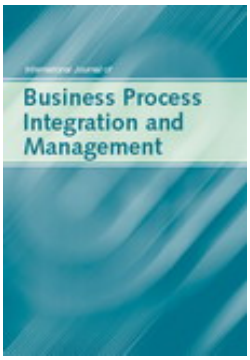


International Journal of Business Process Integration and Management

ISSN online: 1741-8771 - ISSN print: 1741-8763
https://www.inderscience.com/ijbpim

Efficiency evaluation of state cooperative banks employing data envelopment analysis and neural network technique

Triambica Gautam, Amit Srivastava, Shruti Jain

DOI: 10.1504/IJBPIM.2024.10065492

Article History:
Received: 27 April 2022
Accepted: 07 February 2023
Published online: 25 July 2024

Efficiency evaluation of state cooperative banks employing data envelopment analysis and neural network technique

Triambica Gautam and Amit Srivastava*

Department of Humanities and Social Sciences,
Jaypee University of Information Technology,
Solan, Himachal Pradesh, India
Email: triambica.gautam@juitsolan.in
Email: sriam_2000@yahoo.com
*Corresponding author

Shruti Jain

Department of Electronics and Communication Engineering,
Jaypee University of Information Technology,
Solan, Himachal Pradesh, India
Email: jain.shruti15@gmail.com

Abstract: India is one of the fastest-growing economies in the world. Banks have played an important role in this growth and are a critical aspect of the future as well. The banking sector is undergoing tremendous change nowadays to meet the need of the hour. Cooperative and commercial banks are the two major categories of banks. The cooperative banks, in spite of a very small market shares are likely to play an increasingly important role in the future keeping in mind their ability to ensure broader financial inclusion. In this paper, the authors have designed a model employing data envelopment analysis (DEA) for state cooperative banks (StCBs). An input-oriented model was used and both constant returns to scale (CRS) and variable returns to scale (VRS), runs of the model were used to determine efficiencies and rank these banks. Maharashtra State Cooperative Bank emerged as the only efficient bank under the VRS run and Gujarat State Cooperative Bank showed highest score of 0.982 under the CRS run of the DEA model. The model is validated using the neural network technique with an accuracy of 93.5% for 70–30 ratio and an overall R-value of 0.944.

Keywords: cooperative banks; data envelopment analysis; DEA: efficiency; neural network; input oriented.

Reference to this paper should be made as follows: Gautam, T., Srivastava, A. and Jain, S. (2024) 'Efficiency evaluation of state cooperative banks employing data envelopment analysis and neural network technique', *Int. J. Business Process Integration and Management*, Vol. 11, No. 3, pp.179–185.

Biographical notes: Triambica Gautam joined JUIT in 2007 and is an Assistant Professor (Grade-II) at the Department of Humanities and Social Sciences, teaching financial management, managerial economics, principles of management and strategic management. She started her academic career with teaching at the University College of Business Studies, Shimla and the IGNOU study centre at Solan in 1998. She moved to Center for Management Training and Research, Mohali in 2002, teaching in their MBA program. This was followed by a three year association (2004–2007) with the ICFAI University, teaching in their MBA program at the Thrissur (Kerala) and Chandigarh campuses.

Amit Srivastava has been working in JUIT since July 2003. He holds a PhD in Management from JUIT and MPhil (International Business) from Alagappa University. He received his MIBA (Master of International Business Administration) from Banaras Hindu University. He is actively involved in teaching and research and his areas of research include international business, finance and economic development. He has published more than 30 research papers in different international/national journals and conferences. He has been actively involved in organising workshops/conferences/training programs by the department.

Shruti Jain is an Associate Dean (Innovation) and Professor in the Department of ECE. She has received her Doctor of Science (DSc) in ECE. She has teaching experience of around 19 years. She has filed eight patents, of which two are granted and five are published. She has published more than 130 research papers in reputed journals and international conferences. She has

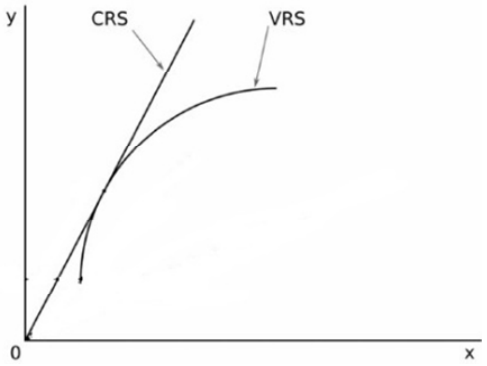
published 16 books. She is a member of the Editorial Board of many reputed journals. She was awarded the Nation Builder Award in 2018-19 and enlisted in 2% scientist of world rankings of 2021 published by Elsevier.

1 Introduction

The Indian banking sector has played a key role in the country's economic growth and is the backbone of the economy (Chakrabarty, 2013; Charnes et al., 1995). The banking system is divided into two types of scheduled banks namely scheduled cooperative banks and scheduled commercial banks (Cooper et al., 2000; Costa et al., 2012). The scheduled cooperative banks are subdivided into two: scheduled urban cooperative banks (UCBs) and scheduled state cooperative banks (StCBs). The scheduled commercial banks are categorised as regional rural banks, foreign banks working in India, public banks and private banks. The private banks are further subdivided into two categories, i.e., new private banks and old private banks while public banks are usually categorised as State Bank of India and other nationalised banks. The cooperative banks, despite an overall small asset base relative to the scheduled commercial banks, are important to the stability of the banking system and also for the key development objectives of financial inclusion and broad-based economic growth (Seiford, 1996; Das, 2010). Due to a lack of professionalism, these organisations have not responded adequately to the post-liberalisation (1991) economic scenario. They are facing a tough time as two-fifths of the UCBs are classified as 'financially weak'. Although cooperatives are not-for-profit organisations, their financial health determines their contribution to society (Coelli, 1995). It has been increasingly observed that ventures that make social sense can also be economically profitable (Seiford and Thrall, 1990).

The review of literature in banking revealed an increasing number of studies using techniques like frontier analysis for evaluating bank's performance. In the past ratio-based methods were the norm to evaluate the functioning of a bank. Data envelopment analysis (DEA) is a frontier analysis technique that is used for assessing the relative efficiency of decision-making units (DMU) in organisations (Coelli et al., 2002). DEA was first initiated by Charnes et al. (1978) based on the research of Farrell (1957) and became popular as the Charnes, Cooper and Rhodes (CCR) model. The CCR model presumes that there is no significant relationship between the efficiency and the scale of operations considering constant returns to scale (CRS), and delivery of overall technical efficiency (Naik, 2012; Ray and Das, 2010). The CCR model was customised by Banker et al. (1984) and became the Banker, Charnes and Cooper (BCC) model, which assesses the efficiency by variable returns to scale (VRS) (Ray, 2004, 2007). The CRS provides the technical efficiency and the VRS assumption provides the measurement of pure technical efficiency (PTE). In very basic terms, it is how a company came to become more or less efficient as it becomes bigger or smaller (Ramu, 2007). Generally, very small companies become more efficient as they become bigger, but there is a tipping point where becoming bigger will reduce efficiency because of the costs of coordination, such as hiring more managers or having more meetings. Figure 1 shows the CRS and VRS model curves where x-axis represents the inputs and y-axis represents the outputs (Řepková, 2013).

Figure 1 CRS and VRS model



Source: Řepková (2013)

In Mitra (2011), issue was raised regarding corporate governance and its overview considering UCBs in India. It was suggested that lack of professionalism, the duality of control, lack of accountability, undue importance to the interests of the borrowers at the cost of the depositors, and inadequate understanding of banking principles at the level of the board of directors and senior management are some peculiar factors ailing the UCBs. Similar issues have been faced by cooperative banking institutions around the world. In Colvin and McLaughlin (2012), Raiffeisenism's banking model's success in Italy and Netherlands and failure in Belgium, Spain, Ireland, and Denmark were discussed. A comparison of the Dutch and Irish experiences led to the conclusion that Raiffeisen banks in Germany were organisations like the cooperative institutions of today; they were owned and operated cooperatively by their creditors or investors. The Netherlands had separate organisations for Catholics and Protestants while in Ireland these banks were dominated by the religious majority, i.e., Roman Catholics which were one reason for their lack of success. Highly segmented markets in the Netherlands allowed Raiffeisen banks to create a niche for themselves while an un-segmented Irish market led to these banks having to compete with other financial institutions.

The literature review also brings out the changes in the banking industry that have occurred after liberalisation in India. These changes in the banking industry occurred in two stages. The first stage saw the introduction of several prudential norms, the formation of a competitive atmosphere, and major changes in the policy framework. In

the second stage human capital development, reorganisation measures, structural development, and technological up-gradation were done. In Dwivedi and Charyulu (2012), it was brought out that the Indian banking sector has raised its total resources more than five times between March 2000 and March 2010. The banking industry recorded a CAGR of 18% as compared to the average GDP growth of 7.2% during the same period. It was also explained that the commercial banks' assets to GDP ratio have increased to nearly 100% while the bank's business to GDP ratio has increased from 68% to 135%. The reforms have shifted the focus from social banking to profit-oriented banking. Returns to scale are used to explain one type of monopoly: a natural monopoly. If the returns to scale are always positive, then companies have an incentive to merge because it helps reduce costs (Kumar and Gulati, 2008; Das and Kumbhakar, 2012; Zhu, 2009).

The main trends emerging from the literature survey are the high growth in the banking sector, the use of modern methods like DEA in the analysis of banks, and the need to focus on cooperative banks to ensure better economic development and financial inclusion. Based on these, the authors have proposed the following research objectives for this paper:

1 To design the DEA model using CRS and VRS.

2 To define the rank of banks using the CRS and VRS models.

3 To validate the CRS model using the correlation coefficient and neural network (NN).

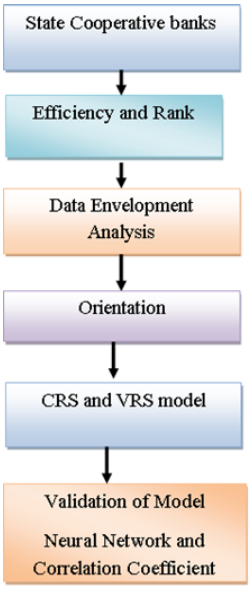
This paper is organised as: Section 2 explains the methodology for evaluating the ranks assuming CRS and VRS model for StCBs, Section 3 explains the model and validation of results followed by concluding remarks and direction for future work.

2 Methodology

Cooperative banking is an important constituent of the banking system. The cooperative banks try to balance the social motive and financial prudence (Reddy, 2002; Coelli and Lawrence, 2006). Unique structure and governance system make it difficult to manage these banks. Better management of these organisations can lead to much greater levels of financial inclusion and push the economy forward (Chakrabarty, 2013). The performance of these institutions shows a wide variation which can be analysed in detail to find solutions to the problems ailing the underperforming institutions. Figure 2 shows the proposed methodology to be followed in this research.

Cooperative banks are divided into rural and urban cooperatives where StCBs are the apex banks for all rural credit cooperative organisations. StCBs have been chosen for this study as they are present in all states and through them, we get a pan-India view of cooperative banking. Efficiency measurement of StCBs has been done using DEA and the efficiency scores obtained have been used to rank the banks. Efficiency measurement can be input-oriented or output oriented. In this case, the input-oriented model has been used as utilising inputs well to create output. Both CRS and VRS runs of the model were calculated to measure the impact of scale on efficiency. The model created was validated using correlation model and NN techniques.

Figure 2 Methodology adopted (see online version for colours)



Traditionally efficiency of banks is evaluated using ratios-based approaches as tabulated in Table 1. The lack of standards for comparing the scores obtained as well as multiple models for evaluating these ratios has increasingly made this approach less popular. DEA has emerged as a better alternative to ratios as it does not require standards for comparison and gives a relative measure of efficiency for all organisations considered for analysis. It also allows multiple inputs and outputs measured in different units to be combined in one score of efficiency.

In this paper, the authors have worked on StCBs. In total data from 14 years has been used for 31 different states. The efficiency and rank are evaluated using the CRS and VRS models of DEA. DEA is used to make an input-output model and the efficiency E_k of the DMU is evaluated (Gautam et al., 2022) using equation (1)

$$E_k = \frac{\sum_{j=1}^{M} u_j O_{jk}}{\sum_{i=1}^{N} v_i I_{ik}} \tag{1}$$

where K is the operating units (DMUs) $k = 1, \ldots, K$, N is the inputs for $i = 1, \ldots, N$, M is the outputs for $j = 1, \ldots, M$, O_{jk} is output j and I_{ik} is the input I of DMU k, v_i and u_j are the weights on the input I, and output O. Also, as per Cooper, there is a thumb rule to select several input outputs using equation (2).

$$K \geq \max\left[(N \times M), 3(N + M)\right] \tag{2}$$

Table 1 Measuring efficiency of banks using ratios-based approach

Growth (21.25%)	*Size (20%)*	*Sustainability of operations (33.75%)*			*Risk (25%)*
		Asset quality (12%)	*Productivity (5%)*	*Efficiency (16.75%)*	
Gr. in-demand deposits (4.8%)	Demand deposits (6%)	Total NPA growth (3%)	Cost to avg. assets ratio (2%)	Cost to income (3.4%)	Capital adequacy ratio (10%)
Gr. in loans and advances (2.7%)	Loans and advances (5%)	NPA provision coverage (3%)	Operating profit per branch (1.5%)	The ratio of operating profit to total income (1.7%)	Tier I to total shareholder's capital (5%)
Gr. in core fee income (3.55%)	Balance sheet size (5%)	Net NPA/net advances (6%)	Operating profit per employee (1.5%)	Return on avg. assets (2.5%)	Risk questionnaire (5%)
Gr. in operating profit (4.8%)	Total no. of branches (2%)			Non-interest income to total income (1.55%)	Risk index (5%)
Gr. in total deposits (2.7%)	Total no. of employees (2%)			Return on avg. net worth (0.8%)	
Gr. in NII (2.7%)				Net interest income to avg. working funds (1.7%)	
				NII (1.7%)	
				NII/total avg. assets (1.7%)	
				Cost of funds (1.7%)	

To evaluate a given unit, k, non-negative weights are considered.

$$\max E_k$$

s.t.

$$E_k \le 100,\ k = 1, \ldots, K$$

which can be formulated as

$$\max \sum_{j=1}^{M} u_j O_{jk}$$

s.t.

$$\sum_{i=1}^{N} v_i I_{ik} = 1 \text{ (normalise weighted input of } k \text{ to one)}$$

$$\sum_{j=1}^{M} u_j O_{jk} \le 100 \sum_{i=1}^{N} v_i I_{ik},\ k = 1, \ldots, K$$

$$u_j \ge 0,\ j = 1, \ldots, M$$

$$v_i \ge 0,\ i = 1, \ldots, N$$

Based on the efficiency, ranks were given to different states. The model is validated using the correlation coefficient (R) and NN. The correlation is the gradient of the regression line multiplied by the ratio of the standard deviations or the covariance divided by the product of the standard deviation. If the standard deviation is equal then the correlation is equal to the gradient. If b_{xy} denotes the regression coefficient of X on Y then $1/b_{xy}$ represents the slope of the regression line of X on Y and is expressed by equation (3). Similarly, b_{yx} represents the regression coefficient of Y on X then $1/b_{yx}$ represents the slope of the regression line of Y on X.

$$\frac{1}{b_{xy}} = \frac{1}{R} \times \frac{\sigma_y}{\sigma_x} \tag{3}$$

where σ_y and σ_x represent the standard deviation and R is the correlation coefficient and the multiplication of $1/b_{yx}$ and $1/b_{xy} = 1/R^2$.

Artificial neural network (ANN) is one of the most accepted machine learning (ML) models. It is bringing us to the next level in artificial intelligence (AI) (Prashar et al., 2020; Pal and Jain, 2022). ANN is a simple mathematical model of the brain which is used to process nonlinear relationships between inputs and outputs in parallel like a human brain does every second (Dogra et al., 2019). NNs and other AI programs require more training data because they need to be more precise and provide a solid baseline for future utilisation (Bhusri et al., 2016).

3 Results and discussion

The cooperative banks need to be evaluated using modern methods of analysis to create a wider view of the progress in the banking sector (Fare and Grosskopf, 1996). The evaluation of banks' efficiency and productivity is increasingly being done using DEA-based methods (Athanasoglou et al., 2009; Ram Mohan, 2002). Authors have analysed the StCBs using DEA considering the number of employees, number of branches, and funds as input and business generated as output variables. For the analysis of results, the authors have considered the 14-year data for 31 StCBs. All the simulations were carried out in MATLAB software. Table 2 tabulates the technical efficiency scores using the CRS model and the PTE score using the VRS model.

Table 2 Efficiency and rank scores for CRS and VRS model

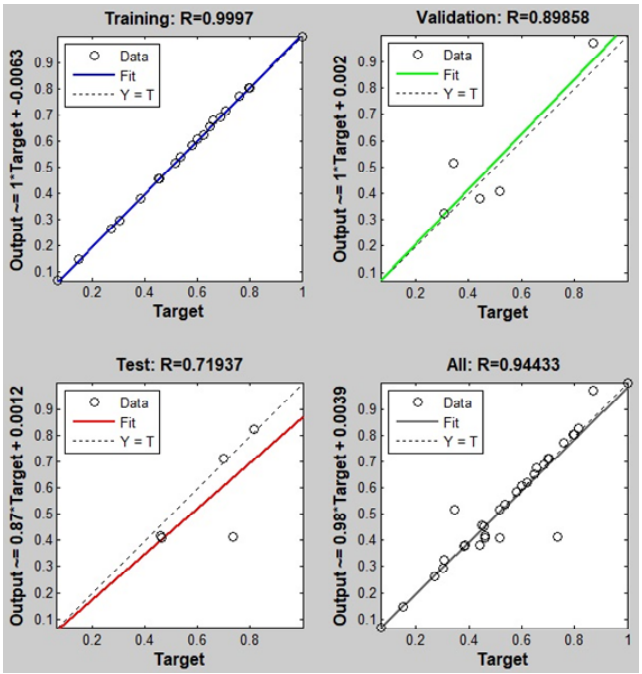
S. no.	*DMU*	*CRS (technical efficiency)*	*Rank based on CRS*	*VRS (pure technical efficiency)*	*Rank based on VRS*
1	Andaman and Nicobar	0.293	28	0.451	30
2	Andhra Pradesh	0.579	14	0.724	15
3	Arunachal Pradesh	0.139	30	0.395	31
4	Assam	0.732	7	0.826	9
5	Bihar	0.395	24	0.618	20
6	Chandigarh	0.596	13	*0.998*	2
7	Chhattisgarh	0.754	5	0.929	6
8	Delhi	0.428	21	0.504	26
9	Goa	0.571	15	0.651	18
10	Gujarat	*0.982*	1	0.984	4
11	Haryana	0.516	19	0.589	22
12	Himachal Pradesh	0.365	25	0.486	28
13	Jammu and Kashmir	0.632	12	0.803	11
14	Karnataka	0.549	16	0.607	21
15	Kerala	*0.813*	2	0.908	7
16	Madhya Pradesh	0.518	18	0.582	23
17	Maharashtra	0.765	4	*1.000*	*1*
18	Manipur	0.083	31	0.668	17
19	Meghalaya	0.425	22	0.468	29
20	Mizoram	0.328	26	0.671	16
21	Nagaland	0.295	27	0.547	24
22	Orissa	*0.791*	*3*	0.823	10
23	Pondicherry	0.544	17	0.646	19
24	Punjab	0.657	10	0.790	12
25	Rajasthan	0.734	6	0.752	14
26	Sikkim	0.266	29	*0.992*	*3*
27	Tamil Nadu	0.658	9	0.841	8
28	Tripura	0.477	20	0.545	25
29	Uttar Pradesh	0.673	8	0.773	13
30	Uttarakhand	0.643	11	0.978	5
31	West Bengal	0.420	23	0.496	27

Based on the efficiencies ranks were allotted to the states and it has been seen that Gujarat results in the first rank using the CRS run of the model. Maharashtra emerged as the only efficient bank in the study under the VRS run of the model. Some of the banks show poor performance. The different reasons attributed to the poor performance of cooperative banks are increasing competition and reduced market power, the duality of control, the small size relative to the competition, and the lack of professional management. To improve the banks' performance authors suggested redefining the business model, treating StCBs as business enterprises rather than people's organisations, bifurcating business into microfinance and commercial bank functions, complementing rather than competing with commercial banks, and improving corporate governance and risk management.

3.1 Model validation using correlation coefficient

The model is validated using the correlation coefficient. The correlation coefficient measures how strong or weak the bond between two independent (predictor) variables is. The correlation coefficient expresses the non-presence or presence of a linear interrelationship between the two observed variables. Figure 3 shows the correlation coefficient of our model showing training, testing, and validation R values.

Figure 3 Correlation coefficient of the CRS model (see online version for colours)



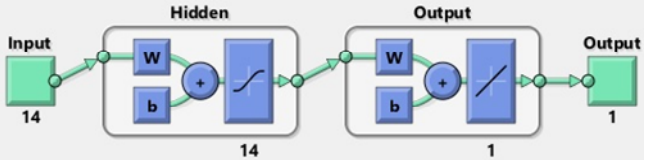
If the linear interrelationship is positive then the correlation coefficient lies between 0 and 1.0 while if it is negative it lies between 0 and –1.0. The overall R-value of 0.944 signifies that our model's linear interrelationship is positive.

3.2 Model validation using NN

The model is validated using a ML technique which is an application of AI that helps to build the ability of the systems to learn automatically and improve from experience without being explicitly programmed. ML focuses on the development of computer programs that can access data and use it to develop for themselves a model based on the most important features which then help to predict future trends. Supervised learning is a type of ML where the output is predicted by the computers using training data that has been labelled. Labelled data is a term used to describe input data that has already been given the correct output. In supervised learning, models are trained using labelled datasets, where the model learns about multiple input types. The model is assessed using test data (a subset of the training set) when

the training phase is over, and it then generates output predictions. In this paper, the authors have used the NN technique for validation. A NN is either a biological network of brain cells (neurons) or an artificial network of mathematical functions designed to perform like brain cells. In biology, the nervous system of even the simplest multi-cellular organisms is a network of neurons, i.e., NNs. Figure 4 shows the model for the proposed system.

Figure 4 NN model for the proposed model (see online version for colours)



The first layer in NN is the input layer, and the last layer is the output layer. In the input layer, the input parameters are required, and possible classes assigned to them by NN are the output layer. The intermediate layers are hidden, that's why intermediate layers are known as hidden layers where the inner computations take place. One of the internal layers is shown in Figure 5. Figure 6 shows the internal diagram used in the tansig function of Figure 5.

Figure 5 One internal layer of the model (see online version for colours)

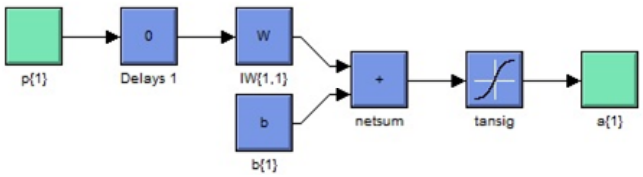
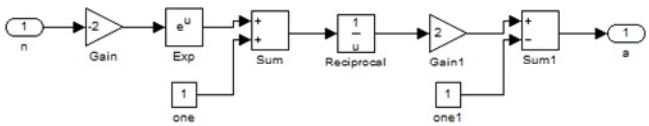


Figure 6 Tansig internal diagram



Training a NN is the process of finding the values for the weights and biases so that error is minimised. The weights and biases are evaluated using equation (4).

$$(n \times h) + h + (h \times m) + m \tag{4}$$

where n is the input node, h is the hidden node, and m represents the output nodes. The input and output values are split in a 70–30 ratio as a training set and a test set respectively. The back-propagation algorithm is used to train the dataset and an accuracy of 93.5% has been achieved. The authors have successfully validated the proposed model using a NN and correlation coefficient.

4 Conclusions and future work

India leans towards providing more technological solutions for addressing the problem of banking service to the poor masses living in rural areas as providing a full-fledged bank branch would be of little use. The banking industry is one of the revenue-generating industries. But over the few decades, it has lost its shine because of the challenges it is facing in recent times. In this paper, the authors have worked on StCBs. For the evaluation of performance parameters, data from 14 years have been assumed for 31 different states. The rank and efficiency are evaluated using the CRS and VRS models of DEA. Maharashtra results in the best efficiency using the VRS run of the DEA model while the CRS run did not show any of the 31 banks considered as efficient. The correlation coefficient and NN Technique are used to validate the model. In the future authors will focus on the detailed performance of the cooperative banking sector in India.

References

Athanasoglou, P.P., Georgiou, E.A. and Staikouras, C.C. (2009) 'Assessing output and productivity growth in banking industry', *A Quarterly Review of Economics and Finance*, Vol. 49, No. 4, pp.1317–1340.

Bhusri, S., Jain, S. and Virmani, J. (2016) 'Breast lesions classification using the amalagation of morphological and texture features', *International Journal of Pharma and BioSciences*, April–June, Vol. 7, No. 2B, pp.617–624.

Chakrabarty, K.C. (2013) 'Indian banking sector: pushing the boundaries', *RBI Bulletin*, Vol. LXVII, No. 3, pp.17–22.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) 'Measuring the efficiency of decision making units', *European Journal of Operational Research*, Vol. 2, No. 6, pp.429–444.

Charnes, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. (1995) *Data Envelopment Analysis: Theory, Methodology and Applications*, Springer-Verlag, New York.

Coelli, T. (1995) 'Recent developments in frontier modeling and efficiency measurement', *Australian Journal of Agricultural Economics*, Vol. 39, No. 3, pp.219–245.

Coelli, T., Rao, P.D.S. and Battese, G.E. (2002) *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic Publishers, London.

Coelli, T.J. and Lawrence, D. (2006) 'Editors' introduction', *Performance Measurement and Regulation of Network Utilities*, pp.1–7, Edward Elgar Publishing, Cheltenham.

Colvin, C.L. and McLaughlin, E. (2012) *Raiffeisenism Abroad: Why Did German Microfinance Fail in Ireland but Prosper in the Netherlands?*, EUI MWP, 2012/01 [online] http://hdl.handle.net/1814/20314 (accessed 24 September 2021).

Cooper, W.W., Sieford, L.M. and Tone, K. (2000) *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA Solver Software*, Springer, New York.

Costa, E.M., Ramos, F.S. and Souza, H.R. (2012) 'Static versus dynamic DEA in federal higher education institutions – IFES', *XVII Encontro Regional de Economia*, ANPEC Regional, Trabalho Completo.

Das, A. and Kumbhakar, S.C. (2012) 'Productivity and efficiency dynamics in Indian banking: an input distance function approach incorporating quality of inputs and outputs function', *Journal of Applied Econometrics*, Vol. 27, No. 2, pp.205–234.

Das, S.K. (2010) 'Financial liberalization and banking sector efficiency: the Indian experience', *12th Money and Finance Conference*, IGIDR, Mumbai, India, 11–12 March.

Dogra, J., Jain, S. and Sood, M. (2019) 'Glioma classification of MR brain tumor employing machine learning', *International Journal of Innovative Technology and Exploring Engineering*, Vol. 8, No. 8, pp.2676–2682.

Dwivedi, A.K. and Charyulu, D.K. (2012) 'Efficiency of Indian banking industry in the post reform era', *International Journal of Business Continuity and Risk Management*, Vol. 3, No. 3, pp.234–243.

Fare, R. and Grosskopf, S. (1996) *Intertemporal Production Frontiers: with Dynamic DEA*, Kluwer, Norwell.

Farrell, M.J. (1957) 'The measurement of productive efficiency', *Journal of the Royal Statistical Society (Series A)*, Vol. 120, No. 2, pp.253–281.

Gautam, T., Srivastava, A. and Jain, S. (2022) 'Data envelopment analysis based efficiency measurement of urban cooperative banks', *Maiden Edition of IEEE Delhi Section International Conference on Electrical, Electronics and Computer Engineering (DELCON 2022)*, 11–13 February.

Kumar, S. and Gulati, R. (2008) 'An examination of technical, pure technical and scale efficiency in Indian public sector banks using data envelopment analysis', *Eurasian Journal of Business and Economics*, Vol. 1, No. 2, pp.33–69.

Mitra, A. (2011) 'Corporate governance of urban co-operative banks in India: an overview', *AICWA,* IEMCON Organized in Collaboration with IEEE, India.

Naik M.P. (2012) 'The role of corporate governance in development of co-operative banks in India', *Excel International Journal of Multidisciplinary Management Studies*, Vol. 2, No. 2, pp.204–212.

Pal, B. and Jain, S. (2022) 'Novel discrete component wavelet transform for detection of cerebrovascular diseases', *Sadhana*, Vol. 47, No. 4, p.237.

Prashar, N., Sood, M. and Jain, S. (2020) 'A novel cardiac arrhythmia processing using machine learning techniques', *International Journal of Image and Graphics*, Vol. 20, No. 3, p.2050023, 17pp.

Ram Mohan, T.T. (2002) 'Deregulation and performance of public sector banks', *Economic and Political Weekly*, Vol. 37, No. 5, pp.393–397.

Ramu, N. (2007) 'Performance and challenges of urban cooperative banks in India', *An Appraisal, Bank Quest*, April–June, Vol. 78, No. 2, pp.63–71.

Ray, S.C. (2004) *Data Envelopment Analysis – Theory and Techniques for Economics and Operations Research*, Cambridge University Press, Cambridge.

Ray, S.C. (2007) 'Are some Indian banks too large? An examination of size efficiency in Indian banking', *Journal of Productivity Analysis*, Vol. 27, No. 1, pp.41–56.

Ray, S.C. and Das, A. (2010) 'Distribution of cost and profit efficiency: evidence from Indian banking', *European Journal of Operational Research*, Vol. 201, No. 1, pp.297–307.

Reddy, Y.V. (2002) 'Monetary and financial sector reforms in India: a practitioner's perspective', *The Indian Economy Conference, USA, Program on Comparative Economic Development (PCED)*, Cornell University.

Řepková, I. (2013) 'Estimation of banking efficiency in the Czech Republic: dynamic data envelopment analysis', *Danube: Law and Economics Review*, Vol. 4, No. 4, pp.261–275.

Seiford, L.M. (1996) 'Data envelopment analysis: the evolution of the state-of-the-art – 1978–1995)', *Journal of Productivity Analysis*. Vol. 7, Nos. 2–3, pp.99–137.

Seiford, L.M. and Thrall, R.M. (1990) 'Recent developments in DEA: the mathematical programming approach to frontier analysis', *Journal of Econometrics*, Vol. 46, Nos. 1–2, pp.7–38, North Holland.

Zhu, J. (2009) *Quantitative Models for Performance Evaluation and Benchmarking Data Envelopment Analysis with Spreadsheets*, Springer Publishing, New York.