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Efficiency of Indian Banks –Data Envelopment Analysis Approach

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Abstract: *Data Envelopment Analysis (DEA) is a methodology based upon an interesting application of linear programming. It was originally developed for performance measurement. It has been successfully employed for assessing the relative performance of a set of firms that use variety of identical inputs to produce a variety of identical outputs. The main aim of the research is to measure the different Efficiency of Banks in India by using Data Envelopment Analysis Models during the period 2011-2012*

Keywords: *Data Envelopment Analysis, Efficiency, Decision Making Units.*

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I. Introduction

The Indian banking sector is broadly classified into scheduled and non-scheduled banks. The scheduled banks are those included under the 2nd Schedule of the Reserve Bank of India Act, 1934. The scheduled banks are further classified into: nationalised banks; State Bank of India and its associates; Regional Rural Banks (RRBs); foreign banks; and other Indian private sector banks.[7] The term commercial banks refers to both scheduled and non-scheduled commercial banks regulated under the Banking Regulation Act, 1949.[10]
The RBI set up a number of committees to define and co-ordinate banking technology. These have included:

- In 1984 was formed the Committee on Mechanisation in the Banking Industry (1984)[34] whose chairman was Dr. C Rangarajan, Deputy Governor, Reserve Bank of India. The major recommendations of this committee were introducing MICR technology in all the banks in the metropolises in India.[35] This provided for the use of standardised cheque forms and encoders.
- In 1988, the RBI set up the Committee on Computerisation in Banks (1988)[36] headed by Dr. C Rangarajan. It emphasised that settlement operation must be computerised in the clearing houses of RBI in Bhubaneshwar, Guwahati, Jaipur, Patna and Thiruvananthapuram. It further stated that there should be National Clearing of inter-city cheques at Kolkata, Mumbai, Delhi, Chennai and MICR should be made operational. It also focused on computerisation of branches and increasing connectivity among branches through computers. It also suggested modalities for implementing on-line banking. The committee submitted its reports in 1989 and computerisation began from 1993 with the settlement between IBA and bank employees' associations.[37]
- In 1994, the Committee on Technology Issues relating to Payment systems, Cheque Clearing and Securities Settlement in the Banking Industry (1994)[38] was set up under Chairman W S Saraf. It emphasised Electronic Funds Transfer (EFT) system, with the BANKNET communications network as its carrier. It also said that MICR clearing should be set up in all branches of all those banks with more than 100 branches.
- In 1995, the Committee for proposing Legislation on Electronic Funds Transfer and other Electronic Payments (1995)[39] again emphasised EFT system.[37]
- In July 2016, Deputy Governor Rama Gandhi of the Central Bank of India "urged banks to work to develop applications for digital currencies and distributed ledgers."[40]
- The DEA is a programming technique which is used by mathematical sciences to observe some of practical applications that made to order the assumption of similar units in organisations. Thus, DEA is an important methodology based upon an application of linear programming technique and it was foremost developed for performance measurement. The two fundamental approaches to measure productive efficiency are parametric and non-parametric. The inceptive approach makes use of parametric function such as Cobb-Douglas, Translog, generalized Leontiff and Zellner- Revankars variables return to scale frontiers and their dual cost functions.
- In Non-parametric approach, the linear programming problems are constructed whose constraints give rise to an empirical production zone and expound to assess productive efficiency of any DMU in focus. In

efficiency measurement for which the approach is either parametric or non-parametric, we come cross input or output orientations

- We have noticed production efficiency differences in a production environment, by a comparison of their inputs and outputs, when a group of production units compete with each other. These variations occurred due to different reasons such as marginal scale of efficiency differences, scale advantages and disadvantages among techniques of production.
- A producer who cannot vary his output enquiries for possible reduction of inputs. If reduction does not appear, he is efficient, otherwise he is inefficient. In this situation producer decrease the total cost of production. In behalf of, if inputs cannot be different, which is frequent in short run the entrepreneur enquires for further output augmentation, if it is not possible he is efficient, otherwise he is inefficient. In this circumstance the positive assumption is revenue maximisation. How so ever, in long run, inputs as well as outputs can be differenced simultaneously where the underline optimization is profit maximisation. If the producer neither decreases inputs nor augments outputs production is profit efficient otherwise inefficient.
- In efficient production process can be in two ways, one of it can be detected by estimated production zone. It may be technically inefficient, if it is unsucceed to produce maximum output from a given input bundle, technical inefficiency result in an equi-propotionate over utilization of all inputs.
- It can also be appropriate inefficient in the power that the marginal revenue product of an input may not be equal to marginal cost of that input.
- Allocatively inefficiency results in utilization of inputs in the wrong ratios, given input costs. Schmidt and Lovell (1979) [82] was developed a method to evaluate technical and allocative efficiencies of variety forms by considering duality between cost functions and production frontier

II. Review Of Literature

When a collection of production units contend with each other in a production environment, by an evaluation of their inputs and outputs we notice production efficiency variances. These variances arise due to a diversity of causes such as marginal scale efficiency differences, scale advantages and disadvantages among the techniques of production.

A manufacturer who cannot differ his output investigates for probable decline of inputs. When he is efficient means reduction is not possible, otherwise he is inefficient. In this case the manufacturer diminishes the total cost of production. Otherwise, if inputs cannot be different, which is often in short run, the industrialist investigates for advance output extension, if such augmentation is not possible he is efficient, otherwise inefficient. In this state the implicit hypothesis is revenue maximization. Though, in long run, inputs as well as outputs can be diverse concurrently, where the fundamental optimization is profit maximization. If the manufacturer neither decreases inputs nor enlarges outputs, production is profit efficient, otherwise inefficient.

There are two ways of a production process can be inefficient. One can be noticed as estimated production frontier. It can be technically inefficient, if it flops to generate maximum output from a particular input bundle, technical inefficiency marks in an equi-proportionate exceed employment of all inputs. It can also be inefficient in the intellect that the peripheral revenue product of an input might not be equal to marginal cost of that input. Allocatively inefficiency fallouts in deployment of inputs in the wrong quantities, given input costs. Schmidt and Lovell (1979)[82] developed a method to estimate technical and Allocative Efficiencies of different forms by considering duality between production frontier and cost functions.

2.1. REFERENCE DMU

Multiple inputs and multiple outputs in DEA are linearly collected using weights. The virtual input of a firm is given by

$$\text{Virtual input} = \sum_{i=1}^{m} \mu_i \; x_i \qquad \dots (2.1.1)$$

Here μ_i is the weight assigned to the i[th] input, x_i and $\mu_{i \geq 0}$
The virtual output of a firm is given by

$$\text{Virtual output} = \sum_{r=1}^{s} v_r \; y_r \qquad \dots (2.1.2)$$

where v_r is the weight assigned to r[th] output and $v_r \geq 0$.
m, is the total number of input
s is the total number of output
The efficiency of a Decision Making Unit (DMU) in converting inputs to outputs can be defined as the ratio of outputs to inputs.

$$\therefore \textit{Efficiency of DMU} = \frac{\textit{Virtual output}}{\textit{Virtual input}} = \frac{\sum_{r=1}^{s} \nu_r \; y_r}{\sum_{i=1}^{m} \mu_i \; x_i} \qquad \text{… (2.1.3)}$$

The very important issue at this stage is the weights assignment. These weights which will maximize its efficiency subject to the condition that the efficiencies of other DMUs is controlled to the values between zero and one

2.2. FRACTIONAL DEA PROGRAMME

Let us take one of the DMUs, say the j_o^{th} DMU, and maximize its efficiency, this j_o DMU is taken as reference DMU. The mathematical programming problem is given by

$$Ej_o = \max \frac{\sum_{r=1}^{s} \nu_r \; y_{rj_o}}{\sum_{i=1}^{m} \mu_i \; x_{ij_o}}$$

subject to … (2.2.1)

$$O \leq \frac{\sum_{r=1}^{s} \nu_r \; y_{rj}}{\sum_{i=1}^{m} \mu_i \; x_{ij}} \leq 1 , \quad j=1,2,\ldots n.$$

ν_r, $\mu_i \geq 0$, r=1,2,...s; i=1,2,...m.

where	E_{j_o}	=	Efficiency of j_o DMU
	Y_{r_j}	=	r^{th} output of j^{th} DMU
	ν_r	=	weight of r^{th} output
	x_{ij}	=	i^{th} input of j^{th} DMU
	μ_i	=	weight of i^{th} input
	j	=	1,2,… n.

The above mathematical programming problem when solved, will give the values of weights, that will maximize the efficiency of the firm j_o. If the efficiency is unity, then the firm is said to be efficient and will lie on the frontier. Otherwise, in firm is said to be relatively

2.3. OUTPUT MAXIMIZATION AND INPUT MINIMIZATION: DEA PROGRAMS

The mathematical programs for DEA are fractional programs. It is generally difficult to solve fractional programs. If they are converted to simple formulations, such as the LP problems, by using the Charnes – Cooper(1962)[23] transformation, the fractional programming problem (2.2.1) can be converted into the LPP.

$$Max \;\; Z = \sum_{r=1}^{s} \nu_r \; y_{rj_o}$$

subject to $\sum_{i=1}^{m} \mu_i \; x_{ij_o} = 1$ … (2.3.1)

$$\sum_{r=1}^{s} \nu_r \; y_{rj} - \sum_{i=1}^{m} \mu_i \; x_{ij} \leq 0; \; \text{j= 1,2,…n.}$$

$\nu_r , \; \mu_i \; \geq \in ;$ r=1,2,…s.

i = 1,2,….m.

The minimization of virtual input gives the following DEA model that can be represented as follows:

$$K_{j_o} = Min \sum_{i=1}^{m} \mu_i \; x_{ij_o}$$

subject to $\sum_{r=1}^{s} v_r \; y_{rj_o} = 1$… (2.3.2)

$$\sum_{r=1}^{s} v_r \; y_{rj} \; - \; \sum_{i=1}^{m} \mu_i \; x_{ij} \; \leq 0; \text{ j=1,2,…n.}$$

$$v_r, \mu_i \geq \in$$

Where $\in$ is a arbitrarily small Archimedean quantity.

2.4. MULTIPLIER DEA AND ITS DUAL PROBLEM

The DEA programs involving weights of inputs and outputs (μ and ν) are called multiplier DEA programs. Those involving weights of firms (θ & λ) are called envelopment DEA programs.

The virtual output maximizing multiplier model, can be written as follows:

$$\theta_{j_o} = Min \; \theta$$

such that

$$\sum_{j=1}^{n} \lambda_j \; x_{ij} \leq \; \theta x_{ij_o} ; \;\; i = 1, 2, ..., m$$

$$\sum_{j=1}^{n} \lambda_j \; y_{rj} \geq \; y_{rj_o} ; \;\; r = 1, 2, ..., s \qquad \text{… (2.4.1)}$$

$$\lambda_j \geq 0, \; j = 1, 2, ..., n$$

θ unrestricted (free)

The model (2.4.1) can also be represented using matrix notation as follows:

$$\theta_{j_o} = \underset{\theta,\lambda}{Min} \; \theta$$

such that… (2.4.2)

$$y\lambda \; \geq y_{j_o}$$

$$x\lambda \; \leq \theta \, x_{j_o}$$

$\lambda \; \geq 0, \; \theta$ is free.

2.5. AXIOMATIC APPROACH TO THE CCR ENVELOPMENT PROBLEM

Let there be n DMUs competing with each other, employing m similar inputs and producing n similar outputs. The multiplier problem and the associated envelopment problem are introduced by Charnes, Cooper and Rhodes (1978)[24].

$$x_j \in R_m^+,$$

$$y_j \in R_s^+,$$

$$j = 1, 2, .. n.$$

Let P be the production possibility set. Then, the axioms are,

i) $(x_j, y_j) \in$ p, j = 1,2,…n. … (2.5.1)

ii) $(x,y) \in$ p, $\bar{x} \geq x, \bar{y} \leq y \Rightarrow (\bar{x}, \bar{y}) \in P$ … (2.5.2)

iii) $(x,y) \in$ p, $\lambda > 0 \Rightarrow (\lambda x, \lambda y) \in$P. … (2.5.3)

iv) P is the intersection of all the production possibility sets which contain (xj, yj), j= 1,2,…n. … (2.5.4)

The first axiom is called the inclusion property. The second axiom allows inefficiency into production. The third axiom refers to say unboundedness. The fourth axiom reflects to minimum extrapolation property.

The Charnes, Cooper and Rhodes (1978)[24] envelopment problem compares inefficient DMU with a frontier hypothetical DMU called virtual DMU.

The inputs and outputs of a virtual DMU may belong widely efficient region. For a clear understanding of the problem consider the following diagram.

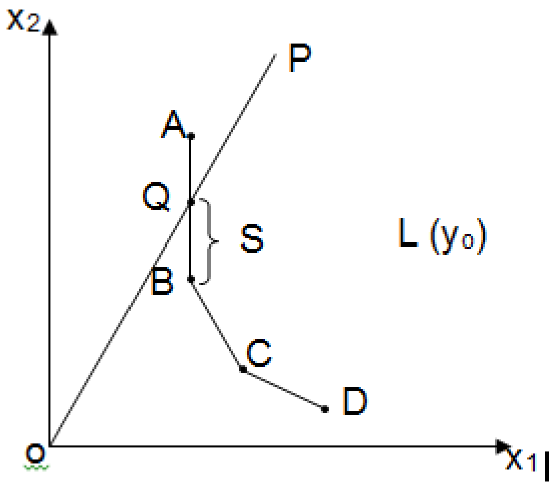

Fig. 2.1. Axiomatic approach to the CCR Envelopment

L(u_o) is the input level set which consists of all input vectors x$\in R_2^+$ capable of producing the output y$\in R_1^+$. The input level set is bounded below by the isoquant which is piecewise linear. The isoquant is determined by the frontier DMUs A,B,C, and D. The points of L(y_o) can be classified into inefficient, weakly efficient and efficient points. All the points which lie above the isoquant of L(y_o) are inefficient input points as such P is inefficient DMU. The line segment AB represents weakly efficient points as such Q is a weakly efficient points that belongs to the isoquant of L(u_o). S represents the non-zero slack in the second stage of optimization, which compares B with P.

The line segments BC and CD constitute efficient points of L(u_o). The CCR envelopment problem compares P with Q and the associated radial input technical efficiency is as follows:

Input Technical Efficiency (ITE) of DMU j_o = DMU P

ITE = $\dfrac{OQ}{OP} = \theta_{J_O}$ … (2.5.5)

$0 \le \theta_{J_O} \le 1$

However, the inputs of P should compared with DMU B instead of Q.

Some boundary points may be 'weakly efficient', because we have non-zero slacks in such cases, the following linear programming in which the slacks are taken to their maximal values is developed:

$$Max\left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+\right)$$

subject to

$$\sum_{j=1}^{n} x_{ij}\ \lambda_j\ + S_i^-\ =\ \theta_{j_o} * x_{ij_o},\quad i = 1,2,....,m \quad \text{… (2.5.6)}$$

$$\sum_{j=1}^{n} y_{rj}\ \lambda_j\ -\ S_r^+\ =\ y_{rj_o},\quad r = 1,2,....,s$$

and $\lambda_j,\ S_i^-, S_r^+ \ge 0,\ \forall i,\ j,\ r$

Here, S_i^-, S_r^+ are slack variables. The choice of S_i^- and S_r^+ do not affect θ^* which is obtained by the first stage optimization.

III. Research Methodology

The CCRs' DEA Model

Envelopment model	Multiplier model
Input oriented form	
Envelopment model	**Multiplier model**
Min $\theta - \in \left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right)$	$Max\ Z = \sum_{r=1}^{s} \mu_r\ y_{r0}$
subject to	subject to
$\sum_{j=1}^{n} x_{ij}\ \lambda_j + S_i^- = \theta\ x_{ij_o},\ \ i = 1,2,....., m$	$\sum_{r=1}^{s} \mu_r\ y_{rj} - \sum_{i=1}^{m} v_i\ x_{ij} \le 0$, j=1,2,..n.
$\sum_{j=1}^{n} y_{rj}\ \lambda_j - S_r^+ = y_{rj_o},\ \ r = 1,2,....., s$	$\sum_{i=1}^{m} v_i\ x_{ij_o} = 1$
$\lambda_j \ge 0$	$\mu_r, v_i \ge \in \ge 0$
Output oriented form	
Envelopment model	**Multiplier model**
$Max\,\phi + \in \left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right)$	$\underset{(\mu,\,\nu)}{Min} \sum_{i=1}^{m} v_i\ x_{i0}$
subject to	subject to
$\sum_{j=1}^{n} x_{ij}\ \lambda_j + S_i^- = \theta\ x_{ij_o},\ \ i = 1,2,....., m$	$\sum_{i=1}^{m} v_i\ x_{ij} - \sum_{r=1}^{s} \mu_r\ y_{rj} \ge 0$, j=1,2,..n.
$\sum_{j=1}^{n} y_{rj}\ \lambda_j - S_r^+ = \phi\, y_{r_0},\ \ r = 1,2,....., s$	$\sum_{r=1}^{s} \mu_r\ y_{r0} = 1$
$\lambda_j \ge 0,\qquad J = 1,2,....., n$	$\mu_r, v_i \ge \in \ge 0$

If the constant $\sum_{j=1}^{n} \lambda_j = 1$ is adjoined to the CCR envelopment problem, then CCRs' models are known as BCC (Banker, Charnes, Cooper) models.

3.1. BCCS' MULTIPLICATIVE DEA MODELS INVOLVING RETURNS TO SCALE CONSTRAINT

Economic data often are subjected to variable returns to scale. The returns to scale influencing such data are constant or increasing or decreasing. Banker, Charness and Cooper (1984)[12] augmented the constraint, $\sum_{j=1}^{n} \lambda_j = 1$ to the CCR envelopment constraints.

The BCC (1984)[12] problem can be expressed as,

θ_{j_o} = Min λ

subject to $\sum_{j=1}^{n} \lambda_j\ x_{ij} \le \lambda x_{ij_o}$, j= 1,2,..n

$\sum_{j=1}^{n} \lambda_j\ y_{rj} \ge y_{rj_o}$, r=1,2,..s … (3.1.1)

$\sum_{j=1}^{n} \lambda_j = 1$

$\lambda_j \ge 0$

This problem allows variable returns to scale. The above LPP obtained by the following axioms.

i. $(x_j, y_j) \in p$, $x_j \in R_m^+$, $y_j \in R_s^+$, j = 1,2,…n.

   This is inclusion axiom.

ii. (x,y) ∈ p, $\bar{x} \geq x, \bar{y} \leq y \Rightarrow (\bar{x}, \bar{y}) \in P$
This inefficiency axiom.

i. (x_j,y_j) ∈ p $\Rightarrow \left(\sum_{j=1}^{n} \lambda_j \ x_j , \sum_{j=1}^{n} \lambda_j \ y_j \right)$ ∈ p

Where $\sum_{j=1}^{n} \lambda_j = 1, \ \lambda_j \geq 0$

this is convexity axiom.

ii. P is the intersection of all the production possibility sets satisfies the axioms from (i) to (iii). This is minimum extrapolation axiom.

3.2 THE DUAL OF THE BCC MULTIPLICATIVE PROBLEM IS AS FOLLOWS

$$Min\ \theta$$

Subject to $\sum_{j=1}^{n} \lambda_j \ x_{ij} \leq \ \theta \ x_{i_0}, \ \ i = 1,2,....n$

$$\sum_{j=1}^{n} \lambda_j \ u_{rj} \geq \ u_{r_0}, \ \ r = 1,2,....s \quad \textbf{... (3.2.1)}$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0$$

3.3. MULTIPLICATIVE DEA MODELS

Generally in DEA models, the inputs and outputs of a DMU are aggregated additively. An alternative method of multiplicative aggregation is possible, using this mode of aggregation, multiplicative DEA models have been constructed. The Cobb-Douglas function is the popular form for production function, with arguments X = (x_1, x_2, …, x_n), and the function is expressed as

$$F(x) = \ A \ \prod_{i=1}^{n} x_i^{\alpha_i} \qquad \text{… (3.3.1)}$$

where $\sum_i \alpha_i = 1$ and A is a positive constant. The above function represents a typical example of multiplicative aggregation, with weights forming the indices.

The condition $\sum_{i=1}^{n} \alpha_i = 1$ reveals that returns to scale are constant.

IV. Empirical Investigation

EFFICIENCY SUMMARY:

DMU	TE	PTE	SE	MODEL
Allahabad Bank	0.94	0.943	0.99	DRS
Andhra Bank	1	1	1	
Bank of Baroda	0.893	0.907	0.99	DRS
Bank of India	0.913	0.916	0.99	IRS
Bank of Maharashtra	0.986	1	0.98	IRS
Canara Bank	1	1	1	
Central Bank of India	1	1	1	
Corporation Bank	0.889	0.9	0.98	IRS
Dena Bank	0.863	0.94	0.92	IRS
IDBI Bank Ltd.	1	1	1	
Indian Bank	0.99	1	0.99	IRS
Indian Overseas Bank	0.99	1	0.99	IRS
Oriental Bank of Commerce	0.98	0.99	1	
Punjab and Sind Bank	1	1	1	
Punjab National Bank	1	1	1	
Syndicate Bank	1	1	1	
Uco Bank	1	1	1	
Union Bank of India	0.92	0.93	0.99	DRS

United Bank of India	0.99	1	0.99	IRS
Vijaya Bank	0.99	1	0.99	IRS
MEAN	0.96	0.98	0.99	

TE=TECHNICAL EFFICIENCY , IRS=INCREASING RETURNS TO SCALE
PTE=PURE TECHNICAL EFFICIENCY, DRS=DECREASING RETURNS TO SCALE
SE=SCALE EFFICIENCY
DMU=DECISION MAKING UNIT

From the above table it has been observed that among 20 banks 14 banks have TE above its average. The remaining 6 banks have TE below its avg. Among these 8 banks stay in the first position. They are Andhra Bank,Canara Bank, Central Bank of India,IDBI Bank Ltd,Punjab and Sind Bank. Punjab National Bank ,Syndicate Bank and Uco Bank. Dena Bank stay in the last position.

From above table it has been observed that 14 banks have PTE Efficient above its avg PTE. Remaining 6 banks are below its avg PTE. Similarly 9 banks have SE above its average SE. 7 banks have equal to its average SE. 4 banks are below its avg SE.

V. Conclusion

By using Data Envelopment Analysis Models we got following results.
Among 20 banks

1. 8 banks stay in the first position with reference to Technical Efficiency.
2. 13 banks stay in the first position with reference to Pure Technical Efficiency.
3. 9 8 banks stay in the first position with reference to Scale Efficiency.

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