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MCB-DEA: A MODIFIED APPROACH FOR BENCHMARKING

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Abstract: Review of existing literature on the study suggests that though non-parametric technique Data envelopment analysis (DEA) can be used to arrive at benchmarks but it has its own limitations, like non-inherent benchmarks, more than one benchmark and different benchmarks for each year, which makes it difficult for an inefficient bank to decide that which benchmark should be followed for feasible improvement. Thus, there is a need to identify a new method which can help in ascertaining benchmarks based on multi period analysis for improving efficiency. The present study endeavours to propose a model which has been named as MCB-DEA model. The same has been illustrated using a data base of sixteen years for twenty five public sector banks operating in India. It was found that the suggested model helps in identifying nearest benchmark, falling in same cluster so as to gradually improve efficiency.

Keywords: Efficiency, Data envelopment analysis, Malmquist TFP Index, Benchmarking, Cluster analysis.

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I. Introduction and Review of Literature

For every DMU to be a quality DMU and to achieve next level of efficiency, benchmarking is required. To benchmark is to compare performance against a standard [1] with the objective to improve performance [2]. It is based on the premise that "why reinvent the wheel when I can learn from someone who has already done it?" [3].Benchmarking which is also known as process benchmarking, internal benchmarking and industry benchmarking [4]is a technique that initially got popular in Japan but considering its huge potential [5] in large firms to small businesses and public as well as semi-public sector [5,6,7,8,9] it gained popularity worldwide [10].

Particularly for benchmarking in banking sector, DEA has been widely used[11,12,13,14,15,16,17,18,19,20]but it has some limitations too. The benchmarks provided by DEA for inefficient DMUs are sometimes largely different in performance behaviour[21], which provides the target performance way too difficult to achieve. Secondly, presence of more than one benchmark creates confusion regarding choice of optimum DMU to be followed. Literature also advocates the use of Malmquist TFP index on DEA results to analyse changes in the efficiency levels in a multi-period environment [22,23,24,25,26,27,28,29,30] but it does not provide any information on benchmarks.Some researchers have also used cluster analysis in combination with DEA to explore relationships between data points in a single time period [10,31,32,33,34].

As evident, studies have made an attempt to calculate benchmarks based on DEA but none of these have used clusters on Malmquist TFP analysis to arrive at benchmarks considering multi period data. Hence the present study proposes to add value to existing literature by proposing a new Malmquist clusteringbenchmarking model based on DEA (MCB DEA) to calculate benchmarks using cluster analysis with DEA based Malmquist TFP index.This paper proposes MCB-DEA model and tests the same on 25 public sector banks operating in India considering temporal data from the year 1998 to the year 2013.

II. Model Formulation

The proposed MCB DEA model has three steps. In the first step, **Charnes, Cooper and Rhodes (CCR)** model of DEA is used for efficiency evaluation of each DMU, for each time period, separately.

Following [35],Consider DMU_j , (j=1,2,….., n) using input vector $X_j = (x_{1j}, x_{2j}, \ldots\ldots, x_{mj})$ to produce output vector

$Y_j = (y_{1j}, y_{2j}, \ldots\ldots, y_{sj})$ for $X_j \geq 0,\ Y_j \geq 0$

For input weights vector $V = (v_1, v_2, \ldots, v_m)$ and output weights vector$U = (u_1, u_2, \ldots, u_s)$ each DMU_k has an optimization problem

$$\text{Maximize } \theta = u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}$$

$$\text{s.t.} \quad v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk} = 1$$

$$u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj} \leq v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj} \text{ for all } j = 1,2, \ldots, n.$$

$v_1, v_2, \ldots, v_m \geq 0;\ u_1, u_2, \ldots, u_s \geq 0$….(*)

Corresponding to $k = 1,2, \ldots, n$ (*) gives a set of 'n' optimization problems. Each problem is then solved for obtaining values of most favourable input weights $v_1, v_2, \ldots, v_m$ and output weights $u_1, u_2, \ldots, u_s$ for each corresponding DMU.

In **Step (2)**of the proposed MCB DEA model,change in efficiency behaviour of each DMU, is analysed over the entire time period, in a multi-period environment, by applying Malmquist TFP index, on the efficiency scores given by DEA for each time period, in Step (1).

The Malmquist TFP index, which measures the change in productivity of a DMU, between two data periods t_1 and t_2 , by calculating the ratio of the distances of each data point relative to a common technology.Following [36], for a firm, at timet_1 , S_{t_1} be the production set,then an output distance function is defined as

$$D^{t_1}(x^{t_1}, y^{t_1}) = \inf\{\ \theta \epsilon R | \left(x^{t_1}, \frac{y^{t_1}}{\theta}\right) \epsilon S_{t_1}\} \ldots \ldots (1)$$

where,$D^{t_1}(x^{t_1}, y^{t_1}) \leq 1;$ with $D^{t_1}(x^{t_1}, y^{t_1}) = 1$ iff DMU is efficient and

further increase in output y^t with same input x^t isnot possible

Also, $D^{t_2}(x^{t_2}, y^{t_2}) = \inf\{\ \theta \epsilon R | \left(x^{t_2}, \frac{y^{t_2}}{\theta}\right) \epsilon S_{t_2}\} \ldots \ldots (3)$

To compute Malmquist productivity index, we define

$$D^{t_1}(x^{t_2}, y^{t_2}) = \inf\{\ \theta \epsilon R | \left(x^{t_2}, \frac{y^{t_2}}{\theta}\right) \epsilon S_{t_1}\} \ldots \ldots (4)$$

Where $D^{t_1}(x^{t_2}, y^{t_2})$ gives the maximum proportional change in outputs y^{t_2} with same inputs x^{t_2}, at time t_1.

and $D^{t_2}(x^{t_1}, y^{t_1}) = \inf\{\ \theta \epsilon R | \left(x^{t_1}, \frac{y^{t_1}}{\theta}\right) \epsilon S_{t_2}\} \ldots \ldots (5)$

Where $D^{t_2}(x^{t_1}, y^{t_1})$ gives the maximum proportional change in outputsy^{t_2} with same inputs x^{t_2}, at time t_2.

[37] had defined Malmquist productivity index with reference to the technology of initial period, t_1 as

$$M^{t_1} = \frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \quad \ldots\ldots\ldots (6)$$

Or alternatively, with reference to the technology of final period, t_2 as

$$M^{t_2} = \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_1}, y^{t_1})} \quad \ldots\ldots\ldots\ldots (7)$$

To avoid an arbitrary choice of reference technology, [36] defined the Malmquist productivity index of TFP, between periods t_1 and t_2 ; $t_1 < t_2$, as the geometric mean of M^{t_1} and M^{t_2} ,

$$M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = \left(\frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_1}, y^{t_1})}\right)^{\frac{1}{2}} \ldots\ldots\ldots (8)$$

Equation (8) can also be written as

$$M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \left(\frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_2}, y^{t_2})} \frac{D^{t_1}(x^{t_1}, y^{t_1})}{D^{t_2}(x^{t_1}, y^{t_1})}\right)^{\frac{1}{2}} \ldots\ldots (9)$$

Equation (9) is the decomposition of the Malmquist productivity index into two factors. The first factor outside the bracket represents the efficiency change (or catching-up effect) component and the second factor, with the bracket, represents the technological change (or Innovation). Thus, for constant returns to scale,TFP change $=$ Change in Efficiency $\times$ Change in Technology … (10)

In **step (3)** of the proposed MCB DEA model,**Cluster Analysis** is used to divide the DMUs into different clusters, on the basis of their overall Malmquist TFP index and its components found in Step (2).Here **Hierarchical clustering** is used to find appropriate number of clusters and **K-meansclustering** is used to find homogeneous clusters. **K-means clustering**, algorithm is a simple clustering technique [38]. It is considered as a top-rated data mining algorithm for its simplicity and vast application areas [30,39].In order to perform k-means clustering, the number of clusters 'k' is chosen, means of these clusters (centroid) are computed, the distance of each object to the centroids is determined using some distance measure. Then the objects are grouped based on minimum distance and new cluster seeds are computed. The process is repeated until the centroids no longer change or convergence is reached.The objective function of K-means algorithm is defined as a minimization function:

$$J = \sum_{i=1}^{N} \sum_{j=1}^{C} D(x_i , c_j)$$

Where N is the number of objects, C is the number of clusters and D is the measure of distance between pointsx_i and cluster mean c_j .

III. Data Base

For the testing of the proposed MCB-DEA model, the data related to 25 public sector banks operating in India,for the time period, starting from the year 1998 till 2013, were collected from the Statistical Tables Relating to Banks in India, published by the Reserve Bank of India. The inputs considered for analysis are Owned funds, Deposits, Borrowings and Wage bills. Whereas, outputs have been taken as Spread and Other income. Table 1 gives the list of public sector banks, chosen for study, considered as DMUs. Although there are total 27 public sector banks, operating in India, but for the purpose of uniformity in data, the IDBI Bank and the Bhartiya Mahila Bank were eliminated as these banks were formulated in the year 2011 & 2015 respectively. Few banks had merged in the year 2015 onwards, So the data till 2013 have been considered.Table 2 gives the detailed description of the selected variables and Table 3 gives the descriptive statistics of the data related to these variables.

As per [40], for accuracy in DEA results, the number of DMUs should be greater than three times of total number of input variables and output variables. In present study, there are 400 observations (25 DMUs * 16 years) and the total number of input-output variables is six (4+2). Thus, this study observes well the property of minimal number of DMUs.

IV. Empirical Findings

This section presents the results of various steps of the proposed MCB-DEA model. In first step, a non-parametric, input oriented CCR model of DEA, assuming constant returns to scale is applied, separately for each financial year, on the data collected for the public sector banks under study, with the objective to find comparative efficiency level of each public sector banks in each year. If DEA efficiency score percentage is equal to one hundred then, public sector bank is identified to be efficient for that year andinefficient, if its DEA efficiency percentage is less than hundred.

The results of CCR model of DEA are listed in Table 4, which gives the efficiency level of each bank under study for each year column wise. The result shows that during all these sixteen years under study, out of total 400 observations, 204 are for efficient banks and 196 are for inefficient banks.

In the second step, change in efficiency behaviour of each public sector bank, for each year based on previous year, is analysed by applying Malmquist TFP index, on the year wise efficiency scores given by DEA, in table 4, to further find overall TFP change during the whole sixteen years time period.Table 5 gives the annual average changes of Total Factor Productivity(TFPCH) and its decomposition into efficiency change (ECH) and technical efficiency change (TCH), for each DMU. It is observed that over the entire period of study, out of total 25 PSBs, 20 have shown an increased TFPCH on average annually. Among these 20 banks, 5 banks have shown improvement in ECH and TCH both, although rate of improvement in ECHis far less than improvement in TCH, with an exception of The Central Bank of India, which has same rate of improvement in both factors i.e. 1.3 percent.Three banks have shown no improvement in ECH but have considerable rate of improvement. Twelve banks have faced a decline in ECH, but even then, high rate of growth of TCHof these banks has resulted into, growth of TFPCH.

In third step, to assess the cluster tendency of the dataset, Hopkins statisticis computed, on the values of variables TFPCH, ECH and TCH, given by table 5. Value of H in Hopkins test lies between 0 and 0.5; close to zero means data is clusterable and close to 0.5 means non clusterable.For the present data, H = 0.2768939, which indicates that the data is clusterable.Further, to find the appropriate number of clusters in which the public sector banks should be divided into, Hierarchical clustering is performed.Results suggest that taking five number of clusters will be most appropriate. The dendrogram in figure 1 gives the detailed division of objects into five clusters and genealogy of clusters.

For proper grouping of objects into homogeneous clusters, K-means clustering is done for k=5, which gives five clusters C1, C2, C3, C4 and C5 of sizes 1, 12, 3, 4 and 5 objects respectively.Cluster means of these clusters are given in Table 6.Geometrical representation of partitioning of DMUs in five clusters, byK-means, is given in figure 2. It is evident that DMUs within each cluster form homogenous groups. Mutual distance in position of any two DMUs tells about the extent of similarity in their efficiency behaviour. Information given by figure 2 is summarized in Table 7.Table 7 shows the clusters in first column and the DMUs present in each cluster are given in column two. Third column gives the number of years, out of total 16 years, for each DMU, for which that DMU is found to be efficient in DEA analysis in step 1(Table4, last column).Cluster C2 is the biggest cluster with 12 DMUs. But DMU 2 is the best performer which has been DEA efficient in all 16 years. Thus, for all other DMUs in cluster C2, benchmark is DMU 2. Cluster C3 has DMU 7 as its best performer. So, for DMU 12 and DMU 20, benchmark is DMU 7. Similarly, in Cluster C4, DMU 16 is a benchmark for DMU 9, DMU 22 and DMU 24. Although benchmark DMU 16 itself is not showing a very good performance, but even then, it is important for the DMUs in this cluster to consider it as a benchmark because improvements are possible in a gradual manner by first achieving a feasible target.Likewise, in Cluster C5, benchmark for DMU 3, DMU 6, DMU 10 and DMU 17 have their benchmark as DMU 14. Cluster C1 has only DMU 15, for its benchmark,C1 can be considered as merged into cluster C3, so, DMU 15 should follow DMU 7 as its benchmark.

V. Conclusion

From theexisting literature review, it is found that Data envelopment analysis (DEA) has been used extensively for efficiency evaluation and as a benchmarking of DMUs,in a single time period. Studies have also applied Malmquist TFP index on DEA results to analyse changes in the efficiency levels, fromone time period to the next. But, none of these researches have given benchmarks considering multi period data. Hence the present study proposes to add value to existing literature by proposing a new Malmquist clustering benchmarking model based on DEA (MCB DEA) to calculate benchmarks using cluster analysis with DEA based Malmquist TFP index.

From the foregoing analysis and development of MCB-DEAmodel and further testing the same on 25 public sector banks operating in India, for the time period from the year 1998 to the year 2013, efficiency of each DMU is evaluated by using CCR model of DEA for each year separately. The result shows that during all these sixteen years under study, out of total 400 observations, 204 results in efficiency and 196 observations indicate inefficiency.Then, the change in efficiency behaviour of each DMU, over the entire time period, is analysed using Malmquist TFP index, on the efficiency scores given by DEA. It is observed that over the entire period of study, out of total 25 public sector banks, 20 have shown an increased TFP on average annually and an improvement in technical efficiency is responsible for this increased TFP.Further, on the basis of the overall Malmquist TFP index and its components, technical efficiency change and efficiency change, public sector banks under study are divided into five homogeneous clusters C1, C2, C3, C4 and C5. The best performing public sector bank in cluster C2 is The State Bank of Bikaner and Jaipur, so it is the benchmark for all other banks falling in cluster C2. Similarly, The Allahabad Bank is the benchmark in clusters C1 and C3 merged together, The Indian Bank is the benchmark in cluster C4 and The Corporation Bank is the benchmark in C5. Hence it is concluded that the benchmarks found on the basis of MCB-DEA model are inherently similar to their respective less efficient banks, thus providing more realistic targets to achieve, in order to improve efficiency gradually.

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Table 1: List of Banks under study

Name of the Bank	Group
State Bank of India	
State Bank of Bikaner and	
State Bank of Hyderabad	

State Bank of Mysore	SBI & Associates
State Bank of Patiala	
State Bank of Travancore	
Allahabad Bank	Other Nationalized Banks
Andhra Bank	
Bank of Baroda	
Bank of India	
Bank of Maharashtra	
Canara Bank	
Central Bank of India	
Corporation Bank	
Dena Bank	
Indian Bank	
Indian Overseas Bank	
Oriental Bank of	
Punjab National Bank	
Punjab and Sind Bank	
Syndicate Bank	
UCO Bank	
Union Bank of India	
United Bank of India	
Vijaya Bank	

Table 2: Description of Input and Output Variables

	Variables	Description
Input Variables	Owned funds	Sum of Capital and Reserves
	Deposits	Total deposits
	Borrowings	Total Borrowings
	Wage Bills	Salaries to all employees
Output Variables	Spread	Interest Earned Minus Interest Expended
	Other Income	Sum of income from Commission, exchange & brokerage etc

Table 3: Descriptive Statistics of Input & Output Variables

	N	Minimum	Maximum	Mean	Std. Deviation
Owned Funds	400	2177.0	988837.0	57197.83	98725.56
Deposits	400	47686.0	12027396.00	852906.29	1292143.55
Borrowings	400	2.0	1691827.0	51514.33	147160.26

Wage Bills	400	1289.0	183809.0	11991.01	19325.68
Spread	400	0.0	443313.0	26146.32	44157.92
Other Income	400	522.0	160348.0	10831.73	18991.88
(All variables are measured in Million Indian Rupees.)					

Source: Authors' own calculations

Table 4 : DEA Efficiency Scores (%)

YEAR / DMUs	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Number of Efficient Years
State Bank of India	95.4	100	83.8	80.6	87.3	81.9	83.6	88	100	94.6	100	100	100	100	100	100	8
State Bank of Bikaner	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16
State Bank of	100	100	100	100	100	100	100	85.8	89.9	100	100	95.9	100	100	100	100	13
State Bank of Mysore	100	100	100	100	100	100	100	100	100	100	100	90.5	100	100	89.5	100	14
State Bank of Patiala	100	100	100	100	100	100	100	100	94.7	89.5	100	91.8	99.5	100	96.9	93	10
State Bank of	100	100	100	100	95	100	100	100	100	100	98.5	100	100	89.9	93.5	94.6	11
Allahabad Bank	100	100	100	95.9	100	100	100	100	100	100	98.2	100	100	94.2	95.8	88.7	11
Andhra Bank	85.5	84	91.2	81.1	90.8	100	100	100	92	98.8	100	93.4	100	100	100	98.7	7
Bank of Baroda	78.8	91.4	85.3	83.2	77.2	89.2	93.7	88.6	84.1	90	89.9	94.5	91.8	94.9	100	100	2
Bank of India	79.3	83.2	76.3	80.5	89.2	94.1	88.7	72.7	86	95.4	98.3	100	88.9	82.8	91	95.7	1
Bank of Maharashtra	85.9	88.9	95.2	100	100	93.2	81.4	75.8	96.5	100	100	99.3	95.6	89.4	97.8	95.2	4
Canara Bank	88.1	94.9	82	84.2	100	100	100	100	100	91.3	100	87.2	100	96.9	100	85.7	8
Central Bank of	90.4	84.6	74.7	75.2	94.3	100	100	100	100	100	100	78.7	94.8	84.9	77.4	74.1	6
Corporation Bank	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16
Dena Bank	93.4	87.3	74.8	69.5	95.6	100	100	84.1	100	100	100	100	100	100	96.7	93.7	8
Indian Bank	59.9	60.6	62.1	67.4	82.7	79	96.2	88.6	89.6	100	100	100	100	100	100	100	7
Indian Overseas	71.9	82.2	100	100	100	100	100	100	100	100	100	98.9	87.4	86.1	85	88.2	9
Oriental Bank of	95.5	100	100	100	100	100	100	100	100	100	99.6	100	100	100	100	100	14
Punjab National	100	100	84.6	88.2	95.2	100	100	87.7	93.1	100	100	100	100	100	99	100	10
Punjab and Sind Bank	75.4	81.4	75.3	88.2	89.5	100	100	100	100	100	94.1	91.1	90.5	78.7	66.6	79.8	5
Syndicate Bank	96.5	100	100	100	100	100	98.3	91.8	99.9	96.7	91.5	93.2	97.2	100	100	96.2	7
UCO Bank	55.3	62.6	67.4	67.2	82.9	86.1	90.3	78.4	90	94	95.6	91.4	89.6	99.5	89.3	100	1
Union Bank of India	88.8	100	58.6	84	100	94.9	87.8	87.2	100	100	100	100	100	89.7	100	96.4	8
United Bank of	71.5	59.1	52.4	56.1	76.3	96.3	100	100	97.4	88.6	69	76.4	100	89.2	92	100	4
Vijaya Bank	68.9	76.5	87.2	88.6	95.5	94.9	100	100	100	100	89.4	99.4	99.9	85.7	78.9	74.7	4
Total No. of Observations = 400; Efficient = 204 ; Inefficient = 196																	

Source: Authors' own calculations

Table 5 : Average Annual Changes in TFP, Efficiency and Technical Efficiency of				
DMU	DMUs	TFPCH	ECH	TCH
1	State Bank of India	1.023546	0.996863	1.026749
2	State Bank of Bikaner and Jaipur	1.02502	1	1.02502
3	State Bank of Hyderabad	1.012457	0.999953	1.01238
4	State Bank of Mysore	1.019448	0.999983	1.019478
5	State Bank of Patiala	1.025155	1.004858	1.02016
6	State Bank of Travancore	1.012633	1.003839	1.008757
7	Allahabad Bank	1.071444	1.008024	1.062966
8	Andhra Bank	1.012455	0.990429	1.022039
9	Bank of Baroda	1.008336	0.984391	1.024633
10	Bank of India	0.996524	0.987436	1.009203
11	Bank of Maharashtra	1.026028	0.993163	1.032957
12	Canara Bank	1.11351	1.001891	1.111482
13	Central Bank of India	1.026666	1.013373	1.013053
14	Corporation Bank	0.995872	1	0.996434
15	Dena Bank	1.176136	0.999873	1.1762
16	Indian Bank	0.993501	0.96631	1.028004
17	Indian Overseas Bank	0.992851	0.986533	1.006571
18	Oriental Bank of Commerce	1.033275	0.996934	1.036451
19	Punjab National Bank	1.028605	1.000001	1.028629
20	Punjab and Sind Bank	1.068782	0.9961	1.072766
21	Syndicate Bank	1.035742	1.000405	1.035484
22	UCO Bank	0.97865	0.961367	1.018124
23	Union Bank of India	1.021955	0.994439	1.027589
24	United Bank of India	1.010761	0.977845	1.033687
25	Vijaya Bank	1.027924	0.994605	1.033539

Source: Authors' own calculations

Table 6: Cluster means			
Clusters	TFPCH	TCH	ECH
C1	1.176136	0.9998730	1.176200
C2	1.025485	0.9987544	1.026762
C3	1.084579	1.0020050	1.082405

C4	0.997812	0.9724782	1.026112
C5	1.002067	0.9955522	1.006669

Source: Authors' own calculations

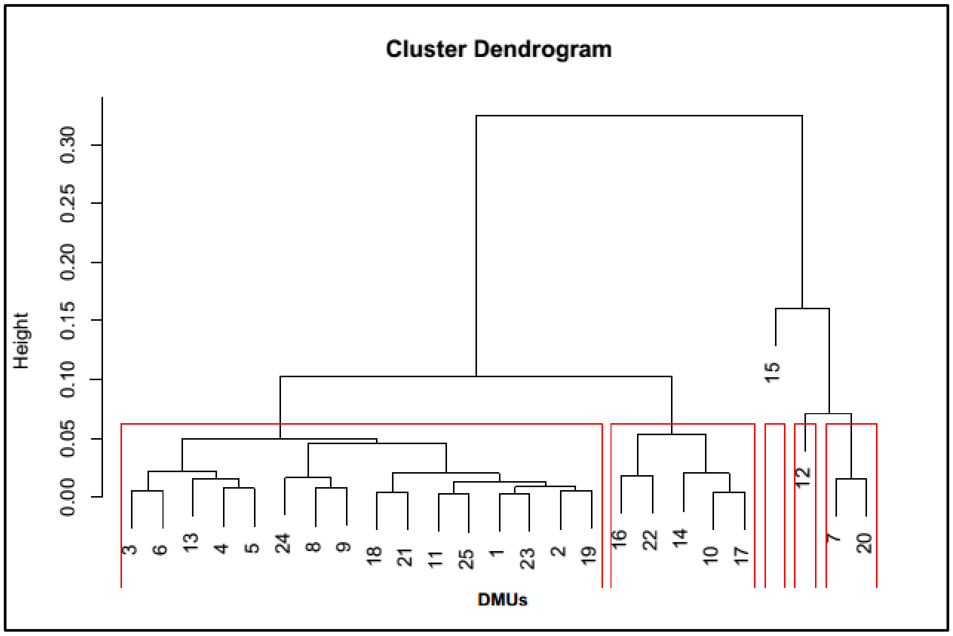

Fig 1: **Two-Dimensional Dendrogram showing partitioning and genealogy of clusters**

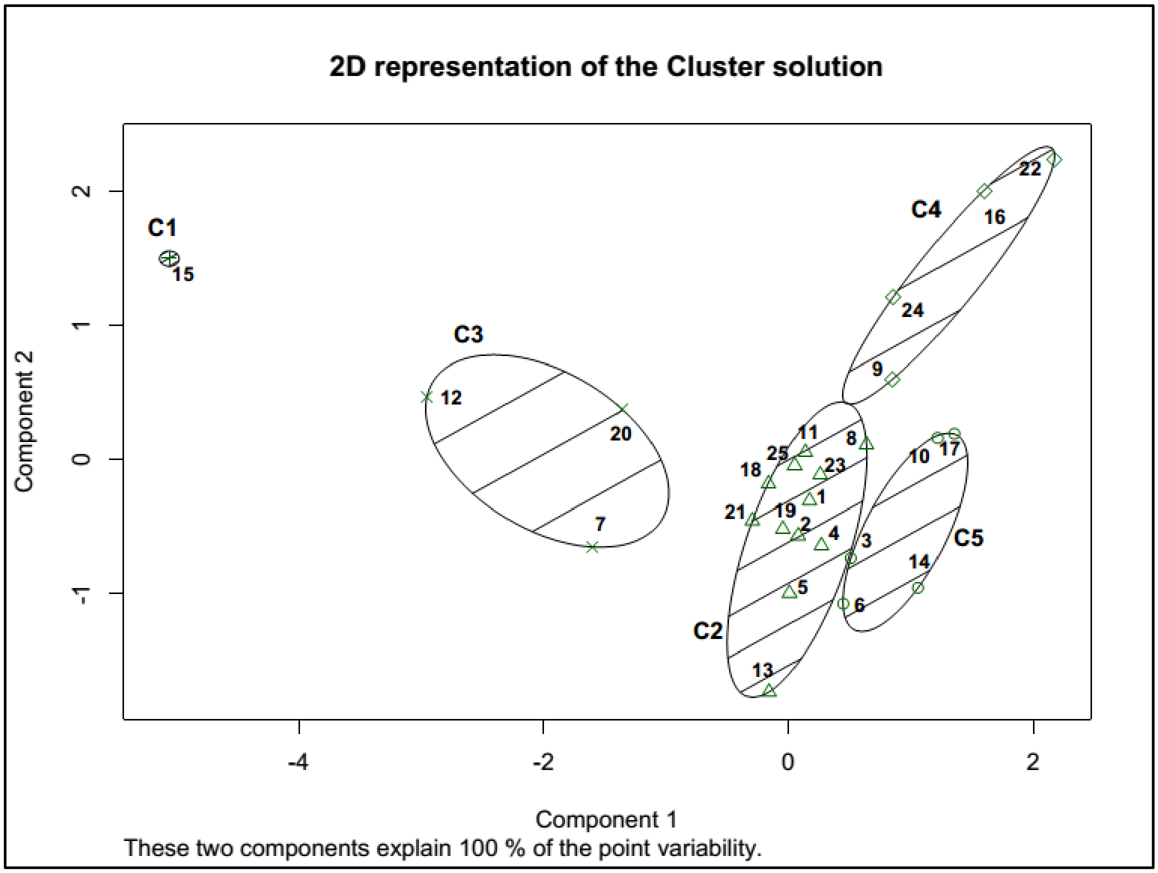

Fig 2: Two-Dimensional representation of K-means clustering results

Source: Authors' own calculations

Table 7: Identification of Benchmarks			
Cluster	DMU Id	No. of years with DEA 'efficient' Status (out of 16)	Benchmark
C1	15	8	DMU 7
C2	1	8	DMU 2
	2	16	
	4	14	
	5	10	
	8	7	
	11	4	
	13	6	

	18	14	
	19	10	
	21	7	
	23	8	
	25	4	
C3	7	11	DMU 7
	12	8	
	20	5	
C4	9	2	DMU 16
	16	7	
	22	1	
	24	4	
C5	3	13	DMU 14
	6	11	
	10	1	
	14	16	
	17	9	
Source: Authors' own calculations			