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Performance Evaluation of Banks in India – A Shannon-DEA Approach

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Abstract

Data Envelopment Analysis (DEA) is widely used in banking sector to measure the efficiency of the banks. This paper evaluates the performance of the banks in India using cost, revenue and profit models of DEA and comes out with a comprehensive efficiency index for banks, by combing the efficiency scores of various DEA models, using the Shannon entropy. In general, the banks included in this study are sound in terms of total assets, manpower, branch network etc., and they have been ranked based on their performance, which depends on optimal utilization of select variables. In order to measure the degree of agreement between rankings of banks based on three different models, namely cost, revenue and profit model, Kendall's coefficient of concordance have been used. The study observes that Shannon-DEA approach provides a comprehensive efficiency index for banks and a reasonable way of ranking.

Keywords: *Shannon's Entropy, Cost Efficiency, Revenue Efficiency, Profit Efficiency, DEA, Banking, Ranking.*

JEL Code Classification*: C61, G210*

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1. Introduction

Data Envelopment Analysis (DEA) is most widely used nonparametric technique to measure the efficiency of banks. The technique of measuring technical efficiency of decision making units (DMUs) was first proposed by Charnes, Cooper and Rhodes in 1978 and later extended by Banker, Charnes and Cooper in 1984. The measurement of efficiency helps banks to channelize their focus to remain competitive, profitable and viable, in an otherwise highly regulated banking industry like India. It would also help to benchmark an individual bank against the 'best practice' bank(s) as well as evaluate the impact of various policy measures on the efficiency and performance of these institutions (Das et al., 2005).

There is a great variety of DEA models to measure the efficiency of DMUs like CCR, BCC, FDH, SBM, Cost, Revenue, Profit models etc. (Cooper et al., 2000; Ray, 2004; Zhu, 2009). In input / output oriented technical efficiency approach, the objective of a firm is to contract all inputs / expand all outputs at the same rate to the extent possible without reducing any output / without increasing any input. Both the approaches measures technical efficiency without using the market prices of inputs and outputs. If market prices of inputs / outputs are available, then a firm would either try to minimize its cost or try to maximize its revenue / profit. In cost minimization process, a firm would seek to minimize the total input cost for a given level of output and in revenue maximization it would look for maximizing the output thereby total revenue for a given level of input. In profit maximization, the objective of the firm would be to select such an input-output mix that generates maximum revenue with minimum cost, for given input and output prices. Thus, maximizing revenue is as much a necessary condition as cost minimization for the maximizing profit. Hence for a profit making firm, profit efficiency is a more important source of information than the cost efficiency, which provides partial information (Ray and Das, 2010).

In literature, there are numerous studies on measuring the efficiency of financial institutions. Berger and Humphrey (1997) reviewed 130 studies that applied frontier efficiency analysis to financial in 21 countries. They observed that various efficiency measures do not necessarily yield consistent results and suggested some ways to make it consistent. Maudos and Pastor (2003) analyzed cost and profit efficiencies of Spanish banks using DEA and observed that there is a positive rank correlation coefficient between cost efficiency and profit efficiency of Spanish banks. Further, if banks are more cost efficient, they are also more profit efficient. Other studies on efficiency of financial institutions include Berger and Mester (1997), Berger (2007), Resende and Silva (2007), Drake et al. (2009). In Indian context, there are number of papers on technical / cost efficiency of banks in India (Das, 2002; Shanmuagm and Das, 2004; Ram Mohan and Ray, 2004; Das and Ghosh, 2006 & 2009; Ray, 2007; Jayaraman and Srinivasan, 2009; Kumar and Gulati, 2008; Gulati and Kumar, 2011). Das *et al.* (2005) analyzed the cost, revenue and profit efficiency of Indian banks for 1997-2003 using DEA. The study observes that results of input-oriented, output-oriented and cost efficiency measures are more or less similar, but the results in respect of revenue and profit efficiencies differ sharply during this period. They found that the bank's size, ownership, listed in stock exchange had a positive impact on the profit efficiency and to some extent revenue efficiency. Ray and Das (2010) studied the cost and profit efficiency of Indian banks using DEA during the post reforms period and observed that public sector banks are more efficient compared to private sector banks and small banks (with assets up to Rs.50 billion) are operating below the efficiency frontier. Also, there is a strong evidence of ownership explaining the efficiency differentials of the banks. Kaur and Kaur (2010) examined the impact of mergers on the cost efficiency of Indian commercial banks using DEA. They observed that the merger has lead to higher level of cost efficiency of merged banks, while the merger between distressed and stronger banks did not yield any significant efficiency gains. Further, they opined that the stronger banks should not merge with the weaker banks, as the weaker banks will have adverse effect upon the asset quality of the stronger banks. Das and Kumhakar (2012) studied the productivity and efficiency of Indian banks using hedonic aggregator function and observed that efficiency of public sector banks surpassed the efficiency of private sector banks during the post reform period 1996-2005.

DEA has several advantages over other parametric methods. First, it does not assume any explicit functional form for production function, like parametric methods. Second, it enables to estimate efficiency from the complex production structure with multiple inputs and outputs. Third, being unit invariant, it allows the input-output bundle to be of different unit of measurement. Fourth, it uses maximum of a ratio of weighted outputs to weighted inputs, where weights are determined by the model so that it gives maximum possible score for each DMU and hence does not require a prior specification of weights. On the other hand, DEA has a few limitations like high sensitivity to data error and outliers, inability to capture random effects etc. Another limitation of DEA may be ranking of DMUs based on efficiency scores obtained from various DEA models. Since efficiency scores obtained from different DEA models may not be same, identifying a suitable model to rank the DMUs is a difficult task. Further, since each model and its viewpoint have some valuable advantage over the other, one may not like to ignore the efficiency scores obtained from various models while ranking the DMUs.

Soleimani-damaneh and Zarepisheh (2009) observed that existing super-efficiency-based ranking methods in the DEA literature (Adler et al., 2002; Andersen and Petersen, 1993) has a desirable feature of differentiating between some of the efficient DMUs that have identical efficiency scores equal to one in the basic DEA models. However, the main drawback these models is that it may happen that the most productive scale size (MPSS) DMUs do not have the best rank among efficient units when they are assessed by super efficiency based models. Since efficiency scores obtained from different models has its own importance while ranking DMUs, Soleimani-damaneh and Zarepisheh (2009) proposed combining of efficiency scores of various DEA models using Shannon's entropy method to provide a more balance ranking of DMU.

Bian and Yang (2010) also used Shannon-DEA procedure to establish a comprehensive efficiency measure for appraising DMUs resource and environment efficiencies. The motivation behind using Shannon's entropy based DEA in their study is as follows: 1) The efficiency discriminatory powers of the DEA models under specific situations are different, and it is hard for us to choose a specific model for performance valuation in a specific scenario. 2) Each of the proposed models evaluates DMUs efficiencies from a different perspective, and has some valuable advantages in the analysis which we could not ignore. Efficiency result of a DMU obtained from a special DEA model cannot replace the corresponding efficiency score calculated by another DEA model. 3) Any single DEA model has limited discriminatory power in efficiency evaluation problems, so it is suitable to integrate different DEA models into evaluation simultaneously.

The objective of this paper is to evaluate the performance of the banks in India during 2005-2012, using cost, revenue and profit models of DEA and construct a composite efficiency index for banks using Shannon entropy. Further, the study ranks the banks based on cost, revenue and profit efficiency DEA models and Shannon composite efficiency index. Ranking plays a major role in identifying the top performing banks in a competitive world, which in turn helps to grow the economy. It also creates a confidence in the banking system as a whole. As banks use public money, ranking helps both the regulator and investors to monitor the bank's performance. Further, DEA being relative efficiency measure, ranking helps to promote internal peer competition. The reason for choosing 2005-2012 as study period is that during this period, banking sector witnessed both robust growth (2005-2008) and economic slowdown due to global financial crisis (2009-2012) and hence considered as an ideal period for studying bank efficiency.

Though, the banks included in this study are sound in terms of total assets, manpower, branch network etc., they can be classified as efficient or less efficient based on the performance and soundness. The performance of these banks depends on the optimal utilization of the select input and output variables under cost, revenue and profit model and it also facilitates ranking these banks under each model. Since different models provide different set of ranking to banks, Kendall's coefficient of concordance have been used to measure the degree of agreement / disagreement between rankings obtained from three different models. The agreement between rankings suggests that a unified ranking of banks is meaningful and in this paper it is achieved by using the Shannon entropy approach. The Shannon entropy method combines the efficiency scores of banks obtained from three different models and provides a comprehensive efficiency index for the banks as well as reasonable way of ranking these banks.

Rest of the paper is organized as follows: Section 2 discusses the overview of the Indian banking system and the performance during period of study. Section 3 describes the various DEA models used in this paper and Section 4 describes the Shannon's entropy method. Section 5 discusses the empirical results of the study and Section 6 summarizes the findings and conclusions.

2. Overview of Indian Banking System

Commercial banks in India constitute the largest segment of the Indian financial system and were predominantly government owned till the early 1990s. Indian banking system consists of scheduled commercial banks (SCBs) and cooperative banks and the SCBs are grouped into: 1) public sector banks comprise of State Bank of India and its associates, and nationalized banks, 2) private sector banks comprise of old and new private sector banks, 3) regional rural banks and 4) foreign banks.

The banking system in India had undergone a metamorphic change with the introduction of the first phase of reform in 1991. The objective of early phase of reform was to create an efficient, productive and profitable financial service industry operating within the environment of operating flexibility and functional autonomy. The focus of the second phase of financial sector reforms in 1998 was strengthening of the financial system and introduction of structural improvements with an aim to align Indian banking standards with the internationally recognized best practices. These reforms promoted diversified, efficient and competitive banking system in India. The operational flexibility resulted in a strong balance sheet growth of the banks during this period. One of the major objectives of banking sector reforms is to enhance efficiency and productivity through enhanced competition. The reform process established a competitive banking system in India driven by market forces and it is evident from considerable reduction in interest spread during the reform period as well as change in business strategy like non-fund based business, treasury and foreign exchange business. Also, greater emphasis on income and expenditure management during the reform period resulted in a general reduction in operating expenditure as a proportion of total assets in spite of large expenditure incurred on technology upgradation and voluntary retirement of staff. A key achievement of banking sector reform has been the sharp improvement in the financial health of banks which reflect in significant improvement in capital adequacy and improved asset quality (Mohan, 2005).

Prior to the global financial crisis i.e. during 2005-2008, the business and financial performance of banks in India was underpinned by strong macroeconomic environment and supporting monetary and financial policies. SCBs exhibited robust growth in terms of aggregate deposits and gross bank credit with improved asset quality and profitability. The effect of global financial crisis was quite visible in Indian banking industry during 2009-2010. Though, the banking industry withstood this test by adopting counter-cyclical prudential regulations framework during credit boom and slowdown period, it was not completely insulated from the effects of the financial crisis. This is evident from decelerated growth of aggregate deposits, loans & advances, net profits and a sharp increase in provisions and contingencies during this period. In 2011, banks in India experienced another test due to challenging operational environment like high interest rates, tight liquidity conditions and high inflation. Consequently, the major concern in 2012 is deterioration of asset quality and growing NPAs. Table 1 presents few key performance indicators of SCBs in the recent periods.

Table 1 : Select Performance Indicators (Amount in Rs. Billion)

Year / Bank Group	2005			2008			2012		
	Pub.	Pvt.	For.	Pub.	Pvt.	For.	Pub.	Pvt.	For.
No. of Banks	28	29	31	28	23	28	26	21	43
No. of Branches	47320	6143	220	55124	8334	279	69498	13408	324
Deposits	14365	3146	864	24539	6750	1912	50020	11746	2774
Advances	8542	2213	753	17974	5184	1611	38783	9664	2301
Investments	6862	1407	429	7998	2786	989	15041	5260	2024
Profit / Loss	154	35	20	266	95	66	495	227	94
Net Interest Income	516	100	51	642	225	138	1562	472	211
Business Per Branch	0.48	0.87	7.35	0.77	1.43	12.63	1.28	1.60	15.66

Source: Database on Indian Economy, RBI Data warehouse

Another major concern since 2007 is the high operating cost of banking system. Chakraborty (2013) observed that effective use of human capital, skills and technology, would help in increasing the productivity and, thereby, lowering the transaction costs, for which the banking system would need to acquire allocative and operational efficiency. In allocative efficiency, banks have to ensure that the precious societal resources are allotted to the most productive activities and that the interests of the vulnerable sections of the society are also taken into account. In operational efficiency, banks have to provide financial products and services to its customers in a safe, secure and speedy manner and to ensure that the cost of financial intermediation is minimized.

3. DEA Models and Selection of Variables

In this paper, three different DEA models, namely cost, revenue and profit models, are used to measure the efficiency of Indian banks. Suppose there are K DMUs producing m outputs $\boldsymbol{y} = (y_1, \dots, y_m) \in \Re^{M+}$ from the given n inputs $\boldsymbol{x} = (x_1, \dots, x_n) \in \Re^{N+}$. Then the production possibility set (PPS) is defined as collection of all feasible input–output vectors and represented as: $T = \{(\boldsymbol{x}, \boldsymbol{y})$: $\boldsymbol{x}$ can produce $\boldsymbol{y}\}$. It is assumed that *T* is closed and convex with freely disposable inputs and outputs. Let $\boldsymbol{p}$ be the output prices of $\boldsymbol{y}$ denoted as $\boldsymbol{p} = (p_1, \dots, p_m) \in \Re^{M+}$ and $\boldsymbol{w}$ be the input prices of $\boldsymbol{x}$ denoted as $\boldsymbol{w} = (w_1, \dots, w_n) \in \Re^{N+}$. Using the input and output prices, the associated cost, revenue and profit DEA models are defined as under (Zhu, 2009; Das et al., 2005):

a) Cost Efficiency: In input-oriented measure of technical efficiency, all inputs are treated equally and the objective is to reduce all inputs by the same proportion to the extent possible. Thus, once any one input becomes binding no further possible reduction in any other input is considered. But when input prices are available, the objective of a DMU would be to minimize the cost of inputs and hence reducing the more costly input assumes a greater priority than reducing the less costly ones. This model is suitable for nonprofit organizations like hospitals, schools, and so forth. Let $x_i^{k^*}$ be the *i-th* input that minimizes the cost for the *k-th* DMU. Then for the *k-th* DMU, the actual cost is defined as: $C\ (w, x^k) = \sum_{i=1}^{n} w_i^k\ x_i^k$ and the cost efficiency is defined as $C\left(w, x^{k^*}\right)/C\ (w, x^k)$, where $C\left(w, x^{k^*}\right)$ is the minimum cost obtained by solving the following model:

$$C\left(w, x^{k^*}\right) = Min \sum_{i=1}^{n} w_i^k\ x_i^{k^*}$$

subject to

$$\begin{aligned} &\sum_{k=1}^{K} \lambda^k\ y_j^k \ \geq\ y_j^k && j = 1,2,\dots,m \\ &\sum_{k=1}^{K} \lambda^k\ x_i^k \ \leq\ x_i^{k^*} && i = 1,2,\dots,n \\ &\sum_{k=1}^{K} \lambda^k = 1\ ;\ \lambda^k \geq\ 0 && k = 1,2,\dots,K \end{aligned} \qquad (1)$$

b) Revenue efficiency: In output-oriented measure of technical efficiency, the objective is to achieve the maximum rate of increase that would be feasible for all outputs. However, as in the case of inputs, some outputs are more valuable than others. When output prices are available, the objective of a DMU would be to maximize its revenue by producing the output bundle that results in the highest revenue at the applicable output prices. Let $y_j^{k^*}$ be the *j-th* output that maximizes the revenue for the *k-th* DMU. Then for the *k-th* DMU, the actual revenue is defined as: $R\ (p, y^k) = \sum_{j=1}^{m} p_j^k\ y_j^k$ and the revenue efficiency is defined as $R\ (p, y^k)/R\left(p, y^{k^*}\right)$, where $R\left(p, y^{k^*}\right)$ is the maximum revenue obtained by solving the following model:

$$R\left(p, y^{k^*}\right) = Max \sum_{j=1}^{m} p_j^k\ y_j^{k^*}$$

subject to

$$\begin{aligned} &\sum_{k=1}^{K} \lambda^k\ y_j^k \ \geq\ y_j^{k^*} && j = 1,2,\dots,m \\ &\sum_{k=1}^{K} \lambda^k\ x_i^k \ \leq\ x_i^k && i = 1,2,\dots,n \\ &\sum_{k=1}^{K} \lambda^k = 1\ ;\ \lambda^k \geq\ 0 && k = 1,2,\dots,K \end{aligned} \qquad (2)$$

c) Profit efficiency: In cost efficiency model, outputs are exogenous and the focus is on the choice of variable inputs in the short run and all inputs in the long run. For commercial firms, which operate for profit, quantities of output to be produced are also choice variables like the input quantities. The objective of the firm is to select the input–output combination that results in the maximum profit at the applicable market prices of outputs and inputs. The only constraint is that the input–output combination selected must constitute a feasible production plan. Let ($x_i^{k^*}$, $y_j^{k^*}$) are the input and output vectors associated with the maximum profit given the corresponding price vectors (***w, p***). Then for the *k-th* DMU, the actual profit is defined as $\pi\,(p,w) = \sum_{j=1}^{m} p_j\, y_j - \sum_{i=1}^{n} w_i\, x_i$ and profit efficiency is defined as $\pi\,(p,w)/\pi^*\,(p,w)$, where $\pi^*\,(p,w)$ is the maximum profit obtained by solving the following model:

$$\boldsymbol{\pi}^*\,(\boldsymbol{p},\boldsymbol{w}) = Max\left(\sum_{j=1}^{m} p_j^k\; y_j^{k^*} - \sum_{i=1}^{n} w_i^k\; x_i^{k^*}\right)$$

subject to

$$\begin{aligned} &\sum_{k=1}^{K} \lambda^k\; y_j^k \;\geq\; y_j^{k^*} && j = 1,2,\dots,m \\ &\sum_{k=1}^{K} \lambda^k\; x_i^k \;\leq\; x_i^{k^*} && i = 1,2,\dots,n \\ &\sum_{k=1}^{K} \lambda^k = 1\,;\; \lambda^k \geq\; 0 && k = 1,2,\dots,K \end{aligned} \qquad (3)$$

Selection of input-output variables plays a crucial role in measuring the efficiency of banks. Because of inter-connectedness of various products and services, selection of input-output variables for banks has not been straightforward. In general, there is no consensus in literature about selection of input-output variables for bank studies and the selection is left to the choice of researchers. Fare et al. (2004), Das et al. (2005), Resende and Silva (2007), Ray and Das (2010) have used borrowed funds (deposits and borrowing), advances and investments as input-output variables to measure the efficiency of bank, along with their associated prices viz., cost of funds, return on advances and return on investments respectively. Nigmonov (2010) used fixed assets, operational expenses and total deposits as inputs and total credits (reserve for possible loan losses), net non interest income and other non-interest income (dividends, forex operations, etc) as outputs in analyzing the Uzbekistan Banks. In Indian context, Saha and Ravishankar (2000) and Mukherjee et al. (2002) have used number of bank branches as inputs and, Das et al. (2005) and Ray (2007) have used equity as fixed input while analyzing the efficiency of banks. In view of the above, this study uses equity, borrowed funds and number of bank branches as inputs and, advances and investments as outputs along with their associated prices.

Of late, there is an emphasis for including non-traditional activities of banks, while studying efficiency of banks (Das et al., 2005; Das and Ghosh, 2009). Considering the increased importance of non-traditional activities of banks, non-interest income from fee, commission, brokerage etc. has been included as one of the output variable. Bank branch networks, which contribute to the business performance of the banks, have been included as one of the input variable. This paper uses four inputs and two outputs to measure the cost, revenue and profit efficiency of banks. The two output variables are: 1) deployed funds comprise of performing loans and investments and 2) non-interest income from fee, commission, brokerage etc. The associated output price for deployed funds is ratio of interest income from performing loans and investments to total deployed funds, and for non-interest income, it is unity (Das *et al.,* 2005). The four input variables are: 1) equity (capital plus reserves & surplus), 2) borrowed funds comprise of deposits and borrowings, 3) work force i.e., number of employees and 4) total number of bank branches. Equity is treated as fixed inputs with no associated cost and the associated cost for borrowed funds is the ratio of interest expenses on deposits and borrowings to total borrowed funds. The associated cost for work force is the ratio of payments to and provisions for employees to total staff strength and the associated cost for total number of bank branches is the ratio of operating expenses excluding payments to and provisions for employees to total number of bank branches.

Using the above input-output bundle, the cost, revenue and profit efficiency of banks in India is analyzed for the period 2005-2012. To make it comparable, only those banks with total assets more than Rs.100 billion and which was operating throughout the period of study is considered for study. This study is based on 34 banks satisfying the above two conditions. Foreign banks and Regional rural banks are excluded from this study because of their nature of operations different from public and private sector banks. Data for this study has been collected from Reserve Bank of India's data warehouse, Database on Indian Economy, various issues of Statistical Tables Relating to Banks in India and Trend and Progress of Banking in India.

4. Shannon's Entropy

Shannon entropy is an important concept in information theory and it was introduced by Shannon in 1948. The idea of using Shannon entropy as a coefficient of importance degree was first propose by Zeleny in 1982 in multiple criterion of decision analysis (Bain and Yang, 2010). The Shannon's entropy procedure proposed by Soleimani-damaneh and Zarepisheh (2009) to combine the efficiency scores of various DEA models is summarized below: Let E_{ij} denote the efficiency score of *i-th* DMU (*i = 1,2,…,n*) obtained from *j-th* DEA model (*j = 1,2,…,k*) and is presented in the matrix form E_{nXk}.

$$E = \begin{pmatrix} E_{11} & E_{12} & \dots & E_{1k} \\ E_{21} & E_{22} & \dots & E_{2k} \\ . & . & & . \\ . & . & & . \\ . & . & & . \\ E_{n1} & E_{n2} & \dots & E_{nk} \end{pmatrix} \quad (4)$$

Step 1: Normalize the efficiency matrix using

$$\bar{E}_{ij} = E_{ij} \Big/ \sum_{i=1}^{n} E_{ij} \quad (i = 1,2, \dots n; j = 1,2, \dots, k) \quad (5)$$

Step 2: Calculate the Shannon's entropy for each model as

$$e_j = -e_0 \sum_{i=1}^{n} \bar{E}_{ij} \ln \bar{E}_{ij} \quad (j = 1,2, \dots, k) \quad (6)$$

where e_0 is the entropy constant and is considered equal to $e_0 = -(\ln n)^{-1}$.

Step 3: For each model, set $d_j = 1 - e_j$ as the degree of diversification (*j = 1,2,…,k*). The degree of diversification (d_j) indicates the discriminatory power of a given DEA model. Larger value of d_j means the more discriminatory power of model *j*. Specifically, if a DEA model yields approximately equal scores for all DMUs, then it means the given DEA model has no discrimination ability and hence it must be considered a small degree of importance.

Step 4: For each model set $w_j = d_j / \sum_{j=1}^{k} d_j$ as the degree of importance (*j = 1,2,…,k*).

Ste p5: Calculate the comprehensive Shannon efficiency index for each DMU as

$$\beta_i = \sum_{j=}^{k} w_j \; E_{ij} \quad (i = 1,2, \dots, n) \quad (7)$$

5. Results and Discussions

In this section, we discuss in detail the result of various DEA models and the Shannon entropy results. Table 2 presents the summary statistics (mean and standard deviation) of the input-output variables used in this study.

Using the cost, revenue and profit models of DEA discussed in Section 3, first, the year-wise efficiency scores for 34 banks is calculated under each model. The average efficiency score for each bank under each model is obtained by averaging the year-wise efficiency score. The average efficiency scores of banks under each model are presented in Table 3.

Table 2: Summary Statistics – Mean & (Standard Deviation)

(Amount in Rs. Billion)

Year	2005	2006	2007	2008	2009	2010	2011	2012
Equity	32.1	40.1	47.7	62.5	79.8	93.5	110.3	132.0
	(39.7)	(50.2)	(60.4)	(85.7)	(115.0)	(128.2)	(136.3)	(153.3)
BFund	478.2	570.7	689.4	850.2	1068.8	1301.2	1545.0	1816.6
	(610.6)	(694.8)	(805.8)	(968.4)	(1239.8)	(1494.2)	(1702.5)	(1953.6)
NBR	1454.3	1496.6	1565.0	1675.0	1796.9	1932.8	2099.6	2277.4
	(1632.2)	(1639.6)	(1648.7)	(1787.7)	(1976.3)	(2143.1)	(2292.4)	(2385.9)
NStaff	23.3	23.6	23.7	24.2	25.4	25.7	27.2	28.5
('000)	(34.9)	(33.7)	(31.5)	(30.5)	(34.6)	(33.7)	(37.4)	(36.7)
CBF	0.04	0.04	0.05	0.06	0.06	0.05	0.05	0.06
	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)	(.01)
PBC	59.31	70.82	66.85	66.96	65.63	64.20	64.13	67.22
	(98.85)	(129.99)	(125.66)	(98.31)	(77.43)	(64.30)	(56.32)	(56.40)
SC (in	3.34	3.66	3.71	3.95	4.67	5.24	7.09	7.04
lakhs)	0.04	0.04	0.05	0.06	0.06	0.05	0.05	0.06
DFund	464.9	561.9	678.9	838.9	1042.3	1256.8	1494.1	1763.9
	(611.3)	(701.8)	(811.4)	(978.3)	(1229.8)	(1472.0)	(1671.9)	(1898.9)
NInc	3.5	4.4	5.6	7.0	8.6	9.8	11.7	12.8
	(6.5)	(8.1)	(10.5)	(13.4)	(15.8)	(18.2)	(21.7)	(23.0)
RDF	0.08	0.08	0.09	0.09	0.10	0.09	0.09	0.10
	(.01)	(.00)	(.00)	(.01)	(.01)	(.01)	(.01)	(.01)

Note: 1) Equity (x_1), 2) BFund - Borrowed Funds (x_2), 3) NBR - No. of Branches (x_3), 4) NStaff - No. of Staff (x_4), 5) CBF - Cost of Borrowed Funds (w_2), 6) PBC - Per Branch Cost (w_3), 7) SC - Staff Cost (w_4), 8) DFund - Deployed Funds (y_1), 9) Ninc - Non Interest Income (y_2), 10) RDF - Return on Deployed Funds (p_1). Since, equity is fixed input with no associated cost and return on non-interest income is unity, same is not reflected in the table

It can be seen from Table 3 that cost, revenue and profit efficiency of banks are in the range of (0.7284, 1), (0.8551, 1) and (0.3723, 1) respectively. As observed by Maudos and Pastor (2003), banks which are cost efficient are also profit efficient and there is a significant positive correlation coefficient between cost efficiency and profit efficiency of banks ($\rho = 0.732$). Out of 34 banks, five banks are cost efficient, nine banks are revenue efficient and ten banks are profit efficient. There are only five banks which are efficient under all the three models, namely cost, revenue and profit models. They are, State Bank of India, Karnataka Bank, ICICI Bank, IDBI Bank and IndusInd Bank. It can be observed that Axis Bank, HDFC Bank, ING Vysya Bank and State Bank of Travancore are profit and revenue efficient, but not cost efficient. On the other hand, UCO Bank is profit efficient, but not cost and revenue efficient. This clearly suggests that banks which are efficient under one model need not necessarily be efficient under the other models. Jayaraman and Srinivasan (2014) discussed in detail the effect of global financial crisis on the profit efficiency of banks.

Table 3: Average Efficiency Scores of Banks under DEA Models

Bank Name	Cost	Revenue	Profit
Allahabad Bank	0.7916	0.9135	0.5503
Andhra Bank	0.7867	0.8787	0.4627
Axis Bank	0.9575	1.0000	1.0000
Bank of Baroda	0.7367	0.8740	0.4325
Bank of India	0.7522	0.9739	0.8420
Bank of Maharashtra	0.7759	0.9220	0.5459
Canara Bank	0.8023	0.9222	0.6119
Central Bank of India	0.7284	0.9403	0.4507
Corporation Bank	0.8282	0.8800	0.5383
Dena Bank	0.7985	0.9077	0.5334
Federal Bank	0.8944	0.9387	0.8627
HDFC Bank	0.8991	1.0000	1.0000
ICICI Bank	1.0000	1.0000	1.0000
IDBI Bank	1.0000	1.0000	1.0000
Indian Bank	0.7793	0.8584	0.5386
Indian Overseas Bank	0.7736	0.9378	0.5918
IndusInd Bank	1.0000	1.0000	1.0000
ING Vysya Bank	0.9947	1.0000	1.0000
Jammu & Kashmir Bank	0.8766	0.8551	0.5765
Karnataka Bank	1.0000	1.0000	1.0000
Oriental Bank of Commerce	0.8263	0.8697	0.5321
Punjab and Sind Bank	0.8112	0.9442	0.7449
Punjab National Bank	0.7352	0.9295	0.6261
State Bank of Bikaner and Jaipur	0.8422	0.9889	0.9493
State Bank of Hyderabad	0.8493	0.9683	0.7919
State Bank of India	1.0000	1.0000	1.0000
State Bank of Mysore	0.8876	0.9872	0.9199
State Bank of Patiala	0.8531	0.9458	0.7732
State Bank of Travancore	0.8694	1.0000	1.0000
Syndicate Bank	0.7477	0.9764	0.8123
UCO Bank	0.7818	0.9982	1.0000
Union Bank of India	0.7866	0.9254	0.5961
United Bank of India	0.7781	0.8670	0.3723
Vijaya Bank	0.8253	0.8900	0.4617

In general, the efficiency score of the banks are not same under three different models. For example, Punjab and Sind Bank has higher efficiencies (0.9442, 0.7449) compared to Oriental Bank of Commerce (0.8697, 0.5321) under revenue and profit efficiency model, while under cost efficiency model, Punjab and Sind Bank's efficiency score (0.8112) is lower than that of Oriental Bank of Commerce (0.8263). Similarly, we observe that cost and profit efficiency scores of Canara Bank is higher compared to Central Bank of India, while the revenue efficiency score of Canara Bank is lower than that of Central Bank of India. Though, in general, banks included in this study are sound in terms of total assets, manpower, branch network etc., their performance under three different models shows that some of them are efficient and others are relatively less efficient. The efficiency of the banks depends on the optimal use of the select input and output variables. Banks with efficiency score 1 operate on the efficient frontier and use their input and output variables optimally, while the other banks which are relatively less efficient need to contract their inputs and expand the outputs to move towards the efficiency frontier. The performance of banks along with the optimal use of the select variables provides a basis for ranking of banks.

Table 4: Ranking Based on Average Efficiency Scores

Bank Name	Cost	Revenue	Profit
Allahabad Bank	18	17	15
Andhra Bank	19	21	21
Axis Bank	3	1	1
Bank of Baroda	28	22	24
Bank of India	26	6	5
Bank of Maharashtra	24	16	16
Canara Bank	16	15	11
Central Bank of India	30	10	23
Corporation Bank	12	20	18
Dena Bank	17	18	19
Federal Bank	5	11	4
HDFC Bank Ltd.	4	1	1
ICICI Bank	1	1	1
IDBI Bank Limited	1	1	1
Indian Bank	22	25	17
Indian Overseas Bank	25	12	13
IndusInd Bank	1	1	1
ING Vysya Bank	2	1	1
Jammu & Kashmir Bank	7	26	14
Karnataka Bank	1	1	1
Oriental Bank of Commerce	13	23	20
Punjab and Sind Bank	15	9	9
Punjab National Bank	29	13	10
State Bank of Bikaner and Jaipur	11	3	2
State Bank of Hyderabad	10	7	7
State Bank of India	1	1	1
State Bank of Mysore	6	4	3
State Bank of Patiala	9	8	8
State Bank of Travancore	8	1	1
Syndicate Bank	27	5	6
UCO Bank	21	2	1
Union Bank of India	20	14	12
United Bank of India	23	24	25
Vijaya Bank	14	19	22

From Table 4 it can be observed that ranking of banks based on three models exhibits a similarity in ranking. Kendall's coefficient of concordance (W = 0.514, Chi-

Square = 34.929) also confirms that there is an agreement in the ranking obtained from the three models. However, ranking of banks based on any one particular model would lead to incorrect ranking. The agreement between rankings suggests that a unified ranking of banks is meaningful.

Since each efficiency model and its viewpoints has some valuable advantage over other, ranking of banks by combining the efficiency scores from three models may be a reasonable way of ranking the banks. The Shannon's entropy discussed in the previous section provides a methodology to combine the efficiency scores as well as a reasonable way of ranking the banks.

In Shannon entropy method, first, the efficiency scores are normalized to obtain the discriminatory power of each model i.e. the degree of diversification. Using the degree of diversification, the degree of importance is calculated for each model and finally comprehensive efficiency index i.e. Shannon index for each bank is obtained a by multiplying the efficiency scores of various models with corresponding degree of importance. Table 5 presents the importance degree of various models:

Table 5: Entropy, Degree of Diversification and Importance

Models	Cost	Revenue	Profit
e_j	0.9985	0.9996	0.9875
d_j	0.0015	0.0004	0.0125
w_j	0.1027	0.0277	0.8696

As mentioned earlier, the degree of diversification indicates the discrimination power of a given DEA model. Larger value of d_j indicates the more discriminatory power of a DEA model. It can be observed from Table 5 that profit model has a larger value of discriminatory power (0.0125) when compared with other two models namely cost and revenue models. Lower value of discriminatory power (d_j) for revenue model indicates that the model has least / no discriminatory ability to differentiate the banks which is due to efficiency scores of banks being approximately equal under this model. The discriminatory power of each model determines the degree of importance or weights for each model (w_j) and it can be seen from Table 5 that profit model has higher degree of importance (0.8696) followed by cost and revenue models with degree of importance 0.1027 and 0.0277 respectively. The comprehensive Shannon index for each bank based on three models and their corresponding ranks based on the index is presented in Table 6.

It can be seen from Table 6 that the Shannon index of banks is in the range of (0.4277, 1). Out of the 34 banks, five banks index is 1 and seven banks index is above 0.9 but below 1. Further, Shannon ranking of 5 banks is similar to the profit model ranking and 4 banks ranking is similar to the cost model ranking. In general, ranking of banks using Shannon index depends on the performance of banks under profit and cost model.

Table 6: Shannon Index and Ranking

Bank Name	Shannon Index	Rank
Allahabad Bank	0.5851	20
Andhra Bank	0.5075	27
Axis Bank	0.9956	3
Bank of Baroda	0.4760	29
Bank of India	0.8364	10
Bank of Maharashtra	0.5799	21
Canara Bank	0.6400	16
Central Bank of India	0.4928	28
Corporation Bank	0.5775	22
Dena Bank	0.5710	25
Federal Bank	0.8681	9
HDFC Bank Ltd.	0.9896	4
ICICI Bank	1.0000	1
IDBI Bank Limited	1.0000	1
Indian Bank	0.5722	23
Indian Overseas Bank	0.6200	18
IndusInd Bank	1.0000	1
ING Vysya Bank	0.9995	2
Jammu & Kashmir Bank	0.6150	19
Karnataka Bank	1.0000	1
Oriental Bank of Commerce	0.5717	24
Punjab and Sind Bank	0.7572	14
Punjab National Bank	0.6457	15
State Bank of Bikaner and Jaipur	0.9394	7
State Bank of Hyderabad	0.8027	12
State Bank of India	1.0000	1
State Bank of Mysore	0.9184	8
State Bank of Patiala	0.7862	13
State Bank of Travancore	0.9866	5
Syndicate Bank	0.8102	11
UCO Bank	0.9775	6
Union Bank of India	0.6248	17
United Bank of India	0.4277	30
Vijaya Bank	0.5109	26

The banks which are operating on the efficient frontier are ranked as 1 under the Shannon method, which includes two public sector banks viz., State Bank of India and IDBI Bank, and three private sector banks viz., ICICI Bank, IndusInd Bank and Karnataka Bank. These banks operate on the efficient frontier and optimally use their inputs and outputs i.e. without any slack. The second group of banks which are very close to the efficiency frontier with Shannon index more than 0.98 and ranked between 2 and 5 are: Axis Bank, HDFC Bank, ING Vysya Bank and State Bank of Travancore. It can be seen from Table 3 & 4 that these banks are profit and revenue efficient but not cost efficient. These banks need to improve their deployed funds and optimally utilize their staff strength to become cost efficient. Banks which are close to profit and cost efficient frontiers are ranked better under Shannon index compared to those which are away from the efficient frontiers. Also, banks which are far away from the efficient frontier are ranked least under Shannon index. Banks which are away from the efficient frontiers need to contract the inputs and expand the outputs, to move close towards the efficient frontier. In general, banks which are closed to efficient frontier are ranked better compared to those which are away from the efficient frontier under Shannon index. Overall, the Shannon entropy method provides a comprehensive efficiency index for banks as well as a reasonable way of ranking these banks.

6. Summary and Conclusion

There are varieties of DEA models to measure the efficiency of DMUs and the efficiency scores of DMUs may vary from one model to other. Hence, selecting a best or suitable model to rank the banks is a main problem in applied DEA. The existing super-efficiency models, though helps to rank the DMUs, has certain drawbacks. Soleimani-damaneh and Zarepisheh (2009) proposed combining of efficiency scores of various DEA models using Shannon's entropy approach to provide a more balanced ranking of DMU.

The objective of this paper is to get a comprehensive efficiency index for the banks in India using DEA models (cost, revenue and profit DEA models) and Shannon entropy method. Out of 34 banks analyzed, five banks are cost efficient, nine banks are revenue efficient and ten banks are profit efficient. There are only five banks which are efficient under all the three models. It is observed that banks which are efficient under one model need not necessarily be efficient under the other models. In general, the efficiency scores of the banks are different under three different DEA models and any ranking based on a particular model, would lead to incorrect ranking of banks. Kendall's coefficient of concordance suggests that there is an agreement in the ranking of banks under three models. The agreement between rankings suggests that a unified ranking of banks is meaningful. Since each DEA model and its viewpoints have some valuable advantage over other, ranking of banks by combining the efficiency scores from three models may be a reasonable way of ranking the banks.

Using the Shannon entropy method, the efficiency scores of banks under cost, revenue and profit models are combined to obtain a comprehensive performance measure viz., the Shannon index for each bank. Results of degree of diversification and degree of importance associated with each model suggest that profit model has a larger value of discriminatory ability and weight compared to cost and revenue models. Banks which are close to profit and cost efficient frontiers are ranked better under Shannon index compared to those which are away from the efficient frontiers. In general, banks which are closed to efficient frontier are ranked better compared to those which are away from the efficient frontier under Shannon index. In conclusion, it may be pointed out that Shannon-DEA approach provides a comprehensive efficiency index for banks as well as a reasonable way of ranking the banks.

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