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DEA Models to Measure the Environmental and Scale Efficiencies of Indian Commercial Banks

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Abstract:- This study attempted to evaluate the efficiency of Indian commercial banks working on Indian soil. The working environment of a bank may affect due to internal and external factors. The nonperforming assets ratio (Net NPAs/Net Advances) is an indicator variable used to measure the effect of internal and external factors. This study proposed environmental DEA models to assess the impact of internal and external factors and scale inefficiency. The results have shown that the effect of the NPA ratio is statistically significant on the efficiency of public and private sector banks. The study reveals that the proposed environmental DEA models accounted for the risk efficiency. Also, these environmental DEA models effectively controlled the spread of the efficiency scores. Overall the public and private sector banks improved their efficiency scores after eliminating the risk and scale inefficiencies.

Keywords:- *Environmental DEA Models, Risk Efficiency, Bank Efficiency, Nonperforming Assets, Scale Inefficiency, Environmental Efficiency.*

I. INTRODUCTION

Globalization bought a competitive environment in the Indian banking system and created huge competition among public, private, and foreign sector banks working in India. Due to this competition, the performance evaluation of a bank became important for banks, customers, and investors. Digitalization created a new era in the functioning of banks. The banks started door-to-door services using digitalization. For survival, all the banks started innovative products to attract customers and investors. The working environment of a bank may play a crucial role in its performance evaluation (Subramanyam T et al., 2020). The public sector banks are working under the ownership of the Indian government. These banks are the mediators between the government and the public to channel the funds for different development schemes. The main objective of these banks is to optimize their services and expand geographically to meet the day-to-day needs of the people (Subramanyam T & Reddy, 2008).

The private and foreign sector banks are working under private ownership. These banks are almost operating in urban areas. Due to the digitization and growing needs of customers, these banks offer doorstep services to attract customers. Due to the working style of the private sector banks, more customers started to be attracted to these banks. As of March 2020, the share of the public and private sector banks in terms of deposits is 64.75% and 30.35% respectively. From the financial year 2015 to 2020, there is an 11% increase in the deposits of the private sector banks (RBI Bulletins).

Due to the high competition, banks may offer different schemes like personal loans, credit cards, housing loans, loans for start-ups, and loans for business purposes to attract more customers and expand their daily business. In the last five years, private sector banks are more proactive in lending loans and acquiring deposits. From the financial year 2015 to 2020, the private sector banks increased their share of loans by around 15% and there is a 14.5% decline in public sector banks. When there is huge competition among the banks and in the banking sector, every bank tries to perform better by providing innovative services and new products.

Due to the introduction of new products and practices, the banks may lead to a risky environment. The performance evaluation of any bank is most important for stakeholders, and policy-makers. The performance of a bank can be evaluated effectively by considering the internal and external risk factors while modelling the banks. The present study aimed at evaluating the efficiency of public, private, and foreign sector banks in India. Some foreign banks are excluded from the study due to their less operational activities. The study focused on assessing the efficiency of banks, scale inefficiency, exogenous environmental risk efficiency, and endogenous environmental risk efficiency with the help of non-performing assets ratio as a nondiscretionary input variable.

II. LITERATURE REVIEW

The efficiency evaluation using frontier analysis was first initiated by M.J Farrell (1957) with multiple inputs. Charnes et al. (1978) and Banker et al. (1984) proposed the frontier models to measure the efficiency of organizational units where multiple inputs and multiple outputs are present under constant and variable returns to scale environment respectively. These models were considered basic data envelopment analysis (DEA) models and are more popular in efficiency evaluation. Many researchers utilized these models and applied them in different fields for measuring the efficiency of organizational units. (Sherman et al., 1985; Berg et al., 1993; Subramanyam and C S Reddy, 2011; Venkateswarlu & Subramanyam, 2015; Subramanyam T, 2015; Henriques et al., 2018). The discretionary power of the DEA models may depend on the number of input and output variables considered for evaluation. The discretionary power of the DEA models can be improved by removing the insignificant input and output variables from the data

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exploration (Subramanyam, 2016; Wilson, 2018; Subramanyam et al., 2021).

The extended DEA models were more population in measuring the risk efficiency of organizational units using environmental variables. Many researchers attempted to measure the risk management of the banking sector using nonperforming loans as an indicator variable (Pastor, 1999; Subramanyam and Reddy, 2008; Subramanyam et al, 2020). Due to the awareness and necessity of the performance of organizational units, several researchers proposed new environmental DEA models to assess the inefficiency due to undesirable environmental input/output variables. The environmental variables are useful to identify the homogeneous working environments of decision-making units in DEA (John Ruggiero, 1996; Subramanyam et al., 2020). J.M Pastor (1999) attempted to measure the efficiency of Spanish banks using nonperforming loans (NPLs) as a risk factor. The risk impact of NPLs decomposed into internal and external factors. This study argued that the provisions for loan losses occur due to internal and external factors.

John Ruggiero (1996) proposed a DEA model that controls the effect of exogenous environmental factors. This study applied to school districts to capture the effect of exogenous environmental factors. The study demonstrated that the basic DEA models overestimated the level of technical inefficiency. The proposed modified DEA models controlled the inefficiency of exogenous factors. This study suggested for the performance evaluation of any decision-making unit governed by external factors should be compared with the DMUs operating in equal and inferior environments. Subramanyam, T & Reddy (2008) proposed DEA models to control the inefficiency of DMUs due to internal and external factors. The risk indicator variable, nonperforming assets identified as undesirable output to assess the impact of the endogenous (internal) and exogenous (external) factors.

The real working environment of any bank can be determined when the possible environmental variables are identified in the study. The environmental variables may be external or internal. These variables are useful to identify the homogenous environment of a decision-making unit (Ruggiero, 2004; Subramanyam et al., 2020). Several environmental variables may simultaneously be included as input/output variables in the efficiency evaluation using environmental DEA models ((Banker et al., 1986; Golany et al., 1993, Ruggiero, 2004). Matsumoto et al., (2020) attempted to evaluate the environmental efficiency of 27 EU countries using a DEA window analysis technique. Ratner et al., (2021) attempted to evaluate the efficiency of investments focused on improving the eco-efficiency of the regional economy in Russia using three different DEA models in the context of technical complexity and practical feasibility.

Due to the flexibility and vast applications of DEA models number of new DEA models are proposed by the researchers using environmental variables. The evaluation of environmental efficiency is most important to measure the real performance of any decision-making unit. This study focuses on the evaluation of the impact of environmental factors as internal and external. The proposed environmental DEA models are discussed in the methodology section.

III. METHODOLOGY

Charnes, Cooper, and Rhodes (1978) proposed a linear programming problem to measure the efficiency of decision making units (DMU) under a homogeneous environment where similar inputs are employed to produce similar outputs. The DMU can be any profit or non-profit organizational unit. Suppose, we have n decision making units, where each DMU_j, $(j = 1,2,\dots,n)$ produces s-outputs, $v_{rj,}$ $(r = 1,2,\dots,s)$, using 'm' inputs, say, u_{ij} $(i = 1,2,\dots,m)$. The DEA model to capture the efficiency of overall efficiency of any DMU, denoted by DMU_0 is

$$\lambda^{CCR} = Min\{\theta: \sum_{j=1}^{n} \theta_j u_{ij} \le \theta u_{i0}; \sum_{j=1}^{n} \theta_j v_{rj} \ge v_{r0}; \theta_j \ge 0\} \quad ---(i)$$

The model (i), is useful to capture the efficiency of a DMU under constant returns to scale. In general, the constant returns to scale environment may not exist for any organization. To capture the scale differences of the DMUs, Banker, Charnes, and Cooper (1984) proposed a DEA model under variable returns to scale. The DEA model to capture the efficiency under variable returns to scale of a DMU, denoted by DMU_0 is

$$\lambda^{BCC} = Min\{\theta: \sum_{j=1}^{n} \theta_j u_{ij} \le \theta u_{i0}; \sum_{j=1}^{n} \theta_j v_{rj} \ge v_{r0}; \sum_{j=1}^{n} \theta_j = 1, \theta_j \ge 0\} \quad ---(ii)$$

The efficiency of DMUs may suffer due to environmental factors along with scale inefficiency. To capture the environmental efficiency of a DMU, researchers proposed environmental DEA models (EDEA) by capturing the effect of environmental variables. These EDEA models utilize reference sets that are homogeneous in nature (Ruggiero, 1996; Subramanyam, et.al, 2020). The present study proposed EDEA models to capture environmental inefficiency using the NPA ratio. The exogenous efficiency of a DMU using the proposed quartiles model is

$$\lambda^{BCC,Exo} = Min\left\{\theta: \sum_{j=J_{0,k}}^{n} \theta_j u_{ij} \le \theta u_{i0}; \sum_{j=J_{0,k}}^{n} \theta_j v_{rj} \ge v_{r0}; \sum_{j=J_{0,k}}^{n} \theta_j = 1, \theta_j \ge 0\right\} - (iii)$$

Here, $J_{0,k}$ represents the reference set using the quartiles, here $k = 1,2,3,4$. The proposed reference sets to capture the environmental efficiency are: $\{J_{0,1} \le q_1\}$, $\{q_1 < J_{0,2} \le q_2\}$, $\{q_2 < J_{0,3} \le q_3\}$ and $\{q_3 < J_{0,4} \le q_4\}$. To measure the endogenous environmental efficiency of a DMU, the indicator variable, non-performing assets included in the model as a non-discretionary input variable. The proposed model to capture the endogenous environmental efficiency of a DMU is

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$$\lambda^{BCC,Endo} = Min\left\{\theta: \sum_{j=J_{0,k}}^{n} \theta_j u_{ij} \leq \theta u_{i0};\ \sum_{j=J_{0,k}}^{n} \theta_j v_{rj} \geq v_{r0};\ \sum_{j=J_{0,k}}^{n} \theta_j z_{ij} \leq z_{i0},\ \sum_{j=J_{0,k}}^{n} \theta_j = 1,\ \theta_j \geq 0\right\} - - - (iv)$$

The ratios, $\frac{(i)}{(ii)}$, $\frac{(ii)}{(iii)}$ and $\frac{(iii)}{(iv)}$ capture the scale efficiency, exogenous and endogenous risk efficiencies respectively. The efficiency scores, $\lambda^{BCC,Endo}$, represents the pure technical efficiency of the DMUs.

IV. EMPIRICAL ANALYSIS

This study considered 48 commercial banks comprising 12 public, 21 private, and 15 foreign sector banks working on Indian soil. The study identified number of employees, fixed assets as input variables, and deposits, interest income and other income as output variables. The NPA ratio (Net-NPAs/Net-Advances) is considered as an environmental variable to capture the environmental risk efficiency in exogenous and endogenous environments. This study attempted to assess the efficiency of Indian banks under four working environments, namely, CCR-Environment (λ^{CCR}), BCC-Environment (λ^{BCC}), BCC-Exo Environment ($\lambda^{BCC,Exo}$), and BCC-Endo Environment($\lambda^{BCC,Endo}$).

TABLE 1: CCR Environment

	Overall	Public	Private	Foreign
Mean	0.3254	0.2205	0.2093	0.5717
Standard deviation	0.2261	0.0318	0.0540	0.2685
Coefficient of Variation (%)	69.51	14.40	25.79	46.96
Efficient banks (%)	2	0	0	7

The efficiency scores under the CCR environment reveal that overall banks experienced 67.46% input losses. The private sector banks experienced more input losses (79.07%) as compared to the public (77.95%) and foreign (42.83%) sector banks. Only one foreign bank namely, Barclays Bank is efficient in this environment. Overall, only two percent of the banks were managed with no input losses under a risk-free environment. The overall banks experienced huge variability in their efficiency scores as compared with the variability of bank sector-wise efficiency scores. The public sector banks have shown more consistency in efficiency as compared to other banks.

TABLE 2: BCC Environment

	Overall	Public	Private	Foreign
Mean	0.6463	0.6503	0.5341	0.8001
Standard deviation	0.2965	0.2293	0.2990	0.2862
Coefficient of Variation (%)	45.88	35.27	55.99	35.77
Efficient banks (%)	25	8	10	60

The efficiency scores under the BCC environment reveal that overall banks experienced 35.37% input losses. Under this environment, private sector banks experienced more input losses (46.59%) as compared to the public (34.97%) and foreign (19.99%) sector banks. Overall, 25% of the banks enjoyed zero input losses. When it comes to bank sector-wise, 60% of the foreign sector banks emerged with 100 percent efficiency. The coefficient of variation reveals that overall there is a decrease in the variation of efficiency scores as compared with CCR environment, but when compared with the variability of bank-sector wise, public and private banks experienced more variability.

- *Environmental Efficiency*

Due to the introduction of the NPA ratio as a non-discretionary input variable, it is observed that there is a huge decrease in input losses and variability.

TABLE 3: BCC-Exo Environment

	Overall	Public	Private	Foreign
Mean	0.9173	0.9779	0.8776	0.9246
Standard deviation	0.1709	0.0431	0.2137	0.1606
Coefficient of Variation (%)	18.63	4.40	24.35	17.37
Efficient banks (%)	65	58	52	80

The efficiency scores under the BCC-Exo environment reveal that there is a drastic decrease in input losses as compared to CCR and BCC environments. Overall, 65% of the banks attained 100 percent efficiency and the average loss of the inputs is around 8.27% only. The coefficient of variation reveals that there is a drastic decrease in the variability of efficiency scores as compared to CCR and BCC environments.

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TABLE 4: BCC-Endo Environment

	Overall	Public	Private	Foreign
Mean	0.9300	0.9868	0.9246	0.0585
Standard deviation	0.1662	0.0393	0.2078	0.1606
Coefficient of Variation (%)	17.87	3.98	22.47	274.76
Efficient banks (%)	73	75	62	80

The inclusion of the NPA ratio for capturing the endogenous environmental effect has shown a significant impact on the efficiency of banks. In this BCC-Endo environment, 73% of the banks experienced no input losses. When it comes to the bank sector-wise, there is no effect for foreign sector banks, but the public and private sector banks have shown a huge change in their efficiency. Around 17% of the public banks and 10% of the private banks became 100% efficient as compared to the BCC-Exo environment. It reveals that public and private sector banks were affected more by the NPA ratio in this study.

➢ *Scale and Risk efficiency*

The ratio, $\frac{\lambda^{CCR}}{\lambda^{BCC}}$ measures the scale efficiency of banks. The results have shown that due to scale inefficiency on average the banks experienced 44.67% input losses. The ratio, $\frac{\lambda^{BCC}}{\lambda^{BCC,Exo}}$ measures the exogenous risk efficiency of banks. Due to the exogenous risk efficiency, on an average the banks experienced 29.63% input losses. The ratio, $\frac{\lambda^{BCC,Exo}}{\lambda^{BCC,Endo}}$ measures the endogenous risk efficiency. Due to the endogenous risk efficiency, on an average the banks experienced 1.27% input losses. The environmental variable, the NPA ratio, played a major role while evaluating the efficiency of banks. It is observed that the effect of the NPA ratio is statistically significant at 5% level of significance (Mann-Whitney U test; $p < 0.05$).

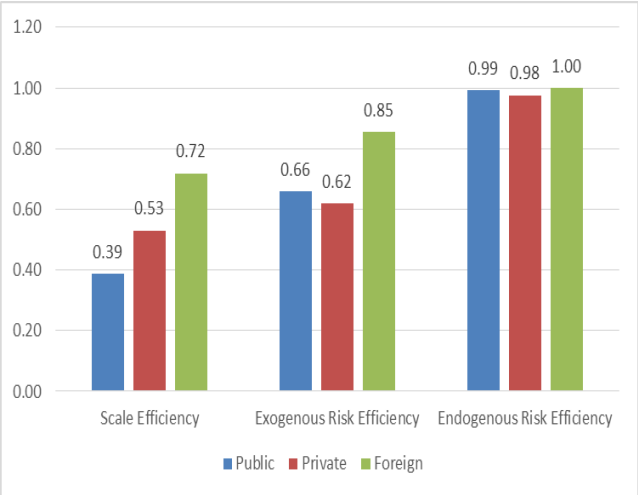

Fig 1. Scale and Risk Efficiency

The above diagram represents the scale, exogenous, and endogenous risk efficiency of public, private, and foreign sector banks. Due to scale inefficiency, the public sector banks experienced more input losses (61%) as compared with private (47%) and foreign sector banks (28%). Due to exogenous risk efficiency, the private banks experienced more input losses (38%) as compared with public (34%) and foreign sector banks (15%). Overall all, the public sector banks experienced more input losses due to scale inefficiency and private sector banks experienced more input losses due to exogenous and endogenous risk efficiency. It reveals that the public and private sector banks together need to improve their internal and external risk management system.

V. CONCLUSION

The present study attempted to measure the environmental risk efficiency of Indian commercial banks using environmental data envelopment analysis models. This study tried to identify the efficiency of EDEA models in reducing the input losses and variability of the efficiency scores. The NPA ratio is considered a nondiscretionary input variable. The method of quartiles was utilized to identify the homogeneous environment using the nonperforming assets ratio. Under a risk-free environment, 98% of the banks became inefficient and experienced around 68% of input losses. To overcome the scale differences, variable returns to scale models were performed and it is observed that around 25% of banks attained 100 percent efficiency. Under BCC-Exo and BCC-Endo environments, around 65% and 73% of the banks became efficient and experienced around 8% and 7% input losses respectively.

The coefficient of variation reveals that due to the environmental variable, there is a huge decrease in the variability of efficiency scores under BCC-Exo and BCC-Endo environments. It indicates that the NPA ratio played a major role in reducing the variability of the scores. This study attempted to measure the input losses under different environments namely, scale, exogenous and endogenous environments. Overall, the banks experienced 46% input losses due to scale inefficiency, 30% input losses due to exogenous risk inefficiency, and only 2% input losses due to endogenous risk inefficiency. After eliminating the endogenous risk inefficiency, around 75% of public sector banks, and 62% of private sector banks attained 100 percent efficiency.

Overall, the private sector banks experienced more input losses due to the environmental variable as compared to public and foreign sector banks. The foreign sector banks are less active in lending loans. Due to this these banks were affected much by the NPA ratio. The public sector banks also experienced more input losses next to the private sector banks. The environmental variable models reduced the variability in efficiency scores and these models worked better for assessing the efficiency of all banks working on Indian soil.

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