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Econometric Analysis of Cost Efficiency of Banking Sector in India: A Three-Stage Approach

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Abstract: The study's main objective is to empirically examine the cost efficiency scores to identify the best and worst performance of all scheduled commercial banks operated by bank groups in India by applying the frontier techniques of Data Envelopment Analysis and Stochastic Frontier Analysis. The study also examines the determinants of cost efficiency using the Logit model from 2005 to 2022. This study aims to fill the gaps in the existing empirical studies on banking cost efficiency in India. The results of the Data Envelopment Analysis show that the public and private banks in India operated more efficiently than foreign banks in India during the study period. However, private banks operating in India have performed better in terms of cost savings with the technology than public banks. Most foreign banks are found to have the least cost efficiency, which means that these banks generate less income, and profit may be incurred due to unwanted costs. The logit results reveal that the coefficients of liquidity risk, diversify mitigate risk, and bank size are expected signs and significant effects on the cost technical efficiency of commercial banks by all bank groups. The findings of the study will be helpful to investors, customers, policymakers, and bank owners in evaluating the economic performance of commercial banks operating in India.

Keywords: Cost efficiency, Indian banks, Data Envelopment Analysis, Logit model, Stochastic Frontier Analysis

I. INTRODUCTION

The growth and development of each economy in the world depends on the financial sector. This sector plays a momentous role as a financial intermediary and continues to be one of the main engines of economic development worldwide (Sensarma, 2005). The financial sector comprises commercial banks, insurance companies, non-banking companies, cooperatives, mutual funds, and smaller financial entities. Economists

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Schumpeter (1911) and Lucas (1988) also argued that the financial sector plays a vital in determining economic growth. The banking sector predominates the financial industry in bringing economic stability, a mediator between depositors and borrowers of funds, creating liquidity, mobilization of savings, capital accumulation, and foreign capital inflows (Banna et al.2017). The structure of the Indian banking system can be broadly divided into scheduled commercial banks, non-scheduled commercial banks, and development banks. The operations of scheduled commercial banks in India are classified into public banks, private and foreign banks. After the independence of India, 14 private banks were first nationalized in 1969, and then 6 private banks were nationalized in 1980 by the government of India. Since 1969, the nationalized banks have played a commendable role in achieving India's economic growth.

However, most of the nationalized commercial banks in India are under various pressures in the form of internal and external competition, non-banking intermediaries, chit funds, information technology, new banking services, internet banking, huge administrative expenses, and non-performing assets(Shanmugam & Das, 2004) are also greatly affected by the economic and political factors. To review the problems of the entire banking sector, the Government of India adopted various banking sector reform committees since the 1970s, such as PEPCommittee (1977), SukhamoyChakravartyCommittee (1985), Padmanabhan Working Group (1991), Narasimham Committee-I (1991), NarasimhamCommittee- II (1997-1998), Verma Committee (1999), etc. The main ambitions of the abovementioned committees are to develop the efficiency of nationalized commercial banks in India. In this circumstance, it is essential to examine whether the banking sector reform committees are really beneficial to the commercial banks operating in India .

Various economists and researchers have given the concept of efficiency in economics. The term' efficiency' was first formulated in the early works of Edgeworth (1881) and Pareto (1927) as a performance indicator in all types of business firms. Farrell (1957) & Drucker (1963) stated that efficiency is the ability of a bank to attain maximum (minimum) outputs (inputs) from a given set of inputs (outputs). Cost efficiency requires achieving the lowest possible cost with current input prices and production. The cost efficiency of commercial banks consists of two components: technical efficiency and allocative efficiency (Farrell, 1957). Technical efficiency refers to the ability of a bank to obtain the maximum possible output from a given set of input resources. Allocative efficiency means the ability of a bank to use the input resources in optimal proportions. Measuring the banks' technical or cost efficiency helps benchmark an individual bank's relative efficiency against

the 'best practice' bank(s) (Das et al. 2005). A commercial bank is economically (cost) efficient, producing the maximum possible output with the appropriate combination of input resources. The efficiency of the banks depends on the different bank-specific elements such as bank capitalization, profitability, real interest rate, competition, and bank ownership effect (Banna et al., 2017).

The rest of the paper is organized as follows: Section II presents a comprehensive Review of the Literature and Research Gap with the Objectives of this Study. Section III presents the sources of Data and Methodology. Section IV discusses the estimated empirical results, and Section V gives the Conclusion.

II. REVIEW OF RELEVANT LITERATURE

The present study briefly reviews the available relevant empirical studies regarding the cost efficiency of commercial banks in the Indian context only. Several studies have been conducted worldwide to examine the technical efficiency of banks in the form of cost efficiency, scale efficiency, allocative efficiency, technical efficiency, pure technical efficiency, etc., using the Data Envelopment Analysis (DEA). It is commonly applied in the field of efficiency assessment. However, most earlier empirical studies use the DEA or SFA method to measure banks' technical and cost efficiency. A study by Berger & Humphrey (1997) provided an extensive review of studies on the efficiency of the banking sector, and it also pointed out that the majority of studies focused on the banking markets of well-developed countries.

With specific reference to India, the following studies have evaluated commercial banks' cost-efficiency performance using DEA. Using DEA, Chatterjee & Sinha (2006) investigated the cost efficiency of 20 public and 10 private banks operating in India from 1996-1997 to 2002-2003. Private banks have higher cost efficiency, allocative efficiency, and scale efficiency scores than public banks. The public banks lagged behind the private banks regarding cost and allocative efficiency. Kumar & Gulati (2010) analyzed the trends of cost efficiency of 27 Indian public banks from 1992-1993 to 2007-2008 using DEA and Panel OLS models. The study indicates that the cost efficiency of public banks improved significantly in the second phase of reform compared to the first phase of reform. Kaur & Kaur (2010) examined the impact of mergers on the cost efficiency of merged banks using DEA from 1990-1991 to 2007-2008. The study's findings show that over the entire study period, the average cost efficiency of public banks was 73.4 percent, private banks were 76.3 percent, and six banks had better efficiency after merger banks 11. Kumar (2013) investigated the trends of

cost efficiency across the Indian public banks during the post-deregulation period 1992-1993 to 2007-2008, applying DEA. The results indicate that deregulation has a positive impact on the cost efficiency of public banks. The results show that the average cost inefficiency of Indian public banks is 25.6 percent. The cost inefficiency for public banks is primarily due to technical inefficiency.

Raina and Sharma (2013) analyzed the cost efficiency of Indian commercial banks using DEA from 2005-2006 to 2010-2011. The results show a substantial inefficiency among the commercial banks over the period due to the regulatory environment in which public banks operate rather than the managerial problems in using financial resources. Bhatia & Mahendru (2018) examined the cost efficiency of all scheduled commercial banks operating in India from 2002-2003 to 2012-2013, applying DEA. The estimated results of DEA indicate that Indian commercial banks have never achieved the total cost efficiency score over the study period. The study found that the scale inefficiency cautions of the Indian scheduled commercial banks are not operated on the optimum scale. Khurana & Khosla (2019) investigated the cost efficiency of sample commercial banks operating in India during the post-reform period 1995-2016, employing DEA and Tobit models. The results indicate a significant variation in bank cost efficiency scores, ranging between 66.94 and 99.49 percent from 1995 to 2016. Cost inefficiency is observed among all sample banks, and allocative inefficiency is slightly higher than its technical inefficiency counterpart.

Very few empirical studies have been undertaken by commercial banks in India that measured the cost efficiency of applying the parametric model of the Stochastic Frontier Approach (SFA). Sensarma (2005) examined the cost and profit efficiency of all commercial banks in India during 1986-2003, applying the SFA. The estimated results show that the cost efficiency of the banking industry increased and profit efficiency declined during the sample period. The study finds that public banks' cost efficiency is higher than private banks. Regarding bank groups in India, public and private banks appeared to be more efficient than foreign banks. Kalluru & Bhat (2009) examined the cost efficiency of Indian commercial banks applying the Stochastic Frontier Approach and Tobit Technique for 1992-2006. The results show that the cost efficiency of all commercial banks decreased during the study period. Foreign banks are relatively more cost-efficient, followed by private and public banks. Tobit results indicate that the earning capacity of banks is the primary determinant factor of efficiency, followed by diversified and strategic noninterest income activities.

Research Gap & Issues

The review of the literature shows that the available empirical studies on the cost efficiency of banks in the Indian context are outdated and never attempted a comparative analysis of the cost efficiency performance of banks employing both the non-parametric frontier-DEA and parametric frontier-SFA and also determinants of cost efficiency of banks using an econometric model across bank ownership. Therefore, this study has the opportunity to fill this noticeable literature gap on the cost-efficiency analysis of banks. Hence, it is essential to investigate the impact of the banking reform committees, which are beneficial to public banks compared to private and foreign banks operating in India from 2005-2022.

Objectives and Contribution of the Present Study

The present study's objectives differ from the available literature on the cost and technical efficiency of banks operating in India. Considering the above research gap, the present study uses a three-stage approach. In the first stage, Cost Technical efficiency (CTE), Technical efficiency (T.E.), and Allocative Efficiency (A.E.) scores of the banks are estimated with the help of DEA to identify the best and worst performing banks operating in India by bank ownership. In the second stage, the parametric Maximum Likelihood Stochastic Frontier Transcendental Production Function (MLSFTPF) is applied to measure banks' cost efficiency and inefficiency across bank groups or ownership in India. Finally, this study used the Logit model to estimate the determinants of cost efficiency of banks by ownership. This analysis will contribute to the existing literature on banking cost efficiency in the Indian financial sector.

III. ECONOMETRIC METHODOLOGY

(a) Source of Data

Data for the present study is collected from the Statistical Tables related to commercial banks from the Reserve Bank of India (RBI) for the period 2005-2022. Many domestic private and foreign banks were established after 2005, and few were closed and merged with other banks during the study period. The required data are not available consistently for all banks for all years. As a result, the paper has an unbalanced panel of 59 banks for 18 years. The study period is confined to 18 data sets from 2005 to 2022. Due to the non-availability of data for some banks, the study selected only 59 banks, including 20 public banks, 19 domestic private banks, and 20 foreign banks are operating in India since 2005. The list of selected commercial banks by bank ownership under study is given in Table 1.

Table 1: List of the selected banks operating in India

Public Banks	*Private Banks*	*Foreign Banks*
Allahabad Bank (ALB)	Axis Bank Ltd (AXIS)	AB Bank Limited (AB)
Andhra Bank (ANB)	Catholic Syrian Bank Ltd (CSB)	Abu Dhabi Commercial Bank PJSC (ACB)
Bank of Baroda (BOB)	City Union Bank Ltd (CUB)	Bank of America, National Association (BOA)
Bank of India (BOI)	DCB Bank Ltd (DCB)	Bank of Bahrain & Kuwait B.S.C. (BBK)
Bank of Maharashtra (BOM)	Federal Bank Ltd (F.B.)	Bank of Ceylon (BOC)
Canara Bank (CNB)	HDFC Bank Ltd (HDFC)	Bank of Nova Scotia (BONS)
Central Bank of India (CBI)	ICICI Bank Ltd (ICICI)	Barclays Bank PLC (BBPLC)
Corporation Bank (C.B.)	Indusind Bank Ltd (IBL)	BNP Paribas (BNPP)
Dena Bank (DNB)	Jammu & Kashmir Bank Ltd (J&K)	CitiBank N.A (CITI.N)
IDBI Bank Limited (IDBI)	Karnataka Bank Ltd (K.B.)	Credit Agricole Corporate And Investment Bank (CACI)
Indian Bank (I.B.)	KarurVysya Bank Ltd (KVB)	Credit Suisse Ag (CSAG)
Indian Overseas Bank (IOB)	Kotak Mahindra Bank Ltd. KMB)	CTBC Bank Co., Ltd. (CTBC)
Oriental Bank of Commerce (OBC)	Lakshmi Vilas Bank Ltd (LVB)	DBS Bank India Ltd (DBS)
Punjab Sind Bank (PSB)	Nainital Bank Ltd (NB)	Hongkong And Shanghai Banking Corpn.Ltd(HSBC)
Punjab National Bank (PNB)	RBL Bank Limited (RBLB)	JPMorgan Chase Bank National Association (JCBNA)
State Bank of India (SBI)	South Indian Bank Ltd (SIB)	MIZUHO Bank Ltd (MIZUHO)
Syndicate Bank (SYB)	Tamil Nadu Mercantile Bank Ltd (TMB)	MUFG Bank Ltd (MUFG)
Union Bank of India (UOB)	Dhanalakshmi Bank Ltd (DB)	Royal Bank of Scotland PLC (RBS)
United Bank of India (UBI)	YES Bank Ltd. (Y.B.)	Shinhan BANK (SB)
Vijaya Bank (V.B.)		Standard Chartered Bank (SCB)

Source: Selected Banks Collected from RBI

Table 2: Measurement of variables used in DEA, SFA, and Logit Analyses

Model	Variables Name (Notation)		Measurement of Variables (Rs in Crore)
DEA	Output	Interest Income (II)	The sum of interest income from loans and advances, deposit and treasury, and NBE bills.
		Noninterest Income (NII)	Sum of commission, fee, and charges on credit, guarantee, etc.
		Total Loans (T.L.)	Loans include commercial, industrial, consumer, and real estate.
	Input	Interest Cost (I.C.)	Interest payments by banks
		Other Costs (O.C.)	Overheads, Operational expenses, fees, commissions, etc.
		Labour Cost (L.C.)	Payments for employees.
MLSFTPF	Dependent	Total Cost (T.C.)	Total cost includes income paid to depositors, overheads, personal expenses, and operational and other financial expenses.
	Independent	Total Loans & Advances(TLA)	Payment on gross advances or loans by banks (loans).
		Other Earning Assets (OEA)	Total earning assets-loans.
		Price of Physical Capital (PPC)	Operating expenditure for salaries and allowances
		Price of Fixed Assets (PFA)	Price of assets such as buildings, furniture, computers, vehicles, etc.
		Price of Labour (P.L.)	The labor cost is calculated as the total salaries and staff expenses.
		Price of Loanable Funds (PLF)	Interest on loanable funds.
LOGIT	Dependent	Cost Technical Efficiency CTE)	CTE score derived from DEA
	Independent	Liquidity Risk (L.R.)	The ratio of total loans to total deposits.
		Diversify Mitigate Risk (DMR)	The ratio of total noninterest income to total assets.
		Administrative Expense (A.E.)	The ratio of total noninterest expenses to total assets.
		Agency Cost (A.C.)	The ratio of total fixed assets to total assets
		Funding Claim Strategy (FCS)	The ratio of customer total deposit to total loans and other earning assets
		Interest Margin (I.M.)	The difference between total interest income and total interest expenses
		Bank Size (B.S.)	The natural log of total assets.
		Demand Deposit (D.D.)	The natural log of total demand deposits.

First Stage: DEA

The available empirical studies suggest that two main approaches are used for measuring bank efficiency like parametric techniques (Stochastic Frontier Analysis) and non-parametric techniques (Data Envelopment Analysis). The empirical analysis of this study is threefold to identify the performance of each commercial bank by bank groups operating in India during the period 2005-2022.

In the first stage, the banks' technical, cost, and allocative technical efficiency scores are estimated with the help of the non-parametric technique of DEA Frontier Software to identify a benchmark decision-making bank for comparing the performance of all other commercial banks. The input-oriented DEA methodology is applied in the first stage to obtain the Technical Efficiency (TE), CostTechnical Efficiency (CTE), and Allocative Efficiency (AE) scores. The DEA is a mathematical linear programming technique that converts multiple inputs and outputs of each decision-making unit (DMU) into a scalar measure of efficiency by assigning weights to the inputs and outputs of the DMU. The most important input-oriented DEA-CCR model, under the Constant Returns to Scale (CRS) assumptions, was developed by Charnes, Cooper, and Rhodes (1978). The AE is computed by CTE and divided by TE. The goal of the input-oriented model is to minimize the inputs while maintaining the same output level. The input-oriented under the DEA-CCR model for CTE and TE are specified in Equation (1) and Equation (2), respectively as:

Cost Technical Efficiency (CTE)

$$(C_e) = \sum_{i=1}^{m}.Piq.Xiq \qquad (1)$$

Subject to Conditions

$$\sum_{j=1}^{n} \lambda j X_{ij} \leq Xiq$$

$$\sum_{j=1}^{n} \lambda j Y_{rj} \geq Yrq$$

$$\lambda j, Xiq \geq = 0$$

Where

X_{iq}-represents i^{th} input that minimizes cost for DMUs
Xij- denotes i^{th} amount of inputs used by j^{th} DMUs
Yrj- denotes r^{th} amount of output produced by j^{th} DMUs
C_e indicates the cost efficiency scores of DMUs
n- represents the n^{th} observation of DMUs
i = 1,2,3,……m, r = 1,2,3,……s
j = 1,2,3,……n

Technical Efficiency (T.E.)

$$Min = \theta p \qquad (2)$$

Subject to Conditions

$$\sum_{j=1}^{n} \lambda j X_{ij} - \theta p X_{ip} \leq 0$$

$$\sum_{j=1}^{n} \lambda j Y_{rj} \geq Yrp$$

$$\lambda j \geq = 0$$

Where

Xij- denotes i^{th} amount of inputs used by j^{th} DMUs
Yrj- denotes r^{th} amount of output produced by j^{th} DMUs
λ_j - represents the weight associated j^{th} DMUs
P- represents the price of inputs
n- represents the n^{th} observation of DMUs
Θp- indicates the technical efficiency scores of DMUs
i = 1,2,3,……m, r = 1,2,3,……s
j = 1,2,3,……n

Second Stage: SFA

In the second stage, the present study applied the parametric method of Maximum Likelihood Stochastic Frontier Transcendental Production Function (MLSFTPF) to measure the banks' cost efficiency parameters with the help of STATA Software. Numerous empirical studies widely applied the MLSFTPF to calculate the cost efficiency of commercial banks. The MLSFTPF has advantages over the DEA technique by including composite error terms. The DEA and MLSFTPF techniques differ according to the assumptions of the dataset and technology. The DEA technique ignores the random factors that can influence the banks' efficiency, and it cannot decompose the error terms into random error (v) and inefficiency (u) errors. In the following studies, Christensen et al. (1975), Aigner et al. (1977), and Meeusen and Broeck (1977) developed the MLSFTPF with composite error terms, namely, random noise term (vi) and residual non-negative random term (ui.) to measure the technical inefficiency.

The inefficiencies are assumed to follow an asymmetric or half-normal distribution, whereas random errors are assumed to follow a symmetric or normal distribution (Aigner et al. 1977). The earlier study by Kirkley et al. (1995) used the half-normal and truncated normal distribution as an assumption on the inefficiency effect model due to the simplicity of estimation and interpretation. The MLSFTPF technique is considered more sophisticated than the non-parametric DEA technique. Following earlier studies, the present study applied and specified the MLSFTPF logarithmic cost function to obtain the cost efficiency of the banking sectors as:

$$\begin{aligned} \ln TC = {} & \beta_0 + \beta_1 \ln(TLA) + \beta_2 \ln(OEA) + \beta_3 \ln(PPC) + \beta_4 \ln(PFA) + \beta_5 \ln(PL) \\ & + \beta_6 \ln(PLF) + \tfrac{1}{2} \beta_7 \ln(TLA)^2 + \beta_8 \ln(TLA) * \ln(OEA) + \beta_9 \ln(TLA) * \\ & \ln(PPC) + \beta_{10} \ln(TLA) * \ln(PFA) + \beta_{11} \ln(TLA) * \ln(PL) + \beta_{12} \ln(TLA) \\ & * \ln(PLF) + \tfrac{1}{2} \beta_{13} \ln(OEA)^2 + \beta_{14} \ln(OEA) * \ln(PPC) + \beta_{15} \ln(OEA) * \\ & \ln(PFA) + \beta_{16} \ln(OEA) * \ln(PL) + \beta_{17} \ln(OEA) * \ln(PLF) + \tfrac{1}{2} \beta_{18} \\ & \ln(PPC)^2 + \beta_{19} \ln(PPC) * \ln(PFA) + \beta_{20} \ln(PPC) * \ln(PL) + \beta_{21} \ln(PPC) \\ & * \ln(PLF) + \tfrac{1}{2} \beta_{22} \ln(PFC)^2 + \beta_{23} \ln(PFA) * \ln(PL) + \beta_{24} \ln(PFA) * \\ & \ln(PLF) + 1/2 \beta_{25} \ln(PL)^2 + \beta_{26} \ln(PL) * \ln(PLF) + \tfrac{1}{2} \beta_{27} \ln(PLF)^2 + \\ & V_{it+} (-U_{it}) \end{aligned} \tag{3}$$

Where TC denotes the total cost for sample banks(i) in t-period, Xit are vectors of inputs and βs are vectors of unknown parameters, V_{it} and U_{it} are error components. V_{it} is is assumed to be $(0, \sigma^2 v)$ and independent of $_{it}$. Ui is a non-negative random variable ($U \leq 0$), considered technical cost inefficiency, and assumed to be iid. The values of U_{it} lie between 0 and 1. For efficient banks, the value of Uit are is equal to 0, which means that the

banks produce the potential cost. For inefficient banks, the values of U_{it} are are more significant than 0, which means that the banks produced below the potential cost.

Third Stage: Logit Model

The goal of the third stage using the Maximum Likelihood Logit Model (MLLM) is to estimate determinants of cost efficiency by bank ownership. Existing studies have widely employed Maximum Likelihood Tobit Model (MLTM) and Maximum Likelihood LogitModel (MLLM) to estimate determinants of cost efficiency. Lema (2017) & Singhet al. (2015) estimated the determinants of the cost efficiency of the commercial banks using the MLTM and explained that the DEA technical efficiency score falls within the interval of 0 and 1. However, McDonald (2009) considered the MLTMas an inappropriate model, known as the censored nature of the regression model, since the technical efficiency data was a fraction of the continuous variable (dependent variable), which was not generating a censoring process. Estimating the bank's technical or cost efficiency using the MLTM regression model will lead to a biased parameter estimate. Empirical studies by Kumar & Gulati (2008) and Adusei (2016) suggested that using the MLLM procedure will be a more appropriate model to examine the banks' technical efficiency determinants obtained by the DEA frontier. In the MLLM, the dependent variable is dichotomous, where 1is taken for an efficient bank (highest cost efficiency score), and 0 is taken for an inefficient bank (lowest efficiency score). All the input and output variables are measured in Indian Rupees. The econometric specification of the MLLM is specified as follows:

$$\left[\frac{Pi}{1-Pi}\right] = \alpha + \Sigma_{i=1}^{m}.\beta iXi + \mu \tag{4}$$

$$CE_{it} = \alpha + \beta_1 LR_{i,t} + \beta_2 DMR_{i,t} + \beta_3 AE_{i,t} + \beta_4 AC_{i,t} + \beta_5 FCS_{i,t} + \beta_6 CR_{i,t} + \beta_7 IM_{i,t} + \beta_7 DD_{i,t} + \mu \tag{5}$$

Where Pi represents the probability of occurrence of banks' cost efficiency in the observations, 1-Pi represents the probability of non-occurrence of banks' inefficiency. Pi/1-Pi represents the ratio of the likelihood of occurrence and non-occurrence, which is given in Equation (4). The subscript' i' denotes the bank's observation, the subscript 't' denotes the time series data in the t^{th} year, β_0 denotes the intercept, β_1 to β_7 denote unknown parameters known as Logit regression coefficients of corresponding input variables, μ denotes the stochastic 'error' term. Table 2 presents the output and input variables measurements in the DEA, MLSFTPF, and MLLM analyses.

IV. EMPIRICAL RESULTS AND DISCUSSION

First Stage Results

Tables 3 and 4 present the analysis of Cost Technical Efficiency (CTE) along with its two components, Technical Efficiency (TE) and Allocative Efficiency (AE) scores for 20 public banks, 19 domestic private banks, and 20 foreign banks operating in India are reported in Tables 3 and 4. Table 3 shows that the selected public, private, and foreign banks of CTE and AE scores are not equal to 100 percent. The estimated technical efficiency (TE) results under DEA show that public and private banks are more efficient than foreign and private banks.

Table 3: Estimated results of overall cost efficiency scores by bank ownership

Bank Name	*Public Banks*			*Bank Name*	*Private Banks*			*Bank Name*	*Foreign Banks*		
	TE	*CE*	*AE*		*TE*	*CE*	*AE*		*TE*	*CE*	*AE*
ALB	0.965	0.657	0.681	AXIS	1.000	0.964	0.964	AB	1.000	0.326	0.326
ANB	0.988	0.691	0.699	CSB	0.843	0.783	0.929	ACB	0.800	0.117	0.146
BOB	0.993	0.830	0.836	CUB	0.994	0.936	0.942	BOA	0.880	0.231	0.263
BOI	0.968	0.759	0.784	DCB	0.908	0.813	0.895	BBK	0.747	0.154	0.206
BOM	0.959	0.662	0.690	FB	0.974	0.943	0.968	BOC	0.942	0.273	0.290
CNB	0.968	0.678	0.700	HDFC	1.000	0.988	0.988	BONS	0.872	0.145	0.166
CBI	0.940	0.639	0.680	ICICI	1.000	0.973	0.973	BBPLC	0.812	0.196	0.241
CB	1.000	0.702	0.702	IBL	0.962	0.903	0.939	BNPP	0.730	0.162	0.222
DNB	0.954	0.661	0.693	J &K	0.955	0.931	0.975	CITI.N	0.779	0.191	0.245
IDBI	1.000	0.680	0.680	KB	0.952	0.862	0.905	CACI	0.916	0.216	0.236
IB	0.987	0.719	0.728	KVB	0.957	0.911	0.952	CSAG	0.951	0.395	0.415
ROB	0.986	0.694	0.704	KMB	1.000	0.929	0.929	CTBC	0.779	0.194	0.249
OBC	0.987	0.646	0.655	LVB	0.928	0.842	0.907	DBS	0.714	0.206	0.289
PSB	0.973	0.671	0.690	NB	0.953	0.895	0.939	HSBC	0.701	0.175	0.250
PNB	0.994	0.768	0.773	RBLB	0.937	0.883	0.942	JCBNA	0.973	0.272	0.280
SBI	1.000	0.816	0.816	SIB	0.964	0.887	0.920	MIZUHO	0.942	0.604	0.641
SYB	0.978	0.695	0.711	TMB	0.974	0.923	0.948	MUFG	0.936	0.647	0.691
UOB	0.988	0.860	0.870	DB	0.862	0.802	0.930	RBS	0.964	0.370	0.384
UBI	0.944	0.344	0.364	YB	1.000	0.948	0.948	SB	0.752	0.192	0.255
VB	0.957	0.612	0.639					SCB	0.627	0.362	0.577
Mean Efficiency	0.976	0.689	0.705		0.955	0.900	0.941		0.840	0.271	0.318
Mean inefficiency	0.024	0.311	0.295		0.044	0.099	0.058		0.159	0.729	0.681
Sample Banks		20				19				20	

Source: Author's calculations

The overall cost efficiency of public and commercial banks is 68.9 percent, indicating that public banks have cost savings of 31.1 percent. This implies that public banks have 68.9 percent of the resources actually used to produce the given output level. The private banks can cut their cost by 9.9 percent to become fully cost-efficient. The results show that at least a percent of the CTE and AE scores are registered in the public banks, particularly in UBI and VB respectively. Similarly, the least percent of the CTE and A.E scores

are registered in the private banks, namely CSB and DCB. The other private banks are considered to be the more cost-efficient banks. This implies that private bank managers are relatively good at using the minimum input level at a given output level. The results suggest that private banks have performed better than public banks regarding cost-saving with the given technology. Private banks' overall inefficiency scores are lower than those of public banks. This finding is similar to the findings of Kaur &Kaur (2010), who found that private banking had better cost-saving banks than public banking in India from 1990-91 to 2007-08 using DEA. However, the public and private banks were more efficient (CTE and AE) than foreign banks in 2005-2022. This finding contrasts with the findings of Bhatia & Mahendru (2018), who found that foreign banks are the most cost-efficient, followed by private and public banks from 2002-2003 to 2012-2013.

The estimated CTE scores of the foreign banks vary from a low of 0.117 to a high of 0.647. Likewise, the AE scores deviate from a minimum of 0.146 to a maximum of 0.691. The cost efficiency score is 31.8 percent, and the inefficiency score is 68.1 percent for foreign banks operating in India. The results reveal that most selected foreign banks have the least CE, whereas AE scores mean that these banks generated less income and profit. These inefficient foreign banks can improve their technical efficiency by reducing the inputs, which implies high wastage among the foreign banks operating in India.

The estimated results of time-varying (trends) mean efficiency of TE, CTE, and AE scores by bank ownership are reported in Table 4. The results show that bank ownership registered a mixed trend in the estimated scores of the TE, CTE, and AE during the study period. The estimated time-varying CTE scores ranged between 31–96 percent in public banks, 70–94 percent in private banks, and 11–75 percent in foreign banks. AE of public banks ranges from a minimum of 0.053 to a maximum of 0.980. The private banks deviate from a minimum of 0.611 to a maximum of 0.970, and foreign banks fall from a minimum of 0.068 to a maximum of 0.868. The overall mean allocative efficiency is 68.7 percent, and inefficiency is 31.2 percent in public banks. Similarly, the mean allocative efficiency is 89 percent, and inefficiency is 11 percent for private banks. Foreign banks' overall mean allocative efficiency (inefficiency) is 31.5 percent (68.5 percent).

The study's findings advocate that the overall average cost efficiency is 71.1 percent, 88.6 percent, and 26.4 percent, respectively, for public, private, and foreign banks during the study period. This indicates that public and private banks have potential cost savings of 28.9 percent and 11.4 percent, respectively. The estimated results reveal that technical and allocative efficiency scores are higher in the public and private banks from 2005 to 2022.

Table 4: Estimated results of time-varying overall mean cost efficiency scoresby bank ownership

Year	*Public Banks*			*Private Banks*			*Foreign Banks*		
	TE	*CTE*	*AE*	*TE*	*CTE*	*AE*	*TE*	*CTE*	*AE*
2005	0.963	0.809	0.839	0.962	0.915	0.956	0.850	0.171	0.088
2006	0.978	0.854	0.874	0.949	0.700	0.945	0.882	0.164	0.079
2007	0.981	0.566	0.854	0.960	0.917	0.954	0.876	0.164	0.078
2008	0.969	0.950	0.980	0.979	0.944	0.970	0.847	0.171	0.086
2009	0.976	0.811	0.829	0.967	0.905	0.611	0.876	0.054	0.068
2010	0.975	0.771	0.794	0.955	0.907	0.954	0.862	0.166	0.191
2011	0.966	0.710	0.732	0.962	0.917	0.957	0.799	0.173	0.207
2012	0.976	0.704	0.684	0.962	0.919	0.959	0.755	0.173	0.219
2013	0.982	0.605	0.686	0.961	0.926	0.968	0.781	0.115	0.130
2014	0.975	0.676	0.623	0.952	0.892	0.943	0.840	0.132	0.139
2015	0.983	0.609	0.618	0.958	0.905	0.951	0.885	0.450	0.563
2016	0.969	0.309	0.300	0.955	0.855	0.899	0.846	0.127	0.139
2017	0.991	0.550	0.552	0.961	0.903	0.944	0.873	0.129	0.152
2018	0.963	0.524	0.543	0.954	0.910	0.955	0.864	0.133	0.143
2019	0.978	0.474	0.481	0.956	0.906	0.951	0.877	0.716	0.854
2020	0.976	0.962	0.053	0.938	0.846	0.909	0.792	0.659	0.850
2021	0.988	0.962	0.976	0.951	0.839	0.894	0.887	0.707	0.823
2022	0.841	0.953	0.959	0.925	0.837	0.904	0.879	0.751	0.868
Mean Efficiency	0.968	0.711	0.6876	0.956	0.886	0.890	0.848	0.264	0.3153
Mean inefficiency	0.032	0.289	0.3124	0.044	0.114	0.109	0.152	0.736	0.6847
Sample Period		18			18				18

Source: Author's calculations

The study found that foreign banks had lower cost efficiency than public and private banks during 2005-2022. The analysis suggests that the foreign banks did not follow the cost-saving technology guidelines during the study period. The public banks obtained the least CTE and AE. efficiency scores during 2013-2019. Similarly, minimum CTE and AE scores were obtained from 2018 to 2022, and foreign banks attained maximum CTE and AE scores from 2020 to 2022. The private banks managed to get maximum CTE and AE scores during the study period from 2005 to 2022.

Second Stage Results

The estimated parameters of determinants of cost efficiency obtained from MLSFTPF are presented in Table 5. The present study theoretically observes that all the estimated parameters have expected signs and are statistically significantly different from zero, indicating that MLSFTPF is a good fit. The estimated parameters of the TLA have a statistically significant positive effect on the total cost in all the specifications by bank ownership.

The estimated results suggest that a 1 unit increase in TLA leads to an increase of 0.044 units, 0.02 units, and 0.30 units in the total cost of public, private, and foreign banks, respectively, ceteris paribus.

Table 5: Estimated results of Stochastic Frontiertranslog cost functions by bank ownership

Parameters		*Dependent Variable: Total Cost*					
		Public Banks		*Private Banks*		*Foreign Banks*	
		Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
β_0	Constant	0.92	1.37	1.10*	6.88	2.37	5.15
β_1	TLA	0.044*	0.02	0.02*	1.00	0.30**	1.82
β_2	OEA	0.27*	1.23	0.08*	1.60	0.10**	0.71
β_3	PPC	0.003	0.01	0.91**	7.58	0.27	1.93
β_4	PFA	-0.47	-1.62	0.05	1.25	0.13	2.17
β_5	PL	1.16**	2.64	0.22	2.20	0.23	1.28
β_6	PLF	0.08**	0.73	0.04**	0.80	0.29*	2.90
β_7	$1/2 *(TLA)^2$	0.04	1.33	0.01**	1.00	0.01	0.50
β_8	(TLA)*OEA)	0.01	0.33	-0.01	-1.00	0.04**	2.00
β_9	(TLA)*(PPC)	0.03	0.38	-0.03	-1.50	0.004	0.005
β_{10}	(TLA)*(PFA)	-0.01	-0.25	-0.01	-1.00	-0.01	-1.00
β_{11}	(TLA)* (PL)	-0.05	-0.63	0.04	2.00	0.04	1.33
β_{12}	(TLA)* (PLF)	-0.02	-1.00	-0.03	-3.00	-0.02	-1.00
β_{13}	$1/2 *(OEA)^2$	0.03	0.75	0.005	0.004	-0.1**	-2.50
β_{14}	(OEA)* (PPC)	-0.09	-1.29	0.03**	1.50	-0.02	-1.00
β_{15}	(OEA)* (PFA)	-0.08**	-2.67	0.01**	1.00	-0.01	-1.00
β_{16}	(OEA)* (P.L.)	0.09	1.50	-0.02	-1.00	0.03	0.75
β_{17}	(OEA)* (PLF)	0.003	0.008	0.004	0.001	-0.01	-0.50
β_{18}	$1/2 *(PPC)^2$	0.58*	2.90	-0.03	-0.43	0.20	10.0
β_{19}	(PPC)*(PFA)	0.06	0.75	0.02	1.00	0.01*	1.00
β_{20}	(PPC)* (P.L.)	-0.53*	-2.65	-0.03	-0.43	-0.08*	-2.67
β_{21}	(PPC)* (PLF)	0.03	0.75	0.01	0.50	0.003	12.0
β_{22}	$1/2 *(PFC)^2$	0.07	1.40	0.007	0.001	0.002	10.2
β_{23}	(PFA)* (PL)	0.02	0.25	-0.05	-2.50	-0.01	-0.50
β_{24}	(PFA)* (PLF)	0.002	0.005	0.02	2.00	0.01	1.00
β_{25}	$1/2 *(PL)^2$	0.41**	1.86	0.04	0.44	-0.01	-0.14
β_{26}	(P.L.)* (PLF)	-0.01	-0.25	0.01	0.50	-0.02	-0.67
β_{27}	$1/2 *(PLF)^2$	0.003	0.00	0.001	0.52	0.01	1.00
	$\sigma^2=\sigma^2_u + \sigma^2_v$	0.3672	131.1	0.075	6.82	3.435	10.5
	$\gamma=(\sigma^2 u / \sigma^2)$	0.270	0.347	0.608			
	Log-Likelihood	84.00	110	-1253			
	Observations	360	342	360			

Source: Author's estimation

Note: (i). * Significant at 1 percent level, ** Significant at 5 percent level, and *** Significant at 10 percent level

(ii). Sigma^2 denotes the total amount of variance in the model.

(iii). Gamma gives the inefficiency term's ratio of variance over the total variance amount.

The estimated parameter of the PPC shows that there is a positive relationship between total cost functions. The estimated results suggest that a 1 unit increase in PPC leads to an increase of 0.003 units, 0.91 units, and 0.27 units in the total cost of public, private, and foreign banks, respectively. Similarly, a 1 unit increase in PL leads to an increase of 1.16 units, 0.22 units, and 0.23 units in the total cost of public, private, and foreign banks, respectively. The parameter PLF positively association with the total cost in all specifications by bank groups. This implies that a 1 percent increase in the price of PLF leads to 0.08 units and 0.04 units and 0.29 units increase in the total cost of public, private, and foreign banks, respectively. The estimated results show that the parameters of all the interaction and square terms have a mixed effect on the total cost function by bank groups in India.

The estimated sigma-squared (2) results show the total variance in the cost functions. The σ^2 values are positive in all specifications (bank groups). The estimated value of σ^2 is (not close to unity) 0.347, which shows the strong impact of the inefficiency score on the private banks' cost variance. The gamma ($\gamma = \sigma^2 u / \sigma^2$) gives the ratio of variance of the inefficiency term over the total amount of variance. To assess the romance efficiency factors, the study uses the gamma parameter, which is the ratio of the change due to inefficiency to the total change in the residuals of the regression model. The estimated values of gamma are 0.270 and 0.347, which imply that about 27 and 34.7 percent of the difference between the actual (observed) and potential (frontier) cost is mainly due to the technically inefficient performance of public and private banks, respectively.

A high gamma value (γ) indicates about 60.8 percent of the actual and potential cost difference, primarily due to foreign banks' technically inefficient performance. The gamma value must lie between 0 and 1. If the gamma is equal to 1, then there is a minor impact of the random error term (v), which means that gamma is determined by the non-negative error term (u). Conversely, if the gamma is equal to 0, then it means that the cost functions are explained as pure noise.

Third Stage Results

The estimated Logit coefficients of determinants of cost efficiency for the public, private, and foreign banks are reported in Table 6. The CTE scores obtained from the DEA model are considered dependent variables. The CTE scores by bank ownership are regressed on the L.R., DMR, AE, AC, FCS, IM, BS, and DD. The results reveal that these expected signs significantly affect the CTE of commercial banks by bank ownership. The results suggest that if all other variables are held constant, there is an increase in LR. by 1

percent, which increases the probability of CTE score by about 0.002 percent in both public and private banks.

The results suggest that if all other variables are held constant, then there is an increase in DMR by 1 percent, which increases the probability of CTE score by 1.67 percent in public banks, 1.88 percent in private banks, and 1.37 percent in foreign banks. Likewise, an increase in AE by 1 percent increases the probability of CTE score by 3.35 percent, 3.17 percent, and 1.96 percent, respectively, in public, private, and foreign banks. The analysis shows that the DMR and AE are dominant factors in determining the CTE score in all the bank ownerships. The estimated coefficient of IM positively affects CTE score and is statistically significant in public banks. The results confirmed the study's findings by Kumar & Gulati (2008), which implied that large banks can handle their resources efficiently, at least technically. The results suggest that a 1 percent increase in the D.D. decreases the probability of CTE score by approximately 0.30 percent in public banks, 0.50 percent in private banks, and 0.06 percent in foreign banks. This implies that more efficient banks are associated with banks with higher DMR and AE. Expanding the banks' DMR and AE might involve extra benefits, improving the banks' efficiency.

Table 6: Maximum likelihood Logitestimates of determinants of cost efficiency

Variables	*Dependent Variable: Cost Technical Efficiency Score*					
	Public Banks		*Private Banks*		*Foreign Banks*	
Independent Variable	*Coefficient*	*T-Value*	*Coefficient*	*T-Value*	*Coefficient*	*T-Value*
Constant	15.472*	2.77	2.101	2.03	-3.335*	0.76
LR	0.002**	4.16	0.002	0.00	0.001	0.00
DMR	1.67*	2.154	1.886*	1.890	1.377	12.9
AE	3.35*	5.76	3.175*	11.0	1.965*	5.31
AC	-5.76***	3.0	-0.962	58.0	-7.39	19.9
FCS	0.173	2.87	-0.001*	0.00	-0.001*	0.00
I'M	0.002*	0.00	0.001	0.00	0.002***	0.00
BS	-1.044*	0.27	0.443	0.40	0.273*	0.08
DD	-0.309**	0.20	-0.501**	0.33	-0.061	0.05
2loglikelihood	-193.35		-39.782		-199.21	
LR-Chi^2	105.69		49.57		59.58	
Pseudo R^2	0.2146		0.3839		0.1301	
Sample Size	360	342	360			

Source: Author's computation

Note: Standard Errors are given in parentheses)

* Significant at 1 percent level, ** Significant at 5 percent level, and *** Significant at 10 percent level

V. CONCLUSION

This study provides empirical evidence by estimating the technical efficiency, cost function, and determinants of cost efficiency by bank groups operating in India from 2005 to 2022, applying a Three-Stage Econometric approach. The results of DEA indicate that the public and private banks operated more efficiently than the foreign banks during the study period. The results suggest that private banks operating in India have performed better in cost savings with the given technology than public banks. However, the results of DEA cost efficiency show that some public banks, namely UBI, VB, SYB, CBI, and BOM, are inefficient. Similarly, only private banks like CSB Bank are inefficient banks. Most foreign banks are found to have inefficiency scores, which means that these banks generate less income and profit, which may be incurred due to unwanted costs. The technical and cost inefficiencies are due to operating at an incorrect scale. The DEA analysis suggests that foreign banks did not follow cost-saving technology during the study period.

The estimated parameters of the TLA, PL, and PLF using the Stochastic Frontier Translog cost function are statistically significant and positively affect the total cost functions in all specifications by bank groups. The estimated Logit results reveal that the coefficient of LR has expected signs and significant effects on CTE in all public and private banks. The calculated result indicates that more efficient banks are associated with the banks with higher DMR and AE.

In Conclusion, public banks' technical efficiency (TE) and cost technical efficiency (CTE) significantly improved except for a few banks due to various banking sector reform committees adopted in India during the study period. The present study has found that most public banks have obtained the TE scores about 90 percent, and the private banks have obtained the TE above 80 percent. The estimated time-varying CTE scores ranged between 31– 96 percent in public banks, 70–94 percent in private banks, and 11–75 percent in foreign banks. The selected public, private, and foreign banks' CTE and AE scores are not equal to 100 percent. The results show that a least percentage of CTE and AE scores are registered in public and foreign banks. The private banks managed to get maximum CTE and AE scores during the study period from 2005 to 2022.

Various factors, including high expenses, poor borrower repayment, non-performing assets, ineffective resource allocation, etc., can cause low technical and cost efficiency scores. We hope the study's research contribution(findings) will help economists, policymakers, and bank owners develop appropriate strategies to improve the inefficient banks operating in India.

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