Global Journal of Enterprise Information System

DOI: 10.15595/gjeis/2014/v6i2/51848

Efficiency of IT Deployment of Public Sector Banks in India

Sanjay Dhingra*

University School of Management Studies, G. G. S. Indraprastha University, Delhi, India; sdhingra342003@yahoo.com

Abstract

This paper evaluates the efficiency of IT deployment of Public sector banks (PSBs) in India for the period 2003 to 2009 using a technique known as Data envelopment analysis (DEA). DEA technique is a non-parametric method used for evaluating the relative efficiency of similar units like banks. The input variables selected for DEA are computerization expenditure to operating expenditure, fully computerized branches to total branches, number of ATMs, PCs per employee, core banking branches to fully computerized branches, while the output variables chosen are business per employee, business per branch and operating profits per employee. The CCR model with output orientation and BCC model with output orientation have been applied separately on the same data to calculate the efficiency of each bank. Results indicate that average technical efficiency of IT deployment of PSBs has gradually improved during the study period. It has also been observed that banks have considerably improved their scale efficiency over the same period.

Keywords: Data Envelopment Analysis, Public Sector Banks, Technical Efficiency, Scale Efficiency

1. Introduction

In tune with global trends and practices, IT innovations in the last few years have changed the landscape of banks in India. Banks in India too started perceiving information technology as a crucial component to achieve strategic and operational goals. Today, information technology seems to be the prime mover of all banking transactions. Trends show that banks in India have been endeavoring to leverage technology to bring about improvements in; quality of customer services, scale and specialization in products, alternative sources of income particularly from fee-based services, geographical reach through communication networks and electronic delivery channels, risk management practices, housekeeping, internal control systems and regulatory compliance, cost efficiencies, and scale economies[1]. To achieve the improvement, banks have taken several technological initiatives such as telebanking, mobile banking, net banking, Automated Teller Machines (ATMs), credit cards, debit cards, smart cards, Customer Relationship Management (CRM) software, electronic payment systems, data warehousing and data mining solutions, which have totally transformed the banking industry. An indication of the extent of investment and percolation of IT in different categories of banks is evident from the data presented in Table 1.

It is clear from Table 1 that banks have invested heavily over the years in IT systems. Looking the dependence of banks on IT, there is no doubt that, IT over the years has become business driver rather than a business enabler.

Table 1. IT percolation in banks in India (as on March 2009)[6]

Parameter	Nationalized banks	State bank group	Old private sector banks	New private sector banks	Foreign banks
Banks	19	07	15	08	31
Branches	39,376	16,062	4,673	4,204	293
ATMs	15,938	11,339	2,674	12,646	1,054
ATMs per branch	0.40	0.71	0.57	3.0	3.6
Fully computerized branches (%)	92.9	100	-	100	100
IT expenditure (in `crores incurred between September 1999 and March 2009)	11,802	6,095	-	-	-

* *Author for correspondence*

IT is considered to be an important tool in improving the efficiency of banks, therefore this paper evaluates the efficiency of IT deployment of Public Sector Banks (PSBs) in India for the period 2003 to 2009. The period 2003 to 2009 is selected as most of computerization of the banks has happened in this period only. The public sector banks have been selected for the study due to the dominant position enjoyed by these banks and their contribution towards socio-economic development of the country. The efficiency of banks has been calculated using the CCR and BCC models of DEA technique.

2. Data Envelopment Analysis

Charnes et al.[2] first proposed DEA as an evaluation tool to measure and compare the DMU's productivity. After that this tool has been extensively used in banking and other areas to measure the DMU's relative productivity. Data Envelopment Analysis is an approach of comparing the efficiency of organizational units such as bank branches, schools, hospitals and other similar instances where there is a relatively homogenous set of units. The analysis will measure output(s) achieved from the input(s) provided and will compare the group of DMUs by their strength in turning input into output. At the end of analysis, the DEA will be able to say which units are (relatively) efficient and which are (relatively) inefficient.

It is a method for mathematically comparing different Decision-Making Units' (DMUs) productivity based on multiple inputs and outputs. The ratio of weighted inputs and outputs produces a single measure of productivity called relative efficiency. DMUs that have a ratio of 1 are referred to as efficient, given the required inputs and produced outputs. The units that have a ratio less then 1 are less-efficient relative to the more efficient unit(s). Because the weights for input and output variables of DMU are computed to maximize the ratio and are compared with similar ratios of best performing DMUs hence the measured productivity is referred as relative efficiency.

2.1 DEA Model Selection

One of the basic choices in selecting a DEA model is to decide, whether to use an input-orientation or an output-orientation. The difference is subtle but important and can typically be best understood by considering whether a DMU emphasize on reducing inputs while achieving the same level of output or emphasize on producing more output given the same level of input.

DEA offers three possible orientations in efficiency analysis[3]:

(a) Input-oriented models are models, where DMUs are deemed to produce a given amount of output with the smallest possible amount of input.

(b) Output-oriented models are models, where DMUs are deemed to produce the highest possible amount of output with the given amount of input.

(c) Base-oriented models are models, where DMUs are deemed to produce the optimal mix of input and output.

2.1.1 Return to Scale

Return to scale refers to increasing or decreasing efficiency based on size. For example, a manufacturer can achieve certain economies of scale by producing thousand integrated circuits at a time rather than one at a time. It might be only 100 times as hard as producing one at a time. This is an example of Increasing Returns to Scale (IRS).

On the other hand, the manufacturer might find it more than trillion times difficult to produce a trillion integrated circuits at a time because of storage problems and limitations on the worldwide silicon supply. This range of production illustrates Decreasing Returns to Scale (DRS). Combining the extreme two ranges would necessitate Variable Returns to Scale (VRS).

Constant Return to Scale (CRS) means that the producers are able to linearly scale the inputs and outputs without increasing or decreasing efficiency. This is a significant assumption. The assumption of CRS may be valid over limited ranges but its use must be justified. But, CRS efficiency scores will never be higher than that of VRS efficiency scores. In a CRS model, the input-oriented efficiency score is exactly equal to the inverse of the output-oriented efficiency score. This is not necessarily true for inefficient DMUs in the case of Variable Return to Scale (VRS) assumption. The CRS version is more restrictive than the VRS and yields usually a fewer number of efficient units and also lower efficient score among all DMUs. In DEA literature, the CRS model is typically referred to as the CCR model after the seminal publication, by Charnes et al.[2]

2.1.2 The CCR Model of DEA

DEA is a linear programming based technique for measuring relative performance of DMUs. CCR model, which was initially proposed by Charnes et al.[2], can be represented as a fractional linear programming problem:

$$E_o = \frac{u_1 y_{1o} + u_2 y_{2o} + \ldots\ldots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \ldots\ldots\ldots + v_m x_{mo}}$$

Subject to

$$\frac{u_1 y_{1j} + u_2 y_{2j} + \ldots\ldots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots\ldots\ldots + v_m x_{mj}} \leq 1 \quad (j = 1, \ldots, n)$$

$$v_1, v_2, \ldots\ldots, v_m \geq 0$$

$$u_1, u_2, \ldots\ldots, u_s \geq 0$$

where E_o = the efficiency of the o^{th} DMU,

y_{so} = s^{th} output of oth DMU,

u_s = weight of s^{th} output
x_{mo} = m^{th} input of the o^{th} DMU
v_m = weight of m^{th} input

Here the DMUj to be evaluated on any trial be designed as DMUo where o ranges over 1,2,…,n.

The constraints meant that the ratio of "virtual output" to "virtual input" should not exceed 1 for every DMU. The above fractional program can be replaced by the following linear program:

Maximize $E_o = u_1y_{1o} + v_2y_{2o} + \ldots + u_sy_{so}$
Subject to $v_1x_{1o} + v_2x_{2o} + \ldots + v_mx_{mo} = 1$
$u_1y_{1j} + u_2y_{2j} + \ldots\ldots + u_sy_{sj} \le v_1x_{1j} + v_2x_{2j} + \ldots + v_mx_{mj}$ (j = 1,….,n)
$v_1, v_2, \ldots v_m \ge 0$
$u_1, u_2, \ldots u_s \ge 0$

The DEA model is a fractional linear program but may be converted into linear form in a straight forward manner by normalizing either the numerator or the denominator of the fractional program objective function, so that the methods of linear programming can be applied. The weighted sum of the inputs is constrained to be unity in the linear program. As the objective function is the weighted sum of outputs that has to be maximized, this formulation is referred to as the output maximization DEA program.

In the model the weights are treated as unknown. They can be obtained by solving the fractional programming problem to obtain values for the input weights (v_i) (i=1,…,m) and the output weights (u_r)(r=1,….,s). The value obtained of these weights will maximize the efficiency of the o^{th} target unit.

2.1.3 The BCC Model of DEA

Banker et al.[4] published the BCC model whose production possibility set PB is defined by:

$P_B = \{(x, y) \mid x \ge X\lambda, y \le Y\lambda, e\lambda=1, \lambda \ge 0\}$

where, $X = (x_j) \in R^{m*n}$ and $Y = (y_j) \in R^{s*n}$ are a given data set, $\lambda \in R_n$ and e is a row vector with all elements equal to 1. The BCC model differs from the CCR model only in the adjunction of the condition $e\lambda = \sum_{j=1}^{n} \lambda_j = 1$. Together with the condition $\lambda_j \ge 0$, for all j, this imposes a convexity condition on allowable ways in which the n DMUs may be combined.

The output-oriented BCC model can be written as

Max. η_B
Subject to $X\lambda \le x_o$
$\eta_B y_o - Y\lambda \le 0$
$e\lambda = 1$
$\lambda \ge 0$

This is the envelopment form of the output-oriented BCC model.

3. Research Methodology

In order to find the efficiency of IT deployment, the required data for the study period on input variables i.e. computerization expenditure to operating expenditure, fully computerized branches to total branches, number of ATMs, PCs per employee, core banking branches to fully computerized branches and output variables i.e. business per employee, business per branch and operating profits per employee required for applying DEA technique has been compiled from secondary sources such as RBI trend and progress reports from 2003 to 2009 and Prowess database, a corporate database developed by Center for Monitoring of Indian Economy (CMIE). The Punjab and Sind Bank has been excluded from the study on account of very low investment in information technology. Expenditure made by the bank on computerization between September 1999 and March 2009 is just `69 crores, which is the minimum expenditure incurred by any of the public sector bank. IDBI has been excluded because it became public sector bank in the year 2004-05 and hence its data was not comparable with other public sector banks. Production approach is being used for choosing the input and output variables. The production approach considers the efficiency, with which inputs (physical variables such as manpower, ATMs, IT expenditure etc) are converted into outputs. DEA-Solver software has been used to solve linear programming model.

In the application of DEA, inadequacy of data or sample size may impair results. The DEA is said to be computationally more convenient when the number of DMUs are larger than the total number of inputs and outputs by at least three times[5]. In the present study, 26 PSBs have been selected which are more than three times that of number of inputs and outputs. The data for the period 2003 to 2009 is being considered for the study, as this was the transformation phase for the public sector banks in terms of IT deployment. Most of the computerization like full computerization of branches, core banking, and ATMs deployment has happened during this period only. On each year of data, CCR output-oriented model (output maximization) and BCC output-oriented model (output maximization) have been applied. Efficiency scores between 0 and 1 have been obtained for every bank, for the each year. The average efficiency of all the banks for each year has been computed.

4. Results

The technical efficiency, management efficiency and scale efficiency obtained by applying CCR model and BCC model of DEA technique are summarized in Table 2, Table 3 and Table 4 respectively.

Table 2. DEA efficiency score of banks with CCR output orientation model

DMU	Eff03	Eff04	Eff05	Eff06	Eff07	Eff08	Eff09
Allahabad Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Andhra Bank	0.55	0.56	0.63	0.57	0.75	0.81	0.71
Bank of Baroda	1.00	1.00	0.82	1.00	1.00	1.00	1.00
Bank of India	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bank of Maharashtra	0.73	0.93	1.00	0.54	0.58	0.68	0.75
Canara Bank	0.77	0.89	1.00	1.00	1.00	1.00	1.00
Central Bank of India	0.89	1.00	1.00	0.80	0.81	0.71	1.00
Corporation Bank	0.46	0.46	0.71	0.73	0.85	1.00	1.00
Dena Bank	0.54	0.56	0.52	0.83	1.00	1.00	0.85
Indian Bank	0.56	0.60	0.56	0.61	0.80	0.82	0.82
Indian Overseas Bank	0.92	1.00	1.00	1.00	1.00	1.00	1.00
Oriental Bank of Commerce	1.00	1.00	1.00	1.00	1.00	1.00	1.00
State Bank of India	1.00	0.99	1.00	0.78	0.79	0.84	0.92
State Bank of Bikaner & Jaipur	0.60	0.50	0.50	0.55	0.72	0.66	0.68
State Bank of Hyderabad	0.80	0.85	0.75	0.79	1.00	0.87	0.93
State Bank of Indore	1.00	1.00	0.83	0.82	1.00	1.00	1.00
State Bank of Mysore	1.00	0.62	0.63	0.70	0.83	0.91	0.88
State Bank of Patiala	0.69	0.77	0.74	0.92	1.00	1.00	1.00
State Bank of Saurashtra	1.00	0.84	0.89	0.75	0.89	0.97	*
State Bank of Travancore	0.85	0.75	0.94	0.95	1.00	1.00	1.00
Punjab National Bank	1.00	0.99	1.00	0.74	0.90	0.78	0.79
Syndicate Bank	1.00	1.00	1.00	1.00	0.59	0.78	0.71
UCO Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Union Bank of India	1.00	1.00	1.00	1.00	1.00	0.97	0.83
United Bank of India	1.00	0.99	1.00	1.00	1.00	1.00	0.91
Vijaya Bank	0.74	1.00	1.00	1.00	1.00	0.91	0.88
Average	0.85	0.86	0.87	0.85	0.90	0.91	0.91

Notes: * State Bank of Saurashtra was merged with State Bank of India in year 2008-09
1. Eff03 to Eff09 represents the technical efficiency for each year for the period 2003 to 2009.

4.1 Outcome of CCR Output Orientation Model

CCR model works on CRS assumption. It assumes that all the DMUs are operating at optimal scale. CCR model output results in measure of efficiency, called Technical Efficiency (TE), which is affected by Scale Efficiencies (SE). Therefore results of CCR model reflect the overall efficiency of banks. The BCC model assumes VRS specification, permits the calculation of TE, without the SE effects. TE obtained from BCC model, without the SE effect is known as pure technical efficiency.

CCR output oriented model is applied on each year of data for the period between 2003 and 2009 using the selected input and output variables. The results of the model are presented in the Table 2.

From the Table 2, which represents output of CCR model with output orientation, it is clear that average IT efficiency of the banks has improved from 0.85 in year 2003 to 0.91 in the year 2009. This means, that average inefficiency of the public sector banks have decreased from 15 percent to 9 percent during the period. Also lowest relative efficiency score of 0.46, which has been achieved by a bank in year 2003 improved to 0.68 in the year 2009. This shows that technical efficiency of PSBs has improved with the deployment of IT over a period of time. This also suggests that, by adopting best practices, PSBs can, on an average further increase their output of business per employee,

Table 3. DEA efficiency score of banks with BCC output orientation model

DMU	Eff03	Eff04	Eff05	Eff06	Eff07	Eff08	Eff09
Allahabad Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Andhra Bank	0.67	0.75	1.00	0.83	0.92	0.83	0.72
Bank of Baroda	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bank of India	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Bank of Maharashtra	0.74	0.94	1.00	0.79	0.81	0.79	0.80
Canara Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Central Bank of India	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Corporation Bank	1.00	0.96	1.00	1.00	1.00	1.00	1.00
Dena Bank	0.71	0.72	0.97	1.00	1.00	1.00	0.96
Indian Bank	0.63	0.73	0.84	0.74	0.90	0.85	0.82
Indian Overseas Bank	0.92	1.00	1.00	1.00	1.00	1.00	1.00
Oriental Bank of Commerce	1.00	1.00	1.00	1.00	1.00	1.00	1.00
State Bank of India	1.00	1.00	1.00	0.90	0.83	0.85	0.96
State Bank of Bikaner & Jaipur	0.69	0.50	0.84	0.59	0.82	0.68	0.69
State Bank of Hyderabad	0.81	0.85	0.96	0.84	1.00	0.87	0.93
State Bank of Indore	1.00	1.00	0.92	0.98	1.00	1.00	1.00
State Bank of Mysore	1.00	0.62	0.79	0.80	0.85	0.91	0.88
State Bank of Patiala	0.83	0.85	1.00	1.00	1.00	1.00	1.00
State Bank of Saurashtra	1.00	0.84	0.93	0.84	0.89	0.98	*
State Bank of Travancore	0.91	0.94	1.00	0.99	1.00	1.00	1.00
Punjab National Bank	1.00	1.00	1.00	0.74	0.90	0.78	0.79
Syndicate Bank	1.00	1.00	1.00	1.00	0.76	0.78	0.74
UCO Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Union Bank of India	1.00	1.00	1.00	1.00	1.00	1.00	0.83
United Bank of India	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vijaya Bank	0.99	1.00	1.00	1.00	1.00	0.96	0.93
Average	0.92	0.91	0.97	0.92	0.95	0.93	0.92

Notes: * State Bank of Saurashtra was merged with State Bank of India in year 2008-09
1. Eff03 to Eff09 represents the pure technical efficiency for each year for the period 2003 to 2009.

business per branch and operating profits per employee by at least 9 percent keeping the same level of inputs.

4.2 Outcome of BCC Output Orientation Model

In order to find scale inefficiency, management inefficiency or pure technical inefficiency the BCC model has been applied. Pure technical inefficiency (obtained from BCC model) i.e. technical inefficiency devoid of scale effects, is totally under the control of management and results directly due to management errors. Thus it is also called management inefficiency. It occurs when more of each input is used, than is required to produce a given level of output. BCC output oriented model is applied on each year of data for the period between 2003 and 2009 using the selected input and output variables. The performance of DMUs is summarized in Table 3.

From the Table 3, which represents output of BCC model with output orientation, it is clear that average IT efficiency of the banks remained more or less same during the period 2003 to 2009 i.e. 0.92. This implies an inefficiency of 8 percent in handing the IT inputs. Allahabad Bank, Bank of Baroda, Bank of India, Canara Bank, Indian Overseas Bank, Oriental Bank of Commerce, UCO Bank and United Bank of India are found to be efficient through out the study period. This indicates that these banks have used their IT resources optimally through out

Table 4. Scale inefficiency in percentage

DMU	Ineff03	Ineff04	Ineff05	Ineff06	Ineff07	Ineff08	Ineff09
Allahabad Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Bank	18.45	25.63	37.13	30.51	18.54	2.50	0.97
Bank of Baroda	0.00	0.00	18.19	0.00	0.00	0.00	0.00
Bank of India	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bank of Maharashtra	0.49	0.89	0.00	31.45	27.79	14.32	5.85
Canara Bank	23.15	11.00	0.50	0.00	0.00	0.00	0.00
Central Bank of India	8.40	0.00	0.00	20.10	19.00	28.99	0.00
Corporation Bank	54.03	51.96	29.34	27.27	14.73	0.00	0.00
Dena Bank	23.44	21.87	47.12	17.04	0.00	0.00	11.14
Indian Bank	11.37	17.95	32.90	18.13	10.62	3.47	0.00
Indian Overseas Bank	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Oriental Bank of Commerce	0.00	0.00	0.00	0.00	0.00	0.00	0.00
State Bank of India	0.00	1.12	0.00	13.51	5.18	0.26	4.22
State Bank of Bikaner & Jaipur	13.60	0.66	39.73	7.69	12.34	2.38	0.86
State Bank of Hyderabad	1.20	0.31	22.26	6.51	0.00	0.12	0.70
State Bank of Indore	0.00	0.00	9.33	16.02	0.00	0.00	0.00
State Bank of Mysore	0.00	0.67	20.75	12.79	2.32	0.37	0.17
State Bank of Patiala	16.71	9.48	26.49	8.49	0.00	0.00	0.00
State Bank of Saurashtra	0.00	0.25	4.54	10.01	0.17	0.64	*
State Bank of Travancore	6.81	20.42	5.88	3.86	0.00	0.00	0.00
Punjab National Bank	0.00	1.20	0.00	1.04	0.02	0.31	0.08
Syndicate Bank	0.00	0.00	0.00	0.00	22.44	0.01	4.43
UCO Bank	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Union Bank of India	0.00	0.00	0.00	0.00	0.00	2.75	0.00
United Bank of India	0.00	1.08	0.00	0.00	0.00	0.00	8.53
Vijaya Bank	24.43	0.00	0.00	0.00	0.00	4.96	5.64
Average	7.77	6.33	11.31	8.63	5.12	2.35	1.70

Notes: * State Bank of Saurashtra was merged with State Bank of India in year 2008-09
1. Ineff03 to Ineff09 represents the scale inefficiency for each year for the period 2003 to 2009.

the study period. The results of CCR model reported above, shows an improvement in average IT efficiency (technical efficiency) from 0.85 to 0.91 during the study period, while BCC model results reported that average IT efficiency (management efficiency) of the banks remained more or less same during the study period i.e. 0.92. This implies that an improvement in technical efficiency has been due to improvement in scale efficiency rather than due to management efficiency or pure technical efficiency.

4.3 Scale Inefficiencies

Scale efficiency is obtained by dividing the efficiency score obtained from CCR model with the efficiency score of BCC model. The percentage inefficiency is obtained by subtracting the score of scale efficiency from unity and multiplying the result with 100. The scale inefficiency calculated for the period 2003 to 2009 is shown in Table 4.

Results show that overall average scale inefficiency of PSBs has reduced from 7.77 percent in the year 2003 to 1.7 percent in the year 2009. This shows that scale inefficiency of PSBs has decreased with the deployment of IT over a period of time. The exceptionally high inefficiency of 11.31 percent, obtained in the year 2005, may be due to heavy investment in core banking by banks. Results clearly show that banks have used the IT successfully to reduce the scale inefficiency by properly deploying ATMs and bringing the branches under core banking.

5. Conclusion

Results of the study show that the average efficiency (technical efficiency obtained by applying CCR model) of the banks' with respect to IT has improved gradually from 0.85 in year 2003 to 0.91 in the year 2009 (Table 2). From the result of BCC model with output orientation, it is clear that average IT efficiency(management efficiency) of the banks remained more or less same during the period 2003 to 2009 i.e. 0.92 (Table 3). This suggests that improvement in average efficiency (technical) for the period 2003 to 2009 is due to improvement in scale efficiency rather than of management efficiency. This calls for proper utilization of IT resources such as finding proper locations of ATMs where they can be maximally utilized and ensuring the minimum downtime of the IT systems. It is also observed that overall average scale inefficiency of PSBs has been reduced from 7.77 percent in the year 2003 to 1.7 percent in the year 2009 (Table 4). This suggests that computerization particularly deployment of ATMs and core banking solution has helped the banks to become scale efficient. Overall it can be concluded that banks have used the IT successfully to reduce the scale inefficiency by properly deploying ATMs and bringing the branches under core banking. However the almost stagnancy of pure technical efficiency or management efficiency observed in banks is still an area of concern to the bankers.

6. Acknowledgement

This work has been carried out as part of my Ph.D. work.

7. References

1. Dhingra S. Measuring IT effectiveness in banks of India for sustainable development.
2. BVICAM's International Journal of Information Technology.2011; 3(2):19–22.
3. Charnes A, Cooper W, Rhodes E. Measuring the efficiency of decision making units. Eur J Oper Res. 1978; 3:429–44.
4. Charnes A, Cooper W, Lewin, YA, Seiford M L. Data envelopment analysis: Theory, methodology and application. Boston: Kluwer Academic Publishers; 1994.
5. Banker RD, Charnes A, Cooper W. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manag Sci.1984; 30:1078–92
6. Dyson RG, Allen R, Camanho AS, Podinosky VV, Sarrico CS, Shale EA. Pitfalls and protocols in data envelopment analysis. Eur J Oper Res.2001; 132(2): 245–59.
7. India. Report on trend and progress of banking in India. Mumbai: Reserve Bank of India; 2009.