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AN ECONOMETRIC ANALYSIS OF TECHNICAL EFFICIENCY OF BANKING SECTOR IN INDIA

R. Mariappan
Department of Econometrics, University of Madras, Chennai. E-mail: drrmmetrics@gmail.com

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Abstract: The objective of the paper is to empirically evaluate the technical efficiency of commercial banks operating in India applying DEA and SFA techniques and determinants of efficiency using Logit technique during the period 2005 to 2022. The study finds that except few banks the public sector banks are operated more efficiently over the period 2005-2022. The estimated results of DEA also reveal that the public and private sectors banks operated more efficiently than foreign sector banks in India during the period of study. It implies that the foreign sector banks operated relatively inefficiently when compared to public and private sectors banks in India. The results of Stochastic Frontier Cobb-Douglas production function indicate that parameters of the TD, TB and TFA are positive and have significant effect on the dependent variable in all types of bank ownership. The Logit results reveal that the coefficients of LR, ROA, and BS have expected signs and have significant effect on the TE of the commercial banks of bank ownership. The findings of the study will be helpful to the policymakers and bank owners to develop banking sectors operating in India.

Keywords: Indian Banking Sector, DEA, Efficiency Measurement, Logit, SFA

JEL Classification: G21, C14, C21, H21, C33.

1. INTRODUCTION

The existing studies emphasized that the financial institutions play pivotal role in stimulating economic growth of the countries all over the world (Sensarma, 2006 & Sufian, 2011). The banking sector promotes economic growth through inflows of foreign capital, mobilisation of financial services, mediator between depositors and borrowers, credit to households, agriculture, governments, small and large scale industries, etc. (Banna, Ahmad & Koh, 2017). The structure of the Indian banking system can be divided into scheduled commercial banks, non-scheduled commercial banks and development banks. The scheduled banks are categorized into public sector banks, domestic private sector banks and domestic foreign sector banks in India. After the freedom, most of the nationalised banks have been facing various pressures in the forms of internal and external competitions, chit funds, information technology, new banking

services, internet banking, huge administrative expenses, non-performing assets, etc. (Shanmugam & Das, 2004).

To review the problems of the Indian banking sector, the Government of India adopted various banking sector reforms to improve the efficiency of the nationalised banks. As a result, it is essential to investigate whether the reforms are really beneficial to the Indian banking sector. The measurement of banking sector efficiency has received significant attention among the researchers. The term efficiency reflects the ability of the business firms to obtain maximum possible output (profit) from given inputs constraints (Farrell, 1957; Drucker, 1963). The efficiency of the banks depends on the bank capitalization, profitability, inflation rate, interest rate, competitions, and bank ownership effect , etc. (Banna, Ahmad & Koh, 2017).

II. REVIEW OF LITERATURE

In this section, the present study briefly reviews the closely related available existing studies in the Indian context. The following previous studies have applied the Data Envelopment Analysis (DEA) model for assessing the performance of Indian banks. Bhattacharya et al (1997) examined the productive efficiency of 70 Indian commercial banks during the period of liberalization (late 1980's to early 1990's) using DEA. The results show that the Indian public sector banks are the most efficient banks followed by foreign sector banks and private sector banks. The foreign banks are the least efficient at the beginning of the sample period, but at the end of the period they are nearly as efficient as the public sector banks.

Ataullah et al (2004) investigated a comparative technical efficiency of commercial banks operating in India and Pakistan by employing the DEA for the period 1988-1998. The data are obtained from the annual reports of Reserve Bank of India and various issues of Financial Analysis of Banks published by the Indian Banks' Association and Annual Banking Statistics published by the State Bank of Pakistan. The study indicates that the overall technical efficiency of the banking in both countries improved after 1995-1996. In the case of India, efficiency increased due to improvement in both pure technical efficiency and scale efficiency, while in Pakistan it was due to an improvement in scale efficiency. Mohan & Ray (2004) examined the revenue efficiency of public, private and foreign sectors banks using physical quantities of inputs and outputs during 1992-2000. The results show that revenue maximization efficiency are significantly better than private sector banks but the efficiency of the frontier sector banks is not significant. The bank efficiency is converged among public and private sectors banks during in the post-reform era. Sanjeev (2006) evaluated the technical efficiency of the banks operating in India in the post-reform era using non-parametric linear programming-based technique. The study has found that the efficiency of the

banks has improved over time and that the foreign banks have performed better than both private and public sectors banks in the post-reform era.

Kumar and Gulati (2007) analysed the technical efficiency of 27 public sector banks in India using the DEA under CCR, and Andersen and Petersen's Super efficiency models with the cross-section data for the financial year 2004-2005. The results show that the technical efficiency scores range fall from 0.632 to 1, with an overall average of 0.885. Andhra Bank is found to be the most efficient bank followed by Corporation Bank. The overall technical inefficiency in the public sector banks is found to be around 11.5 per cent. The foreign sector banks are found to be more cost-efficient but less profit-efficient relative to domestically owned private banks and state-owned banks. The banks affiliated with SBI group are found to outperform the nationalized banks in terms of operating efficiency. Rezvanian et al. (2008) using DEA examined the effects of the ownership on the efficiency in the Indian banking industry over the period 1998 to 2003. The results indicated that foreign banks had significantly more efficient when compared to privately-owned and publicly owned-banks. Puri & Yadav (2013) attempted to measure TE, PTE and SE of public and private sector banks in India for the year 2009-2010 applying DEA approach. The results show that the nationalised banks, SBI & its associate banks have performed better technical efficiency in all categories than private sector banks. The results show that the contribution of scale inefficiency in overall technical inefficiency have been observed to be smaller than the contribution of pure technical inefficiency. The highest and lowest levels of average overall technical inefficiency are 48.8 per cent for public sector banks and 2.2 per cent for SBI & its associates.

Khosla & Khurana (2019) examined the technical efficiency and its correlates of the banking sector in India during 1995-2016 using DEA with RBI data set for 51 banks. The results reveal that mean technical efficiency score for all the banks is 0.8949. It implies that the inputs of these banks are required to be reduced by 10.51 per cent. The managerial performance (pure technical inefficiency) account is 5.27 per cent and the remaining per cent is scale inefficiency. Both managerial and scale inefficiencies contribute almost equally in the technical inefficiency. The public, private and foreign sectors banks are found to have operated at 89.33, 87.64 and 97.76 per cent of overall technical efficiency respectively. Mariappan (2022) analysed a comparative technical efficiency of commercial banks by bank ownership applying the input-oriented DEA model and further investigate the determinants of banks efficiency employing both OLS and Logit models during 2005-2019. The results of DEA show that the public and private sectors banks are more efficient than foreign sector banks in India over the period of study. The estimated results of the OLS and Logit models indicate that the coefficients of LR, ROA and BS have significant positive effect on the bank technical efficiency.

The following few studies examined the Indian bank efficiency applying stochastic frontier production function (Shanmugam and Das, 2004 & De, 2004). Shanmugam and Das (2004) investigated the technical efficiency of banks using stochastic frontier Cobb-Douglas production function during the reform period, 1992-1999. They consider four input variables namely deposits, borrowings, labour and fixed assets and four output variables namely net interest income, non-interest income, credits and investments. The results show that deposit is more dominant factor in producing all outputs across the commercial banks. The reform measures that have not helped the banks in raising their interest margin and also the private and foreign banks have performed better than public sector banks. The results indicate that due to technical inefficiency actual output of Indian banks is less than potential output. The Banks of SBI group and private foreign groups have performed better than their counterparts.

De (2004) estimates the technical efficiency of banks by ownership in both pre-reform and post-reform periods using the Stochastic Frontier Cobb-Douglas production function. The study obtained panel data of 65 banks from 1985-86 to 1995-96 from the various reports of Indian Banks' Association. The results reveal that the liberalisation has no effect on the efficiency of Indian banking sector but foreign sector banks are more efficient when compared to the public and private sector banks. The results show that the efficiency of the banking sector has not improved after liberalisation. The foreign sector banks have to yield the highest efficiency of the output measure. The results also show that technical efficiency has increased only 14 banks out of 18 banks in the post-liberalisation period. The Vijaya Bank is worst affected by efficiency in the post-liberalisation period. Among the public sector banks, the State Bank of Indore has gained most in technical efficiency in the post-liberalisation era.

The following available few empirical studies (Ataullah, Cockerill, & Hang, 2004; Ataullah & Howcroft, 2006; Jaffry, Ghulam & Cox, 2007) investigated the impact of deregulation on the banks' efficiency of cross-countries (India, Pakistan and Bangladesh) using DEA approach. The above received literature reveals that most of the Indian studies examined the technical efficiency of banks applying non-parametric approach. Only few studies have analysed the technical efficiency of banks using stochastic frontier approach, but their results are mixed.

The available literature indicates that any Indian study never examined a comparative analysis of technical efficiency of commercial bank operating in India by bank ownership using nonparametric (DEA) and parametric (SFA) techniques and finally determinants technical efficiency employing Logit model. Therefore, the present study gets an opportunity to fill this literature gap on efficiency of the banking sectors in India. The study's findings will be helpful to the policymakers and group of banks to take appropriate strategies to improve the efficiency of the banking sector.

SOURCE OF DATA AND METHODOLOGY

Source of Data

The present study collected data for the period 2005-2022 from the Bank Statistical Tables Reserve Bank of India (RBI). The required data sets are not available consistently for all banks for all years. Most of the private domestic sector banks and foreign sector banks are established after 2005. Some banks are closed and merged with other banks during the period 2005-2022. Since the non-availability of balanced data sets for some private and foreign sectors banks, the present study selected only 20 public sector banks, 19 private sector banks and 20 foreign sector banks. Since, the present study is an unbalanced panel of 59 banks for 18 years of data sets from 2005 to 2022. The selected commercial banks operating India are presented in Table 1.

Table 1: List of the Selected Commercial Banks

Public Sector Banks		*Private Sector Banks*		*Foreign Sector 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	(FB)	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	(CB)	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	(KB)	Credit Agricole Corporate And Investment Bank	(CACI)
Indian Bank	(IB)	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)
				MIZUHO Bank Ltd	
State Bank of India	(SBI)	South Indian Bank Ltd	(SIB)	(MIZUHO)	
Syndicate Bank	(SYB)	Tamilnad 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.	(YB)	Shinhan BANK	(SHINHAN.B)
Vijaya Bank	(VB)			Standard Chartered Bank	(SCB)

Econometric Applications

To identify the performance of commercial banks operating in India during the period 2005-2022, the present study estimated the technical efficiency of the banks applying both Non-parametric Data Envelop Analysis (DEA) and Parametric Stochastic Frontier Analysis (SFA) techniques. Finally, the determinants of technical efficiency are estimated employing the Maximum Likelihood Logit technique with help of the DEA-Frontier and STATA Software.

The existing empirical studies are widely employed both DEA frontier and SFA techniques to measure the efficiency of the commercial banks. Both the DEA and SFA

techniques are differed according to the assumptions of the dataset and technology. The DEA technique ignores the random factors that can influence the efficiency of the banks and it is unable to decompose into inefficiency (U) and random error (V) components. But the SFA technique decomposes the error terms into inefficiency term (U) and random term (V). The DEA frontier converts the multiple inputs and multiple outputs of each commercial bank into a scalar measure of efficiency score by assigning weights to the inputs and outputs of a Decision Making Units (DMUs).

The input-oriented and output-oriented DEA-CCR models under the assumptions of the Constant Returns to Scale (CRS) are developed by Charnes, Cooper, and Rhodes (1978). Similarly the input-and output oriented, DEA-BCC models under the assumptions of the variable returns to scale (VRS) are defined by Banker, Charnes and Cooper (1984). Both models are most frequently employed by existing studies to calculate the efficiency score. The basic difference between both models is the addition of convexity constraints $\Sigma_{j=1}^{n}\lambda = 1$ in the BCC model. The scale efficiency (SE) is computed by TE being divided by PTE. The technical maximisation problem can be formulated based on the earlier empirical studies.

DATA ENVELOP ANALYSIS FRONTIER

The mathematical specifications of the input-oriented CCR and BCC for technical efficiency models are specified in equations (1) and (2)

Technical Efficiency under CCR-CRS: Equation(1)

Zp = Min θp

Subject to Conditions

$$\Sigma_{j=1}^{n}\lambda_j X_{ij} - \theta_p X_{ip} \leq 0$$

$$\Sigma_{j=1}^{n}\lambda_j Y_{rj} \geq Y_{rp}$$

λj ≥ = 0

Technical Efficiency under BCC–CRS: Equation(2)

Zp = Min θp

Subject to Conditions

$$\Sigma_{j=1}^{n}\lambda jX_{ij} - \theta pX_{ip} \leq 0$$

$$\Sigma_{j=1}^{n}\lambda jX_{rj} \geq Y_{rp}$$

$$\Sigma_{j=1}^{n}\lambda = 1$$

$\lambda j \geq = 0$

Where

λ_j, j = 1,2,…n are weights of DMUs

X_{ip}- is a vector of input prices of DMUp

X_{ij} = the amount of ith input used by jth DMU

Y_{rj} = the amount of rth output produced by jth DMU

Z_p = Efficiency score for the DMUp

i = 1, 2, ……mth input

r = 1, 2, …….sth output

j = 1, 2, ……nth DMU

Each DMU takes 'm' different inputs to produce 's' different outputs

Stochastic Frontier Analysis

The SFA technique is considered to be more sophisticated compared to non-parametric technique. Numerous empirical studies broadly employed the Cobb-Douglas Stochastic Frontier-Production Functions (CDSFPF) to measure the commercial banks' technical efficiency parameters. The Stochastic Frontier Analysis (SFA) takes advantage over other models by inclusion of composite error terms. The empirical studies (Aigner et al 1977 and Meeusen and Broeck 1977) developed the SFA production function with a composite error terms namely random noise (v_i) and technical efficiency term (u_i) to measure the technical efficiency. In order to capture the effects of composite error terms, the specification of the CDSFPF in the logarithmic expression can be written as:

$$\ln (TI_{it}) = \beta_0 + \beta_1 \ln TD_{i,t} + \beta_2 \ln T B_{i,t} + \beta_3 \ln TW_{i,t} + V_{it} + (-U_{it}) \quad (3)$$

The definitions of variables are presented in Table 2. V_{it} and U_{it} denote the error terms. The non-negative random variable (U_{it}) lies between 0 and 1 and it is associated with technical inefficiency of the banks. For the efficient banks, the residual variables (u_{it}) are equal to 0; it means that the banks produce the potential output. For the inefficient banks, the residual variables (u_{it}) are greater than 0, which means that the banks produce below the potential output. The inefficiencient banks are assumed to follow an asymmetric distribution, while random errors are assumed to follow asymmetric distribution (Aigner *et al.*, 1977 & Kirkley, *et al.* 1995). The random variables (v_{it}) are assumed to be independently distributed as truncations with mean 0 and variance $\sigma^2 v$. The total variance of the model will be: σ^2 ($=\sigma^2_u + \sigma^2_v$). A measurement of this value, with respect to the total variance will be: $\gamma = (\sigma^2 u / \sigma^2)$.

Logit Model

Finally, the present study uses the Logit model to explore the determinants of banks technical efficiency by bank ownership. The following empirical studies (Lema, 2017; Singh & Fida, 2015) estimated the determinants of the technical efficiency of the commercial banks applying Tobit model and explained that the DEA efficiency score lies between 0 and 1. Though, McDonald (2009) has stated that the Tobit model is an inappropriate model and it is also known as the censored nature of the regression model, the data of technical efficiency is a fraction of continuous dependent variable which is not generating a censoring process. Estimating the determinants of technical efficiency applying Tobit model would lead to a biased parameters. Therefore, McDonald recommended that the Ordinary Least Squares method would be an appropriate method to estimate the determinants of the technical efficiency. The following existing studies (Ray, 1991; Chirkos & Sears, 1994; Stanton, 2002) used the OLS model to explore the banks' technical efficiency determinants.

On the contrary, the following empirical studies (Kumar & Gulati, 2008; Adusei, 2016) suggested that the use of the Maximum Likelihood Logit (MLL) procedure would be a more appropriate model to examine the determinants of the banks' technical efficiency. In the MLL model, the dependent variable is dichotomous, where the value 1 is taken for an efficient bank (highest efficiency score) and 0 is taken for an inefficient bank (lowest efficiency score). Therefore, the present study employs the MLL model to examine the determinants of technical efficiency (dependent variable) obtained from DEA frontier. The specification of the MLL Model can be written as:

$$TE_{i,t} = \beta_0 + \beta_1 LR_{i,t} + \beta_2 ROA_{i,t} + \beta_3 BS_{i,t} + \beta_4 CR_{i,t} + e_{i,t} \quad (4)$$

Where TE (= Pi/1-Pi) represents the ratio of the probability of occurrence and non-occurrence. Pi represents the probability of occurrence of events (Bank efficiency) in the observation; 1-Pi represents the probability of non-occurrence of events (Bank inefficiency) in the observation. The subscript 'i' denotes i^{th} observation of bank, the subscript't' denotes the time series data t^{th} observation, β_0 denotes the 'intercept' from β_1 to β_4 denote the unknown parameters and e denotes the stochastic 'error' term.

EMPIRICAL FINDINGS AND DISCUSSION

All the input and output variables are measured in the Indian rupees in the DEA, SFA and Logit analyses which are presented in Table 2.

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

Variable	*Data Envelopment Analysis*	
	Variable Name & Notation	Measurement of the Variable : Units of measurement in Crore
OV	Interest Income (II)	Sum of interest income from loans and advances, deposit and treasury and NBE bills.
	Non-Interest Income (NII)	Sum of commission, fee and charges on credit, guarantee and local transfer, etc.
	Total loan & Advance (TLA)	Loans include commercial, industrial, consumer and real estate.
IV	Interest Expenses (IE)	Sum of payment on fixed deposits, saving and demand deposits.
	Operating Expenses (OE)	Sum of salary and benefits, administrative, provision for doubtful debt, audit fee, etc.
	Total Deposits (TD)	Sum of demand, time and saving deposit.
	Maximum likelihood Stochastic Frontier Analysi	
DV	Total income (TI) : Interest income & Non Interest	Sum of interest income from loans and advances, deposit and treasury and NBE bills. The sum of commission, fee and charges on credit, guarantee and local transfer, etc.
IV	Total Deposits (TD)	Total deposits are the input variable that represents deposits from customers and other banks.
	Total Borrowings (TB)	Borrowing by Banks
	Total Workers (TW)	Number of workers
	Maximum likelihood Logit Analysi	
DV	Technical Efficiency (TE)	The efficiency score derived from DEA
	Liquidity Risk (LR)	Ratio of Loans to Deposits
IV	Return on Assets (ROA)	Ratio of net income to Total assets
	Bank Size (BS)	Size of operation of assets
	Market Share (MS)	Ratio of Total assets of a bank to Total assets of all banks
	Credit Risk (CR)	Ratio of Total loans to Total assets)

Note: OV = Output Variables, IV = Input Variables, DV= Dependent Variable, IV= Independent Variables

The estimated DEA results of the technical efficiency of the banks by bank ownership are reported in Table 3. The results showed that the input-oriented technical efficiency scores are asymmetrical among the bank ownership. The public and private sectors banks performed the highest technical efficiency scores during the period 2005-2022. It implies that these banks adopted the best practice technology to reduce their inputs of physical capital and labour. However, the reduction of inputs from adopting the best practices varies from bank to bank. The findings of Kumar and Gulati (2008) reveal that the public sector banks are operated at 88.5 per cent of overall technical efficiency and this finding supported the present study. The results show that among the 20 public sector banks, the TE scores are found to be equal to 100 per cent in CB, IDBI and SBI banks. Among the private sector banks, the TE scores are found to be equal to 100 per cent in AXIS, HDFC, ICIC, KM and YBL banks and among the 20 foreign sector banks, the TE score is found to be equal to 100 per cent in AB bank only.

Table 3: Estimated Results of Output Mean Technical Efficiency Score Values by Bank Groups

Public Bank				*Private Bank*				*Foreign Private Bank*			
Bank Name	*TE*	*PTE*	*SE*	*Bank Name*	*TE*	*PTE*	*SE*	*Bank Name*	*TE*	*PTE*	*SE*
ALB	0.965	0.972	0.994	AXIS	1.000	0.997	0.994	AB	1.000	1.000	1.000
ANB	0.988	0.994	0.993	CSB	0.843	0.884	0.955	ACB	0.800	0.829	0.964
BOB	0.993	0.999	0.994	CUB	0.994	0.996	0.998	BOA	0.880	0.990	0.889
BOI	0.968	0.983	0.984	DCB	0.908	0.971	0.935	BBK	0.747	0.781	0.958
BOM	0.959	0.985	0.973	FB	0.974	0.979	0.995	BOC	0.942	1.000	0.942
CNB	0.968	0.998	0.970	HDFC	1.000	1.000	1.000	BONS	0.872	0.908	0.955
CBI	0.940	0.945	0.995	ICICI	1.000	0.995	0.996	BB PLC	0.812	0.970	0.839
CB	1.000	1.000	0.997	IBL	0.962	0.974	0.988	BNP	0.730	0.911	0.801
DNB	0.954	0.992	0.961	J & K	0.955	0.963	0.991	CITI.N	0.779	1.000	0.779
IDBI	1.000	1.000	1.000	KBL	0.952	0.962	0.989	CACI	0.916	0.951	0.962
IB	0.987	0.992	0.994	KVB	0.957	0.967	0.989	CS AG	0.951	0.971	0.978
IOB	0.986	0.989	0.996	KMB	1.000	1.000	1.000	CTBC	0.779	0.937	0.830
OBC	0.987	0.989	0.998	LVB	0.928	0.945	0.981	DBS	0.714	0.957	0.745
PSB	0.973	1.000	0.973	NB	0.953	1.000	0.953	HSBC	0.701	0.983	0.712
PNB	0.994	0.997	0.997	RBLB	0.937	0.984	0.953	JCBNA	0.973	0.984	0.988
SBI	1.000	1.000	1.000	SIB	0.964	0.970	0.994	MIZUHO	0.942	0.972	0.969
SYB	0.978	0.982	0.996	TMB	0.974	0.982	0.992	MUFG	0.936	0.988	0.947
UOB	0.988	0.993	0.995	DBL	0.862	0.914	0.944	RBS	0.964	0.976	0.988
UBI	0.944	0.974	0.969	YBL	1.000	0.997	0.998	SHINHAN	0.752	1.000	0.752
VB	0.957	0.989	0.967					SCB	0.627	0.968	0.649
0.976	0.989	0.987		0.956	0.973	0.981		0.841	0.954	0.882	
0.024	0.011	0.013		0.044	0.027	0.019		0.159	0.046	0.118	

Source: Author's calculations

The present study finds that the public and private banks are more efficient than foreign sector banks over the period 2005-2022. The mean technical efficiency score is found to have least score for foreign sector bank, particularly BNP, DBS, HSBC and SCB banks. Except these banks, the other banks are considered to be the most efficient banks. These inefficient foreign banks can improve their technical efficiency by reducing the inputs. This finding is similar to the study of Puri and Yadav (2013), which found that the public banking sector is more efficient than the private banking sector in India for the years 2009 to 2010 using the DEA.

The estimated trends (time varying) of mean efficiency scores for TE, PTE and SE by bank ownerships are reported in Table 4. The results show that the overall mean of technical efficiency score values under the TE scores are falling from 84 to 99 per cent for 20 public sector banks, from 92 to 97 per cent for 19 private sector banks and from 75 to 88 per cent for 20 foreign sector banks.

Table 4: Estimated Results of Time-varying Output Mean Technical Efficiency Scores

Year	*Model*	*Public Banks*				*Domestic Private Banks*				*Foreign Private Banks*			
		Min	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*
2005	TE	0.889	1.000	0.963	0.037	0.835	1.000	0.962	0.058	0.497	1.000	0.850	0.153
2006	TE	0.918	1.000	0.978	0.026	0.820	1.000	0.949	0.063	0.455	1.000	0.882	0.162
2007	TE	0.922	1.000	0.981	0.025	0.857	1.000	0.960	0.055	0.637	1.000	0.876	0.139
2008	TE	0.863	1.000	0.969	0.037	0.899	1.000	0.979	0.034	0.587	1.000	0.847	0.156
2009	TE	0.892	1.000	0.976	0.032	0.840	1.000	0.967	0.051	0.656	1.000	0.876	0.135
2010	TE	0.888	1.000	0.975	0.037	0.765	1.000	0.955	0.068	0.534	1.000	0.862	0.146
2011	TE	0.891	1.000	0.966	0.036	0.821	1.000	0.962	0.059	0.547	1.000	0.799	0.170
2012	TE	0.924	1.000	0.976	0.025	0.770	1.000	0.962	0.066	0.458	1.000	0.755	0.206
2013	TE	0.924	1.000	0.982	0.023	0.842	1.000	0.961	0.055	0.498	1.000	0.781	0.183
2014	TE	0.920	1.000	0.975	0.024	0.818	1.000	0.952	0.062	0.549	1.000	0.840	0.166
2015	TE	0.939	1.000	0.983	0.023	0.807	1.000	0.958	0.066	0.517	1.000	0.885	0.131
2016	TE	0.878	1.000	0.969	0.034	0.822	1.000	0.955	0.054	0.560	1.000	0.846	0.168
2017	TE	0.924	1.000	0.991	0.021	0.794	1.000	0.961	0.060	0.590	1.000	0.873	0.142
2018	TE	0.876	1.000	0.963	0.041	0.814	1.000	0.954	0.055	0.486	1.000	0.864	0.142
2019	TE	0.909	1.000	0.978	0.028	0.785	1.000	0.956	0.070	0.621	1.000	0.877	0.144
2020	TE	0.926	1.000	0.976	0.029	0.759	1.000	0.938	0.784	0.393	1.000	0.792	0.185
2021	TE	0.942	1.000	0.988	0.020	0.806	1.000	0.951	0.067	0.427	1.000	0.887	0.161
2022	TE	0.999	1.000	0.841	0.353	0.746	1.000	0.925	0.076	0.521	1.000	0.879	0.152
overall Mean(2005-2022)		0.862	1.000	0.968	0.047	0.811	1.000	0.956	0.100	0.530	1.000	0.848	0.158
2005	PTE	0.906	1.000	0.981	0.032	0.850	1.000	0.973	0.051	0.719	1.000	0.951	0.090
2006	PTE	0.945	1.000	0.989	0.020	0.858	1.000	0.967	0.054	0.694	1.000	0.969	0.082
2007	PTE	0.923	1.000	0.990	0.021	0.857	1.000	0.977	0.044	0.639	1.000	0.961	0.098
2008	PTE	0.881	1.000	0.982	0.031	0.907	1.000	0.983	0.032	0.606	1.000	0.963	0.093

Year	*Model*	*Public Banks*				*Domestic Private Banks*				*Foreign Private Banks*			
		Min	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*
2009	PTE	0.934	1.000	0.987	0.022	0.845	1.000	0.975	0.047	0.663	1.000	0.969	0.084
2010	PTE	0.916	1.000	0.988	0.028	0.777	1.000	0.964	0.059	0.560	1.000	0.928	0.142
2011	PTE	0.933	1.000	0.984	0.024	0.824	1.000	0.968	0.050	0.592	1.000	0.943	0.120
2012	PTE	0.928	1.000	0.993	0.017	0.834	1.000	0.971	0.052	0.716	1.000	0.948	0.103
2013	PTE	0.925	1.000	0.991	0.018	0.865	1.000	0.977	0.041	0.783	1.000	0.956	0.073
2014	PTE	0.955	1.000	0.992	0.014	0.877	1.000	0.975	0.043	0.672	1.000	0.942	0.096
2015	PTE	0.952	1.000	0.994	0.013	0.891	1.000	0.980	0.035	0.755	1.000	0.947	0.087
2016	PTE	0.941	1.000	0.988	0.017	0.883	1.000	0.979	0.036	0.655	1.000	0.957	0.094
2017	PTE	0.925	1.000	0.995	0.017	0.897	1.000	0.985	0.031	0.886	1.000	0.991	0.027
2018	PTE	0.928	1.000	0.987	0.024	0.903	1.000	0.979	0.033	0.747	1.000	0.967	0.066
2019	PTE	0.911	1.000	0.989	0.025	0.822	1.000	0.981	0.041	0.717	1.000	0.961	0.086
2020	PTE	0.928	1.000	0.983	0.026	0.812	1.000	0.966	0.055	0.400	1.000	0.916	0.157
2021	PTE	0.953	1.000	0.993	0.015	0.826	1.000	0.975	0.048	0.447	1.000	0.934	0.145
2022	PTE	0.982	1.000	0.997	0.007	0.759	1.000	0.959	0.060	0.529	1.000	0.962	0.112
overall Mean (2005-2022)		0.931	1.000	0.989	0.021	0.849	1.000	0.974	0.045	0.654	1.000	0.954	0.098
2005	SE	0.889	1.000	0.982	0.028	0.884	1.000	0.989	0.027	0.521	1.000	0.895	0.139
2006	SE	0.931	1.000	0.989	0.019	0.881	1.000	0.981	0.032	0.504	1.000	0.910	0.144
2007	SE	0.960	1.000	0.992	0.013	0.874	1.000	0.983	0.036	0.646	1.000	0.913	0.115
2008	SE	0.925	1.000	0.987	0.020	0.959	1.000	0.995	0.011	0.599	1.000	0.881	0.141
2009	SE	0.936	1.000	0.988	0.018	0.920	1.000	0.992	0.019	0.707	1.000	0.905	0.117
2010	SE	0.923	1.000	0.988	0.022	0.909	1.000	0.989	0.021	0.740	1.000	0.931	0.086
2011	SE	0.927	1.000	0.982	0.029	0.898	1.000	0.993	0.023	0.597	1.000	0.849	0.147
2012	SE	0.943	1.000	0.984	0.022	0.920	1.000	0.990	0.025	0.458	1.000	0.799	0.203
2013	SE	0.944	1.000	0.990	0.017	0.899	1.000	0.983	0.029	0.520	1.000	0.818	0.183
2014	SE	0.929	1.000	0.982	0.021	0.857	1.000	0.976	0.040	0.617	1.000	0.889	0.131
2015	SE	0.953	1.000	0.989	0.016	0.903	1.000	0.976	0.041	0.517	1.000	0.936	0.117
2016	SE	0.878	1.000	0.981	0.031	0.912	1.000	0.975	0.031	0.622	1.000	0.883	0.144
2017	SE	0.963	1.000	0.996	0.011	0.863	1.000	0.975	0.042	0.610	1.000	0.881	0.135
2018	SE	0.876	1.000	0.976	0.035	0.881	1.000	0.975	0.037	0.651	1.000	0.890	0.119
2019	SE	0.939	1.000	0.990	0.017	0.829	1.000	0.974	0.048	0.621	1.000	0.913	0.121
2020	SE	0.889	1.000	0.981	0.030	0.778	1.000	0.970	0.050	0.889	1.000	0.982	0.029
2021	SE	0.967	1.000	0.993	0.011	0.824	1.000	0.975	0.049	0.884	1.000	0.989	0.027
2022	SE	0.985	1.000	0.998	0.005	0.752	1.000	0.965	0.058	0.521	1.000	0.904	0.137
overall Mean (2005-2022)		0.980	1.000	0.987	0.020	0.875	1.000	0.981	0.034	0.624	1.000	0.898	0.124

Source: Author's calculations

The mean efficiency is stable for foreign sector banks. It increases during 2005-2009, and then it decreases during 2010-2015, and then increases during 2015-2020. The results show that the overall mean of TE is 96.8 per cent in public sector banks for all the years, suggesting that mean input waste is 3.2 per cent. The overall time-varying mean of TE is 84.8 per cent in foreign sector banks; suggesting mean input waste is 5.2 per cent. The overall time-varying of mean efficiency score of TE is 95.6 per cent, in private sector suggesting that mean input waste is 4.4 per cent. In DEA literature, the DMUs getting TE scores equal to 1 are referred as 'globally technical efficient. The estimated results of DEA reveal that the efficiency scores for public sector banks are recorded above 95 per cent under the estimation of CRS and VRS.

The mean of overall PTE scores is 0.987 indicating that the extent of pure technical inefficiency (PTIE) in the Indian public sector banks is 1.3 per cent. The results suggest that Indian public sector banks are primarily attributed to managerial inefficiency (1.3 per cent). The overall mean value of SE scores is 0.987 which indicates that the public sector banks are operated at optimum scale size. If the value of scale efficiency (SE) score is equal to 1; it implies that the particular bank is operating at most productive scale size i.e. optimal scale size. On the contrary, if the value of SE score is not equal to 1; it implies that the bank is experiencing inefficiency because it is not operating at its optimal scale size. However, the TE, PTE and SE score values are lower in foreign sector when compared to public and private sector banks during the period 2005-2022.

Results of SF Cobb-Douglas Function

The estimated parameters of Maximum Likelihood Cobb-Douglas Stochastic Frontier Production Function are presented in Table 5. From the analysis, the present study theoretically observes that all the estimated parameters have expected signs and statistically significant, indicating a goodness of fit. The estimated results show that parameters of the independent variables TD, TB and TFA have positive effect on the dependent variable and are statistically significant at 1 per cent level in all groups of bank ownership. The estimated results suggest that 1 unit increase in TD leads to increase of 0.795 units, 0.822 units and 0.235 units in TI of public, private and foreign sectors banks respectively, ceteris paribus. Similarly, 1 unit increase in TB leads to increase of 0.064 units, 0.022 units and 0.256 units in TI of public, private and foreign sectors banks respectively, ceteris paribus. Among the input factors, TD is a dominating factor in generating more income in all bank groups. The estimated parameter of value of labour has a significant negative effect on the output.

The estimated values of the technical terms $\sigma^2 = (\sigma^2_u + \sigma^2_v)$ and $\gamma = (\sigma^2 u / \sigma^2)$ are positive and statistically significant at 1 per cent level, showing that the observed outputs

significantly differ from frontier outputs due to factors, which are within the control of banks. The estimated value of γ is 0.58, implying that about 58 per cent of the difference between the actual and potential outputs are primarily due to technically inefficient performance of the foreign banks.

Table 5: Maximum Likelihood Parameter Estimates for Stochastic Frontier Output Functions by Bank Groups

Parameters & variables	*Dependent Variable: Total Income (TI)*					
	Public Banks		*Private Banks*		*Foreign Banks*	
	Coefficient	*T-value*	*Coefficient*	*T-value*	*Coefficient*	*T-value*
β_0 (Constant)	-0.919*	-6.1	-1.465**	-2.3	3.325	14.8
β_1 (TD)	0.795*	49.7	0.822*	19.1	0.235*	8.7
β_2 (TB)	0.064*	10.7	0.022	1.2	0.256*	10.2
β_3 (TFA)	0.069*	5.3	0.169*	6.3	0.073*	2.8
β_4 (TW)	-0.007*	-3.5	0.0005	0.0	0.012	0.5
$\sigma^2 = (\sigma^2_u + \sigma^2_v)$	0.01512	15.1	0.6035	13.7	3.519	10.6
$\gamma = (\sigma^2 u / \sigma^2)$	0.000024		0.0002		0.587	
Log-Likelihood	240.925		-464.220		-1225.13	
Sample Size	356		398		677	

Source: Author's calculations

Note: (i) * Significant at 1 per cent level, ** Significant at 5 per cent level and *** Significant at 10 per cent level

Results of Logit

The estimated Logit coefficients of determinants of technical efficiency for the public, private and foreign sectors banks are reported in Table 6. The results reveal that the coefficients of LR, ROA, and BS have expected signs and significant effect on the TE by bank ownership. The present results confirm that the findings of the study by Adusei (2016) show that the ROA is a significant predictor of TE in the banking sector in India. The estimated Logit regression results suggest that if all other variables hold constant, then there is an increase in LR by one per cent, it increases the probability of TE score by 0.001 per cent in all banks by ownership. The results suggest that if all other variables hold constant, then there is an increase in ROA by one per cent, it increases the probability of TE score by 28.97 per cent in public sector banks, by 21.73 per cent in private sector banks and by 22.57 per cent in foreign sector banks.

Table 6: Maximum Likelihood Logit Estimates of Determinants of Output Efficiency

Variables	*Dependent Variable : Technical Efficiency*					
	Public Sector Banks		*Private Sector Banks*		*Foreign Sector Banks*	
	Coefficient	*Std Error*	*Coefficient*	*Std Error*	*Coefficient*	*Std Error*
Cons	0.201	2.08	0.064	1.93	0.530	0.60
LR	0.001**	9.19	0.001	0.00	0.001	0.00
ROA	28.979**	28.8	21.738*	21.7	22.572*	9.10
BS	0.001*	0.00	0.001*	0.00	-0.001*	0.00
CR	0.272*	3.85	5.095**	3.15	0.933*	0.97
2lOGLikelihood	-88.308		-65.277		-133.503	
LR-chi^2	4.39		27.19		16.59	
Pseudo R^2	0.0242		0.1724		0.0585	
Sample Size	356		341		377	

Source: Author's computation

Note: Standard Errors are given in parenthesis)

* Significant at 1 per cent level, ** Significant at 5 per cent level and *** Significant at 10 per cent level.

The results suggest that the ROA is a dominant factor in determining the TE score in all the ownership of banks. The estimated coefficient of BS has a positive effect on TE score and is statistically significant in public sector banks. The results confirmed the findings of the study by Kumar and Gulati (2008), which implied that large banks can handle their resources efficiently, at least technically. The results suggest that if 1 per cent increases in the CR, then it increases the probability of TE score by approximately 0.272 per cent in public sector banks, 5.09 per cent in private sector banks and 0.93 per cent in foreign sector banks.

CONCLUSION

This paper examines a comparative technical efficiency analysis of public, private and foreign sectors banks over the period 2005-2022 applying DEA and SFA techniques and then the determinants of technical efficiency scores are regressed against the environmental variables using the MLL model. The estimated results showed that the public sector banks have operated more efficiently during the period 2005 to 2022. It implies that the Indian banking sector reforms helped the public sector banks since public sector banks have performed better than other sectors banks in raising their income and non-interest income. The results indicate that both the public and private sectors banks operated more efficiently than that of the foreign sector banks during the

study period. The results suggest that the foreign sector banks operated relatively inefficiently when compared to public and private sectors banks operating in India. The estimated results of Cobb-Douglas production function showed that parameters of the TD, TB and TFA have positive and significant effect on the total income in all the ownership of banks. The estimated MLL results reveal that the coefficients of LR, ROA, and BS have expected signs and have significant effect on the TE of the commercial banks by bank ownership. Finally, we hope that the present study will be helpful to the policymakers and bank owners to make appropriate strategies to resolve the inefficient banks and improve the efficiency of the banking sector.

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