ORIGINAL RESEARCH PAPER

Commerce

KEY WORDS: AGVB, DEA, Efficiency, Branches, Tobit

A STUDY ON EFFICIENCY ON ASSAM GRAMIN VIKASH BANK BRANCHES

Dr. Ayekpam Ibemcha Chanu Assistant Professor (Sr.), Department of Commerce, Assam University Diphu Campus

Shibu Das* Research Scholar Department of Commerce, Assam University, Diphu Campus*Corresponding Author

ABSTRACT

This paper is an effort to measure the efficiency of nineteen AGVB branches by using Data Envelopment Analysis. It also examines the impact of external and branch specific factors on branch's efficiency during the financial year 2016-2017. The results indicate that level of efficiency of the various branches varies and that there is room for improvement. The findings reveal that there is variance in the efficiency score among the select branches in AGVB and out of different variables, off balance sheet activities and location have significant bearing on level of efficiency of the branches. It is revealed that inefficient branches require modification of their financial policies, number of employees and managerial policies to increase level of efficiency.

Introduction:

The efficiency of a bank can be explained from the perspective of banks level of output from given quantities of input. Hence, efficiency of bank branch refers to the ability of the branch's production to produce the maximum possible output from given quantities of inputs (Al-Tamimi, et al. 2007, P. 334). Productivity and efficiency analyses in the branch level of bank are now considered as a part of bank's management practices. Such analyses can help bank management to identify and eliminate the underlying causes of inefficiency, thus providing the branches competitive advantage, to meet the challenges from others. In the present paper, an analysis is done on the branches of Assam Gramin Vikash Bank (AGVB), the largest regional rural bank in terms of its geographical operation in the North Eastern region of the country.

The AGVB operates a large number regional branch networks in Assam, ranging from rural to urban areas. It is an important player of the regional financial system. The efficiency analysis in the branch level of AGVB is required not only to identify the efficient/ inefficient branches but also to examine the area of opportunities available to the bank branches to improve their productivity and efficiency.

Significance of the study:

Branch level of efficiency studies provide information as well as throw a light on the proper utilization of inputs of the organization. Such studies help the organization to formulate policies to improve their level of outputs. The present study is an attempt to study the technical efficiency of the select AGVB branches. This type of study is important to AGVB to formulate the policies and programmes to improve their level of efficiency.

Review of literature:

This section provides an overview of literature on branch level of efficiency studies published during the period from 1985 to 2017. There are a number of studies conducted to measure efficiency of banks and branches by using Data Envelopment Analysis (DEA) technique to find out level of efficiency of branches; some of them are Sherman et al. (1985), Oral et al. (1990), Giokas (1991), Sherman et al. (1995), Schaffnit et al. (1997), Soteriou et al. (1999), Camanho et al. (1999), Athanassopoulos (2000), Cook et al. (2001), Hartman et al. (2001), Manandhar et al. (2002), Stanton (2002), Paradi et al. (2004), Camanho et al. (2005), Camanho et al. (2006), Valami (2009), Wu et al. (2006), Yang et al. (2006), Howland et al. (2006), Pastor et al. (2006), McEachern et al. (2007), Al-Tamimi et al. (2007), Portela et al. (2007), Camanho et al. (2008), Noulas et al. (2008), Lotfi et al. (2010), Paradi et al. (2010), Tsolas (2010), Deb, J. (2011), Minh, et al. (2012), Singh, H. (2013), Zarinkamar et al. (2014), Azarbad et al. (2015), Chanu & Shibu (2016), Shibu & Chanu (2017) and Chanu & Shibu (2018).

Research Gap:

Though there are a good number of studies on efficiency of Bank branches, there is no study on operating efficiency of AGVB branches in general and Guwahati regional office in particular in the existing literature. So, the present study is an attempt to fill the existing research gap.

Objectives:

1. To measure the level of efficiency of AGVB branches;
2. To examine the factors responsible for the level of efficiency or inefficiency of AGVB branches.

Hypothesis:

1. H_{01}=There is same level of efficiency of AGVB branches of the study area.

Methodology:

Type of study : Empirical in nature.

Type of data :The present study is based on both primary and secondary data.

Study Area : Guwahati regional office

Population Size : Nineteen (total number of AGVB branches under Guwahati regional office which started CBS system during 2010-2011). Out of seven regional offices, Guwahati regional office is having highest number of bank branches and all the bank branches have been considered for the study; hence census method is applied.

Period of Study : The present study covers one financial year (2016 to 2017).

Software Used :Data is analyzed by using the DEA Excel Solver and STATA.

Data Envelopment Analysis (DEA) technique to measure efficiency: The DEA was developed by Charnes, A., Cooper, W. and Rhoades, E. in the year 1978 in their seminal work published in the European Journal of Operation Research and it is based on linear programming. It is applied to several studies that measure the operating efficiency of bank branches (Al-Tamimi, et al. 2007, P. 335). Efficiencies estimated by DEA are relative, that is, relative to the best performing bank branch. The best-performing bank branch is assigned an efficiency score of unit one and the performance of other bank branches vary, between zero and one relative to this best performance (Ramanathan, R., 2003, P 26). Under this model, all deviations from the estimated frontier represent inefficiency. In the present study, Technical efficiency constant return to scale and pure technical efficiency variable return to scale are used to measure the level of efficiency of branches.

The concept of Input Oriented Approach and Output Oriented Approach: Based on the study of Roy (2004, P. 28), the input-oriented approach of AGVB branch is examined to what extent it is

possible to reduce its input(s) without reducing the output(s) and the output-oriented approach of AGVB branch is examined to what extent it is possible to increase its output(s) without increasing the inputs(s).

Table 1: Details of input & output Variables

Inputs	Interest Expended	Interest on deposits
	Operating Expenditure	Payments to employees, printing and stationary, Advertisement and publicity, Law charges etc.
Outputs	Loans and Advances	Bills purchased and discounted, Cash credits, Overdrafts and loans repayable on demand, Term loans, Secured by tangible assets, Unsecured.
	Interest Earned	Interest on Advance, interest on loan.
	Other Income	Commission, exchange, brokerage etc.
	Deposits	Current Account, Saving Bank Deposits, Term Deposits

Source: Researchers' compilations

Limitation of the study:
The study is limited to only one regional office of AGVB. The study period is limited to a single year due the availability of the data.
Analysis and Interpretation of the Results:

Table 2: Statistical Summary of input and output oriented approaches

Particulars	Input Oriented		
	TECRS	PTEVRS	SE
Total Number of DMUs	19	19	19
Number of fully efficient DMUs	6	8	6
Number of inefficient DMUs	13	11	13
Maximum efficiency score	1	1	1
Minimum efficiency score	0.5658	0.5689	0.8127
Std. dev of efficiency	0.1107	0.1109	0.0638
Average of efficiency M	0.8735	0.9161	0.9555
Average of inefficiency	0.1265	0.0839	0.0445
Percentage of the DMU in 1	31%	42%	31%

Source: Researchers' Calculations

Table 3 Statistical Summary on Return to Scale

Return To Scale (RTS)	Numbers	Percentage
Increasing Return To Scale (IRS)	7	37%
Decreasing Return To Scale (DRS)	1	5%
Constant Return To Scale (CRS)	11	58%

Source: Researchers' Calculations

Table 2 presents statistical summary of efficiency score of nineteen AGVB branches under TECRS, PTEVRS and SE models under input oriented approach for the financial year 2016-2017.

Efficiency Results under Input Oriented Approach:
Table 2 indicates that out of nineteen branches, the number of fully efficient branches are 6, 8 and 6 respectively and the number of inefficient branches are 13, 11 and 13 respectively under TECRS, PTEVRS and SE models respectively. The table also shows that the lowest score stands at 0.5658, 0.5689 and 0.8127 under TECRS, PTEVRS and SE models respectively. Average efficiency score of all the branches is 0.8735, 0.9161 and 0.9555 under TECRS, PTEVRS and SE models respectively; and their average inefficiency score is 0.1265, 0.0839 and 0.0445 under the same models respectively. The result implies that inputs could be decreased proportionately without decreasing the level of outputs. All the selected branches in average are not fully efficient under any model. Standard deviation stands at 0.1107, 0.1109 and 0.0638 under TECRS, PTEVRS and SE models respectively. Large dispersion is noticed under TECRS and PTEVRS models.

It is evident from the table 3 that the average scale efficiency of all the AGVB branches for the year 2016-2017 is 95.55%. That means the selected branch units can maximize their scale efficiency by 4.45% after decreasing the inputs.

The returns to scale (RTS) results which are presented in Table 3 also reveals that seven number of bank branches are considered to operate under increasing return to scale (IRS), therefore, the result of the analysis indicates that about thirty seven percent of the branches are operating below their optimal scale. There is one branch classified as decreasing return to scale (DRS), it means five percent of the branches are above their optimal scale and hence could increase their technical efficiency by decreasing their size. Lastly, there are eleven branches working on constant return to scale (CRS); therefore, fifty eight percent are operating at their optimal scale.

Table 3: Ranking of AGVB branches based on TECRS and PTEVRS

Sl. No.	DMUs	Input Oriented	
		TECRS	PTEVRS
1	Jharobari	13	9
2	Bamundi	1	1
3	Muktapur	9	1
4	Kamalpur	7	10
5	Kukurmara	16	11
6	Sonapur	1	1
7	Beltola	1	1
8	Kulhati Chessamukh	10	13
9	Changsari	18	17
10	Sualkuchi	14	15
11	Rangia	11	14
12	Dharapur	17	18
13	Morigaon	1	1
14	Chandmari	8	12
15	Lalganesh	19	19
16	Fancybazar	1	1
17	Panjabari	12	16
18	Guwahati	15	1
19	Ganeshguri	1	1

Source: Researchers' Calculations

Table 3 provides ranking of AGVB branches of the study area by assuming input oriented approach and output oriented approach. Bamundi, Sonapur, Beltola, Morigaon, Fancybazar and Ganeshguri are the best AGVB branches under this model.

Factors responsible for efficient scores and inefficient scores:
Tobit Regression analysis is carried out to test hypotheses concerning the relationship between level of efficiency and other indicators related to branches staff productivity, size(total assets), size* (total number of employees), exposures to off balance, staff productivity, loan quality, non-interest expenses and location dummy variables. in the tobit regression model, the efficiency scores from the first stage are (as dependent variable) regressed upon nineteen AGVB branches specific and environmental variables to determine what causes differences in efficiency levels across the DMUs under a given study period. Tobit model used in this study may be specified as:

$$Yi^{*}=\boldsymbol{\alpha} + \boldsymbol{\beta}1(\text{Size}) + \beta 2(\text{Size}^{*}) + \beta 3(\text{OFF\_BALANCE}) + \beta 4(\text{SP}) + \beta 5(\text{LQ}) + \beta 6(\text{Dummy}) + \varepsilon$$

Table 4: Description of the Independent Variables and expected signs of the predictors included in the regression analysis

Predictor	Symbol	Descriptions	Expected Sign	Hypotheses
Size	SIZE	Log(Total Assets)	+	A branch bank size is not expected to have any ascertained relationship with efficiency measure
Size*	SIZE*	(total number of employees)	+	A branch bank size is not expected to have any ascertained relationship with efficiency measure
Exposures to off-balance sheet activities	OFF_BALANCE	X100	+	More the exposure of bank branches in non traditional activities, higher will be the bank branches' efficiency
Staff Productivity	SP	)	+	A positive relationship with efficiency is expected
Loan Quality	LQ		-	Higher levels of NPAs will indicate in lower efficiency levels
Location	Dummy	Dummy variable taking value 1 for urban and 0 for semi-Urban	+	No?? a priori relationship is expected between location and efficiency.

Source: Researchers' compilations

In the second stage analysis, the DEA efficiency scores are regressed on branch specific characteristics of AGVB in order to identify sources of efficiency inefficiency. Since level of efficiency scores range between 0 and 1, Tobit model is employed. Positive co-efficients show a rise in efficiency, whereas negative co-efficient show fall in efficiency.

Table 5a: Determinants of Efficiency of AGVB Branches

Independent Variables	Dependent Variables: TECRS			
	Coefficient	Std. Error	z	p-value
Constant	1.54983	1.41308	1.0968	0.2727
Size	–8.77378	6.82208	–1.2861	0.1984
SIZE*	1.09003	0.808914	1.3475	0.1778
OFF_BALANCE	99.1172	52.8756	1.8745	0.0609*
Staff Productivity	8.74896	6.73105	1.2998	0.1937
Loan Quality	–0.06372	0.279922	–0.2277	0.8199
Location	0.0641401	0.101353	0.6328	0.5268
Chi-square = 2.13799		Log-likelihood = 1.929887		

Source: Researchers' Compilations

From table 5a, the observations made in TECRS are: the co-efficients of explanatory variables Size (total assets), size* (total number of employees), Staff productivity, loan quality and location_urban branch are found to be statistically insignificant that is, it rejects the null hypotheses; however, the Branch Exposure off Balance-sheet are observed as statistically significant that is, it accepts null hypothesis at 10% level of efficiency. The positive coefficient means increase off_balance sheet activities and increasing the level of efficiency of branches.

Table 5b Determinants of Efficiency of AGVB Branches

Independent Variables	Dependent Variables: PTEVRS_IOM			
	Coefficient	Std. Error	z	p-value
Constant	5.03607	389.144	0.0129	0.9897
Size	–33.5029	3803.75	–0.0088	0.9930
SIZE*	4.16287	475.236	0.0088	0.9930
OFF_BALANCE	134.426	50.6528	2.6539	0.0080***
Staff Productivity	33.133	3803.75	0.0087	0.9931
Loan Quality	0.1187	0.239973	0.4946	0.6209
Location	0.175471	0.120318	1.4584	0.1447
Chi-square = 17.81555		Log-likelihood = 6.039765		

Source: Researchers' Calculations

From table 5b, the observations made in TECRS are: the coefficients of explanatory variables Size (total assets), size* (total number of employees), Staff productivity, loan quality and location_urban branch are found to be statistically insignificant that is, it rejects the null hypotheses; however, the Branch Exposure off Balance-sheet are observed as statistically significant that is, it accepts null hypothesis at 1% level of efficiency. The positive coefficient means increase off balance sheet activities increasing the level of efficiency of branches.

Conclusion:

The present study indicates that the level of efficiency is not same among the branches of AGVB Guwahati regional office during 2016-2017. Though there are good number of efficient AGVB branches, the number of inefficient AGVB branches is higher than the efficient ones. Further, the tobit regression results reveal that off-balance sheet activities and region have been identified as the most influential determinants of operating efficiency. Hence, there is an urgent need to check the issues immediately in order to make further reforms in other AGVB branches.

Future scope for the study:

The future research may extend our work in several ways. While using data over a longer period, one may use the DEA super efficiency, slack efficiency input and output oriented approach to measure efficiency of AGVB branches and one can measure the total factor productivity change in their branches. There is further scope to study cost efficiency, economic efficiency and market service efficiency.

References:

1. Al-Tamimi, H. A. H., & Lootah, A. M. (2007). Evaluating the operational and profitability efficiency of a UAE-based commercial bank. Journal of Financial Services Marketing, 11(4), 333–348. Doi: 10.1057/palgrave.fsm.4760043.
2. Annual Report, (2012). Assam Gramin Vikash Bank, financial year 2010-2011. Guwahati.
3. Annual Report, (2017). Assam Gramin Vikash Bank, financial year 2016-2017. Guwahati
4. Athanassopoulos, A. D., & Giokas, D. (2000). The Use of Data Envelopment Analysis in Banking Institutions: Evidence from the Commercial Bank of Greece. Interfaces, 30(2), 81-95. Retrieved from http://www.jstor.org/stable/250 62582 on 02-06-2017.
5. Avkiran, N.K. (2006). Productivity analysis in the services sector with data envelopment analysis. (3rd ed.), University of Queensland Business School, The University of Queensland, Brisbane. Retrieved from http://www.users.on.net/~necmi/financesite/DEA%20Book%203rd%20Edition%202006_AVKIRAN.pdf on 29-5-2015.
6. Azarbad, M., Soltani, A & Shojaie, A. (2015). An empirical DEA investigation for development of new bank's branches. Management Science Letters, 5(4), 331-336. Retrieved from http://www.growingscience.com/msl/Vol5/msl_2015_28.pdf on 29-08-2017.
7. Benston, G. J. (1965). Branch Banking and Economies of Scale. The Journal of Finance, 315-331.
8. Berger, A.N., & Humphrey, D. B. (1997). Efficiency of Financial Institutions: International Survey and Directions for Future Research. European Journal of Operational Research, 98, 175-212 Retrieved from http://d1c25a6gwz7q5e.cloudfront.net/papers/67.pdf on 29-5-2015.
9. Berger, A.N., & Mester, L. (1997). Inside the black box: what explains differences in the efficiency of financial institutions? Journal of Banking and Finance, 21(7), 895-947Retrieved from http://www.federalreserve.gov/pubs/feds/1997/199710/199710pap.pdf on 29-5-

2015
10. Camanho, A. S., & Dyson, R. G. (2005). Cost Efficiency, Production and Value-Added Models in the Analysis of Bank. The Journal of the Operational Research Society, 56(5), 483-494. Retrieved from http://www.jstor.org/stable/4102102 on 07/12/2012.
11. Camanho A. S., & Dyson R. G. (2006). Data envelopment analysis and Malmquist indices for measuring group performance. Journal of Productivity Analysis, 26, 35–49. DOI 10.1007/s11123-006-0004-8.
12. Camanho, A. S., & Dyson, R. G. (2008). A generalization of the Farrell cost efficiency measure applicable to non-fully competitive settings. Omega, 36, 147–62. doi:10.1016/j.omega.2005.12.004.
13. Camanho, A. S., & Dyson, R. G. (1999). Efficiency, size, benchmarks and targets for bank branches: an application of data envelopment analysis. Journal of the Operational Research Society, 50, 903-915. Retrieved from http://www.stockton-press.co.uk/jor on 21-6-2017.
14. Chanu, A. Ibemcha., & Das. Shibu. (2016). A Study on Efficiency of Select Regional Rural Banks in India. The Indian Journal of Commerce, 69(4), 48-59.
15. Cook, W. D. & Hababou, M. (2001). Sales performance measurement in bank branches. Omega, 29, 299–307. Retrieved from www.elsevier.com/locate/dsw on 15-10-2017.
16. Charnes, A, Cooper, W.W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. European Journal of Operational Research, 2(6), 429-444. Retrieved from http://www.utdallas.edu/~ryoung/phdseminar/CCR1978.pdf on 1-6-2015
17. Das, Shibu., & Chanu, A. Ibemcha. (2017). Measuring the Efficiency of Regional Rural Banks in India. International Journal of Business and Administration Research Review, 3(18), 57-66.
18. Deb, J. (2011.). Post-Reform bank efficiency in North-East India: a branch level analysis. (Ph.D Thesis, North-Eastern Hill University, India). Retrieved from http://shodhganga.inflibnet.ac.in/handle/10603/5308 on 20-3-2014. (Unpublished).
19. Gebremichael, B., Z. (2013). Efficiency, Outreach & Sustainability of Ethiopian microfinance Institutions. (Doctoral Dissertation, Andhra University, Andhra Pradesh, India). Retrieved from http://www.shodhganga.inflibnet.ac.in/handle/10603/12700. on 2-1-2014.
20. Giokas, D. (1991). Bank branch operating efficiency: a comparative application of DEA and the log-linear model. Omega International Journal of Management Science, 19(6), 549-57.
21. Gulati, R. (2011). Efficiency in Indian Commercial Banks: A Post-deregulation Experience. (Doctoral Dissertation, Guru Nanak Dev University, Amritsar, India). Retrieved from http://shodhganga.inflibnet.ac.in/handle/10603/10226 on 19-2-2016. (Unpublished).
22. Hartman, T. E., Storbeck, J. E., & Byrnes, P. (2001). Allocative efficiency in branch banking. European Journal of Operational Research, 134, 232–42.
23. Howland, M., & Rowse, J. (2006). Measuring bank branch efficiency using data envelopment analysis: managerial and implementation issues. INFOR Journal, 44(1), 49–63. DOI: 10.1080/03155986.2006.11732739.
24. Lotfi, F. H., Jahanshahloo, G. R., Ebrahimnejad, A., Soltanifar, M., & Mansourzadeh, S. M. (2010). Target setting in the general combined-oriented CCR model using an interactive MOLP method. Journal of Computational and Applied Mathematics, 234, 1–9. doi:10.1016/j.cam.2009.11.045.
25. Manandhar, R., & Tang, J. C. S. (2002). The evaluation of bank branch performance using data envelopment analysis: a framework. Journal of High Technology Management Research, 13, 1–17.
26. Minh, N. K., Khanh, P. V., & Tuan, P. A. (2012). A New Approach for Ranking Efficient Units in Data Envelopment Analysis and Application to a Sample of Vietnamese Agricultural Bank Branches. American Journal of Operations Research, 2(3), 126-136. Retrieved from http://dx.doi.org/10.4236/ajor.2012.21015 on 15-4-2017.
27. McEachern, D., & Paradi, J. C. (2007). Intra- and inter-country bank branch assessment using DEA. Journal of Productivity Analysis, 27, 123–36. DOI 10.1007/s11123-006-0029-z.
28. Noulas, A. G., Glaveli, N., & Kiriakopoulos, I. (2008). Investigating cost efficiency in the branch network of a Greek bank: an empirical study. Managerial Finance, 34, 160–71. DOI 10.1108/03074350810848045.
29. Oral, M., & Yolalan, R. (1990). An empirical study on measuring operating efficiency and profitability of bank branches. European Journal of Operational Research, 46(3), 282-294.
30. Paradi, J. C., & Schaffnit, C. (2004). Commercial branch performance evaluation and results communication in a Canadian bank — a DEA application. European Journal of Operational Research, 156, 719–35. doi:10.1016/S0377-2217(03)00108-5.
31. Pastor, J. T., Lovell, C. A. K., & Tulkens, H. (2006). Evaluating the financial performance of bank branches. Annals of Operations Research, 145, 321–37. DOI 10.1007/s10479-006-0038-3.
32. Paradi, J. C., Vela, S., & Zhu, H. (2010). Adjusting for cultural differences, a new DEA model applied to a merged bank. Journal of Productivity Analysis, 33, 109–23. DOI 10.1007/s11123-009-0158-2.
33. Paradi, J. C. & Zhu, H. (2013). A survey on bank branch efficiency and performance research with data envelopment analysis. Omega, 41, 61–79. doi:10.1016/j.omega.2011.08.010.
34. Portela, M. C. A. S., & Thanassoulis, E. (2007). Comparative efficiency analysis of Portuguese bank branches. European Journal of Operational Research, 177, 1275–88. doi:10.1016/j.ejor.2006.01.007.
35. Ramanathan, R. (2003). An Introduction to Data Envelopment Analysis A Tool for Performance Measurement. Sage Publications India Pvt Ltd, India.
36. Roy, C. (2004). Data Envelopment Analysis Theory and Techniques for Economics and Operations Research. UK: Cambridge University Press.
37. Sathye, M. (2003). Efficiency of Banks in a Developing Economy: The Case of India. European Journal of Operational Research, 148(3), 662-671.
38. Schaffnit, C., Rosen, D., & Paradi, J. C. (1997). Best practice analysis of bank branches: an application of DEA in a large Canadian bank. European Journal of Operational Research, 98, 269–89.
39. Schaffnit, C., Rosen, D. & Paradi, J. C. (1997). Best practice analysis of bank branches :an application of DEA in a large Canadian bank. European Journal of Operational Research, 98, 269–289.
40. Sherman H. D. & Gold, F. (1985). Bank Branch Operating Efficiency: Evaluation with Data Envelopment Analysis. Journal of Banking and Finance, 9, 297-315. Retrieved From Http://Booksc.Org/Book/16211981/13e29c on 26-08-2017.
41. Sherman, H. D., & Ladino, G. (1995). Managing Bank Productivity Using Data Envelopment Analysis (DEA). Interfaces, 25(2), 60-73. Retrieved from http://www.jstor.org/stable/25061993 on 02-06-2017.
42. Singh, H. (2013). Efficiency of Indian commercial banks during post reform period. (Master's thesis, Punjabi University, Amritsar). Retrieved from http://shodhganga.inflibnet.ac.in/handle/10603/25862 on 2-8-2016.
43. Soteriou, A. C., & Stavrinides, Y. (1997). An internal customer service quality data envelopment analysis model for bank branches. International Journal of Operations and Production Management, 17, 780-789.
44. Stanton, K. R. (2002). Trends in relationship lending and factors affecting relationship lending efficiency. Journal of Banking and Finance, 26, 127–52.
45. Tsolas, I. E. (2010). Modeling bank branch profitability and effectiveness by means of DEA. International Journal of Productivity and Performance Management, 59, 432–51.
46. Valami, H. B. (2009). Group performance evaluation, an application of data envelopment analysis. Journal of Computational and Applied Mathematics, 230, 485–90.
47. Wu, D., Yang, Z., & Liang, L. (2006). Using DEA-neural network approach to evaluate branch efficiency of a large Canadian bank. Expert Systems with Applications,
48. Yang, Z., & Paradi, J. C. (2006). Cross firm bank branch benchmarking using ''handicapped'' data envelopment analysis to adjust for corporate strategic effects, system sciences. Proceedings of the 39th Annual Hawaii International Conference. Hawaii.
49. Zarinkamara, R. T., & Alam-Tabrizb, A. (2014). Bank branch operating efficiency: evaluation with data envelopment analysis. Management Science Letters, 4, 2307-2312. Retrieved from http://www.growingscience.com/msl/Vol4/msl_2014_276.pdf on 2-8-2016.