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Article

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Unveiling the financial landscape: analyzing profitability, productivity, and efficiency of banks in an emerging economy using the CAMELS framework and panel analysis

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ABSTRACT

This study examines the banking sector's performance by conducting a two-step analysis using balanced panel data from 46 commercial banks operating in India between 2011 and 2023. Initially, we utilized the Data Envelopment Window Analysis and Malmquist Productivity Index measures to analyze the efficiency and total factor productivity index. Second, applying panel regression, we used the CAMELS framework to regress various bank and country-specific factors against Indian banks' performance indicators. The results show that the banking industry in India witnessed a consistent pattern throughout the study period. Despite this, an examination of each bank's performance at the individual level reveals that public banks consistently display the highest average efficiency score, whereas foreign banks are more productivity-advanced. The regression results suggest that Indian Banks have been significantly affected by bank, country-specific and market structure factors. Government initiatives to consolidate banks, positively affect the profitability, productivity, and efficiency of banks, and smooth resource mobilization might cushion an emerging economy such as India.

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1. Introduction

Banks have been playing a significant role in economic growth and development in financial research for decades (Al-Homaidi et al., 2018; Akhtar et al., 2021b; Khan et al., 2024). The literature suggests that a sound banking framework underpins sustained economic growth (Azmi et al., 2020; Karkowska et al., 2023; Maude et al., 2023; Naeem Azmi and Akhtar, 2024). The sound banking framework also ensures the economy's financial stability, supporting inclusive growth, and encouraging investor confidence, which in turn gains investors' confidence (Emara & El Said, 2021; Alam et al., 2024). Like other emerging economies, India is continuously striving towards sustainable growth and prosperity, which requires strengthening sound banking (Barbier & Burgess, 2023; Naseema et al., 2024). However, the recent COVID-19 pandemic has dramatically affected bank profitability, asset management, liquidity management, and digital transformation, which directly impacted Indian economic development (Akhtar et al., 2020b; Karim & Shetu, 2023; Alam & Akhtar, 2024).

The banking sector in India is composed of banks, which can be categorized as 44 foreign banks, 21 private banks, and 12 public banks. During the fiscal years 2018–2023, there was a significant increase in bank assets across several industries, reaching a total of US \$2.70 trillion. In the fiscal year 2023, the combined assets of Public and Private Sector Banks amounted to US\$ 1686.70 billion and US\$ 1016.39 billion, respectively. During the fiscal years 2016–2023, following the implementation of demonetization, there was an observed increase in bank credit at a compound annual growth rate (CAGR) of 0.29%, resulting in a significant surge to a total of US\$ 1487.60 billion. Additionally, deposits experienced a

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growth at a CAGR of 12.38%, reaching a total of US\$ 2.41 trillion. Notably, the digital payment interface known as UPI recorded a substantial number of transactions, amounting to 7.82 billion, with a total value of US\$ 153.77 billion in December 2022¹. According to Economics Times, there is an anticipated increase in credit growth of 16% in FY 22–23, which would be the highest performance in the past eight years².

In the wake of this, the banking system has begun facing several constraints as the economy continues to deteriorate with the involvement of bank fraud, scams, demonetization, the banking crisis in the US and Europe and Covid-19 has exacerbated the situation. In response, banks constantly attempt to improve their end results by implementing various efficiency strategies (Akhtar et al., 2021a). As a result, the Reserve Bank of India (R.B.I.) merged underperforming banks with better-performing banks to avoid economic stagnation. Considering the aforementioned circumstances, academics and policymakers should study and evaluate Indian bank performance.

Therefore, the following question is developed.

1. Does the level of productivity, efficiency, and profitability vary significantly among banks in India?
2. Do internal and external factors affect the productivity, efficiency, and profitability of banks in India?

To explore the answers to the above concerns following research objective is developed.

1. To compute the efficiency score of banks in India using Data Envelopment Window Analysis (DEWA).
2. To compute the productivity score of Indian banks using the Malmquist Productivity Index.
3. To identify and study the impact of internal and external banking factors on the productivity, efficiency, and profitability of Indian banks.

To address the objectives, developing an accurate appraisal of the performance of the Indian banks has become more illuminating. The previous studies have evaluated the performance of banks employing various measures (Haslem et al., 1999; Mercan et al., 2003; Avkiran, 2006; Ho & Wu, 2006; Spokeviciute et al., 2019; Ahmad et al., 2020; Ansari et al., 2023) and reported a strengthened banking sector will boost economic synergies. However, the majority of the studies were undertaken in developed economies (Staub et al., 2010; Avkiran, 2011; Řepková, 2014; Shawtari et al., 2015; Yuan et al., 2022; Jigeer & Koroleva, 2023). In the Indian context, (Bhattacharyya et al., 1997; Saha & Ravisankar, 2000; Mukherjee et al., 2002) were the earlier studies that examined various performance-related issues in the Indian banking sector followed by (Kumar & Gulati, 2009; Roy, 2014; Goyal et al., 2019; Ghose & Maji, 2022; Rakshit, 2023). However, the majority of these studies suffer from various limitations.

The current study intends to fill the empirical void by providing new insights into Indian bank's performance. In this regard, we collected data from 46 banks operating in India from 2011 to 2023 to assess three performance parameters (profitability, productivity, and efficiency) for India's public, private, and foreign banking sectors. By using a two-stage analysis, we investigated the correct picture of the efficiency and productivity score of Indian Banks. First in stage one, by using DEWA, we determine the efficiency score and by Malmquist Productivity Index we determine the total productivity score under the CRS assumption and regress the output variables on banking industry-specific and macro-economic variables using Panel regression on the CAMELS framework in stage two to determine the respective impacts. In the second stage, for variables specific to the banks, apart from others, we have utilized the 'S' as mentioned in the CAMELS framework for sensitivity to market risk ratio to evaluate the consequences of the dynamics pertaining to the rate of interest and foreign exchange, equity and commodity prices onto the capital held by banks.

The findings support a constant efficiency and productivity trend in India during the study period. However, the results of the analysis conducted at the bank-level individually stress that public sector banks record the highest overall average efficiency score, whereas foreign sector banks are more productivity-advanced. The regression analysis findings demonstrate that the Capital Adequacy Ratio (C.A.R.) exerts a statistically significant positive impact on the efficiency, productivity, and profitability of all commercial banks operating in India over the observed time frame. Secondly, business per employee (B.P.E.), management efficiency, and profit per employee (P.P.E.) significantly positively impact all three bank performance parameters, indicating increased staff productivity, leading to a boost bank efficiency,

productivity, and profit. Thirdly, the sensitivity ratio, which was calculated using the ratio of each bank's assets to the total assets of the banking industry as a proxy variable, shows that there is a positive and statistically significant effect on productivity and efficiency. On the other hand, asset quality has a significantly negative effect on all three parameters of bank performance, indicating inefficiency increments, negative profitability, and lower productivity. Additionally, this study also found a negative effect of liquid assets to total assets (LATA) and liquid assets to short-term liability (LASTL) over bank efficiency and productivity. In addition, there is the detailed finding of each independent variable effect discussed and supported by the latest literature in results and discussion.

The remainder of this paper is organized as follows. Section Existing knowledge provides a recapitulation of previously discussed theories. Section [Data and Methodology](#) offers an elaborate account of the dataset, the selection of variables, and the methods employed. Section [Empirical Results and Discussion](#) comprises a two-stage analysis of the results followed by a discussion. Section Conclusion delineates the constraints of our empirical findings and proposes potential avenues for future investigation.

2. Existing knowledge

The global financial meltdown of 2007 has prompted investigations on the influence of bank performance on economies. This topic has been subject to comprehensive examination by regulators, economists, and policymakers in their pursuit of understanding and providing answers. There has been a recent surge in research examining banking performance at the international or multinational level, as evidenced by the works of Kacem and El Harbi (2023), and Buallay et al. (2021). Additionally, scholars have also explored this topic at the regional level, as demonstrated by the studies conducted by Baselga-Pascual and Vähämaa (2021), Alfadli and Rjoub (2020), and Ladeira et al. (2024). Furthermore, there has been a considerable focus on country-specific analyses, with studies conducted by Chaturvedi et al. (2021), and Khan et al. (2021). A thorough analysis of academic literature on financial research reveals a substantial body of theoretical and empirical studies focused on evaluating performance in the banking industry. However, the process of choosing suitable criteria for assessing performance continues to be a subject of ongoing discussion.

Many preliminary studies have specifically concentrated on analyzing profitability and productivity as key factors influencing bank performance. The literature on banking performance has expanded considerably, with a specific emphasis on profitability. Profitability is a core principle in the fields of business and economics. It refers to a company's capacity to make earnings in relation to its expenses and other pertinent costs. Profitability is crucial in financial analysis for evaluating the health and effectiveness of enterprises, especially banks. The primary metrics commonly employed to assess bank profitability include return on assets (ROA), return on equity (ROE) ratio, and net interest margin (NIM) (Ozili & Ndah, 2024; Horobet et al., 2021; Le & Ngo, 2020; Eljelly & Elobeed, 2013). Although Return on Equity (ROE) remains the main performance indicator for most investors and analysts, there are instances where Return on Assets (ROA) can offer a more comprehensive assessment of a company's performance (Hagel et al., 2009). According to analysts at the European Central Bank, a high return on equity (ROE) might indicate either strong profitability or a relatively small amount of equity capital (Bank, 2010).

Additionally, bank performance has also been explored through the lens of productivity and efficiency. Productivity in the banking sector is commonly measured by the ratio of outputs, such as loans and financial services, to inputs, including labor, money, and technology. Berger and Humphrey (1997) describe productivity as a measure of a bank's capacity to generate services using the available resources. Productivity can be evaluated using many approaches, such as total factor productivity (TFP) and measures of partial productivity (Berhe & Ali, 2021). The Total Factor Productivity (TFP) takes into account all inputs as a whole, whereas partial measurements may concentrate on individual inputs such as labor or capital.

Another dimension of bank performance is its efficiency, as it has a direct influence on the stability of the banking sector and the efficacy of the country's economic policy (Nhan et al., 2021; Proença et al., 2023). Bank efficiency ratings serve as indicators of the overall performance of the banking industry (Dang, 2011; Sadalia et al., 2018). Efficiency in banking is described as maximizing outputs from a given set of inputs or minimizing inputs needed to produce a certain level of output. It covers both cost

efficiency, which involves minimizing costs for a given output level, and allocative efficiency, which focuses on the optimal allocation of resources (Farrell, 1957). Efficiency can be measured using frontier analysis techniques like Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). These methods assess the performance of individual banks by comparing them to the best practice frontier, which shows how efficiently a bank operates (Nhan et al., 2021).

Productivity and efficiency growth are parameters that have been an area of immense interest for policymakers. One strand of research posits that economic growth relies on the expansion of inputs and is not limited to marginal growth in output, as it is inevitably subject to diminishing returns (Kumar & Gulati, 2009). The “Malmquist productivity index” and DEWA method are prominently employed to analyze the productivity and efficiency of banks across the nations (Berger and Humphrey, 1997; Tanna et al., 2017; Mansour & El Moussawi, 2020; Hafsal et al., 2020; Rusydiana & As-Salafiyah, 2021). Moreover, several studies have employed DEA to assess the productivity and efficiency of banking institutions (Wang et al., 2014; Fernandes et al., 2018; Shair et al., 2021). In the Indian scenario, total factor productivity index scores have also been widely used in previous studies (Mondal & Ghosh, 2012; Kaur & Gupta, 2015; Kamath, 2015; Tripathy et al., 2015; Maji & Goswami, 2016; Oppong and Pattanayak, 2019). However, the existing literature on Indian banks has been mostly case studies and lacks a comprehensive evaluation of the overall sector, employing the latest techniques for calculating productivity and efficiency scores. The current work intends to bridge the research gap in the literature.

More recently, the CAMEL framework has gained significant recognition as a relevant paradigm for assessing banking performance, aiming to address challenges related to variable selectivity. The CAMEL model is a widely acknowledged and utilized five-parameter framework employed by regulators and policymakers for the purpose of risk assessment. The CAMEL model, was initially developed by the US Federal Reserve, and the Office of the Comptroller. Subsequently, the CAMEL model gained significant popularity and was widely adopted by numerous countries as a means to regulate and oversee the banking sector (Jothr et al., 2021). The CAMEL model is a specialized grading system used by banks to assess their level of security and stability, which is specifically intended for on-site supervision (Qureshi & Siddiqui, 2023). In addition, the CAMEL model rating enhances the precision of predicting the bank's success and failure (Cole & Gunther, 1998). For banking, specifically, it is advisable to use the traditional approach of ratio analysis inside the CAMEL technique (Wanke et al., 2022).

Multiple prior research has indicated that the CAMEL framework is an effective approach for both variable selection and precise assessment of bank performance in both developed and developing countries (Akhtar et al., 2023; Chowdhury & Rasid, 2016; Garcia & Guerreiro, 2016). Nevertheless, the CAMEL technique lacks a comprehensive assessment of the sensitivity ratio. Hence, in order to evaluate the performance of banks, the enlarged CAMELS framework is employed, which incorporates essential elements such as financial and managerial indicators, which are represented by the ‘S’ factor (Bansal et al., 2022; Saeed et al., 2020; Alrafadi et al., 2014; Roman & Şargu, 2013; Sarker, 2005). Despite its perceived superiority, there is a lack of empirical research employing the CAMELS framework to assess the performance of Indian banks. Therefore, the present study endeavors to evaluate the performance of Indian banks based on the CAMELS framework.

3. Data and methodology

3.1. Data

This study measured the effectiveness of banks operating in India with a panel dataset of 46 banks (12 banks in the public domain, 17 in the private domain, and 17 foreign banks) during the period 2011–2023 by using DEWA for efficiency and Malmquist Productivity Index for productivity measure in the first stage. In the second stage, we employed panel regression to evaluate the impact of bank and country-specific variables on the profitability, efficiency and productivity of all three sector banks. We utilize annual data of a secondary nature for our analysis, which is freely available in public databases and annual reports of banks.

For evaluating the technical efficiency (TE) and total factor productivity (TFP) in stage one four input variables, namely deposits, borrowing, labour and physical capital and two output variables

namely interest income and non-interest income were taken into consideration. The input and output variables utilized in the first stage were extracted from annual reports of banks, which can be obtained from the official website of banks. The second stage was to check the impact of bank-specific variables namely capital adequacy, asset quality, asset management, management efficiency, earning quality, liquidity, sensitivity ratio, deposits, bank size and operational efficiency whereas, macro-economic variables namely, gross domestic product and inflation were considered. The variables used in the second stage of the analysis were collected from the Reserve Bank of India (RBI) database.

The choice of banks considered for the analysis is based on two exclusion criteria. Banks that cease to exist or have merged with other banks during the study period and those banks with less than 13 years of data have been excluded. The final dataset comprises of 46 banks, providing 598 observations (13 years), in total for the study period (2011–2023). The time duration of the study, helps researchers compare and evaluate the performance of all three categories of banks in a more prominent manner. The information was gathered from banks' annual reports (input and output variables) and statistical tables relating to banks in India available from the Reserve Bank of India (RBI) database. The sources of data used for the study are freely available to the general public and do not require the users to obtain rights and permission. The data obtained have been analyzed, employing STATA, DEA Solver and DEAP software for analysis.

3.2. Variable selection to estimate efficiency and productivity

Picking suitable input and output variables is the first stage in evaluating the productivity and efficiency of a bank. The appraisal process of an organization is a multifaceted undertaking that encompasses a range of criteria. Prior studies have demonstrated that the evaluation of bank performance can be achieved by the utilization of a multi-factor performance model (Bourke, 1989; Akhtar et al., 2021a). In the financial literature, intermediation and production approaches are often employed methods for selecting input and output structures. The concept of intermediation claims that the primary goal of commercial banks is to assist the conversion of liabilities, primarily deposits, into assets, notably loans. According to Řepková's (2014) research, financial institutions engage in the utilisation of labour resources to facilitate the transformation of deposited funds into loanable assets.

Moreover, this approach evaluates the output in terms of monetary value, where the aggregate expenses encompass both interest and operational expenditures. Conversely, the manufacturing strategy places emphasis on the allocation of financial resources and operational expenditures. The exclusion of interest expenses associated with the value of deposits in this method is due to the perception of deposits as outputs. Nevertheless, there is scepticism around both methods due to the inclusion of deposits that consist of both input and output components, making it challenging to objectively separate them (Kumar, 2008; Henriques et al., 2020).

While the production technique is thought to be the most appropriate method for determining efficiency at the branch level, Berger and Humphrey (1997) state that the intermediation methodology is appropriate for evaluating bank efficiency. Additionally, gathering data related to manufacturing planning presents considerable obstacles. In order to overcome the limitations described before and achieve our goal of analyzing bank efficiency, we utilized the intermediation technique in this study.

Previous research has created a range of methodologies for selecting parameters to assess bank performance (Banker et al., 1984; Sherman & Gold, 1985; Berg et al., 1993; Saha & Ravisankar, 2000; Sathye, 2003; Sahoo et al., 2007; Kumar, 2008; Kumar et al., 2016; Akhtar et al., 2023). The study utilized deposits (x1), borrowings (x2), labour (x3), and physical capital (x4) as inputs. In essence, banks engage in the collection of funds from individuals with surplus capital and subsequently allocate these funds to individuals in need, with the objective of generating profit. This process involves the selection of suitable investment opportunities. Banks engage in borrowing activities by obtaining funds from reserve banks and other commercial banks. In general, the diverse individual expenses, encompassing wages and other related charges, constitute the third component of labour input, which significantly contributes to the bank's overall expenditure. Furthermore, the ultimate contribution of physical capital is considered to be the net worth of acquired fixed assets, after deducting the depreciation value from the overall value of fixed assets.

The output constructs for measuring efficiency and productivity have recently been considered, based on previous research. The interest income is denoted as y_1 and the income other than interest is denoted as y_2 , which is the output construct for the efficiency framework employed in the present research. The distinction between advanced loans and interest paid to depositors is called interest revenue. Banks' non-interest income comes from a variety of sources, including fees, currency income, commissions, bill discounting, and brokerage.

The relationship between the input and output factors was tested using a correlation analysis to corroborate the choice of variables employed in the current study. The degree of correlation significantly affects the resilience of a model (Yang, 2009; Akhtar et al., 2023). The input and output variables were positively and significantly correlated. On the other hand, a weak correlation between any input and the study's output variables indicates a weak fitness of the input variable in the model. Table 1 presents the results of the correlation analysis.

The coefficient of the correlation between the input and output constructs employed in the investigation are listed in Table 1. The test findings show that both the input and output constructs have a positive and significant correlation at the 1% significance level. The results clearly showed that the study uses legitimate input and output components.

3.3. Independent variable selection to estimate the impact on bank performance

The current study has three explanatory variables namely, bank-specific, market structure, and macroeconomic variables which are shown in Table 2. The bank-specific is measured through the capital adequacy, asset quality, asset management, management efficiency, earning quality, liquidity, sensitivity ratio, deposits, bank size, and operating efficiency; for market structure, we have used the Herfindahl–Hirschman Index (HHI) whereas, macroeconomics is measured through gross domestic product and inflation. The detailed measurement of the variable is highlighted in Table 2.

a. Capital adequacy

Capital adequacy pertains to a bank's capacity to satisfy its capital requirements, gauged through a comparison of its available capital with risk-weighted credit exposures, which are adjusted to account for risk factors. This ratio serves to protect depositors' funds and fosters stability and effectiveness within the financial system. The assessment considers two categories of capital: Tier I and Tier II. A greater proportion signifies decreased reliance on external funding, signifying greater bank profitability and efficiency. A favorable connection is expected between a bank's performance and capital adequacy (Berger, 1995; Goddard et al., 2004).

H_1 : There is a positive relation between capital adequacy and performance parameter (efficiency, productivity and profitability).

b. Asset quality

A bank possesses assets that are current and fixed in nature. It also procures assets in the form of loans and advances to fulfill the demand arising from both individuals and institutions. Moreover, banking operations are substantially influenced by loans and advances as they significantly contribute to their overall income. A bank maintains a portfolio of such loans and advances, and its quality is directly

Table 1. Correlation matrix.

Variables	Interest income	Non-interest income	Borrowings	Deposits	Labour	Physical capital
Interest income	1.000					
Non-interest income	0.713* (0.000)	1.000				
Borrowings	0.891* (0.000)	0.824* (0.000)	1.000			
Deposits	0.967* (0.000)	0.926* (0.000)	0.942* (0.000)	1.000		
Labour	0.983* (0.000)	0.840* (0.000)	0.927* (0.000)	0.951* (0.000)	1.000	
Physical capital	0.461* (0.000)	0.217* (0.000)	0.374* (0.000)	0.459* (0.000)	0.427* (0.000)	1.000

The table report correlation results between input and output variables that are used to evaluate technical efficiency score. Input variables are defined as borrowings, deposits, labour and physical capital whereas, output variables are interest and non-interest incomes. * denotes significance at 1% level.

Table 2. Measurement of variables.

Determinants	Variable	Measurement	Notation
<i>Dependent variables</i>			
	Efficiency	Technical efficiency through DEWA	TE
	Productivity	Total factor productivity through Malmquist Productivity Index	TFP
	Profitability	Return on Asset (ROA) – net profit/total assets	ROA
		Return on Equity (ROE) – net profit/equity	ROE
<i>Independent variable</i>			
Bank-specific variables	Capital adequacy	Total capital/risk-weighted assets	CAR
	Asset quality	Total loan/total assets	TLTA
	Asset management	Total investment in total assets	TITA
	Management efficiency	Profit per employee – Net profit/total number of employees	PPE
		Business per employee – Total revenue/total number of employees	BPE
	Earning quality	Net interest margin – (Interest revenue – interest expense)/total assets	NIM
	Liquidity	Liquid assets/total assets	LATA
		Liquid asset/short-term liability	LASTL
	Sensitivity ratio	Individual bank total asset/total asset of the banking sector	SR
	Deposits	Total deposits to total assets	TDTA
		Total loan to total deposit	TLTD
	Bank size	Natural logarithm of total assets	LOGSIZE
	Operating efficiency	Total operating expense to net interest income	TOENII
	Herfindahl–Hirschman index	$\sum_{i=1}^n S^i$ is the sum of squared market share of all banks	HHI
Macro-economic variables	Gross domestic product	Annual real GDP growth rate	GDP
	Inflation	Annual inflation rate	INF

influenced by its efficiency. To inquire into the quality aspect of the banks' assets, the ratio of total loans to total assets (TLTA) was utilized as a proxy in the present study. Menicucci and Paolucci (2016) and Rani and Zergaw (2017) find the opposite relationship between asset quality and bank performance. Therefore, we tested the same relationship in the present study.

H_2 : There is a positive relation between asset quality and performance parameter (efficiency, productivity and profitability).

c. Asset management

Total investment in total assets (TITA) is a popular asset management measure. A higher TITA ratio is advantageous for banks. Past research argues that the TITA and bank performance have a positive relationship with each other (Masood & Ashraf, 2012).

H_3 : There is a positive relation between asset management and performance parameter (efficiency, productivity and profitability).

d. Management efficiency

The expansion of a bank is contingent upon the maintenance of stability and strength in its entire administration. This statement highlights the capacity of the Board of Directors (BODs) and senior managers to effectively identify, quantify, assess, and manage risks associated with banking operations. Therefore, it can be deduced that assigning responsibilities to risk management procedures and strategies is a qualitative indicator of good management (Naeem et al., 2017; Saeed et al., 2020). The metric of profit per employee (PPE) and business per employee (BPE) was utilized as a substitute to facilitate estimation. There is an expectation that there will be a higher proportion and a direct relationship between the effectiveness of management and the performance of the bank.

H_4 : There is a positive relation between management efficiency and performance parameter (efficiency, productivity and profitability).

e. Earning quality

Earnings quality is represented by the Net Interest Margin (NIM). The NIM shows the significance of bank management in utilizing interest revenue for profit-making by representing banks' effectiveness in

creating profits (Khan et al., 2022; Khan et al., 2021; Chaturvedi et al., 2021; Akhtar et al., 2020a; Bank, 2010). It is anticipated to have a greater ratio because it shows a better interest in generating money, which improves bank efficiency. NIM and bank performance should be significantly and favorably correlated (Ketkar & Ketkar, 2008).

H_5 : There is a positive relation between earning quality and performance parameter (efficiency, productivity and profitability).

f. Liquidity

The term "liquidity" is used to describe a bank's ability to meet its external obligations in a timely manner. The impact of liquidity on a bank's performance is a subject of ongoing discussion and analysis. Akhtar et al. (2020a) conducted a study and discovered a positive correlation between liquidity and both the bottom line and bank productivity. Hence, the utilization of the liquid assets to total assets ratio (LATA) and liquid assets to short-term liability (LASTL) is applied as a means to forecast the impact of liquidity on the performance of banks.

H_6 : There is a positive relation between liquidity and performance parameter (efficiency, productivity and profitability).

g. Sensitivity ratio

Over recent years, the incorporation of the sensitivity ratio (SR) into the CAMEL characteristics has given rise to the development of CAMELS. The aforementioned study conducted by Suresh and Paul (2014) provides a comprehensive analysis of the impact of fluctuations in interest rates, equity prices, foreign exchange rates, and commodity prices on the capital and earnings of banks. The inclusion of this component as the sixth element in the CAMELS architecture has frequently been neglected in prior research. Several scholars (Sarker, 2005; Roman & Şargu, 2013; Kumari, 2017) perceive the sensitivity ratio as a measure that exclusively examines the relationship between the aggregate assets of individual banks and the aggregate assets of the entire banking sector. Therefore, it is expected that there exists a positive correlation between the sensitivity ratio and efficiency, as suggested by Saeed et al. (2020).

H_7 : There is a positive relation between sensitivity ratio and performance parameter (efficiency, productivity and profitability).

h. Deposits

The major function of a bank is to create credit, which largely depends on the acceptance of deposits. Deposits serve as a crucial source of funds and greatly impact a bank's financial performance. However, banks must ensure that they maintain sufficient liquidity (Singh & Sharma, 2016). The calculation of deposits and the assessment of their impact on bank performance depend on the ratio of total deposits to total assets (TDTA) and total loan to total deposit (TLTD). The utilization of this ratio allows banks to convert their deposits into lucrative profits, rendering it extremely advantageous.

H_8 : There is a positive relation between deposits and performance parameter (efficiency, productivity and profitability).

i. Bank size

The bank's size in terms of assets it has acquired over the period is a vital component to measure its efficiency, as it emphasizes reducing costs and enhancing benefits. Therefore, the natural logarithm has been utilized as a proxy variable to investigate the cost-benefit pertaining to the size of a bank (Azmi & Akhtar, 2023). Previous researchers (Boyd & Runkle, 1993; Pasiouras and Kosmidou, 2007) have suggested that the size and performance of a bank possess a favorable connection. They argue that larger banks endowed with more substantial assets are presumed to attain efficiency by reducing costs through economies of scale. Nevertheless, there are relatively few studies that underscore the possibility of reduced

profits due to increased bank size. This is attributed to the operational intricacies of larger banks (Naceur, 2003; Athanasoglou et al., 2008; Sufian, 2009).

H_9 : There is a positive relation between bank size and performance parameter (efficiency, productivity and profitability).

j. Operating efficiency

The ratio of total expenditure to total revenue received from a commercial activity is known as operating efficiency. The computation of this ratio depends on the relationship between banks' operating expenses and interest income for banks (Rashid & Jabeen, 2016). Total operating expense to net interest income (TOENII) is anticipated to have an inverse relationship with bank performance (Masood & Ashraf, 2012).

H_{10} : There is a negative relation between operating efficiency and performance parameter (efficiency, productivity and profitability).

k. Herfindahl–hirschman Index (HHI)

The market structure is measured by using HHI which refers to the sum of squared market shares of all banks in the market, where the market shares are considered as weightage. The formula to calculate HHI is $\sum S_i^2$, where S_i is the market share of firm i in the market and the n is the number of firms. Several scholars in the finance literature argue that the HHI affects bank performance positively (Ab-Rahim & Chiang, 2016; Rakshit & Bardhan, 2019; Maji & Hussain, 2021).

H_{11} : There is a positive relation between HHI and performance parameter (efficiency, productivity and profitability).

l. Gross domestic product

Previous research has widely used GDP as a macroeconomic indicator to determine how macroeconomic circumstances affect the profitability of a bank. It presents a summary of the total activities pertaining to an economy (Petria et al., 2015; Rani & Zergaw, 2017; Akhtar et al., 2020a).

H_{12} : There is a positive relation between GDP and performance parameter (efficiency, productivity and profitability).

m. Inflation rate

The inflation rate is defined as the magnitude of the surge in the overall price of products and services. It is an indicator of declining purchasing power (Singh & Sharma, 2016). Several scholars in the finance literature argue that the inflation rate affects bank profitability (Anbar & Alper, 2011; Masood & Ashraf, 2012; Jara-Bertin et al., 2014; Chowdhury & Rasid, 2016).

H_{13} : There is a positive relation between inflation rate and performance parameter (efficiency, productivity and profitability).

3.4. Methodology

The plan of action was partitioned into three distinct sub-components. The initial section provides an explanation of the DEWA technique that is utilised for the evaluation of technical efficacy scores. The subsequent section elucidates the operational mechanisms of the Malmquist Productivity Index, which is employed for the computation of the comprehensive alteration in total factor productivity across successive periods. The final section of the paper elucidates the static panel regression methodology employed to assess the impact of macroeconomic and bank-specific factors on the financial performance of commercial banks operating in India.

3.4.1. Data envelopment window analysis (DEWA)

Initially, the concept of an efficient frontier study was developed by Farrell (1757) to evaluate bank efficiency through various inputs. Charnes et al. (1978) extended the work of Farrell (1957) by introducing the concept of Data Envelopment Analysis (DEA). As stated by Asmild et al. (2004), DEA is a non-parametric technique that is based on the concept of linear programming, and with the help of this technique, various inputs and outputs can be studied in a particular period. Cooper et al. (2000) stated that the main objective of using this technique is dichotomous, which means increasing the output or reducing the input. Here, maximizing the output connotes the output orientation, which indicates an increment in the output levels without any input change. However, minimizing the amount of inputs implies an input-oriented approach, where the goal is to decrease input levels without altering output levels.

According to Seiford and Thrall (1990), the Data Envelopment Analysis (DEA) method allows for the assessment of the relative efficiency of Decision-making Units (DMUs) in comparison to other DMUs of the same nature. This is achieved by assuming that all DMUs should ideally be positioned at or below the efficiency frontier. According to Charnes et al. (1997), the use of Data Envelopment Analysis (DEA) facilitates the identification of inefficient Decision Making Units (DMUs), allowing for the determination of their level of inefficiency and the sources of their input and output. The primary emphasis of this study methodology lies in the computation of banks' efficiency individually, instead of aggregating all DMUs' averages. The relative efficiency of specific Decision Making Units (DMUs) is assessed by comparing the integer values of their inputs and outputs to those of other DMUs.

According to Sathye (2003), the DEA approach is subject to specific restrictions. One of the identified limitations is the presence of constraints, namely constraint (a). When a data integrity violation occurs, it is not possible to provide a definitive explanation for the results obtained from the Drug Enforcement Administration (DEA). The user's text does not provide any information. The efficiency of the DMUs in question is somewhat higher when compared to the other DMUs in the sample. Simultaneously, it is conceivable that the decision-making units (DMUs) located beyond the sample may demonstrate greater efficiency than the DMU with the highest efficiency within the sample. By conducting a comparative analysis of efficient and inefficient organisations, analysts are able to enhance their ability to identify the underlying causes of inefficiency and make informed decisions regarding the reallocation of resources in order to improve productivity.

Using the D.E.A. technique, the performance can be analyzed for a certain year. However, this hinders the estimation of changes in efficiency in the case of a longer research period. Consequently, the DEA must repeat such an estimation, as in the case of window analysis, which includes both time-series and cross-sectional samples in the form of panel data (Charnes et al., 1995). However, this would aid in the development of a result that is continuous rather than stationary viewpoint (Sengupta, 1996).

Data Envelopment Window Analysis (DEWA) is a technique that analyzes productivity that changes over time. This method of evaluating efficiency is based on the moving average principle (Yue, 1992; Cooper et al., 2007). The DEWA technique to measure the efficiency of panel data (comprising time series and cross-section data) and evaluate the performance of DMUs over time was first propounded by Charnes et al. (1984). In DEWA, each DMU is regarded as an independent unit during distinct fiscal years. This increased the number of data points in the sample. In simple words, we can state that every DMU in a different period is considered an independent DMU but is comparable with each other in the same window (Cooper et al., 2011). Cooper et al. (2011) stated that this ability improves the discriminatory power of D.E.A. models in a small sample with more input and output. This eliminates the issue of small sample size. In the words of Asmild et al. (2004), using the DEWA technique, the bank's performance for a certain window can be compared to that of other banks.

A single bank's (DMU) performance is measured against the performance of that DMU only across time (horizontally) during a specified window as well as the performance of other banks over the same time frame (vertically for a specific time frame). As the number of data points increases, the results of these investigations become increasingly significant, especially in the case of small sample sizes. As specified by Paradi et al. (2001), the time zone is changed from contemporaneous analysis with a single-time frame observation to intertemporal analysis with complete time frame observation with regard to the breadth of the window for the study period. The DEWA dataset allows for the temporal extent of a

window to encompass any or all of the specified time periods. Observations that occur within a given window will be duly considered. According to the findings of Tulkens and Eeckaut (1995), the analysis of observations inside a chosen window width is conducted in an intertemporal fashion.

There is a potentially infinite number of banks, referred to as Decision Making Units (DMUs), that can be included in the analysis of efficiency scores utilising the D.E.A. technique. Individual bank data from various periods can, thus, be merged with observations by treating each time as a unique bank. As a result, the performance of an individual bank can be compared over a period of time (up to window width) with the performance of other banks in the same manner. By adding more of these windows, it will be easier to analyze the bank's efficiency score sensitivity over time while considering changing environmental conditions and modifying the reference set of banks. Additionally, regardless of the window, a bank's limited efficiency is merely a result of the presence of other banks in the sample. However, external variables may be at play if a bank does well within a certain window. DEWA also assists in examining a bank's short-term efficiency evaluation. Nonetheless, comparing the efficiency scores of extended periods generated by DEWA may be misleading at times due to the underlying economic structure or significant change in technology (Yue, 1992).

The following is a concise overview of the D.E.A. window analysis. Pursuant to the studies conducted by Asmild et al. (2004) and Gu and Yue (2011), we will examine a set of 'N' decision-making units (DMUs), where 'n' represents the index of each unit ranging from 1 to N. These DMUs are observed throughout 'T' time periods, denoted by 't' ranging from 1 to T. The production process of these DMUs involves 'r' inputs and results in 's' outputs. Consider DMU_n^t denote a decision-making unit (DMU) in period 't', characterized by a 'r'-dimensional input vector $x_n^t = (x_n^{1t}, x_n^{2t}, \dots, x_n^{rt})$, and a 's'-dimensional output vector $y_n^t = (y_n^{1t}, y_n^{2t}, \dots, y_n^{st})$. The input metric is determined when a window commences at time k (where k is a value between 1 and T) with a width of w (where w is a value between 1 and t - k). The specified measure for input has been defined as:

$$X_{kw} = (x_1^k, x_2^k, \dots, x_N^k, x_1^{k+1}, x_2^{k+1}, \dots, x_N^{k+1}, x_1^{k+w}, x_2^{k+w}, \dots, x_N^{k+w}) \quad (1)$$

The output metric can be represented as:

$$Y_{kw} = (y_1^k, y_2^k, \dots, y_N^k, y_1^{k+1}, y_2^{k+1}, \dots, y_N^{k+1}, y_1^{k+w}, y_2^{k+w}, \dots, y_N^{k+w}) \quad (2)$$

The C.C.R. model of the DEWA problem DMU_k^t is obtained by computing the given linear programming equation:

$$\min \theta, \quad (3)$$

$$\theta'X_t - \lambda'X_{kw} \geq 0, \quad (4)$$

subject to

$$\lambda'Y_{kw} - Y_t \geq 0, \quad (5)$$

$$\lambda_n \geq 0 (n=1, 2, \dots, N \times w). \quad (6)$$

According to Asmild et al. (2004), there is no technological change within each window even when all DMUs in a single window are matched to one another. Therefore, they suggested using a window that was restricted in width. According to Charnes et al. (1995), the attainment of an optimal outcome in terms of information and stability of the efficiency score is more pronounced when the window width is either 3 or 4. Consequently, a window width of three was employed in our investigation.

This analysis used data from the first window spanning three years (2011, 2012, and 2013). The data for this study were collected from 2011 to 2013. The first window row is created using data from 2011 to 2013, the second window row is created using data from 2012 to 2014, and so on. For the purpose of our study, we used this procedure for a total of eight separate instances ($T - w + 1 = 10 - 3 + 1$) in order to calculate an efficiency score for each window.

3.4.2. Malmquist Productivity Index

The current study employed the linear programming method of data envelopment analysis, namely the Malmquist Productivity Index, to quantitatively evaluate productivity and its various components in order to understand the overall fluctuations in productivity throughout a specific timeframe. The origins of DEA can be attributed to Farrell's seminal publication titled "The Measurement of Productive Efficiency" in 1957. Grifell-Tatjé and Lovell (1996) argue that the Malmquist Index is not contingent upon assumptions of profit maximization or cost reduction. Furthermore, this approach is favored in cases when there is a scarcity or absence of input and output variables, such as pricing data. Finally, changes in productivity can be classified into two components: technical efficiency change, commonly referred to as the catching-up index, and technical change, which is applicable when panel data is available and is also known as the change in best practice index. The approach employed in this study involves the utilization of panel data to evaluate the alterations in technical efficiency among the clusters. This includes examining technological modifications, changes in total factor productivity, scale, and pure technical efficiency (Krishnasamy et al., 2004). The output-based Malmquist productivity index as defined by Färe et al. (1994) is given as follows:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \left\{ \frac{d_0^t(x^{t+1}, y^{t+1})}{d_0^t(x^t, y^t)} \times \frac{d_0^{t+1}(x^{t+1}, y^{t+1})}{d_0^{t+1}(x^t, y^t)} \right\}^{1/2} \quad (7)$$

The equation above represents the productivity of production points (x^{t+1}, y^{t+1}) in comparison to production points (x^t, y^t) ; a value in excess of one indicates overall productivity growth from period t to period $t+1$. However, the index is calculated as the geometric mean of the two output-based Malmquist indices. The intervals " t " and " $t+1$ " are utilized in the index to represent changes in technology.

Färe et al. (1989); Färe et al. (1994) have provided a deconstruction of the Malmquist productivity indicator described above in the following manner:

$$M_0(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{d_0^t(x^{t+1}, y^{t+1})}{d_0^t(x^t, y^t)} \times \left(\frac{d_0^t(x^{t+1}, y^{t+1})}{d_0^{t+1}(x^{t+1}, y^{t+1})} \times \frac{d_0^t(x^t, y^t)}{d_0^{t+1}(x^t, y^t)} \right)^{1/2} \quad (8)$$

The expression outside the parentheses in the equation above represents the quantification of changes in relative technical efficiency over different time periods, (t) and $(t+1)$. Conversely, the terms enclosed in the brackets are geometric depictions of the two distinct ratios depicted in the equation, signifying a displacement in technology by two units, specifically in the case of commercial banks. This indicates that the change in efficiency is calculated by comparing the efficiency in period $(t+1)$ with the efficiency in period (t) . We split the above equation to obtain the efficiency and technical changes, as illustrated below.

$$\text{Efficiency Change} = \frac{d_0^t(x^{t+1}, y^{t+1})}{d_0^t(x^t, y^t)}$$

$$\text{Technological Change} = \left(\frac{d_0^t(x^{t+1}, y^{t+1})}{d_0^{t+1}(x^{t+1}, y^{t+1})} \times \frac{d_0^t(x^t, y^t)}{d_0^{t+1}(x^t, y^t)} \right)^{1/2} \quad (9)$$

If there is no significant change between the time periods, MPI will be equal to 1, which is explained by $x^t = x^{t+1}$, as well as $y^t = y^{t+1}$.

3.4.3. Static panel model

The present study used panel data analysis to investigate the impact of bank-specific and macroeconomic factors on bank performance. The assessment of performance was conducted by evaluating key indicators such as profitability, efficiency, and productivity. Panel regression distinguishes itself from traditional time series and cross-sectional models by employing dual subscripts. Panel regression offers several additional benefits. Firstly, it enables the handling of unobserved variables that vary over time but remain consistent across distinct entities. Secondly, the inclusion of temporal effects in panel model estimation helps to successfully handle individual variability by accommodating random or fixed effect components specific to each firm (Baltagi, 2008).

The current study employed panel data estimation for multiple purposes. Panel models often recognize firms as heterogeneous. Nevertheless, the presence of diverse characteristics is not apparent in datasets that involve observations over time or across different sections, thereby leading to distorted results (Azmi et al., 2024). Hence, the ability to efficiently manage diversity is an essential component. Moreover, this approach provides a wider range of diverse datasets, a larger quantity of meaningful data, reduced multicollinearity, and a significant level of flexibility combined with improved effectiveness (Gujarati, 2021). The study employed a model consisting of n cross-sectional units, where n varies from 1 to N . These units were observed at each time interval, ranging from $t=1$ to T . The dataset consists of a collection of observations with dimensions $n \times t$. Previous studies have confirmed the existence of panel data structures (Brooks, 2019; Chowdhury & Rasid, 2016). The panel regression model employed a similar framework to that of the panel dataset, as outlined by the authors described above.

$$y_{nt} = \alpha + \beta x_{nt} + e_{nt} \quad (10)$$

In this setting, the symbol y_{nt} represents the regression, α represents the intercept, β represents a $K \times 1$ vector of parameters that are going to be computed, and x_{nt} represents the n^{th} observation on K regressors, which is a $1 \times K$ matrix. The variables t and n represent the indices for time and observations, respectively, with t ranging from 1 to T and n ranging from 1 to N . The aforementioned model can be operationalized as follows:

$$(\text{Profitability} / \text{Efficiency} / \text{Productivity}) = f(\text{Bank-specific and Macro-economic factors}), \quad (11)$$

where, profitability refers to the measure of financial performance that evaluates the returns generated by a company's assets and equity. The technical efficiency score, which is derived using DEWA, is the measure of efficiency. Productivity refers to the comprehensive measure of productivity change during a specific period, as quantified by the Malmquist Productivity Index. The characteristics that are special to banks include the capital adequacy ratio, asset quality, management efficiency, earnings ratios, liquidity, asset management, bank size, deposit, and sensitivity ratio. Gross Domestic Product (GDP) and inflation are considered as macroeconomic variables. The subsequent four models have been created to examine the influence of bank-specific and macroeconomic factors on the financial performance of commercial banks in India. This is achieved by incorporating the proxies utilized in equation 11.

$$\begin{aligned} TE_{nt} = & \alpha_n + \beta_1 CAR_{nt} + \beta_2 TLTA_{nt} + \beta_3 TITA_{nt} + \beta_4 PPE_{nt} + \beta_5 BPE_{nt} \\ & + \beta_6 NIM_{nt} + \beta_7 LATA_{nt} + \beta_8 LASTL_{nt} + \beta_9 SR_{nt} + \beta_{10} TLTD_{nt} \\ & + \beta_{11} TDTA_{nt} + \beta_{12} LOGSIZE_{nt} + \beta_{13} TOENII_{nt} + \beta_{14} HHI_{nt} + \beta_{15} GDP_{nt} \\ & + \beta_{16} INF_{nt} + \varepsilon_{nt} \end{aligned} \quad (12)$$

$$\begin{aligned}
TFP_{nt} = & \alpha_n + \beta_1 CAR_{nt} + \beta_2 TLTA_{nt} + \beta_3 TITA_{nt} + \beta_4 PPE_{nt} + \beta_5 BPE_{nt} \\
& + \beta_6 NIM_{nt} + \beta_7 LATA_{nt} + \beta_8 LASTL_{nt} + \beta_9 SR_{nt} + \beta_{10} TLTD_{nt} \\
& + \beta_{11} TDTA_{nt} + \beta_{12} LOGSIZE_{nt} + \beta_{13} TOENII_{nt} + \beta_{14} HHI_{nt} \\
& + \beta_{15} GDP_{nt} + \beta_{16} INF_{nt} + \varepsilon_{nt}
\end{aligned} \tag{13}$$

$$\begin{aligned}
ROA_{nt} = & \alpha_n + \beta_1 CAR_{nt} + \beta_2 TLTA_{nt} + \beta_3 TITA_{nt} + \beta_4 PPE_{nt} + \beta_5 BPE_{nt} \\
& + \beta_6 NIM_{nt} + \beta_7 LATA_{nt} + \beta_8 LASTL_{nt} + \beta_9 SR_{nt} + \beta_{10} TLTD_{nt} \\
& + \beta_{11} TDTA_{nt} + \beta_{12} LOGSIZE_{nt} + \beta_{13} TOENII_{nt} + \beta_{14} HHI_{nt} \\
& + \beta_{15} GDP_{nt} + \beta_{16} INF_{nt} + \varepsilon_{nt}
\end{aligned} \tag{14}$$

$$\begin{aligned}
ROE_{nt} = & \alpha_n + \beta_1 CAR_{nt} + \beta_2 TLTA_{nt} + \beta_3 TITA_{nt} + \beta_4 PPE_{nt} + \beta_5 BPE_{nt} + \beta_6 NIM_{nt} + \beta_7 LATA_{nt} + \beta_8 LASTL_{nt} \\
& + \beta_9 SR_{nt} + \beta_{10} TLTD_{nt} + \beta_{11} TDTA_{nt} + \beta_{12} LOGSIZE_{nt} + \beta_{13} TOENII_{nt} + \beta_{14} HHI_{nt} + \beta_{15} GDP_{nt} + \beta_{16} INF_{nt} + \varepsilon_{nt}
\end{aligned} \tag{15}$$

Where:

n – represents individual banks; t – indicates years; α_n – constant term; β_n – Co-efficient of independent variables; TE is technical efficiency; TFP indicates total factor productivity change score; ROA and R.O.E. are return on assets and return on equity; TDTA is total deposit to total assets; TLTA is total loan to total assets; TLTD is total loan to total deposit; B.P.E. is business per employee; LASTL is liquid asset to short-term loan; TITA is total investment to total assets; NIM is net interest margin; LATA is liquid assets to total assets; P.P.E. is profit per employee; LOGSIZE is the natural logarithm of total assets; TOENII is total operating expenses to net interest income; CAR is capital adequacy ratio; SR is sensitivity to market risk; HHI is Herfindahl–Hirschman Index; INF is inflation rate; GDP is gross domestic product; ε_{nt} – random error term.

3.4.4. Dynamic panel model

We utilize panel data analysis to investigate the influence of bank-specific and macroeconomic factors on the performance of commercial banks in India, specifically focusing on profitability and productivity indicators. Panel regression offers distinct advantages over transverse studies by accommodating unobservable factors that fluctuate across time but remain constant across units. Additionally, it integrates temporal effects to address individual heterogeneity through random or fixed effect components specific to each entity (Baltagi, 2008).

While banks demonstrate operational continuity over time (Berger et al., 2000), García-Herrero et al. (2009) highlight potential endogeneity issues in the analysis of factors affecting bank profitability. Hence, we advocate for the use of Generalised Method of Moments (GMM) estimators in our research, incorporating lagged dependent variables to mitigate endogeneity and persistence concerns (Athanasoglou et al., 2008). GMM is preferred due to its ability to manage individual heterogeneity (Saona, 2016; Khan et al., 2022), ensure low correlation between independent variables, and reduce biases that may arise with conventional panel data estimators, especially when including lagged dependent variables in the equation.

GMM techniques are employed to address these challenges. Two methodologies, namely discrepancy and framework, are appropriate for handling heteroscedasticity, autocorrelation, fixed individual effects, small time-series and large cross-sectional panels, and weakly external predictor variables (Roodman, 2006). Saona (2016) devises a dynamic panel model employing proxies for various macroeconomic and bank-specific parameters to assess their impact on the financial performance of commercial banks in India.

$$\begin{aligned}
TE_{nt} = & \alpha_n + \beta_1 TE_{nt-1} + \beta_2 CAR_{nt} + \beta_3 TLTA_{nt} + \beta_4 TITA_{nt} + \beta_5 PPE_{nt} + \beta_6 BPE_{nt} + \beta_7 NIM_{nt} + \beta_8 LATA_{nt} + \beta_9 LASTL_{nt} \\
& + \beta_{10} SR_{nt} + \beta_{11} TLTD_{nt} + \beta_{12} TDTA_{nt} + \beta_{13} LOGSIZE_{nt} + \beta_{14} TOENII_{nt} + \beta_{15} HHI_{nt} + \beta_{16} GDP_{nt} + \beta_{17} INF_{nt} + \varepsilon_{nt}
\end{aligned} \tag{16}$$

$$TFP_{nt} = \alpha_n + \beta_1 TFP_{nt-1} + \beta_2 CAR_{nt} + \beta_3 TLTA_{nt} + \beta_4 TITA_{nt} + \beta_5 PPE_{nt} + \beta_6 BPE_{nt} + \beta_7 NIM_{nt} + \beta_8 LATA_{nt} + \beta_9 LASTL_{nt} \\ + \beta_{10} SR_{nt} + \beta_{11} TLTD_{nt} + \beta_{12} TDTA_{nt} + \beta_{13} LOGSIZE_{nt} + \beta_{14} TOENII_{nt} + \beta_{15} HHI_{nt} + \beta_{16} GDP_{nt} + \beta_{17} INF_{nt} + \varepsilon_{nt} \quad (17)$$

$$ROA_{nt} = \alpha_n + \beta_1 ROA_{nt-1} + \beta_2 CAR_{nt} + \beta_3 TLTA_{nt} + \beta_4 TITA_{nt} + \beta_5 PPE_{nt} + \beta_6 BPE_{nt} + \beta_7 NIM_{nt} + \beta_8 LATA_{nt} + \beta_9 LASTL_{nt} \\ + \beta_{10} SR_{nt} + \beta_{11} TLTD_{nt} + \beta_{12} TDTA_{nt} + \beta_{13} LOGSIZE_{nt} + \beta_{14} TOENII_{nt} + \beta_{15} HHI_{nt} + \beta_{16} GDP_{nt} + \beta_{17} INF_{nt} + \varepsilon_{nt} \quad (18)$$

$$ROE_{nt} = \alpha_n + \beta_1 ROE_{nt-1} + \beta_2 CAR_{nt} + \beta_3 TLTA_{nt} + \beta_4 TITA_{nt} + \beta_5 PPE_{nt} + \beta_6 BPE_{nt} + \beta_7 NIM_{nt} + \beta_8 LATA_{nt} + \beta_9 LASTL_{nt} \\ + \beta_{10} SR_{nt} + \beta_{11} TLTD_{nt} + \beta_{12} TDTA_{nt} + \beta_{13} LOGSIZE_{nt} + \beta_{14} TOENII_{nt} + \beta_{15} HHI_{nt} + \beta_{16} GDP_{nt} + \beta_{17} INF_{nt} + \varepsilon_{nt} \quad (19)$$

Where:

n – represents individual banks; t – indicates years; α_n – constant term; β_n – Co-efficient of independent variables; TE_{nt-1} is technical efficiency change; TFP_{nt-1} indicates total factor productivity change score; ε_{nt} – random error term.

4. Empirical results and discussion

The empirical result starts with the first evaluation stage, where the technical efficiency score (T.E.) and total factor productivity (T.F.P.) scores from the DEWA and Malmquist productivity index were computed. The findings obtained in the preliminary stage depict the growth of the banking sector in India in terms of general efficiency, during the course of the study period. In addition, the findings of individual group analysis indicate that the final efficiency score of 0.91 (average), obtained by the banks in the public sector, is the highest among all types of banks in the industry. The second highest efficiency score 0.64 (average) was achieved by foreign banks, with private banks coming a distant third by scoring a 0.23 (average) on the efficiency scale. Hence, public banks have been witnessed to be the highest-performing banks, while private banks are tagged with the least-performing banks among their counterparts in the industry. Moreover, we discovered that state banks exhibited greater effectiveness throughout the study period, while foreign banks have shown better stability but were less efficient. Even the changes in the average TFP score at the first stage during the year record a consistent direction during the period. Group analysis of individual banks shows that the overall productivity change of foreign private sector banks is 1.01, trailed by banks in the private and public sectors, obtaining a score of 0.98 (individual average). In light of these findings, the present research highlights that foreign banks demonstrate a greater degree of technological progress compared to the banks in the other two sectors, with a score of more than 1. The results of the T.F.P. and T.E. scores are tabulated below. [Table 3](#) displays the outcomes of the T.F.P. scores, whereas [Table 4](#) presents the findings of the T.E. scores.

Moving toward the second evaluation stage, [Table 5](#) presents descriptive statistics for the variables used in the current research. The major dependent variables included in the research model of the current study are technical efficiency (T.E.), total factor productivity (T.F.P.), return on assets (ROA), and return on equity (R.O.E.). In contrast, the independent variables are the capital adequacy ratio, asset quality ratio, management efficiency ratio, earnings ratio, liquidity ratio, sensitivity ratio, bank size, deposit ratio, operating efficiency ratio, and macro-economic variables (G.D.P. and inflation). The mean readings of every single variable in the examined model were found to be greater than their corresponding standard deviations. This suggests that the data has a reduced degree of variability and is more closely aligned with the mean line.

To validate the research model used in this work, diagnostic tests were conducted following the descriptive statistics. The results are shown in [Tables 6, 7](#). To ensure the validity and reliability of static panel models, it is necessary to subject them to three diagnostic tests. The choice of the most suitable model is contingent upon the satisfaction of all three diagnostic tests. In order to obtain unbiased results, it is essential to conduct a pre-testing method before executing the model in the 15 edition of the STATA (software package). This approach ensures the fulfillment of the essential premise of a model envisioned as a static panel. This procedure ensures that the necessary assumption of a static panel

Table 3. T.F.P. score of Indian Commercial Banks.

Sr. No	Name of the banks	Public banks												Overall
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Bank of Baroda	0.91	1.01	1.13	1.02	0.93	1.03	0.89	0.99	1.00	1.05	0.98	1.01	1.00
2	Bank of India	0.88	0.94	1.22	0.97	0.93	0.99	0.97	0.91	1.01	0.99	1.02	0.97	0.98
3	Bank of Maharashtra	0.92	1.11	1.07	1.02	1.06	1.00	0.93	0.93	0.97	0.98	0.99	1.01	1.00
4	Canara Bank	0.92	0.95	1.21	1.01	0.99	0.97	0.99	0.91	0.92	0.96	0.98	0.97	0.98
5	Central Bank of India	0.88	1.08	1.16	0.97	1.04	1.01	0.99	0.86	1.01	0.96	1.04	1.09	1.01
6	Indian Bank	0.98	0.78	1.05	1.02	0.93	1.02	0.90	0.93	0.93	0.90	0.89	0.92	0.94
7	Indian Overseas Bank	0.95	0.88	1.21	1.04	0.98	0.98	1.03	0.92	1.05	0.98	1.01	0.99	1.00
8	Punjab and Sind Bank	0.93	1.06	1.23	1.04	0.92	1.05	0.97	0.99	0.82	0.87	0.81	0.85	0.96
9	Punjab National Bank	0.94	0.96	1.12	1.11	0.90	0.99	0.90	1.02	0.87	0.90	0.92	0.96	0.97
10	State Bank of India	1.03	0.96	0.95	0.94	1.00	0.99	0.94	0.89	0.96	0.92	1.01	1.09	0.97
11	UCO Bank	1.01	1.05	1.18	1.06	0.92	1.02	0.85	0.89	0.93	0.95	0.98	1.02	0.99
12	Union Bank of India	0.93	0.96	1.14	1.01	1.03	1.02	0.94	0.95	1.00	0.98	0.92	1.00	0.99
	Average	0.94	0.98	1.14	1.02	0.97	1.01	0.94	0.93	0.96	0.95	0.96	0.99	0.98
Sr. No	Name of the banks	Private banks												Overall
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Axis Bank	1.08	0.82	1.02	1.05	1.04	0.94	1.00	1.02	0.91	1.04	0.98	1.01	0.99
2	Catholic Syrian Bank Ltd	0.88	1.00	1.14	1.14	0.98	2.18	0.86	1.55	0.66	0.98	1.02	1.07	1.12
3	City Union Bank Limited	0.87	0.60	0.89	0.98	1.21	1.58	0.62	1.11	0.77	0.86	0.97	1.04	0.96
4	DCB Bank Limited	0.80	0.89	1.10	0.96	1.10	1.02	1.02	0.95	0.93	0.96	0.98	1.03	0.98
5	Dhanlaxmi Bank	0.89	0.94	1.41	0.99	0.93	1.01	1.08	0.94	0.90	0.95	0.99	0.97	1.00
6	Federal Bank	0.97	0.94	1.15	0.94	1.08	0.99	0.90	1.08	1.01	1.04	1.01	1.03	1.01
7	HDFC Bank	0.94	0.94	1.05	0.97	0.99	1.01	0.92	1.07	1.03	1.08	1.02	0.94	1.00
8	ICICI Bank	0.98	0.79	1.04	1.01	1.06	1.05	1.05	1.04	0.85	0.90	0.88	0.91	0.96
9	Indusind Bank	0.89	1.04	1.15	1.03	1.09	1.03	1.04	1.05	0.90	0.92	1.01	0.98	1.01
10	Jammu & Kashmir Bank Ltd	0.92	0.96	1.09	1.21	0.91	1.05	0.92	0.95	0.89	0.92	0.96	0.99	0.98
11	Karnataka Bank Ltd	0.20	0.89	1.16	1.00	1.00	0.98	1.00	1.07	1.10	1.05	0.97	0.99	0.95
12	Karur Vysya Bank	0.52	0.97	1.10	1.04	1.05	1.03	0.92	0.98	0.87	0.90	0.94	0.96	0.94
13	Kotak Mahindra Bank Ltd	0.78	1.02	1.10	1.00	0.99	0.97	0.93	0.96	0.92	0.95	0.99	0.96	0.96
14	Lakshmi Vilas Bank	1.08	0.92	1.16	1.06	0.97	1.00	0.99	0.95	0.93	0.92	0.97	0.99	1.00
15	RBL	0.88	0.70	0.36	1.06	1.14	0.99	1.00	0.97	0.96	0.98	0.99	1.00	0.92
16	South Indian Bank	0.92	1.05	0.84	0.91	1.03	0.97	0.98	0.90	0.92	0.95	0.97	0.99	0.95
17	Yes Bank Ltd.	1.06	0.96	1.14	1.04	1.09	1.01	0.91	1.00	0.92	0.96	0.98	0.98	1.00
	Average	0.86	0.91	1.05	1.02	1.04	1.11	0.95	1.04	0.91	0.96	0.98	0.99	0.98
Sr. No	Name of the banks	Foreign banks												Overall
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Abu Dhabi Commercial Bank	0.71	0.79	1.73	0.96	1.35	0.86	1.14	0.90	0.69	0.81	0.92	1.01	0.99
2	Bank of Bahrain & Kuwait B.S.C.	0.26	1.50	1.28	1.17	1.41	0.84	1.47	1.02	0.75	0.85	0.96	0.98	1.04
3	Bank of Ceylon	0.53	0.89	0.56	0.84	1.59	1.64	0.99	0.95	1.49	1.06	1.17	1.09	1.07
4	Bank of Nova Scotia	0.99	0.85	1.20	0.86	1.83	0.62	0.89	0.71	0.98	1.02	1.08	1.17	1.02
5	Barclays Bank PLC	1.00	1.04	1.00	1.09	1.30	1.28	1.02	1.18	0.80	0.88	0.94	1.14	1.06
6	BNP Paribas	1.27	0.83	0.98	1.12	1.14	1.02	1.22	0.96	0.98	1.01	1.09	1.11	1.06
7	Citibank N.A.	0.90	0.76	1.07	0.99	1.18	1.12	1.01	1.69	0.68	0.79	0.86	0.94	1.00
8	Credit Agricole	1.01	1.03	1.15	0.76	0.66	1.15	0.66	1.01	0.95	1.02	1.08	0.99	0.96
9	CTBC Bank	0.89	0.96	1.41	0.81	0.93	1.23	0.83	0.99	1.07	1.12	0.97	0.98	1.02
10	DBS Bank LTD.	1.19	0.71	1.07	1.18	0.72	1.01	0.74	1.21	0.60	0.81	0.89	0.94	0.92
11	Deutsche Bank AG	0.82	1.21	1.50	0.58	0.86	1.28	0.94	1.03	0.92	0.96	1.02	1.09	1.02
12	HongKong and Shanghai Banking CORPN.LTD.	1.00	1.00	0.99	0.71	0.82	1.09	1.05	1.51	0.82	0.87	0.95	0.98	0.98
13	JP Morgan Chase Bank N.A.	0.33	2.35	1.06	1.45	1.19	1.06	0.95	0.76	0.64	0.75	0.82	0.94	1.03
14	Mizuho Bank LTD	0.78	1.38	1.64	0.70	0.90	0.95	0.66	0.91	0.96	0.99	0.97	0.92	0.98
15	Royal Bank of Scotland N.V.	0.96	0.95	0.85	0.65	1.02	0.71	1.24	0.30	1.48	1.23	1.15	0.97	0.96
16	SBM Bank(Mauritius) LTD	0.59	1.51	1.50	1.74	1.09	0.95	1.09	0.50	1.18	0.97	1.01	1.12	1.10
17	Standard Chartered Bank	0.99	0.83	1.10	0.82	1.26	0.99	0.79	0.99	0.85	0.94	0.97	0.99	0.96
	Average	0.84	1.09	1.18	0.97	1.13	1.05	0.98	0.98	0.93	0.95	0.99	1.02	1.01

Table 4. T.E. score of Indian Commercial Banks.

Sr. no	Name of the banks	Public banks											Overall
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Bank of Baroda	0.95	0.94	0.93	0.98	0.98	0.98	0.96	1.00	0.98	0.97	1.00	0.97
2	Bank of India	0.97	0.99	0.94	0.98	1.00	1.00	0.99	0.99	0.98	1.00	0.99	0.98
3	Bank of Maharashtra	0.82	0.81	0.85	0.80	0.82	0.77	0.84	0.92	0.96	0.90	0.88	0.85
4	Canara Bank	0.94	0.93	0.94	0.93	0.97	0.99	0.98	0.94	0.97	0.92	0.95	0.95
5	Central Bank of India	0.92	0.87	0.84	0.83	0.84	0.80	0.81	0.84	0.88	0.81	0.83	0.84
6	Indian Bank	0.68	0.67	0.66	0.67	0.73	0.78	0.78	0.85	0.86	0.91	0.82	0.76
7	Indian Overseas Bank	0.88	0.91	0.99	0.99	0.99	0.98	0.93	0.89	0.91	0.94	0.90	0.94
8	Punjab and Sind Bank	0.94	0.95	0.92	0.90	0.95	0.95	0.89	0.91	0.93	0.90	0.88	0.92
9	Punjab National Bank	0.78	0.79	0.78	0.78	0.79	0.77	0.83	0.94	0.96	0.99	0.93	0.85
10	State Bank of India	1.00	1.00	1.00	1.00	1.00	0.95	0.97	1.00	0.99	1.00	1.00	0.99
11	UCO Bank	1.00	1.00	1.00	0.97	0.94	0.94	0.95	0.97	0.99	0.94	0.91	0.96
12	Union Bank of India	0.98	0.90	0.81	0.83	0.92	0.91	0.95	0.95	0.97	0.98	0.96	0.92
	Average	0.91	0.90	0.89	0.89	0.91	0.90	0.91	0.93	0.95	0.94	0.92	0.91

Sr. No	Name of the banks	Private banks											Overall
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Axis Bank	0.21	0.21	0.20	0.20	0.21	0.20	0.20	0.19	0.22	0.26	0.35	0.22
2	Catholic Syrian Bank Ltd	0.18	0.16	0.20	0.19	0.28	0.37	0.49	0.71	0.51	0.57	0.50	0.38
3	City Union Bank Limited	0.53	0.44	0.33	0.30	0.30	0.30	0.28	0.21	0.24	0.30	0.32	0.32
4	DCB Bank Limited	0.09	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.20	0.21	0.22	0.13
5	Dhanlaxmi Bank	0.28	0.09	0.09	0.08	0.09	0.11	0.15	0.17	0.22	0.24	0.26	0.16
6	Federal Bank	0.24	0.25	0.23	0.22	0.19	0.17	0.17	0.18	0.23	0.25	0.28	0.22
7	HDFC Bank	0.20	0.21	0.22	0.24	0.26	0.22	0.23	0.25	0.29	0.31	0.27	0.25
8	ICI Bank	0.21	0.18	0.18	0.14	0.16	0.17	0.18	0.17	0.24	0.22	0.31	0.20
9	Indusind Bank	0.14	0.15	0.16	0.14	0.14	0.13	0.14	0.16	0.22	0.24	0.31	0.18
10	Jammu & Kashmir Bank Ltd	0.25	0.27	0.33	0.31	0.27	0.23	0.22	0.22	0.24	0.28	0.34	0.27
11	Karnataka Bank Ltd	0.42	0.15	0.19	0.21	0.16	0.15	0.16	0.18	0.20	0.22	0.23	0.21
12	Karur Vysya Bank	0.44	0.23	0.20	0.16	0.15	0.16	0.18	0.20	0.22	0.24	0.26	0.22
13	Kotak Mahindra Bank Ltd	0.23	0.22	0.21	0.20	0.19	0.16	0.16	0.17	0.23	0.32	0.34	0.22
14	Lakshmi Vilas Bank	0.17	0.15	0.14	0.16	0.15	0.15	0.14	0.13	0.20	0.24	0.22	0.17
15	RBL	0.91	0.71	0.42	0.12	0.11	0.11	0.13	0.16	0.22	0.26	0.25	0.31
16	South Indian Bank	0.29	0.31	0.29	0.21	0.17	0.15	0.15	0.16	0.20	0.26	0.25	0.22
17	Yes Bank Ltd.	0.27	0.30	0.29	0.29	0.25	0.23	0.22	0.22	0.24	0.30	0.30	0.26
	Average	0.30	0.24	0.22	0.19	0.19	0.18	0.20	0.21	0.24	0.28	0.29	0.23

Sr. No	Name of the banks	Foreign banks											Overall
		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
1	Abu Dhabi Commercial Bank	0.40	0.36	0.41	0.50	0.46	0.44	0.34	0.30	0.35	0.40	0.45	0.40
2	Bank of Bahrain & Kuwait	0.40	0.28	0.38	0.43	0.40	0.34	0.33	0.31	0.32	0.41	0.44	0.37
3	Bank of Ceylon	0.90	0.80	0.78	0.78	0.80	0.93	1.00	1.00	0.99	1.00	0.97	0.90
4	Bank of Nova Scotia	0.64	0.59	0.58	0.64	0.66	0.72	0.63	0.51	0.62	0.71	0.82	0.65
5	Barclays Bank PLC	0.63	0.56	0.61	0.73	0.82	0.94	1.00	1.00	0.97	0.99	1.00	0.84
6	BNP Paribas	0.80	0.77	0.71	0.75	0.67	0.67	0.57	0.58	0.62	0.71	0.83	0.70
7	Citibank N.A.	0.65	0.57	0.56	0.57	0.53	0.56	0.63	0.66	0.71	0.64	0.75	0.62
8	Credit Agricole	0.93	0.98	0.89	0.90	0.93	0.94	0.94	0.81	0.98	0.91	0.93	0.92
9	CTBC Bank	0.51	0.57	0.49	0.42	0.38	0.39	0.45	0.43	0.52	0.49	0.47	0.47
10	DBS Bank Ltd.	0.58	0.50	0.47	0.46	0.45	0.38	0.33	0.27	0.32	0.41	0.53	0.43
11	Deutsche Bank AG	0.69	0.76	0.81	0.78	0.68	0.71	0.65	0.64	0.69	0.72	0.79	0.72
12	HSBC	0.43	0.44	0.50	0.51	0.45	0.44	0.50	0.53	0.58	0.62	0.59	0.51
13	JP Morgan Chase Bank	0.90	0.85	0.97	1.00	1.00	1.00	1.00	1.00	0.99	0.97	1.00	0.97
14	Mizuho Bank Ltd	0.47	0.60	0.84	0.98	0.97	0.90	0.78	0.60	0.88	0.94	0.98	0.81
15	Royal Bank of Scotland	0.53	0.48	0.42	0.52	0.57	0.69	0.44	0.59	0.64	0.52	0.63	0.55
16	SBM Bank (Mauritius) Ltd	0.31	0.33	0.55	0.65	0.67	0.65	0.51	0.42	0.52	0.61	0.58	0.53
17	Standard Chartered Bank	0.40	0.40	0.44	0.48	0.49	0.51	0.44	0.41	0.46	0.49	0.51	0.46
	Average	0.60	0.58	0.61	0.65	0.64	0.66	0.62	0.59	0.66	0.68	0.72	0.64

Table 5. Descriptive statistics.

Variables	OBS	Mean	STD. DEV
<i>Dependent variables</i>			
TE	506	0.521	0.311
TFP	552	0.981	0.207
ROA	598	1.214	0.316
ROE	598	7.613	2.426
<i>Independent variables</i>			
CAR	598	17.245	12.612
TLTA	598	0.457	0.142
TITA	598	0.326	0.083
PPE	598	1.816	0.527
BPE	598	174.582	148.612
NIM	598	3.149	1.043
LATA	598	0.273	0.138
LASTL	598	0.694	0.404
SR	598	0.021	0.037
TLTD	598	0.738	0.213
TDTA	598	0.692	0.202
LOGSIZE	598	5.643	0.854
TOENII	598	0.579	0.431
HHI	598	0.051	0.011
GDP	598	7.214	1.362
INF	598	7.597	2.170

Source: Author's Calculation (STATA).

model is satisfied. Table 6 summarizes the outcomes of the initial diagnostic test, specifically the multi-collinearity test, which assesses the correlation between a pair of independent variables. The test utilises the Variance Inflation Factor (VIF) and the Pearson Correlation Matrix. The findings indicated that every independent parameter exhibited a VIF score below 10.0 and a correlation coefficient below 0.80, suggesting the absence of collinearity among the explanatory factors (Gujarati, 2021).

The second test conducted in this study is the test for heteroscedasticity, which seeks to determine whether the error term has a constant variance. To assess heteroscedasticity, the researchers employed the Breusch-Pagan test as suggested by Torres-Reyna (2007). Table 7 presents the findings indicating that Models 1 exhibits homoscedasticity, but Models 2, 3, and 4 do not demonstrate this characteristic. A test for autocorrelation was conducted to evaluate the linear relationship between a variable and its lagged values at different time intervals. The Wooldridge test, as proposed by Wooldridge (2010), was employed for this objective. Models 1, 3, and 4 exhibit serial correlation, as demonstrated by the data displayed in Table 7. To tackle the problems of heteroscedasticity along with the presence of autocorrelation in the models, the current study utilized a robust methodology called the Huber-White Sandwich estimator (Huber, 1967; White, 1980).

After passing the diagnostic test, every regression equation in a static panel must go through with fixed and random effect models. However, the Hausman test was performed to choose the appropriate model between the two types of models. Table 7 highlights the result that shows a chi-square value less than 0.05, which means F.E.M. is selected for all the models (null: R.E.M.; alt: F.E.M.), as all four models have either the presence of serial correlation. Therefore, a robust technique was employed for all the four models.

Unlike other studies, the current study used the second-stage D.E.A. measure to check the effect of variables specific to the bank and those of macroeconomic variables (selected from the CAMELS framework) on all three bank performance parameters (Coelli et al., 2005). Stage one involves computing the T.E. and T.F.P. scores; and stage two involves regressing it using static panel regression. While running the regression equations, T.E., T.F.P., ROA, and R.O.E. were considered regressand, as shown in Table 8. The equation shows the casual relation of the regressand with bank-specific and macro-economic variables. The current work illustrates four models that, explain the mixed results (both positive and negative). Overall, it can be concluded that static panel regression is a superior method of evaluating bank performance. First, the outcomes of most of the variables were consistent throughout all the regressions. Second, our findings indicate that all exogenous variables have anticipated signals and are statistically distinct from zero at times.

Table 6. Pearson correlation matrix and VIF.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	VIF
(1) CAR	1.0000																1.52
(2) TLTA	0.0621**	1.0000															3.42
(3) TITA	-0.0496*	0.2109	1.0000														1.06
(4) PPE	0.3710*	0.0051**	-0.2634*	1.0000													3.17
(5) BPE	0.2140***	-0.0124**	0.0541**	-0.1682*	1.0000												1.73
(6) NIM	0.1364**	-0.2942**	0.0217**	-0.0061**	-0.0679**	1.0000											1.80
(7) LATA	-0.0052*	0.0468	0.1639	-0.2491**	-0.0679**	-0.1642*	1.0000										3.64
(8) LASTL	0.2116	0.0761*	0.1267**	0.5173***	-0.3677	-0.1559*	0.1647*	1.0000									3.05
(9) SR	-0.0061**	-0.0840**	0.0383*	0.0041*	-0.0136*	0.0797**	-0.0210**	0.1440**	1.0000								1.43
(10) TLTD	0.1522**	-0.0569*	0.1131**	-0.0754**	0.1559*	0.2842**	0.2542*	0.0856**	0.0189*	1.0000							2.76
(11) TDTA	0.2848*	-0.5407**	0.1508	-0.0205*	0.2797**	0.4109*	-0.0793*	0.3216	0.1508**	0.7497*	1.0000						4.09
(12) LOGSIZE	0.3083	0.1522*	0.0366**	0.0263*	0.0736**	0.2336**	0.2880	0.2284**	0.0434**	0.1187*	0.0085*	1.0000					2.19
(13) TOENII	0.1388***	0.1415	-0.1009	0.2170	0.3212*	0.4341	0.1536*	0.1853**	0.0601	0.1026**	0.2357	0.2120*	1.0000				2.69
(14) HHI	0.0054**	0.2145	-0.3145	0.0234*	0.0731**	0.1643*	0.0042	-0.0019	0.0475***	-0.2145	0.3426**	0.4861**	-0.2769	1.0000			2.42
(15) GDP	0.0347**	0.0408*	-0.0114*	0.0146*	0.0248*	-0.0368**	0.0004*	-0.0153*	-0.0151**	0.0561*	-0.0378**	0.0394*	0.0256*	0.0314	1.0000		2.10
(16) INF	0.0754*	-0.0695*	-0.0847*	-0.1691**	0.3561*	0.1315*	-0.0437*	-0.0977**	-0.0028**	0.0086*	0.0793*	0.1138*	0.0845*	0.0056	-0.1891*	1.0000	1.19
Mean VIF																	2.39

Note: *** ** and * denotes level of significance at 1%, 5% and 10%.

Source: Author's Calculation (STATA).

Table 7. Diagnostic test.

Dependent variable	Heteroscedasticity test		Auto-correlation test		Hausman test	
	Chi2(1)	Prob. > chi2	F (1.45)	Prob. > F	Chi2(15)	Prob. > chi2
Model 1 – TE	2.57	0.1042	38.41	0.0000***	68.13	0.0000***
Model 2 – TFP	22.64	0.0000***	0.30	0.2163	31.51	0.0075***
Model 3 – ROA	0.18	0.0001***	11.73	0.0007***	45.69	0.0001***
Model 4 – ROE	71.54	0.0000***	6.79	0.0232**	56.25	0.0000***

Note: ***, ** Statistically significant level at 1% and 5%.

Source: Author's Calculation (STATA).

Table 8. Static panel regression results.

Variables	Model 1 (TE)	Model 2 (TFP)	Model 3 (ROA)	Model 4 (ROE)
<i>Bank-specific factors</i>				
CAR	0.003* (1.65)	0.002*** (2.64)	−0.001* (−0.90)	0.007* (0.21)
TLTA	−0.092* (−0.48)	−0.109* (−0.26)	−1.059** (−1.65)	2.940 (2.17)
TITA	0.010 (0.09)	0.017 (0.06)	−2.463 (−4.42)	−2.584 (−0.38)
PPE	0.003*** (3.10)	0.002* (0.45)	0.144*** (1.04)	0.172*** (2.21)
BPE	0.002** (2.64)	−0.001 (−0.72)	−0.002 (−2.92)	−0.017 (−2.45)
NIM	0.039** (2.26)	0.063** (1.85)	0.202*** (2.11)	−2.549*** (−2.71)
LATA	−0.445** (−1.93)	−0.486* (−1.09)	−0.083 (−0.16)	−2.246 (−1.53)
LASTL	−0.151*** (−2.92)	−0.142* (−1.66)	−0.213 (−2.81)	−3.095 (−0.98)
SR	0.092* (0.92)	0.239* (1.16)	−3.115*** (−3.17)	−1.440* (−1.29)
TLTD	−0.031 (−1.35)	0.047 (1.00)	−0.175 (−1.39)	−2.849 (−3.92)
TDTA	−0.075 (−0.52)	0.297 (0.85)	−1.560 (−3.12)	−8.003 (−0.95)
LOGSIZE	0.311*** (2.62)	0.212*** (3.00)	−0.008 (−0.15)	−5.586 (−3.36)
TOENII	−0.040 (−0.79)	−0.058 (−0.42)	−1.652*** (−8.36)	−6.372*** (−4.89)
<i>Market structure factor</i>				
HHI	0.321*** (0.25)	0.413** (0.21)	0.017 (0.14)	0.275** (1.09)
<i>Macro-economic factors</i>				
GDP	−0.006** (−1.95)	−0.007** (−0.80)	−0.026* (−0.91)	−0.0384* (−0.18)
INF	−0.008*** (−2.12)	−0.017*** (−4.76)	−0.004* (−0.32)	0.233** (2.15)
Constant	2.017*** (2.84)	−0.464* (−0.69)	4.465*** (5.03)	3.719** (4.94)
R-Squared	0.358	0.349	0.607	0.403
F-Test	3.69***	8.82***	14.50***	11.62***
No. of observations	506	552	598	598

Note: ***, ** and * denotes level of significance at 1%, 5% and 10%.

Source: Author's Calculation (STATA).

The findings of the regression analysis demonstrate that the Capital Adequacy Ratio (C.A.R.) exerts a statistically significant positive impact on the efficiency, productivity, and profitability of all commercial banks operating in India over the observed time frame. A greater ratio is indicative of reduced reliance on external finance, hence reflecting a bank's elevated levels of profitability, productivity, and efficiency. Furthermore, this study demonstrates the proficiency of banks in effectively managing the exposure of shareholder risk and their ability to withstand external shocks. As a result, the potential for financial liabilities and the need for external financial support are diminished due to the presence of well-capitalized banks, which exhibit a lower probability of experiencing insolvency. This finding aligns with the conclusions reached by Berger (1995) and Akhtar et al. (2020a).

For asset quality, total loans to total assets are used as proxy variables. Asset quality has a significantly negative effect on all three parameters of bank performance, indicating inefficiency increments, negative profitability, and lower productivity. The non-performing assets in large stocks lead to declining asset quality as one of the primary issues of inefficiency. Banks lost money on this defective portfolio, and provisioning against such loans also cut their earnings. Furthermore, the results also reveal the presence of credit tightening, whereby banks place greater emphasis on overseeing their current portfolios rather than prioritizing new lending. The same results are as per the suggestions of (Resti, 1997; Barr et al., 2002; Sackett & Shaffer, 2006; Akhtar et al., 2020a). In contrast, the ratio of total investment to total assets has been utilized as a proxy variable pertaining to asset management, which shows an insignificant effect on all three parameters of bank performance during the sample period.

The proxies for business per employee (B.P.E.), management efficiency, and profit per employee (P.P.E.) significantly positively impact all three parameters of bank performance, indicating an improvement in staff productivity over the sample period. This ultimately leads to an improvement in overall efficiency, productivity, and profitability. This result is consistent with those of Maiti and Jana (2017) and Akhtar et al. (2020a). The regression analysis results show that a proxy variable for earnings calculated by the

Net Interest Margin (NIM) showed a positively significant impact on bank performance for all three parameters, which indicated that more profit will be generated by banks that have better efficiency positions. Simply stated, profitable banks turn away consumers with low credit ratings, increasing the efficiency of the banking sector. Our findings align with those of earlier research (See for instance, Isik & Hassan, 2002; Hasan & Marton, 2003; Perera & Wickramanayake, 2016; Al-Homaidi et al., 2020).

Similarly, liquid assets to total assets (LATA) and liquid assets to short-term liability (LASTL) have been used as proxies for liquidity. The results show that both the proxies negatively affect efficiency and productivity. This shows that banks target more risky assets for investments, which results in banks being less efficient and unable to match productivity. However, it is imperative for banks to diversify their portfolios and allocate funds to non-government securities in order to maintain enough liquidity, which is crucial for meeting current and future obligations. Bougatef (2017) and Al-Homaidi et al. (2020) show similar findings. Contrarily, neither of the liquidity proxies has significant implications for profitability during the observed time frame. This discovery supports the findings of Raphael (2013), Al-Homaidi et al. (2018) and Almaqtari et al. (2019).

The sensitivity ratio, estimated using a proxy variable that includes the ratio of individual bank assets to total assets of the banking industry, posits a positive and statistically significant impact on efficiency and productivity. Similarly, a negative and statistically significant effect on profitability occurs in the sample period. This suggests that higher bank assets for the designated banking sector may result from a higher sensitivity ratio. In other words, if the assets of individual banks grow, the banking industry's concentration will grow, which will result in a significant disparity between larger and smaller banks. As a result, small banks become less efficient, while large banks become more effective. According to Alkhazaleh and Almsafir (2014), bigger banks possess a distinct advantage in terms of competitiveness when compared to their smaller counterparts and are better at negotiating, making it easier for them to profit from economies of scale and specialization. When moving on to the proxy for deposits, total loan to total assets (TLTA), and total deposit to total assets (TDTA), the result illustrates an insignificant impact on all three parameters of bank performance during the entire time frame.

Another important bank-specific parameter is bank size (LOGSIZE), calculated using the natural logarithm of total assets. The result depicts a significant positive impact on efficiency and productivity, indicating that larger banks depict a positive impact and are more efficient, just because of the arguments of the economics of scale. Huge sums are placed in bank vaults as a result of the demonetization impact, which increases banks' asset power. These findings are consistent with Sufian and Noor (2009) findings that bank efficiency, loan intensity, size, and capitalization are all positively correlated. The insignificant impact reported on profitability indicates that bank size does not matter with regard to profitability. This implies that smaller banks tend to be more lucrative than their larger counterparts despite having fewer assets (Singh & Malik, 2018).

The last bank-specific factor is operating efficiency, estimated total operating expenses, and net interest income (TOENII). It shows an insignificant impact on efficiency and productivity and a significant negative effect on profitability. This corresponds to the concept that with an increase in operating expenses, profitability will decrease. These results are supported by those of previous studies by Chowdhury & Rasid (2016); Francis (2013) and Yahya et al. (2014).

In our models, we also considered HHI as a market structure factor. HHI has shown a positive and statistically significant impact on bank performance as a gauge of the level of concentration in the Indian banking system. This result suggests that more concentration in Indian banking correlates with improved performance. The purpose of this indicator is to quantify the impact of activity restrictions on bank competitiveness. The result is in line with the previous study Ab-Rahim and Chiang (2016); Rakshit and Bardhan (2019) and Maji and Hussain (2021).

In the case of external determinants, the impact of G.D.P. on all three parameters was significantly negative, which is in line with the previous research of Curak et al. (2012); Petria et al. (2015); Garcia and Guerreiro (2016); and Akhtar et al. (2020a). The I.N.F. also showed a negatively significant effect on all three parameters. Rashid and Jabeen (2016) also supported this result.

For robust estimation and to overcome the endogeneity problem we have applied GMM regression, the result is projected in Table 9. The GMM estimation confirmed no order correlation between errors. This can be ascertained from our findings, the p-values of AR (2) and the Sargan test justify the GMM

Table 9. Robust technique.

Variables	Model 1 (TE)	Model 2 (TFP)	Model 3 (ROA)	Model 4 (ROE)
<i>Bank-specific factors</i>				
TE (−1)	0.462*** (2.729)			
TFP (−1)		0.382*** (2.472)		
ROA (−1)			0.427*** (3.821)	
ROE (−1)				0.210*** (2.941)
CAR	0.045* (2.19)	0.104* (2.61)	0.094* (1.56)	0.125 (1.71)
TLTA	1.812** (0.26)	0.148** (0.57)	−1.547 (−1.24)	11.574* (1.42)
TITA	0.161 (0.96)	−1.497 (−0.51)	3.276 (2.79)	−3.406 (−1.61)
PPE	0.184** (1.61)	1.417* (1.05)	2.630** (2.17)	1.617*** (1.83)
BPE	1.645** (0.73)	−2.496 (−1.08)	−1.617 (−2.37)	−1.712 (−0.64)
NIM	1.430** (0.61)	2.719** (1.83)	1.976** (2.13)	−3.734 (−1.65)
LATA	−2.672 (−0.29)	1.549 (1.43)	1.346 (1.68)	3.470 (2.24)
LASTL	1.631* (2.09)	2.379** (1.72)	1.631** (0.35)	−2.417 (−0.64)
SR	1.731** (0.40)	1.064*** (1.92)	2.691 (1.53)	2.372* (1.67)
TLTD	−1.634 (−0.29)	−2.196 (−1.73)	2.841 (1.36)	−2.317 (−1.07)
TDTA	1.524** (0.37)	1.276* (1.04)	2.710 (1.59)	3.067 (2.71)
LOGSIZE	3.471* (1.26)	2.92** (1.43)	1.619 (0.75)	4.027 (2.10)
TOENII	−1.730* (−0.64)	1.679 (1.92)	−2.19 (−1.37)	−3.67** (−1.40)
<i>Market structure factor</i>				
HHI	0.247** (1.67)	1.930 (2.07)	0.083** (1.72)	1.452* (0.68)
<i>Macro-economic factors</i>				
GDP	0.279** (1.26)	1.621 (0.43)	0.074* (1.07)	1.324 (0.31)
INF	1.061* (0.71)	1.961** (2.06)	1.092 (0.68)	2.740** (1.43)
Constant	2.479** (1.61)	1.329* (0.54)	1.248*** (2.16)	1.472** (2.40)
F-Test	5.791***	9.423**	13.618***	11.804***
No. of observations	506	552	598	598
Hansen J-statistics	9.527	9.423	11.764	10.673
Sargan test	342.37	318.57	282.49	310.39
AR(1)	−3.768***	−3.496***	−4.853***	−3.739***
AR(2)	−0.079	−0.061	−0.084	−0.092

Note: ***, ** and * denotes level of significance at 1%, 5% and 10%.

Source: Author's Calculation (STATA).

results, as they are insignificant. The result indicates that the capital adequacy ratio, managerial efficiency, earnings, asset quality, sensitivity ratio and market structure variable have been found to significantly impact all three banks' performance metrics throughout the research duration. The bank's magnitude, alongside liquidity, has an impression on the productivity and efficiency of banks, mainly Indian banks, on the contrary, operational efficiency influences the efficiency and profitability of Indian banks. The overall result is similar to static panel regression.

5. Conclusion

This study analyzes the effects of bank-specific and macroeconomic factors on the efficiency, productivity, and profitability of Indian commercial banks using a two-stage Data Envelopment Analysis. In the first step, we determined the TE and TFP scores of the commercial banks and in the second stage using the CAMELS framework, we regress all bank and country-specific components on the three performance indicators of Indian banks. According to the findings of the first stage, the TE trend was consistent. On the other hand, each group analysis shows that public sector counterparts are getting more efficient by scoring 0.91 an average efficiency. Foreign sector counterparts followed suit and scored 0.64 on average efficiency, while private banks scored the least at average efficiency with values of 0.23. Furthermore, foreign banks were relatively steady but recorded as inefficient during the study period, whereas their public counterparts were more efficient. Similarly, the average TFP change score in the first stage exhibited a regular pattern throughout the year. According to individual group research, the overall productivity change for foreign sector banks is 1.01, followed by 0.98 for public and private sector banks. The study discovered that foreign banks with a score greater than 1 are more technologically advanced than the other two sector banks. The regression results also show that all three bank performance metrics are linked to various factors. This shows that during the course of the study, the capital adequacy ratio, asset quality, management effectiveness, earnings, sensitivity ratio and market structure variable significantly affect the performance parameters of all three banks. The productivity and efficiency of Indian banks are

unaffected by liquidity. However, robust technique estimation differs in the case of banks magnitude, liquidity, and operational efficiency.

This research aids in the evaluation of the Indian banking industry's sustainability by regulators, policymakers, bankers, and promoters. The consequences of competition and technology corresponding to bank performance are pertinent and cannot be neglected because of the important policy implications. This suggests that the government's approach of consolidating banks is likely to generate significant synergy and could act as a safeguard for an emerging economy like India during times of crisis or upheaval and positively affects banks' profitability and efficiency and helps in allocating resources and improving the financial stability of commercial banks. This approach has the potential to assist the government in directing its attention towards banks that exhibit inefficiencies and low productivity, so enabling the formulation of suggestions aimed at enhancing both input and output levels. This may also facilitate future research endeavors in assessing bank performance by employing the identical set of variables employed in the present study. This may also aid policymakers in evaluating a series of fundamental measures of bank performance.

The conclusions should be taken in light of the study's duration, sample size, and empirical methodology used. To analyze bank performance, future research is needed utilizing other factors, such as integrating risk exposure components in regression analysis, analysing the variations in the cost and allocative efficiency over time and using cluster analysis to assess key performance metrics for banks. Furthermore, empirical exploration of the impact of additional variables, such as macroeconomic and microeconomic factors, along with the inclusion of ESG and SDG factors as moderating variables, on the performance and efficiency of Indian banks relative to those in other Asian nations, is also feasible for analysis.

Notes

1. <https://www.ibef.org/industry/banking-presentation>.
2. <https://economictimes.indiatimes.com/industry/banking/finance/banking/bank-credit-growth-at-16-2-more-than-double-last-years-pace/articleshow/94406548.cms?from=mdr>.

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Author contributions

Conceptualization – S.A. and S.N.A. Methodology – S.A., P.A.K and S.N.A. Investigation – A.A.J and Z.A. Analysis and interpretation of the data – S.A., A.A.J and S.N.A. Writing – Original Draft – S.A., P.A.K and S.N.A. Review and Editing – Z.A. and A.A.J. Project Administration – S.A. and S.N.A. All authors agree to be accountable for all aspects of the work.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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