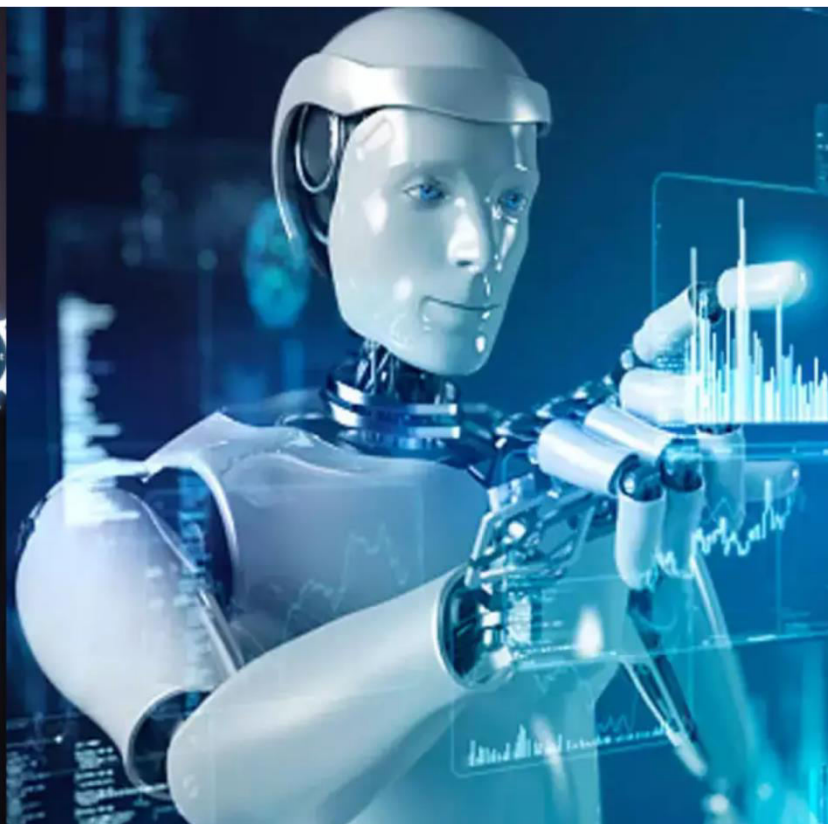




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Selection of Input-Output Variables and Productive Efficiency of Private Sector Banks through Data Envelopment Analysis

B. Parvati, S. G. U. Maheswari, Prof. K. Pushpanjali

Research Scholar, Department of Statistics, Sri Krishna Devaraya University, Anantapur, India

Research Scholar, Department of Statistics, Sri Krishna Devaraya University, Anantapur, India

Research Supervisor, Department of Statistics, Sri Krishna Devaraya University, Anantapur, India

ABSTRACT: Measuring efficiency and performance is important in the context of management in banking system. Indian banking system made numerous modifications have in regulations to upgrade the Indian business model to international standards. The interest in the measurement of performance and efficiency in banking has increasing day by day. Evaluating bank's effectiveness in choosing the right variables is the most important issue. A comprehensive analysis of input variables(I) and output variables(O) helps in developing and analysing models for performance measurement and analysis. Besides that, an understanding of productivity growth is also required. The present study attempts to identify the appropriate variables then to find the efficiency of private sector banks operating in India during 2022-2023 using BCC VRS model and also examines the changes in Total Factor Productivity among the years 2021, 2022 and 2023.

KEYWORDS: Efficiency, Input variables, Output variables, BCC model, Malmquist.

I. INTRODUCTION

Private sector banks, on the other hand, are chartered by individuals. However, they are also subject to strict government regulations [4]. Banks have the most involvement in financial intermediation and have more accountability for achieving the government's social objectives. Countries should strive for advanced banking systems to enhance competitiveness and efficiency. Market regulators should establish rules to control or decrease risk while measuring banking system's efficiency. Measuring the efficiency of the banking system can identify performance and areas for improvement. This information can be valuable for market regulators and bank managers in their decision-making process. Ultimately, a strong banking system contributes to a competitive financial environment. Efficiency estimation methods include parametric (econometric) and nonparametric (mathematical programming) techniques. The parametric method, Stochastic Frontier Analysis (SFA), is commonly used but requires an exact model's definition. Data Envelopment Analysis (DEA) is a non-parametric approach that allows quantification of the efficiency in one number and is formed as a piecewise linear combination of best-practice observations.

The Reserve Bank of India (RBI) serves as the nation's central bank of India, responsible for overseeing commercial banks and implementing monetary policy. India's banking system is divided into commercial and cooperative banks, with commercial banks accounting for 90% of assets. These banks are further classified into scheduled and unscheduled commercial banks, with the latter being divided into public sector, private sector, and foreign banks. Public Sector Banks are largely owned by the federal government. Private sector banks, on the other hand, are chartered by individuals. However, they are also subject to strict government regulations (Banerjee et al. 2004). The larger part of past research has found that public sector banks have outperformed private sector banks [3,12,13]. According to a number of recent studies, private sector banks are doing superior than nationalized banks [10,15]. For this study, we choose India's PSBs because these banks contribute significantly to the advancement of the Indian economy and the overall banking sector. They face competition from various financial institutions to attract customers and increase the percentage of their market share through various financial products and services.

In 1978, Charnes et al. introduced a DEA model with a constant return to scale [2], followed by Banker et al.'s model with a variable return to scale [5]. These models are appropriate when all entities operate under optimal size conditions. The non-parametric approach is ideal for ranking bank efficiency (Kamecka 2010, Apergis 2011, Holod a Lewis 2011, Sevcovic [7], Halicka, Brunovsky 2001), while the DEA model identifies sources and levels of inefficiency for inefficient DMUs (Stavarek, Repkova 2011). Classical DEA models, as described by CCR (1978), assume that inputs must be minimized and outputs maximized. This This approach has been used by numerous authors, including Casu and Molyneux (2000), Fioderlisy Marques (2010), Sevcovic, Halicka, Brunovsky (2001), and Stavarek and Repkova (2011). All these papers used the simple DEA CCR (Constant Returns to Scale also CRS model) and BCC (variable returns to scale, in other literature also VRS) model. Economic efficiency of a bank includes allocative and technical efficiency, which measure the bank's ability to maximize output from limited inputs and optimal output production. Estimating this efficiency requires determining an unknown production frontier. This production frontier is estimated parametrically using SFA and non-parametrically by DEA [6].

Numerous DEA models have been developed, either input or output-oriented, based on the demand of the decision-making unit, and projecting inefficient DMUs into the efficient frontier. There are two possibilities: models that are Input-Oriented try to minimize the input levels without compromising the current output levels. Output-oriented models optimize output levels without raising inputs. In a review of the first 40 years of academic work on DEA, found an exponential increase in publications related to the theory and practice of SEA in use [8].

II. THEORY

The DEA employs a deterministic approach that assesses the relative efficiency of decision-making units (DMUs) using data from selected inputs and outputs [1]. It identifies efficient DMUs as reference points, defines the efficiency frontier, and evaluates inefficient DMUs below it. Performance is measured on a scale of 0 to 1; where 1 indicates perfect performance. An efficient DMU will form and be in the frontier line. The DEA emphasizes productivity and technical efficiency, stating that production transforms the input into outputs to create desirable outcomes which serves as the primary objective of the production.

Charnes et al. (1978) created DEA employing the CRS model and extended by Banker et al. in 1984 to incorporate VRS. Over time, a number of techniques have evolved to extend DEA toward the measurement of both allocative and technical efficiency. Using input or output orientation, DEA models are developed and these models refer to proportional reduction of excessive inputs (input slacks) or proportional augmentation of insufficient outputs (output slacks). But there are some models available. where both output augmentation and input reduction at the same time by improving output slacks and decreasing input slacks. These slack-based models are also called additive models or non-oriented models in DEA literature [9].

a) CCR Model

The DEA terms emphasize productivity and technical efficiency, stating that production transforms input into outputs to create desired outcomes [13]. the CCR (1981) addressed the problem of measuring efficiency by determining the effectiveness of multiple input/output variable. Suppose there are N firms from the production possibility set, each having the m outputs and n inputs. Firm s uses the input function $x^s = (x_{1s} x_{2s} \dots \dots x_{ns})$ to produce the output function $y^s = (y_{1s} y_{2s} \dots \dots y_{ms})$. The firm S average productivity measure is as follows

$$AP_s = \frac{\sum_{r=1}^m u_{rs} y_{rs}}{\sum_{i=1}^n v_{is} x_{is}}$$

In DEA from the production possibility set, the average productivity of the firm s is not more than unity. Thus, the following is how the productivity function is formulated:

$$P_s = \frac{\sum_{r=1}^m u_{rs} y_{rs}}{\sum_{i=1}^n v_{is} x_{is}} \leq 1 \quad (j = 1, 2 \dots \dots N)$$

$$u_{is} \geq 0; \quad (i = 1, 2 \dots \dots n);$$

$$v_{rs} \geq 0; \quad (r = 1, 2 \dots \dots m)$$

The fractional problem mentioned above can be converted into a linear programming problem by applying the Charnes, Cooper transformation (1984) as follows.

$$\begin{aligned} \lambda(\text{CCR}) &= \text{Min } \lambda \\ \text{Subject to } \quad &\sum_{r=1}^s \lambda_j x_{ij} \leq \lambda x_{ij} \\ &\sum_{i=1}^m \lambda_j y_{rj} \geq y_{rj} \quad (j = 1, 2, 3, \dots, n) \\ &\lambda_j \geq 0 \\ &\lambda_{rj} \rightarrow s^{\text{th}} \text{ output for } n^{\text{th}} \text{ DMU} \\ &x_{ij} \rightarrow m^{\text{th}} \text{ input for } n^{\text{th}} \text{ DMU} \end{aligned}$$

According to the fundamental theorem of duality, the objective function is equal to

$$\text{Max } \sum_{r=1}^s u_r y_{rj_0} = \text{Min } \lambda$$

The objective of the CCR is

- 1) Maximizes the input level that satisfies at the given output level
- 2) Maximizes the output without a rise in the level of observed input values.

CRS is what the CCR strategy adheres to. i.e., the proportionate change in input followed a corresponding change in output.

Definition 1:

The optimum solution to the linear problem is CCR efficiency if

- (i) $\theta^* = 1$
- (ii) All slacks are zero ($S^{-*} = 0, S^{+*} = 0$) satisfies.

Otherwise CCR problem is inefficient. Variable Returns to Scale (VRS) cannot be attained by using the CCR technique.

b) Drawback of the CCR Model:

The radial-CCR model's shortcoming is that it projects the efficiency score θ^* without accounting for non-radial slack. Non-radial slack generally plays a significant part in demonstrating efficiency in many circumstances. In this instance, the model can mislead potential decisions by using the efficiency score θ^* as the only metric for assessing DMUS performance.

c) BCC Model:

The existing CCR approach was extended by Banker R, Charnes A and Cooper W (BCC) in the year 1984. This approach follows the VRS. The objective of this model is of increasing, decreasing and constant characteristics at different points on the production frontier. The production frontier of the BCC model exposed the convexity condition λ

The minimal input-oriented BCC is given as

$$\begin{aligned} \theta^*(\text{BCC}) &= \text{Min}(\theta) \\ \text{Subject to } \quad &\theta^* x_0 - X\lambda \geq 0 \\ &Y\lambda \geq y_0 \\ &e\lambda = 1, \lambda \geq 0 \\ &\text{Where } \theta^* \text{ is a scalar} \end{aligned}$$

If the BCC fits the following definition, it is considered efficient.

Definition:

If an optimal solution obtained in this process for (BCC_0) satisfies it has no slack ($S^{-*} = 0, S^{+*} = 0$) and $\theta^* = 1$, then DMU_0 is said to be efficient.

This study used the non-parametric Malmquist index to examine changes in productivity in Indian private sector banks. This index measures the efficiency of a production unit in converting inputs into outputs from time t to time $t+1$. It can be expressed using various distance functions.

d) Malmquist productivity index:

Malmquist introduced the Malmquist productivity index for analysing input consumption. Afterwards, using DEA, Fare et al. directly created a Malmquist productivity index based on input data and output data. A Malmquist productivity index based on DEA (DEA-MI) creates an efficiency frontier over a sample and calculates the distance between each observation from it. In practice, this DEA-MI is good tool to measure how DMUs productivity has changed over time. A firm's productivity is determined by its value. If the value is greater than 1, the firm is growing, if the value is less than 1, the level of productivity is dropping, value equal to 1 means the productivity is stagnant.

The (output-oriented) DEA-MI, which measures the productivity change of a particular DMU₀ at time $t+1$ and t , can be expressed as

$$MI_0 = \left[\frac{D_0^t(x_0^t, y_0^{t+1})}{D_0^t(x_0^t, y_0^t)} \frac{D_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{D_0^{t+1}(x_0^t, y_0^t)} \right]^{1/2}$$

A value of $MI_0 > 1$ signifies an increase in the DMU₀'s overall factor productivity between periods t and $t+1$. indicates progress in the total factor productivity of the DMU₀ from the period t to $t+1$, while $MI_0 = 1$ and $MI_0 < 1$ means the status is stagnant and decay in production respectively.

III. RESULTS AND DISCUSSION

Starting with two inputs and five outputs, the stepwise technique selects the outputs from the total of outputs [5]. The BCC (1984) model was applied to 21 Indian PSB's individually, using a stepwise procedure to identify suitable input variables and output variables for efficiency measurement and analysis in DEA [11,14].

***	Mean efficiency	Efficient DMUs	Average Efficiency Change
Start (2 inputs, 5 outputs)	0.931	15	
Variables to be Dropped			
Advances	0.763	12	0.168
Deposits	0.845	11	0.086
Net Profit	0.875	13	0.056
Investment	0.81	9	0.121
NPA	0.854	12	0.077

Based on the results above, the least influenced output variable on efficient DMUs compared to the other variables is **Net Profit, NPA**. So, we can say that the variables Net Profit and NPA are the least influenced variables on efficient DMUs with average efficiency changes of 0.056 and 0.077 which can be dropped from the DEA efficiency exploration. Finally, from the above procedure, we choose the following input variables and output variables for further DEA exploration as follows

Inputs(I):

1. Number of Employees
2. Assets

Outputs(O):

1. Advances
2. Deposits
3. Investment

Table –I: Comparison of 2 Inputs, 5 Outputs BCC VRS and 2 Inputs, 3 Outputs BCC VRS

DMU NO	DMU Name	Efficiency Scores of 2 inputs & 5 outputs	Efficiency Scores of 2 inputs & 3 outputs
1.	City union bank (CUB)	1	0.969
2.	Tamilnad mercantile bank (TMB)	1	0.765
3.	Catholic syrian bank (CSB)	1	1
4.	Dhanlaxmi bank (DLB)	0.932	1
5.	The Federal bank (FBL)	0.784	1
6.	The Jammu & Kashmir bank (JKG)	1	1
7.	The Karnataka bank (KTB)	1	1
8.	The Karur Vysya bank (KVB)	1	1
9.	The Nainital bank (NTB)	1	1
10.	RBL bank limited (RNB)	0.606	0.986
11.	The South Indian bank (SIB)	0.879	1
12.	Axis bank (AXB)	0.479	0.417
13.	DCB bank Ltd (DCB)	0.694	1
14.	Housing development finance corporation (HDFC)	0.376	0.814
15.	ICICI bank (ICI)	0.387	0.795
16.	Indusind Bank (IIB)	0.701	1
17.	Kotak Mahindra bank (KMBL)	1	0.967
18.	YES bank (YBS)	0.049	0.412
19.	Bandhan bank (BDN)	1	1
20.	IDFC First bank (IDC)	1	1
21.	IDBI bank (IDB)	1	0.862
Mean		0.805	0.904

From Table 1 it is evident that the BCC average efficiency score for two inputs and five outputs is lower than the BCC average efficiency score for two inputs and three outputs. So, the efficiency score maximized if we exclude the less-affected variables from the analysis those are net profit and NPA.

Output of BCC Measure of Efficiency

Table –II: Efficiency Benchmark of BCC VRS method of DMUs using DEA

DMU No	DMU Name	Score	Rank
1.	City union bank (CUB)	0.969	14
2.	Tamilnad mercantile bank (TMB)	0.765	19
3.	Catholic syrian bank (CSB)	1	1
4.	Dhanlaxmi bank (DLB)	1	1
5.	The Federal bank (FBL)	1	1
6.	The Jammu & Kashmir bank (JKG)	1	1
7.	The Karnataka bank (KTB)	1	1
8.	The Karur Vysya bank (KVB)	1	1

9.	The Nainital bank (NTB)	1	1
10.	RBL bank limited (RNB)	0.986	13
11.	The South Indian bank (SIB)	1	1
12.	Axis bank (AXB)	0.417	20
13..	DCB bank Ltd (DCB)	1	1
14.	Housing development finance corporation (HDFC)	0.814	17
15.	ICICI bank (ICI)	0.795	18
16.	Indusind Bank (IIB)	1	1
17.	Kotak Mahindra bank (KMBL)	0.967	15
18.	YES bank (YBS)	0.412	21
19.	Bandhan bank (BDN)	1	1
20.	IDFC First bank (IDC)	1	1
21.	IDBI bank (IDB)	0.862	16
Mean		0.904	

In this study, one Decision making unit (DMU) is used as one bank i.e., CUB as DMU 1, TMB as DMU 2 etc. This study includes 21 PSBs with two inputs and five outputs. The PSBs are subject to the common production frontier on the production possibility set of DEA. The objective of BCC is VRS approach and it is supposed to be decrease, increase and constant. Technically the DMUs are efficient based on the efficiency score of 1. while the rest are inefficient with an efficiency score lower than 1. The output of BCC VRS approach from private sector banks exhibits the results as the efficient banks are CSB (DMU 3), Dhanlaxmi (DMU 4), Federal (DMU 5), Jammu & Kashmir (DMU 6), Karnataka (DMU 7), KVB (DMU 8), Nainital (DMU 9), SIB (DMU 11), DCB (DMU 13), Indusind (DMU 16), BDN (DMU 19) and IDC (DMU 20). On the frontier line of production possibility set, these banks are efficient under VRS and these are the benchmark to the inefficient banks. According to BCC VRS results, 12 of the 21 DMUs are efficient, while the remaining 9 DMUs are inefficient. But City Union Bank DMU (1), RBL Bank DMU (10) and Kotak Mahindra Bank DMU (17) are good performing DMUs as their efficiency value is more than average efficiency. The banks whose efficiency is declining under VRS is YBS (DMU 18) whose efficiency score is 0.412. Technically, this DMU needs to improve by 59% in order to become an efficient DMU. Similarly, the other inefficient DMUs are Axis Bank Ltd. (DMU 12) (0.417), TMB (DMU 2) (0.765), IDBI Ltd (DMU 21) (0.862). One noteworthy finding from the efficiency score is that ICICI, HDFC, the biggest commercial bank, performed poorly as its efficiency score declined at BCC VRS. For ICICI to become an efficient DMU, it must raise its efficiency score by 30.2% and HDFC Bank must improve its efficiency by 18% to do the same. Under this model, RNB (DMU 10) (0.986) has more scope to reach an efficient DMU as this bank just needs to improve 0.14% efficiency.

Table – III: Benchmarking BCC VRS technique for DMUs

S. No	DMU	VRS Benchmark (Lambda)	VRS Peer
1.	City union bank (CUB)	KVB (0.375), BDN (0.588), CSB (0.036)	0
2.	Tamilnad mercantile bank (TMB)	BDN (0.003), SIB (0.350), KVB (0.096), CSB (0.003)	0
3.	Catholic syrian bank (CSB)	CSB	2
4.	Dhanlaxmi bank (DLB)	DLB	0
5.	The Federal bank (FBL)	FBL	1
6.	The Jammu & Kashmir bank (JKG)	JKG	6
7.	The Karnataka bank (KTB)	KTB	0
8.	The Karur Vysya bank (KVB)	KVB	2
9	The Nainital bank (NTB)	NTB	0
10.	RBL bank limited (RNB)	IIB (0.711), SIB (0.267), JKG (0.022)	0
11.	The South Indian bank (SIB)	SIB	2
12.	Axis bank (AXB)	JKG (0.785), IIB (0.215)	0

13.	DCB bank Ltd (DCB)	DCB	1
14.	Housing development finance corporation (HDFC)	JKG (0.779), IIB (0.221)	0
15.	ICICI bank (ICI)	JKG (0.132), IIB (0.868)	0
16.	Indusind Bank (IIB)	IIB	6
17.	Kotak Mahindra bank (KMBL)	JKG (0.148), IIB (0.836), IDC (0.016)	0
18.	YES bank (YBS)	JKG (0.148), IIB (0.048), IDC (0.742)	0
19.	Bandhan bank (BDN)	BDN	3
20.	IDFC First bank (IDC)	IDC	3
21.	IDBI bank (IDB)	IIB (0.485), IDC (0.257), FBL (0.257)	0

The BCC technical efficiency benchmark for each PSB using the VRS approach is shown in Table III. A peer score is a representation of the weights that are utilized to combine the efficient banks in a linear combination in order to show an inefficient one. Based on the number of efficient DMU peers IIB (DMU 16) and JKG (DMU 6) are employed more frequently than other DMUs that are BDN (DMU 19), IDC (DMU 20), CSB (DMU 3), KVB (DMU 8), SIB (DMU 11), FBL (DMU 5) and DCB Bank Ltd (DMU 13) as peer. So, using BCC VRS output technical efficiency DEA, the DMUs 6 and 16 are more efficient than other efficient DMUs 3,5,8,11,13,19 and 20 possess an efficiency score of one.

When inefficient DMUs reach the benchmark's performance, they become more efficient, and the above table is helpful for assessing benchmark performance for inefficient DMUs. DMUs 6 and 16 have the most cases benchmarked against other inefficient DMUs under the VRS result. Peer count serves as a standard for determining which DMU is the most effective. Although the efficiency scores of Dhanalakshmi (DMU 4), The Karnataka Bank Ltd (DMU 7) and Nainital (DMU 9) are all equal to one, these DMUs are not peers or reference sets for the other inefficient DMUs shown in the above table; rather, they are peers themselves.

Table – IV: Malmquist Productivity Index for the year 2021-2022

S.no	DMU	Tfpch
1.	City union bank (CUB)	0.867
2.	Tamilnad mercantile bank (TMB)	0.958
3.	Catholic syrian bank (CSB)	1.3
4.	Dhanlaxmi bank (DLB)	0.836
5.	The Federal bank (FBL)	1.047
6.	The Jammu & Kashmir bank (JKG)	0.342
7.	The Karnataka bank (KTB)	1.135
8.	The Karur Vysya bank (KVB)	1.025
9.	The Nainital bank (NTB)	1.298
10.	RBL bank limited (RNB)	1.678
11.	The South Indian bank (SIB)	1.427
12.	Axis bank (AXB)	3.469
13.	DCB bank Ltd (DCB)	0.887
14.	Housing development finance corporation (HDFC)	0.867
15.	ICICI bank (ICI)	0.372
16.	Indusind Bank (IIB)	0.528
17.	Kotak Mahindra bank (KMBL)	2.305

18.	YES bank (YBS)	0.75
19.	Bandhan bank (BDN)	1.125
20.	IDFC First bank (IDC)	1.569
21.	IDBI bank (IDB)	2.716
mean		1.345

Tfpch – Total factor productivity change

For the year 2021-2022, the average total factor productivity change is 34.5% ($1.345-1=0.345*100=34.5\%$). In the case of DMU 12, the total factor productivity change was 246.9% ($3.469-1=2.469*100=246.9\%$) was more than those of other banks. Total factor productivity change was higher for DMU 3, DMU 5, DMU 7, DMU 8, DMU 9, DMU 10, DMU 11, DMU 17, DMU 20, and DMU 21. Similarly, for DMUs 1,2,4,6,13,14,15,16 and 18 total factor productivity change declined. However, the DMUs 6 and 16 which are considered as best previously have a decline in total factor productivity change.

Table – V: Malmquist Productivity Index for the year 2022-2023

S.no	DMU	tfpch
1.	City union bank (CUB)	0.996
2.	Tamilnad mercantile bank (TMB)	1.046
3.	Catholic syrian bank (CSB)	0.775
4.	Dhanlaxmi bank (DLB)	1.826
5.	The Federal bank (FBL)	1.131
6.	The Jammu & Kashmir bank (JKG)	1.014
7.	The Karnataka bank (KTB)	1.048
8.	The Karur Vysya bank (KVB)	1.012
9.	The Nainital bank (NTB)	0.513
10.	RBL bank limited (RNB)	0.498
11.	The South Indian bank (SIB)	0.62
12.	Axis bank (AXB)	0.612
13.	DCB bank Ltd (DCB)	1.04
14.	Housing development finance corporation (HDFC)	0.653
15.	ICICI bank (ICI)	0.776
16.	Indusind Bank (IIB)	2.089
17.	Kotak Mahindra bank (KMBL)	0.457
18.	YES bank (YBS)	0.251
19.	Bandhan bank (BDN)	0.832
20.	IDFC First bank (IDC)	0.783
21.	IDBI bank (IDB)	1.063
mean		0.819

tfpch – Total factor productivity change

For the year 2022-2023, the average total factor productivity change decreased to 18% which exhibits a downward tendency in comparison to 2021–2022. In DMU 16, the total factor productivity change (108.9%) was greater in comparison to other banks. Out of 21 DMUs, the total factor productivity change of only 9 DMUs has increased growth. Six of these nine DMUs show relatively little growth. There is negative growth in the remaining 12 DMUs.

Table –VI: Malmquist Index summary of annual means

Year	effch	techch	pech	sech	tfpch
2021-22	1.073	1.254	1.008	1.064	1.345
2022-23	0.968	0.846	0.971	0.998	0.819
mean	1.019	1.03	0.989	1.03	1.05

effch - Efficiency change, techch - Technical efficiency change, pech - Pure efficiency change, sech- Scale efficiency change, tfpch - Total factor productivity change.

According to Table VI, we can conclude that the average Total Factor Productivity Change (tfpch) was 5% ($1.05 - 1 = 0.05 \times 100 = 5\%$). This is because the efficiency change has increased to the degree of 19%, Changes in Technical efficiency and Scale efficiency are about 3% but pure efficiency change was declined.

Table -VII: Malmquist Index summary of the firm means

S.no	DMU	Tfpch
1.	City union bank (CUB)	0.929
2.	Tamilnad mercantile bank (TMB)	1.001
3.	Catholic syrian bank (CSB)	1.004
4.	Dhanlaxmi bank (DLB)	1.236
5.	The Federal bank (FBL)	1.088
6.	The Jammu & Kashmir bank (JKG)	0.589
7.	The Karnataka bank (KTB)	1.091
8.	The Karur Vysya bank (KVB)	1.019
9.	The Nainital bank (NTB)	0.816
10.	RBL bank limited (RNB)	0.914
11.	The South Indian bank (SIB)	0.941
12.	Axis bank (AXB)	1.457
13.	DCB bank Ltd (DCB)	0.961
14.	Housing development finance corporation (HDFC)	0.753
15.	ICICI bank (ICI)	0.538
16.	Indusind Bank (IIB)	1.05
17.	Kotak Mahindra bank (KMBL)	1.027
18.	YES bank (YBS)	0.434
19.	Bandhan bank (BDN)	0.967
20.	IDFC First bank (IDC)	1.082
21.	IDBI bank (IDB)	1.399

In the study period 2021 to 2023 Axis Bank (DMU 12) was more efficient (since the total factor productivity change was 45.7% which, in contrast to other DMUs, was higher) followed by IDBI (DMU 21), Dhanlaxmi Bank (DMU 4) also had good per cent of total factor productivity change. Among 21 private sector banks, only 11 banks had an increase in total factor productivity change. The remaining 10 banks had declined growth.

IV. CONCLUSION

The study examines 21 private sector banks using BCC model under VRS production frontiers. The BCC VRS approach shows that 12 of the 21 DMUs are efficient, while the remaining 9 are inefficient. The largest commercial bank, ICICI, HDFC, shows poor performance, needing to increase efficiency by 30.2% and 18%, respectively. RBL, with a score of 0.986, has more scope to become an efficient DMU, needing to improve efficiency by 0.14%. The study highlights the need for banks to improve their efficiency scores to become more efficient. Table III displays the BCC technical efficiency benchmark for private sector banks using the VRS method. The peer count shows that Indusind Bank Ltd and Jammu & Kashmir Bank Ltd are the most efficient, with an efficiency score equal to one.

For the year 2021-22, the average total factor productivity change is 34.5%, with DMU 12 experiencing a higher rate of 246.9%. Other banks including DMUs 3, 5, 7, 8, 9, 11, 17, 20, 21, and DMU 21 have experienced decreased productivity. The average total factor productivity change in 2022-2023 decreased to 18%, with DMU 16 having the highest change of 108.9%. Out of 21 DMUs, 11 DMUs show positive growth and 9 DMUs have negative growth. From 2021-2023, Axis Bank (DMU 12) showed higher efficiency, with a total factor productivity change of 45.7%, followed by IDBI and Dhanlaxmi Bank, with 8 banks experiencing growth.

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