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Application of Slack Based Measure of Efficiency in Data Envelopment Analysis: Review on Public Sector Banks in India

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ABSTRACT: In Indian banking system efficiency performance analysis play major role for review and development of banking sector. Analysis of banking system useful in identification of key factor which is genuinely influencing on banking system as well as in which factor need to improve can feasible to identify. The development of banking is the indicator of National growth and the potential improvement in banking is the remarkable and acceptable in the modern society. In this present study an attempt has been made on efficiencyevaluation of public sector banks using Data Envelopment Analysis (DEA) during the financial year 2018-19. A basic methodology CCRisused for measuring the efficiency of Decision Making Units (DMU) with respect to identified input, output variables. In addition to these models for minimizing the slacks, Slack Based Measure (SBM) of efficiency used for scalar measure which deal with input excess and output shortfall of given variables. In this empirical study non-zero slacks lived in the input and output variables it represents a substantial amount of inefficiency. To overcome this non-zero slacks, Slack Based Measure used and which is directly effect on input excess and output shortfall of the optimum solution. The result from the analysis exhibits the banks Punjab & Sind Bank (DMU 13), Central Bank of India (DMU 7) and Indian (DMU 10) banks are outperformers from public sector banks in India.

KEYWORDS: DEA, Efficiency, DMU, CCR, SBM, MixedEfficiency

I. INTRODUCTION

The Data Envelopment Analysis is a non-parametric mathematical approach which measures the efficiency of identified DMUs and this methodology is the branch of Operations Research (1984). The DEA is efficiency methodology related to the benchmark of DMUs. The benchmarking is the procedure to identify efficient DMU among the given set of DMUs. The DEA exhibits the reliable information in terms of estimation of efficiencies from each DMU. This approach identifies a peer (reference set) of wealthy DMUs used for estimating and effecting these evaluations. In DEA analysis, effective DMUs are presented on the frontier line of production possibility set and the efficient DMU are known as Benchmarking. In this methodology there is a scope of inefficient DMUs become efficient once they proceed and followed by benchmarking DMUs constraints. The main objective of the DEA is the efficiency of identified DMU should lie between zero and unity.

In DEA, the basic DEA model is CCR which is first proposed by Charns, Cooper and Rhodes (CCR) in 1978. This approach evaluates the efficiency by taking the ratio of multiple outputs and inputs variable of the DMU with the combination among all the given DMUs. The other main important aim of CCR is minimize input which satisfying at least the given output level and maximize the output without considerable level of observed input values. CCR approach follows the Constant Returns Scale (CRS) it represents the proportional change in the input and it followed by the proportionate change in its output. The optimum solution of CCR_0 is represented byλ^*, $s^{-*}s^{+*}$and wheres^{-*}, and s^{+*} represents input excesses and output shortfall respectively.

CCR model evaluate the radial (proportional) efficiency of the set DMUs θ^* but not taking into consideration of minimizing input and output shortfall that leads to the non-zero slacks. It indicates the Drawback because of θ^* does not include the non-zero slacks. To eliminate the non-zero slack deficiency, Tone introduced (1997, 2001) a model is called Slack-based measure of efficiency (SBM). SBM efficiency is

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introduced to evaluate the efficiency based on the slacks.

A SBM of efficiency used to measure the efficiency evaluation, and which effected in objective and invariant to the unit of measure used at different variables with respect to the DMUs. SBM is the better approach than earlier models and which is directly concentrated on the slacks of variables. The main aim of SBM is an 'inefficient' DMU is 'efficient' by concerned with DMUs reference set.

Therefore, the decision to measure of efficiency obtained from its reference set and should not affect or influenced by extreme values and whole data set. The major property of the SBM is given by

1. Unit Invariant with respect to the each input and output variables.
2. Monotone decreasing in each input and output slack.

II. THEORY AND METHODOLY

The productivity and Technical efficiency terms used in DEA such way that the production act as transforming its input into outputs because of the objective of the production is to create the values through transforming from the input to desirable outcomes (outputs). The production technology create a function using input and output variables

2.1 CCR Measure

CCR (1981) introduced a method of DEA to deal with the problem of efficiency measurement for DMUs with multiple input and output variables.

Suppose there are N firms from the production possibility set, each yield the m outputs from n inputs. Firm s uses the input function $x^s = (x_{1s}x_{2s} \dots \dots \dots x_{ns})$ to produce the output function$y^s = (y_{1s}y_{2s} \dots \dots \dots y_{2ms})$. The average productivity measure of productivity of the given firms 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, no average productivity of the firms more than unity. From this case the productivity function formulates as follows

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

$$u_{is} \geq 0; (i = 1, 2, \dots \dots n); \ v_{rs} \geq 0; \ (r = 1, 2, \dots \dots . . m)$$

Applying Charnes, Cooper transformation (1978) to the above fractional programming problem can be transformed into a linear programming problem at input minimization function is as follows

λ(CCR)=Min λ

$$\text{Subject to} \sum_{r=1}^{s} \lambda_j x_{ij} \leq \lambda x_{ij}$$

$$\sum_{i=1}^{m} \lambda_j y_{rj} \geq y_{rj} \quad j = 1,2,3, \dots, n.$$

$$\lambda_j \geq 0$$

$y_{rj} \rightarrow S^{th}$ output for n^{th} DMU

$x_{ij} \rightarrow m^{th}$ input for n^{th} DMU

From the fundamental theorem of duality the objective functions are equal

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

The objective of the CCR is it minimizes the input which satisfying at least the given output level and maximize the output without considerable level of observed input values. CCR approach follows the Constant Returns Scale (CRS) it represents the proportional change in the input and it followed by the proportionate change in its output.

Definition 1: The optimum solution of linear problem satisfies to call it is a CCR-efficient

(i) $\theta^* = 1$

(ii) All slacks are zero($s^{-*} = 0, \quad s^{+*} = 0$)Otherwise CCR-inefficient.

CCR approach fails to attain Variable returns scale.

CCR approach not much involve in reducing the account of input excesses and output shortfalls that leads to the non-zero slacks. To eliminate such non-zero slack deficiency, Tone introduced (1997, 2001) a model is called Slack-Based Measure (SBM) of efficiency. This methodology considers the account of the input excesses and output shortfalls that leads to the non-zero slacks. It indicates the Drawback because of θ^* does not include the non-zero slacks (2002).

The Computation Procedure of SBM is as follows

Let us consider with n DMUs corresponding input and output indices X = (x_{ij}) and Y = y_{ij} respectively. Here we assumed that (X, Y)> 0

The production possibility set P is given by

P = $\{(x, y) / \ x \geq X\lambda, \ y \leq Y\lambda, \ \lambda \geq 0$

Where λ is a nonnegative vector

Consider the expression of a certain DMU (x_0, y_0) as

$$x_0 = X\lambda + s^-$$

$$y_0 = Y\lambda - s^+$$

With $\lambda \geq 0, \ s^- \geq 0 \ and \ s^+ \geq 0$. The slacks$s^-$, s^+ represents the input surplus and output shortage, respectively.Using slack and surplus behaviour the index ρ is given as follows

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$$\rho = \frac{1 - \frac{1}{k}\sum_{i=1}^{k} s_i^- \,/\, x_{i0}}{1 + \frac{1}{m}\sum_{i=1}^{m} s_i^+ \,/\, y_{io}}$$

The above function should satisfies the property of Unit invariant and Monotone and the function should satisfies the range of SBM ρ

$$0 < \rho < 1.$$

Definition: A DMU (x_0, y_0) is SBM-efficient in its $\rho^* = 1$ and s^{-*}=0 and $s^{+*} = 0$ i.e,. There is no input excess and output shortfall in the optimum solution (2009).

2.2 SBM CCR Measure

Slack-based measure under CCR Model can be formulated as follows

(CCR) Min θ

Subject to $\theta\, x_0 = X_\mu + t^-$

$y_0 = Y_\mu - t^+$

$\mu \geq 0, t^{-1} \geq 0, t^+ \geq 0.$

The optimum solution of (CCR) is($\theta^*, \mu^*, t^{-*}, t^{+*}$) obtained by

$$x_0 = X\mu^* + t^{-*} + (1 - \theta^*)x_0$$

$y_0 = Y\mu^* - t^{+*}$.

Thus, (λ, s^-, s^+) is feasible for (SBM) and the objective value can be expressed as follows

$$\rho = \frac{\theta^* - \frac{1}{k}\sum_{i=1}^{k} t_i^{-*} \,/\, x_{i0}}{1 + \frac{1}{m}\sum_{i=1}^{m} t_i^{+*} \,/\, y_{io}}$$

Theorem: Tone (1997) A DMU (x_0, y_0) is CCR-efficiency if and only if it is SBM-efficient (2010).

Definition-1: $\theta = 1$ and $(t^- = s^-, t^+ = s^+) \neq (0,0)$. In this case, an optimum solution for (CCR) is inefficient.

Definition-1: $\theta = 1$ and $(t^- = s^-, t^+ = s^+) = (0,0)$. In this case, an optimum solution for (CCR) is efficient.

Definition-3: $\theta < 1$. In this case, (x_0, y_0) is CCR-inefficient.

2.3 Mixed Efficiency

Mix.Efficiency is the ratio of two efficiency and which is used to reduce the error rate from the two efficiency score of CCR, SBM model, it is defined as

$$\text{Mix. Efficiency} = \frac{\text{SBM Efficiency}}{\text{CCR Efficiency}} = \frac{\rho^*}{\theta^*}$$

III. RESULTS AND DISCUSSIONS

Table 1: Descriptive statistics of public Sector banks for the year 2018-19

***	Borrowings	Number of Employees	Operating Expenses	Capital
Max	4030171	257252	36809143	23194448
Min	22037.2	8973	1089821	4802.9
Average	380806	40349	5081469	1292374
SD	856042	52237	7572163	5046133

***	Loans & Advances	Deposits	Investment	Net Profit	Net Income	NPA's
Max	21858769	29113860	14474870	862	792013	658947.4
Min	519589.7	985576	261729.3	-9975	24578	40183.7
Average	2986500	4148795	2537714	-2993.05	110454	142561.4
SD	4511749	5940639	4158872	3035.63	163372.4	136935.8

[Amount of variables Rs. in millions]

The above table represents the primary information of descriptive statistics of input, output variables. The efficiency computed in the present study is relative in nature. The banking performance is relatively not assessed in an absolute manner but is compared with the best in the industry i.e., benchmark with purpose of improving the banks in the industry. Using the given data efficiency can be determined by comparing the relative sizes of various efficiency measures. The above table shows the descriptive statistics of the sample of n=20 public sector banks.

3.1 Output of CCR Model

Table 2: Efficiency Benchmark under CRS method of DMUs obtained using DEA

S.No	DMU	Score	Rank	CRS Benchmark (Lambda)	CRS Peer
1	Allahabad	0.9487	19	CBI (0.016); Dena (0.412); P & SB	--

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				(1.514); Vijaya (0.108)	
2	Andhra	0.9988	14	Indian(0.053); P& SB (1.99); PNB(0.003); Vijaya (0.078)	--
3	BOB	1	1	BOB	0
4	BOI	1	1	BOI	2
5	BOM	0.9715	16	BOI(0.041); CBI (0.019); Indian (0.186); P& SB (0.695)	--
6	Canara	1	1	Canara	0
7	CBI	1	1	CBI	5
8	Corporation	0.9532	18	CBI (0.01); P& SB (1.474); Vijaya (0.06)	--
9	Dena	1	1	Dena Bank	2
10	Indian	1	1	India Bank	4
11	IOB	1	1	IOB	1
12	OBC	0.954	17	CBI (0.016); Indian(0.218); P&SB (1.378); Vijaya (0.224)	--
13	P&SB	1	1	P & S B	6
14	PNB	1	1	PN B	2
15	SBI	0.9833	15	BOI (1.32); Indian (9.81); PNB (0.117)	--
16	Syndicate	1	1	Syndicate	0
17	UCO	0.9446	20	CBI (0.017); Dena (0.716); IOB (0.115); P&SB (0.963)	--
18	UBI	1	1	UBI	0
19	UNBI	1	1	UNBI	0
20	Vijaya	1	1	Vijaya	4

The public sector banks are exposed to a common production frontier. All the efficiency scores of DEA are obtained using SaiTechInc DEA Solver software. The methodology CCR follows Constant Returns-to-Scale (CRS) and it assumed to be constant. The largest θ(CCR) efficiency score 1 imply DMU(s) is technically efficient and the rest of the DMUs are inefficient whose efficiency score is less than 1.

The minimum efficiency score corresponds to UCO Bank (DMU 17) (0.9446) and the next least performer banks is Allahabad bank (DMU 1) (0.9487). From CCR Model in efficiency evaluation, 20 public sector banks are involved. We see that under the CRS result 7 banks are inefficient and 13 banks are technically efficient. A remarkable thing from the efficiency score is that overall score of PSBs efficiency nearer to unity it means that the overall performance of public sector banks during the year 2018-19 outperformed.

From the above result, the largest commercial bank SBI (DMU 15) (0.9833) is inefficient as it should improve its efficiency score of 2.67% without increasing input to become an efficient DMU. Due to constant returns to scale, SBI may get its efficiency score low. Under the CCR Technical efficiency, Andhra bank (DMU 02) (0.9988) having more flexibility to became an efficient bank as its efficiency score is most nearly equal to units.

Table-2 shows the technical efficiency benchmark (peers) for all the PSBs under CRS method. The peer score represents the weights to construct a linear combinational of the efficient banks to represents an inefficient one. From the peer counts of efficient banks, DMU 13 is more used than CBI (DMU 7), Canara (DMU 10), Vijaya (DMU 20), BOI (DMU 4), Dena (DMU 9), PNB (DMU 14), and IOB (DMU 11) as peer. So, using CRS input technical efficiency DEA, the DMU 13 is most efficient than other efficient DMUs 7, 10, 20, 4, 9, 14 and 11 have the efficiency score equal to one. Hence, DMU 13 is most efficient and referred DMU for other DMUs.

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The above table useful for the evaluation of benchmark to the inefficient DMUs and inefficient DMUs become efficient once they attain the benchmark DMUs performance. Under the CRS result a DMU 13 is the maximum number of cases benchmark to other inefficient DMUs. Hence peer count is the benchmark to identify a DMU is most efficient. The DMUs BOB (DMU 03), Canara (DMU 06), Syndicate (DMU 16), UBI (DMU 8), UNBI (19) are just efficient banks as its input efficiency score is equal to one but these DMUs are not reference set (peer) with other inefficient DMUs presented in the above table and these DMUs are peer themselves.

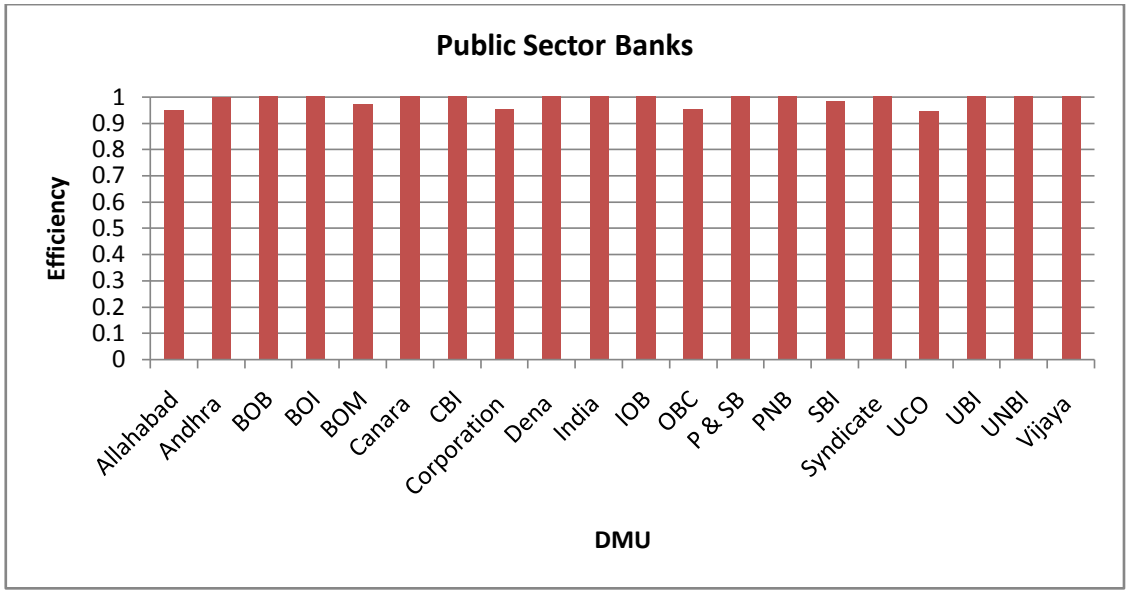

Fig – 1: Efficiency score projection of CRS model using DEA

The project of above efficiency scores helps to identify the efficient DMUs and it is found that maximum number of banks attain its efficiency score touch the top edge efficiency score 1 and other efficiency DMUs are nearer to top edge from the above graph.

3.2: Output of Slack Based Measure of Efficiency

Table - 3: Efficiency Benchmark of SBM CRS method of DMUs using DEA

S. No	DMU	Score	Rank	CRS Benchmark (Lambda)	CRS Peer
1	Allahabad	0.6892	17	CBI (0.019); Indian (0.05); P & SB (1.993)	
2	Andhra	1	1	Andhra	0
3	BOB	1	1	BOB	0
4	BOI	1	1	BOI	1
5	BOM	0.6211	19	CBI (0.019); Indian (0.035); P& SB (1.283)	
6	Canara	1	1	Canara	0
7	CBI	1	1	CBI	4
8	Corporation	0.8097	15	CBI (0.009); Indian (0.263); P& SB (1.199)	
9	Dena	1	1	Dena Bank	0
10	Indian	1	1	India Bank	6
11	IOB	1	1	IOB	0
12	OBC	0.7914	16	CBI (0.015); Indian(0.419); P&SB (1.287)	
13	P&SB	1	1	P & S B	6

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14	PNB	1	1	PN B	1
15	SBI	0.5358	20	BOI (0.807); Indian (7.631); PNB (0.12); P&SB (6.836)	
16	Syndicate	0.6317	18	Indian (0.346); P&SB (2.058)	
17	UCO	1	1	UCO	0
18	UBI	1	1	UBI	0
19	UNBI	1	1	UNBI	0
20	Vijaya	1	1	Vijaya	0

The public sector banks are exposed to a common production frontier. The objective of SBM CCR is Constant Returns-to-Scale (CRS) and it assumed to be constant. The largest θ(SBM) efficiency score 1 imply DMU(s) is technically efficient and the rest of the DMUs are inefficient whose efficiency score is less than 1.

From the output of this approach, the minimum efficiency score is from SBI (DMU 15) (0.5358) and the next least performer is BOM (DMU 5) (0.6211). In the efficiency evaluation from SBM CRS Model, 20 public sector banks are involved. We see that under the SBM CRS result 6 banks are inefficient and 14 banks are technically efficient. A remarkable thing from the efficiency score is that the largest commercial bank SBI showed poor performance as its efficiency score is decline at SBM CRS. To become an efficient DMU, the SBI need to recover 46.42% of its efficiency score without increasing its input.

Under the SBM CRS approach, Corporation banks having more flexibility become an efficient DMU as its efficiency score (0.8097) is comparatively better than other DMUs. As the Slack based measure of efficiency, efficiency scores obtained in this approach comparatively small in figure due to focused on slacks of the input and output variable and above efficiency are reliable than previous methods. The previous CCR, BCC models are focused only on evaluating efficiency score without affecting on its slacks.

Table-3 shows the SBM technical efficiency benchmark (peers) for all the PSBs under CRS method. The peer score represents the weights to construct a linear combinational of the efficient banks to represents an inefficient one. From the peer count of efficient DMUs, P&SB (DMU 13), Indian bank (DMU 10) are more used than CBI (DMU 7), BOI (DMU 4) and PNB (DMU 14) as peer. So, using SBM CRS input technical efficiency DEA, the DMU 10, 13 are most efficient than other efficient DMUs 2, 3, 4, 6, 7, 9, 10, 11, 14, 17, 18, 19 and 20 have efficiency score equal to one. Hence, DMU 10, 13 are most efficient and referred DMU for other DMUs.

The above table useful for the evaluation of benchmark to the inefficient DMUs and inefficient DMUs become efficient once they attain the benchmark DMUs performance. Under the CRS result a DMU 10, 13 is the maximum number of cases benchmark to other inefficient DMUs. Hence peer count is the benchmark to identify a DMU is most efficient. The DMUs Andhra (DMU 2), BOB (DMU 03), Canara (DMU 06), Dena (DMU 9), IOB (DMU 11), UCO (DMU 17), UBI (DMU 18), UNBI (DMU 19) and Vijaya bank (DMU 20) are just efficient banks as its input efficiency score is equal to one but these DMUs are not reference set (peer) with other inefficient DMUs presented in the above table and these DMUs are peer themselves.

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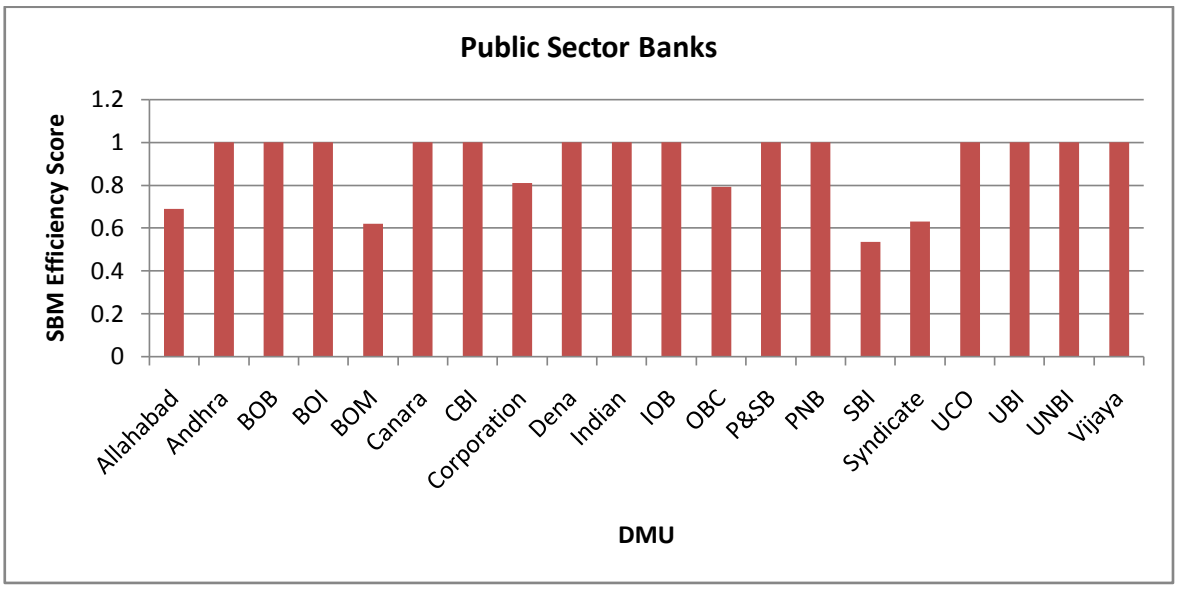

Fig - 2: Efficiency score projection of SBM CRS model using DEA

The project of above efficiency scores helps to identify the efficient DMUs and it is found that maximum number of banks attain its efficiency score touch the top edge efficiency score 1 and other efficiency DMUs are nearer to top edge from the above graph. The SBI bank projects fewer peaks comparatively with other DMUs.

Mix Efficiency is the ratio of CCR, SBM model and which used for measure the revised efficiency score of CCR and SBM approach. Using this ratio measure can eliminate error variability in two models before exhibiting the efficiency scores of identified DMUs.

Mix. Efficiency = $\frac{\text{SBM}}{\text{CCR}}$

3.3: Mixed Efficiency of CCR, SBM Model

Table - 4: Mix. Efficiency of public sector banks using DEA for the year 2018-19

DMU	CCR Efficiency	SBM Efficiency	Mix. Efficiency
Allahabad	0.95	0.69	0.73
Andhra	1.00	1.00	1.00
BOB	1.00	1.00	1.00
BOI	1.00	1.00	1.00
BOM	0.97	0.62	0.64
Canara	1.00	1.00	1.00
CBI	1.00	1.00	1.00
Corporation	0.95	0.81	0.85
Dena	1.00	1.00	1.00
Indian	1.00	1.00	1.00
IOB	1.00	1.00	1.00
OBC	0.95	0.79	0.83
P&SB	1.00	1.00	1.00
PNB	1.00	1.00	1.00
SBI	0.98	0.54	0.54
Syndicate	1.00	0.63	0.63
UCO	0.94	1.00	1.00
UBI	1.00	1.00	1.00
UNBI	1.00	1.00	1.00
Vijaya	1.00	1.00	1.00

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From the result of Mixed Efficiency, The DMUs which are efficient over the period are Andhra, BOB,BOI, Canara, CBI, Dena, Indian, IOB, P&SB, PNB, UCO, UBI, UNBI and Vijaya Bank. These banks have showed efficiency score is 1 and treated as efficient DMUs. The maximum numbers of banks are efficient in CCR, SBM model and the same potential performance exhibited in the Mix. Efficiency approach.The Mix. Efficiency model is the error free approach of providing efficiency of public sector banks at identified variables. Similarly, the banks whose financial performances are decline in the financial year 2018-19 are Allahabad, BOM, Corporation, OBC, SBI, and Syndicate Banks. These banks showed poor performance due to lack of control in the above said input, output variables. If these poor performed DMUs follows benchmark of efficient DMUs, in the short period of time these DMUs become an efficient bank or they can improve their efficiency score is feasible.

Table- 5: Descriptive statistics of CCR, SBM and Mixed Efficiency using DEA

	CCR Efficiency	SBM Efficiency	Mix. Efficiency
Average	0.99	0.90	0.91
Min	0.95	0.54	0.54
Max	1.00	1.00	1.00
S.D	0.018	0.160	0.152

Above descriptive statistics represents the basic information of three approaches and which represents the variability within the individual modes. From the results, the maximum efficiency score occurred in CCR Model but this model is not familiar than SBM because of not removal of slacks at optimal solution. The mixed efficiency is the second highest among three approaches. The variability within the model is expected be less in CCR model comparatively. From the result need to give priority of efficiency scores because of mixed efficiency model is the error free approach.

IV. STATISTICAL ANALYSISOF SIGNIFICANCE AMONG THREE APPROACHES

The DEA is the non-parametric approach used to measure the efficiency of identified DMUs at input, output variables. This approach is free from the assumption Normality and it is depends on the ranking of the efficiency scores of given DMUs. To test the significance among identified three models of DEA, the best non-parametric approach is **krushkal Wallis H-Test**. The aim of this non-parametric approach is test the significance of efficiency among identified model using its ranks of the efficiencies.

Test Statistic

The H statistic is computed as shown in the following formula:

$$H = \frac{12}{N(N+1)}\left[\frac{R_1^2}{n_1} + \frac{R_2^2}{n_2} + \frac{R_3^2}{n_3} + \cdots\right] - 3*[N+1]$$

$$H = 0.003*55913.8 - 183$$

$$H = 0.3239$$

Using the P-value approach: The p-value is p = 0.85049

Since p=0.85049>0.05, it is concluded that the null hypothesis is not rejected.

Conclusion

It is concluded that the null hypothesis Ho is not rejected. Therefore, there is not enough evidence to claim that efficiency score of three approaches differ significantly.

V. CONCLUSION

The benchmarking is the method used for identified the best performers of the given DMUs and these DMUs are role model to the inefficient DMUs. The DEA is the benchmark non-parametric approach used to measure the efficiency DMUs at selected input and output variables. The conclusion of this article is based on SBM, Mixed efficiencymodels in DEA. The CCR approach is based on the proportional reduction of input (output) variables and which do not take account of slacks. In contrast to the CCR DEA methodology, SBM deals directly with input excess and output shortfall.Peer count (reference set) is the procedure to identify outperformer banks among efficient banks.

The result obtained from CCR model is the banks P&SB (DMU 13), CBI (DMU 7), Indian (DMU 10) and BOI (DMU 04) are most efficient banks in the sequence. These banks are having better performance than all other banks from Public

Sector and peer counts of these banks are higher than other banks in the sequence.

From the SBM CCR model, the outperformer banks are P&SB (DMU 13), Indian (DMU 10), CBI (DMU 7), BOI (DMU 04) and SBI (DMU 14). These banks have better performance as its efficiency and peer count are higher than other efficient banks in the sequence. The overall best performer banks from the above said models are P&SB (DMU 13), CBI (DMU 7) and Indian (DMU 10) banks.

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