency, achieving perfect scores in Overall Technical Efficiency (OTE), Pure Technical Efficiency (PTE), and Scale Efficiency (SE). Bank of Baroda and Bank of Maharashtra also perform well across all efficiency parameters. In contrast, State Bank of India (SBI) records the lowest efficiency, indicating challenges in both scale and managerial effectiveness, requiring better input optimization. Moderate performers such as Punjab National Bank, Canara Bank, and Union Bank need improvements, particularly in scale efficiency.

In the private sector, RBL Bank emerges as the most efficient, with near-perfect scores in all categories. Federal Bank, J&K Bank, and Yes Bank also demonstrate strong efficiency, benefiting from balanced managerial strategies and optimal scale. However, major banks like HDFC, ICICI, and Axis Bank exhibit lower efficiency, highlighting inefficiencies in resource utilization and operational scale. While some banks, such as IDBI and IDFC, perform well in specific areas (PTE or SE), they require further improvements to achieve balanced efficiency. Overall, the findings emphasize the need for larger banks to enhance managerial practices and optimize scale efficiency to improve performance.

Table 6 Efficiency Score of Public Sector and Private Sector Banks

DMU No.	*DMU name*	*Mean OTE*	*Mean PTE*	*Mean SE*
PUBLIC SECTOR BANKS		Under CRS	Under VRS	Under VRS
1	SBI	0.06528	0.32421	0.20135
2	BOB	0.97478	0.99550	0.97918
3	PNB	0.22794	0.56873	0.40079
4	CANARA	0.27401	0.46928	0.58390
5	UNION	0.30629	0.48346	0.63353
6	BOI	0.24317	0.27397	0.88758
7	INDIAN	0.71255	0.84991	0.83838
8	CENTRAL	0.43363	0.64413	0.67320
9	IOB	0.60632	0.73342	0.82670
10	UCO	0.77861	0.86770	0.89732
11	BOM	0.93143	0.97142	0.95883
12	PSB	1.00000	1.00000	1.00000
PRIVATE SECTOR BANKS				
1	HDFC	0.11882	0.21875	0.54317
2	ICICI	0.10245	0.28327	0.36167
3	AXIS	0.12312	0.23300	0.52839
4	INDUSIND	0.40007	0.67163	0.59567
5	KOTAK	0.50760	0.74075	0.68525
6	YES	0.57220	0.75152	0.76139
7	IDBI	0.52374	0.89636	0.58430
8	FEDERAL	0.63475	0.83339	0.76165
9	IDFC	0.47773	0.51120	0.93454
10	BANDHAN	0.58612	0.60000	0.97687
11	J&K	0.78775	0.95151	0.82790
12	RBL	0.99237	1.00000	0.99237

Source: Authors' calculation

Tobit Regression- A two Stage Analysis

One of the criticisms of the traditional DEA approach is the difficulty of drawing statistical inference. The same has been addressed by Grosskopf (1996), who suggested a two-stage procedure. In the first stage, DEA is used to estimate efficiency scores. In the second stage, regression analysis is used to explain the efficiency scores. One concern, however, is that efficiency scores are censored. Accordingly, Tobit regression model which accommodates both continuous and categorical variables is used as it can account for truncated data. The Tobit regression is used in two stage analysis. The empirical model designed to explain efficiency is described below:

$$\theta_i = \alpha + \beta_1 AQ + \beta_2 BPE + \beta_3 NPA + \beta_4 SIZE + \beta_5 AGE + \beta_6 ROA + \beta_7 PPE + \beta_8 OWN + \varepsilon \text{------} Eq\ (1)$$

Where,

θ_i : OTE, PTE & SE score of the i^{th} bank derived from CCR model and BCC model
AQ: Asset quality
BPE: Business per employee;
NPA: Provision for NPA
SIZE: Size of the bank
AGE: Age of bank;
ROA: Return on asset
PPE: Profit per employee;
OWN: Ownership

$\beta 0, \beta 1, \beta 2 \ldots\ldots \beta 8$ are the regression parameters to be estimated by using the Tobit model and ε = error

Table 7 Variables used in the Tobit Regression Model

Variable	*Symbol*	*Measurement*	*Mean*	*SD*	*Min*	*Max*
Dependent Variable						
Efficiency Scores	OTE	Estimated DEA Efficiency scores for business DMUs	0.515	0.296	0.065	1
	PTE		0.661	0.263	0.218	1
	SE		0.726	0.220	0.201	1
Independent Variable						
Ownership	Own	Major stake of banking sector contributed by Public Sector Banks (PSB) and Private Sector Banks (PVT)	0.502	0.501	0	1
Return on Assets	ROA	The average net income/profit to total Assets	0.629	1.1399	-5.15	4.45
Provision for NPA	NPA	Log of Total Loss Provisions kept by the banks as per regulatory guidelines for any dilution in the value of assets.	8455.164	27042.05	0	452912.9
Large size of the bank is dummy	SIZE	Value 1 is considered for the banks whose average business size is more than 4 lakh crores	0.791	0.406	0	1
New aged bank is dummy	AGE	Value 1 is considered for the private banks that got established after the year 1991. The year is known for its major economic reform in India. AGE Dummy is not used for PSBs as all the PSBs in India were established prior to 1991.	0.666	0.472	0	1
Business per employee	BPE	Add Deposit+ Advance is divided by total Employees	14.476	6.534	0	37.67
Asset Quality	AQ	Asset quality measured as a ratio of net NPA to Net advances may bear a negative impact on the efficiency of banks if the same is sub-standard.	4.373224	12.11049	0	125.996
Profit per employee	PPE	Total Profit / Number of employees	0.055004	0.130161	-0.877	0.338

Source: Authors' calculation

The Table 7 presents the efficiency and key financial factors of 24 Indian commercial banks from 2010 to 2024. DEA efficiency scores indicate considerable variation, with Overall Technical Efficiency (OTE) averaging 0.515, Pure Technical Efficiency (PTE) at 0.661, and Scale Efficiency (SE) at 0.726, highlighting suboptimal operational scales. Ownership distribution is nearly even between public and private sector banks. Return on Assets (ROA) shows significant disparity (0.629 mean, -5.15 min), while Provision for NPA (NPA) varies widely (8,455.164 mean, 452,912.9 max), reflecting asset quality concerns. Structural factors show that 79.1% of banks are large-sized, and 66.6% of private banks were established post-1991. Business per Employee (BPE) and Profit per Employee (PPE) display high variability, with some banks facing operational inefficiencies. Overall, efficiency levels differ significantly, with larger banks needing strategic reforms to enhance resource utilization and mitigate NPA risks for sustainable growth.

Table 8 Tobit Regression

Dependent Variable:	*Overall Technical Efficiency (OTE)*		
	coefficient	z-score	p-value
Constant	0.596***	9.256	0.000
NPA	-0.014**	−2.345	0.019
AQ	0.003**	2.172	0.030
ROA	0.060*	1.839	0.066
PPE	−0.437	−1.564	0.118
BPE	0.002	0.554	0.580
OWN	−0.081	−1.598	0.110
AGE	0.255***	4.405	0.001
SIZE	−0.324***	−6.794	0.001

*** 0.001 significance level, ** 0.01 Significance level, * 0.05 Significance level

Source: Author’s own calculation

The Tobit regression (Table 8) highlight key factors influencing Overall Technical Efficiency (OTE) in Indian commercial banks. The constant (0.596, $p < 0.01$) indicates a strong baseline efficiency. Non-Performing Assets (NPA) have a significant negative impact (-0.014, $p = 0.019$), suggesting that higher NPAs reduce efficiency, whereas Asset Quality (AQ) positively affects efficiency (0.003, $p = 0.030$), implying that better asset management enhances performance. Return on Assets (ROA) has a weak positive effect (0.060, $p = 0.066$), showing that profitability slightly improves efficiency. However, Profit per Employee (PPE), Business per Employee (BPE), and Ownership (OWN) are statistically insignificant, indicating minimal direct influence. Bank Age (AGE) positively impacts efficiency (0.255, $p = 0.001$), meaning newer private banks perform better, while Bank Size (SIZE) negatively affects efficiency (-0.324, $p = 0.001$), suggesting operational inefficiencies in larger banks. Overall, asset quality, NPAs, and bank size emerge as crucial determinants of banking efficiency.

Table 9 Tobit Regression

Dependent Variable:	*Pure Technical Efficiency (PTE)*		
	coefficient	z-score	p-value
Constant	0.533***	7.617	0.000
NPA	0.013**	−2.007	0.045
AQ	0.004**	2.136	0.033
ROA	0.121***	3.392	0.001
PPE	−0.889***	−2.935	0.003
BPE	0.004	1.126	0.260
OWN	−0.174***	−3.205	0.001
AGE	0.368***	5.873	0.001
SIZE	−0.155***	−2.997	0.003

*** 0.001 significance level, ** 0.01 Significance level, * 0.05 Significance level

Source: Author's own calculation

The regression results (Table 9) reveal key determinants of Pure Technical Efficiency (PTE) in Indian commercial banks. The constant (0.533, $p < 0.01$) indicates a strong baseline efficiency. Non-Performing Assets (NPA) have a significant negative effect (0.013, $p = 0.045$), suggesting that higher NPAs lower managerial efficiency, while Asset Quality (AQ) has a positive impact (0.004, $p = 0.033$), implying that better asset management enhances efficiency. Return on Assets (ROA) significantly improves efficiency (0.121, $p = 0.001$), highlighting the role of profitability in effective resource utilization. However, Profit per Employee (PPE) negatively affects PTE (-0.889, $p = 0.003$), indicating that higher profit per employee does not necessarily translate into better managerial efficiency. Business per Employee (BPE) is insignificant, showing no direct impact. Ownership (OWN) has a strong negative effect (-0.174, $p = 0.001$), suggesting private sector banks are more efficient than public banks. Bank Age (AGE) positively influences efficiency (0.368, $p = 0.001$), indicating that newer private banks perform better. Conversely, Bank Size (SIZE) negatively affects efficiency (-0.155, $p = 0.003$), suggesting that larger banks face managerial inefficiencies. Overall, profitability, asset quality, ownership structure, and bank size play crucial roles in determining PTE.

Table 10 Tobit Regression

Dependent Variable:	*Scale Efficiency (SE)*		
	coefficient	z-score	p-value
Constant	0.592***	9.915	0.001
NPA	-0.026	−0.465	0.641
AQ	0.001	0.948	0.343
ROA	0.064**	2.100	0.036
PPE	−0.377	−1.453	0.146

BPE	0.012***	3.962	0.001
OWN	0.090*	1.940	0.052
AGE	0.051	0.957	0.338
SIZE	−0.140***	−3.173	0.002

*** 0.001 significance level, ** 0.01 Significance level, * 0.05 Significance level

Source: Author's own calculation

The regression results (Table 10) highlight key determinants of Scale Efficiency (SE) in Indian commercial banks. The constant (0.592, $p < 0.01$) indicates a strong baseline efficiency. Return on Assets (ROA) has a significant positive impact (0.064, $p = 0.036$), suggesting that higher profitability improves operational efficiency. Business per Employee (BPE) also positively influences SE (0.012, $p = 0.001$), indicating that workforce productivity contributes to better scale efficiency. Ownership (OWN) has a weak positive effect (0.090, $p = 0.052$), implying that public sector banks may have a slight advantage in scale efficiency. However, Bank Size (SIZE) negatively affects SE (-0.140, $p = 0.002$), suggesting that larger banks struggle with optimizing their scale. Other variables, such as Provision for NPAs (PNPA), Net NPAs to Net Advances (NNPANA), Profit per Employee (PPE), and Bank Age (AGE), are statistically insignificant, indicating minimal direct influence on scale efficiency. Overall, profitability, workforce productivity, ownership structure, and bank size play key roles in determining SE.

Discussion

This study undertakes the first stage analysis by using data envelopment analysis for determining the efficiency score of private and public sector banks. Further, in two stage analysis Tobit regression is used to determine the key determinants of efficiency score of private and public sectors banks separately.

The analysis of 24 Indian commercial banks from 2010 to 2024 highlights efficiency variations using the DEA model in "R" software. Public and private sector banks exhibit differing performance levels, with Punjab & Sind Bank emerging as the most efficient among PSBs, while RBL Bank leads in the private sector. Large institutions like SBI, HDFC, ICICI, and Axis Bank show lower efficiency, indicating challenges in resource optimization and operational scale.

Regression results indicate that NPAs negatively impact Overall Technical Efficiency (OTE) and Pure Technical Efficiency (PTE), while better Asset Quality (AQ) enhances efficiency. Higher Return on Assets (ROA) improves efficiency, though its effect on OTE is weak. Bank Age (AGE) has a positive impact, showing newer private banks perform better, whereas larger banks face inefficiencies. Scale Efficiency (SE) is influenced by ROA, workforce productivity (BPE), and ownership structure.

Overall, improving asset quality, managing NPAs, and optimizing bank size are crucial for enhancing efficiency in Indian banking operations.

Conclusion

This study employs an input-oriented DEA model to evaluate the operational efficiency of SBI using the intermediation approach, where interest income and interest expense serve as key inputs and outputs. Assessing bank efficiency is crucial, particularly in the context of mergers, where stronger banks absorb weaker ones to ensure financial stability. Regular evaluations help identify performance gaps and guide policy recommendations. The merger and acquisition strategy has enhanced the performance of weaker banks by leveraging technology and optimizing resources. SBI has demonstrated notable improvements in efficiency parameters post-merger. The government and RBI have aimed to eliminate policy paralysis and implement technology-driven reforms to strengthen the formal economy. Public and private sector banks in India face increasing pressure to enhance competitiveness. This study examines SBI's operational efficiency before and after its merger, focusing on intermediation factors such as interest income and interest expense using secondary data from 2012-13 to 2021-22. The findings emphasize the need for SBI's management and regulators to monitor efficiency trends and improve other key performance indicators.

However, this study has limitations. It does not include financial parameters like net profit, ROA, ROE, deposits, and capital adequacy, which are critical for a comprehensive efficiency assessment. Additionally, alternative models such as CAMEL, ratio analysis, and DEA time-series methodologies could be explored in future research. Expanding the study period and comparing SBI with other scheduled commercial banks would provide deeper insights into long-term efficiency trends.

Conflict of Interest

The Authors declare no conflict of interest regarding the publication of this paper.

References

Aparna Bhatia, M. M. (2019). Financial Efficiency Evaluation of Indian Scheduled commercial banks. Jindal Journal of Business Research, Sage Publication, 1-14.

Banker, Charnes, & Cooper. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 1078-1092.

Bhattacharya, A. (1998). The impact of liberalization on the productive efficiency of Indian commercial banks. European Journal of Operational Research, 332-345.

Biswajit Patra, P. C. (2023). Efficiency of Indian Banks – private versus public sector banks: A two-stage analysis. Cogent Economics & Finance, 1-17.

Chakrabarti, R. &. (2005). Banking efficiency in India since the reforms: An assessment. Money and Finance, 31-47.

Chaluvadi, S., Raut, R., & Gardas, B. B. (2018). Measuring the performance efficiency of banks in a developing economy: The case study of Indian public sector vs private sector". Benchmarking: An International Journal, 575-606.

Chansarn, S. (2008). The Relative efficiency of commercial banks in Thailand: A DEA approach. International Research Journal of Finance and Economics, 53-68.

Charnes, A., Cooper, W., & Rhodes. (1978). Measuring the efficiency of decision-making units. European Journal of Operational Research, 429-444.

Das, A. &. (2006). Financial deregulation and efficiency: An empirical analysis of Indian banks during the post reform period. Review of Financial Economics, 193-221.

Das, A. (1997). Technical, allocative and scale efficiency of public sector banks in India. Reserve Bank of India Occasional Papers, 279-301.

Das, A. (2009). Financial deregulation and profit efficiency: A non-parametric analysis of Indian banks. Munich Personal RePEc Archive, 15-23.

Das, A. N. (2005). Liberalization, ownership and efficiency in Indian banking a nonparametric analysis. Economic and Political Weekly, 1190-1197.

Das, K. K., & S. P. (2019). Post-Merger Performance of SBI: A Study of SBI and its Five Associate Banks. International Journal of Scientific and Research Publications, 462-466.

Debaprosanna Nandy, M. K. (2012). Efficiency Study on Proposed Merger Plan of State Bank of India (SBI) and its Subsidiaries: A DEA Perspective. International Journal of Productivity Management and Assessment Technologies, 1-17.

Dr. Jasvir S. Sura, D. K. (2023). Efficiency of Indian Public and Private Sector Banks: A Two-Decade Analysis (2001-2021) Using Data Envelopment Analysis. International Journal for Research Publication and Seminar, 361-377.

Dwivedi, A. (2011). Efficiency of Indian banking industry in the post-reform Era. research and publications, 45-49.

Galagadera, D. U. (2005). Performance of Indian commercial banks An application of data envelopment analysis and Malmquist productivity index. Working paper, 125.

Hendrawan, R. a. (2019). 'Assessing bank's efficiency in Indonesia using data envelopment analysis (DEA). Test Engineering and Management, 2755-2763.

j.Burgstaller. (2013). 'Bank office outreach, structure and performance in regional banking Markets. Regional Studies, 1131-1155.

Jayaraman, A., Srinivasan, M., & Arunachalam, R. (2022). Impact of merger and acquisition on the efficiency of Indian banks: a pre-post analysis using data envelopment analysis. International journal of financial services and management, 1-18.

Jolly Puri, S. P. (2014). A fuzzy DEA mode lwit hundesirable fuzzy outputs and its application to the banking sector in India. Expert Systems with Applications Elsevier, 1-14.

Kaur, P. &. (2010). Impact of mergers on the cost efficiency of Indian commercial banks. Eurasian Journal of Business and Economics, 27-50.

Maity, S., & Sahu, T. N. (2017). Pre-merger performance measures of state bank of India and pre-merger performance measures of state bank of India. Business Spectrum, 16-26.

Mohan, R. (2006). Reforms, productivity, and efficiency in banking: The Indian experience. The Pakistan Development Review, 45(4), 437–463.

Mukherjee, A. (2002). Performance benchmarking and strategic homogeneity of Indian Banks. International Journal of Bank Marketing, 122-139.

Rammohan, T. T. (2004). Productivity growth and efficiency in Indian banking: A comparison of public, private, and foreign banks. Economics Working Papers, 27.

Rawat, & R, V. (2018). An Empirical Analysis of the Impact of Merger on the Performance of State Bank of India. Journal of Management and Science, 14-21.

Ray, S. (2007). Are some Indian banks too large? An examination of size efficiency in Indian Banking. Journal of Productivity Analysis, 41-56.

Reddy, A. (2005). Technical efficiency and its decomposition in Indian banks in post liberalization. Capital Markets Conference, Indian Institute of Capital Markets Paper, 8.

Saha, A. &. (2000). Rating of Indian commercial banks: A DEA approach. European Journal of Operational Research, 187-03.

Sahoo, B. K. (2007). Productive performance evaluation of the banking sector in India using data envelopment analysis. International Journal of Operations Research, 63-79.

Sathye, M. (2003). Efficiency of banks in a developing economy: The case of India. European Journal of Operational Research, 662-671.

Shenoy, S. S., & T, S. V. (2021). Impact of Merger on Operational and HR Efficiency: A Case Study of the State Bank of India. International Journal of Case Studies in Business, IT, and Education, 87-99.

Singh, G. &. (2019). The Impact of Merger on Profitability: A Study of State Bank of India and its Associate Banks. Journal of Accounting, Finance and Auditing Studies, 34-46.

Sinha, R. a. (2015). 'Potential gains from merger: a study on SBI and its associates. The IUP Journal of Bank Management, 57-60.

Sunil Kumar, R. G. (2009). Measuring efficiency, effectiveness and performance of Indian public sector banks. International Journal of Productivity and Performance Management, 51-74.

Suryanarayanan, S. (2018). Merger of State Bank of India with its Associate Banks: A Critical Analysis. Asia Pacific Journal of Research in Business Management, 37-42.

Thapa, B. (2019). An Analysis of Merger between State Bank of India and its Associate Banks. International Journal of Marketing and Business Communication, 1-10.

Titko, J., Stankeviciene, J., & lace, N. (2014). Measuring bank efficiency: DEA application. Technological and economic development of economy, 739-757.

Tiwari, & Kumar. (2019). Analyzing the Impact of Merger on Financial Performance of SBI. International Journal of Research in Finance and Marketing, 1-9.

Yadav, P., & Chauhan, K. (2018). Merger of SBI with its Associate Banks: A Study of Financial Performance. International Journal of Scientific Research and Review, 191-197.