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NPA as an Undesirable Output in Indian Commercial Banking: Additive Slack Based Efficiency DEA Model

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Abstract: ***Non- performing assets (NPA) reflect the risk factor of the concerned commercial bank. Some of these banks operate at a threshold point where further reduction of NPA is not possible without reducing loans and advances, a desirable output. Pursuing an additive slack based efficiency DEA model the potential rate of reduction of NPA is explored for 50 commercial banks operating on Indian soil.***

Keywords: Nonperforming assets, Decision Making Unit (DMU), additive slack based efficiency

1. Introduction

A commercial bank is an organization controlled by government regulations which change from time to time. Its dual objectives are profit maximization and risk minimization. The commercial banks compete with several other financial institutions to handle the savings and credit needs of customers.

The banking industry is influenced by the fiscal policies of the government and the monetary policies of the central bank. Never the less its transactions are affected by the business cycles. Apart from these broad factors, local factors, and the philosophical attitudes of the management also influence the bank's business.

Fiscal policy intercepts income, savings and expenditure of the economy. Monetary policy intervenes into lending and investment activities of the commercial banks.

Commercial banking has traditionally remained for many years a protected industry in many emerging economies and India was not an exception. Regulated deposit and lending rates and restrictions on competition enabled the industry to sail smoothly and securely. Lending and deposit taking have continued to remain two major activities.

If economy is on the path of rapid expansion and inflation is mounting at an alarming rate, reduction of government expenditure and increase in taxes combined with increase in rate of interest appear to bring down the rate of inflation and the expansion can be slowed on the other hand, if recession is observed, so that the economy is contracting, increase in government expenditure, reduction of taxes and cutting down the interest rates lead to the expansion of the economy. Thus, business cycles and interest cycles affect the business of commercial banks.

The commercial banks and other similar financial institutions are to reserve a part of their deposits and the remains enable the banks to create more money which contributes to money supply. These funds are used as advances and investments.

To help economic recovery in periods of inflation and recession fiscal and monetary policy must work in union. Other factors which influence commercial bank business are local such as the structure of the bank, bank's community and the management.

Commercial banks are viewed as financial intermediaries that channel funds between savers and borrowers. Banking business is to satisfy both the users and the suppliers of bank funds. The balance sheet and income statement of banks reveal bank's success in managing its assets and liabilities.

Banking business has been undergoing drastic changes; consequently financial stability has come to occupy center stage as one of the prime policy concerns facing central banks worldwide. In recent years there was a significant improvement in the performance of the commercial banking system, measured in terms of net profits and marketability.

Every debt instrument of a bank carries some degree of risk. Credit risk and interest risk are the two basic types of risks in bank investments and loans.

Credit risk arises if the borrowers of loan or the issuer of a security fails to pay interest and the principal amount. Such defaults tend to increase the **non-performing assets of a bank**[1]. Banks can reduce the credit risk by a careful review of the borrower's present financial position and his past credit history.

Investment issues are also subjected to some degree of credit risk when the issuer of the investment securities fails to meet the promises in the debt contract due to the interruption or reduction of income. The organization's credit rate drops down and its borrowing costs will increase.

A bank requires strong profits to pay dividends to stock holders and build stock holders equity, to offset losses due to non-performing assets, to pay operating expenses and to expand products and services. 'Return on Assets' and 'Return on Equity' are the performance or profitability measures of a commercial bank. Carefully balancing the credit risk, banks should improve the qualities of their assets and liabilities.

The concept of 'risk concentration' has become a focal point for all the commercial banks. Large credit exposure to an individual customer or a group of related borrowers is to be avoided; otherwise, the bank will liquidate if the borrowers fail to repay the advances given to them. The recommendation of the World Bank is 25 percent of bank's capital is the limit for an individual large exposure, in India this limit is only 15 percent.

For commercial banks which have gone for public issue a two stage optimization is desirable. 'Profitability' and 'Marketability' are the two issues concerned to the banks which have gone for public issue. 'Profit' and 'Revenue' are the outputs of stage (1) optimization and theses outputs are treated as inputs in stage (2) optimization, concerned with marketability. Measurement of efficiency and ranking of Indian Commercial Banks are of serious concern not only to the management of an individual bank but also to the policy maker. Non-performing assets (NPA) reflect the risk factor of the concerned commercial bank. The performance measures treat good and bad outputs differently by valuing good outputs and ignoring bad outputs. Undesirable output such as NPA is not freely (costlessly) disposed. Therefore, weak disposability[2] of bad outputs is a suitable hypothesis in the presence of NPA. The burden of NPAs is a millstone round the necks of the banks.

Non-performing assets are due to political interference, willful defaults, target lending and fraudulent behavior of banks themselves. The commercial banks should concentrate on somehow reducing the amount and number of accounts of NPA category. RBI extended help since 1992 to reduce non-performing assets. The commercial banks are instructed to classify the NPA accounts as per the guidelines issued by it.

2. DEA Models

Data Envelopment Analysis[3] is employed to measure efficiency of 50 commercial banks operating on Indian soil. DEA models were initiated by Charnes, Cooper and Rhodes; Banker, Cooper and Rhodes. Subsequently, these models received attention worldwide and the models were suitably tailored and improved to meet a variation of needs.

Measurement of returns to scale and their characterization, assurance region approach, introduction of categorical variables, use of interval data, super efficiency measurement, sensitivity analysis for model selection, identification of robust efficient decision making units, identification of single observed peer of inefficient DMU, derivation of closset targets, classification and ranking of decision making units, productivity measurement, estimation of input and output congestion, quantification of degree of returns to scale, are some of the uses of data envelopment analysis. Active research is going to explore network models choosing DEA basic tool.

DEA compares the performance of an inefficient decision making unit with a point on the frontier of production possibility set[4] which may be convex or non-convex. To measure the distance between inefficient and bench mark performances several models were developed and efficiency measures invented. Radial DEA models, additive DEA models, Free Disposable Hull (FDH) models, non-radial DEA models, directional DEA models are some of the important DEA approaches that a researcher comes across in his endeavors of efficiency measurement.

Radial efficiency measures are oriented, they enquire possible input reduction, output augmentation without changing input or output mix, therefore, these measures acquired the name 'technical efficiency'. The additive models are non-oriented in input and output quantity space which radically differs from the radial efficiency models. These models account for not only input reduction and output augmentation but also changes in input and output mix.

Non-radial measures which do not call for equi proportional changes of inputs or outputs are particularly interesting since the observed inefficient performance is compared with a point that belongs to Pareto-Koopman set of efficient points and the case with radial measures is not so always. If inefficiency due to changes in input and/or output mix is of primary concern, radial measures are not of much use.

Fare-Lovell proposed non-radial measurement, which is oriented, resulting in Russel non-radial efficiency measure. The hyperbolic technical efficiency measure introduced by Fare et.al is non-oriented and non-radial. Non-oriented and non-radial measures simultaneously seek for input reduction with a possible change in input mix, output augmentation with change in output mix.

The efficiency measures radial or non-radial, oriented or non-oriented mentioned above assumes convex production possibility set. For an inefficient DMU its peer may be an observed DMU or a convex combination of more than one efficient DMUs in the peer list, which is hypothetical DMU. If one observed DMU serves as a peer of an inefficient DMU it can pick and implement the practices of the peer DMU as its best practices in an endeavor of gaining efficiency.

If the production possibility set is convex its input and output sets are bound to be convex. But the converse is not true. A Production possibility (PP) set which is non-convex but whose input and output sets are convex is Free Disposable Hull, a mixed-integer programming problem solved under non-orientation yields input and output slacks. The Free Disposable Hull-Production possibility (FDH-PP) set is a subset of BCC-PP set, as such efficient targets implied by the former are closer than those set by the later approach.

The Range Adjusted Measure (RAM), Fare's generalization of hyperbolic measure of efficiency (FGL), the slack based efficiency measure (SBM) oriented and non-oriented, Chambers et.al directional efficiency (DE) are also used for efficiency measurement.

If a DMU is Pareto-Koopman efficient then its efficiency score is 100 percent whatever the approach we choose. However, for inefficient decision making units efficiency ratings are method depended.

3. Model for Efficiency Measurement

One of the objectives of efficiency measurement is target setting for inefficient commercial banks. The targets are method dependent. Since the additive models seek input reduction and output augmentation simultaneously not in an equiproportionate manner, for target setting this appears to be a more useful model. Undesirable outputs like non-performing assets are treated as inputs; the additive model considered is a non-oriented model.

Additive Model- Non-Orientation - Non- Performing Assets:

The basic additive model is postulated as follows:

Max $\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^+ = x_{i0}$, i =1,2…….. m.

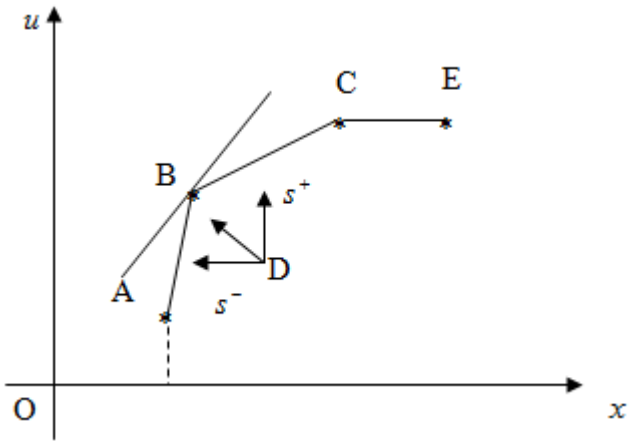
$\sum_{j=1}^{n} \lambda_j u_{bj} + s_b^- = u_{b0}$ $\sum_{j=1}^{n} \lambda_j u_{rj} - s_r^+ = u_{r0}$, r =1,2…… s.

$\sum_{j=1}^{n} \lambda_j = 1$

$\lambda_j \geq 0$, j=1,2…….. n.

where the subscript b refers to undesirable (bad) output.

The following is a graph illustration of additive model:



The line segments AB, BC and CD determine the frontier production function. Maximization of the sum of input and output slack moves the inefficient DMU D onto the frontier production function. The reference DMU of D is DMU B.

A commercial bank is additive efficient if and only if all of its slacks vanish, so that the objective function reduces to zero. Another variation of an additive model[5] is slack based efficiency model, where

$\rho = \dfrac{1 - \sum_{i=1}^{m+1} \left(\frac{s_i^-}{x_{i0}} \right)}{1 + \sum_{r=1}^{s} \left(\frac{s_r^+}{u_{r0}} \right)}$, measures slack based technical efficiency.

ρ requires to solve the following fractional programming problem:

Min $\rho = \dfrac{1 - \frac{1}{m+1} \sum_{i=1}^{m+1} \left(\frac{s_i^-}{x_{i0}} \right)}{1 + \frac{1}{s} \sum_{r=1}^{s} \left(\frac{s_r^+}{u_{r0}} \right)}$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{i0}$, i = 1,2,…….,m.

$\sum_{j=1}^{n} \lambda_j u_{bj} + s_b^- = u_{b0}$

$\sum_{j=1}^{n} \lambda_j u_{rj} - s_r^+ = u_{r0}$, r = 1,2,……..,s.

$\sum_{j=1}^{n} \lambda_j = 1$

$\lambda_j \geq 0$. , where $s_b^- = s_{m+1}^-$

Adjusting terms we express, $\rho = \dfrac{\frac{1}{m} \sum_{i=1}^{m} \left(\frac{x_{i0} - s_i^-}{x_{i0}} \right)}{\frac{1}{s} \sum_{r=1}^{s} \left(\frac{u_{r0} + s_r^+}{u_{r0}} \right)}$

$\frac{x_{i0} - s_i^-}{x_{i0}}$ measures the relative rate of reduction i[th] input. Thus, numerator of ρ measures the mean reduction rate of inputs due to technical inefficiency. $\frac{u_{r0} + s_r^+}{u_{r0}}$, augmentation rate of r[th] output. Thus, denominator of ρ measures the mean augmentation rate of outputs due to technical inefficiency.

An advantage with additive model is that it is translation invariant. A DMU is said to be translation invariant if translation of the original input and/or output values results in a new problem that has the same optimal solution for the envelopment form as the old one.

4. Inputs and Outputs – Empirical Results

To select inputs and outputs of commercial bank business we depended on asset-liability statement. Data on Number of employed, Deposits, Interests expended, Operational expenses, Capital and Reserves and Surplus, Borrowings,

Fixed Assets, Other assets and Total assets are available in the balance sheet of commercial banks.

In historical studies of efficiency of banks, different authors used different sets of variables: Labour or employees, Assets, Deposits, Number of branches, Stock holder's equity, Establishment expenditure, Non-establishment expenditure, Interest expenditure, Fixed assets, Work space, Number of Computers, Number of tellers, Operational Costs and Rent.

A common input for all the studies is 'Number of employees', 'Total assets' is another input variable widely used in DEA. Total assets are the sum of fixed and other assets.

In commercial banks usually advances appear to be a fraction of deposits, which is evidenced in Indian Commercial Banks. Between, advances and deposits with intercept zero, slope is estimated and tested for significance, the calculated value of t- statistic is found to be 70.49, which is highly significant. The null hypothesis is rejected. The sample correlation emerged to be 0.9932. 'Advances' are chosen to be one output and deposits are ignored[6].

Total income of a Commercial bank is comprised of interest and non- interest income. Further, increase in loans and advances results in increased interest income. The estimated correlation coefficient between 'loans and advances' and 'interest income' is sufficiently close to unity, which signals the choice of one of these to be included in the list of DEA outputs. Estimated correlation coefficient is 0.9981 and t-statistic value is 166.49 'Non-interest income' emerged to be another DEA output Variable.

In slack based efficiency measurement, the undesirable output NPA is chosen to be as input. In the table below third input slack refers to the slack of NPA.

Table (1a): Slack based efficiency

S.No.	*Commercial Bank*	*Input1 (Slack)*	*Input2 (Slack)*	*Input3 (Slack)*	*Output1 (Slack)*	*Output2 (Slack)*	*Slack Based Efficiency*
1	State Bank of Bikaner and Jaipur						1
2	State Bank of Hyderabad	3807.1	58664.95	0	0	24661.13	0.706942224
3	State Bank of India						1
4	State Bank of Indore	0	1107238	0	0	4570.85	0.768064935
5	State Bank of Mysore	0	2166766	0	100670	0	0.709248224
6	State Bank of Patiala	0	1699593	0	0	24977.92	0.64261173
7	State Bank of Sourashtra	2404.79	225492.2	0	0	6709.6	0.654949019
8	State Bank of Travancore	0	2456888	0	0	21339.09	0.529741915
9	Allahabad Bank	0	2616267	65.7	0	43610.43	0.53890381
10	Andhra Bank	3776.9	651410.5	0	0	22739.76	0.688206354
11	Bank of Baroda	4217.73	2256468	0	0	69700.27	0.70201383
12	Bank of India	8380.04	1814071	0	0	38008.87	0.793527608
13	Bank of Maharashtra	829.36	3124871	284.97	0	13889.78	0.473238317
14	Canara Bank						1
15	Central Bank of India	10165.08	3392668	1167.89	0	42102.83	0.44385379
16	Corporation Bank	0	2701730	0	0	0	0.829179547
17	Dena Bank	0	2294639	298.9	161042.2	0	0.596636519
18	IDBI Ltd						1
19	Indian Bank	6242.58	2520974	0	36984.31	0	0.745991116
20	Indian Overseas Bank	4104	2900126	0	0	65462.4	0.44707344
21	Oriental Bank of Commerce	0	2451649	496.13	0	50688.43	0.546237606
22	Punjab & Sind Bank	1997.65	1935657	0	114116.5	0	0.605387407
23	Punjab National Bank	3871.72	2371750	638.52	0	61890.75	0.66777858
24	Syndicate Bank	0	2865079	256.28	0	43016.55	0.621967353
25	UCO Bank	0	2373772	278.66	0	42321	0.563337112
26	Union Bank of India	0	2193761	305.18	0	63811.75	0.597013074
27	United Bank of India	4147.58	3590516	304.94	0	7086.65	0.45950956
28	Vijaya Bank	0	2798097	36.85	0	14509.8	0.599690384
29	Bank of Rajasthan	811.32	792862	0	13398.45	0	0.704055947
30	Catholic Syrian Bank	0	397654.6	13.52	198524	5138.67	0.348263051
31	Centurion Bank of Punjab	5658.58	235677.1	0	568320.4	0	0.65992258

32	City Union Bank	0	426311.7	7.2	7439.97	445.97	0.672216561
33	Development Credit Bank	0	171984.1	47.92	164711.6	0	0.596781789
34	Dhanalakshmi Bank	0	246644.3	35.05	72194.98	1392.98	0.447044094
35	Federal Bank	0	1355947	126.23	0	0	0.726558497
36	HDFC Bank						1
37	ICICI Bank						1
38	IndusInd Bank	0	534053.8	108.55	0	0	0.809443729
39	ING Vysya Bank						1
40	Jammu &Kashmir Bank	0	1589257	133.62	0	13314.1	0.513131165
41	Karnataka Bank	0	1088365	174.6	0	0	0.625980086
42	KarurVysya Bank	0	720019.4	45.88	0	208.96	0.70187772
43	Kotak Mahindra Bank	0	990591.4	0	190003.6	0	0.767457499
44	Laksmi Vilas Bank	0	447972.3	46.91	0	1626.95	0.530193851
45	Nainital Bank	323.65	34206.73	0	0	694.97	0.431433891
46	Ratnakar Bank	0	36782.36	9.32	58917.34	1327.52	0.271724778
47	SBI Comm.&Intl Bank						1

Table (1b): Slack based efficiency

S.No.	*Commercial Bank*	*Input1 (Slack)*	*Input2 (Slack)*	*Input3 (Slack)*	*Output1 (Slack)*	*Output2 (Slack)*	*Slack Based Efficiency*
48	South Indian Bank	0	989924.7	143.78	0	3394.06	0.52297049
49	Tamilnad Mercantile Bank	0	498619	89.7	34924.32	0	0.583740166
50	UTI Bank						1

Slack based efficiency measurement identifies nine out of fifty commercial banks efficient. These banks are, State Bank of Bikaner and Jaipur, State Bank of India, Canara Bank, IDBI Ltd, HDFC Bank, ICICI Bank, ING Vysya Bank, SBI Comm. & Intl Bank and UTI Bank.

Table 2: Additive Model – Bench Mark

	Commercial Bank	*Bench mark*
1	State Bank of Bikaner and Jaipur	41
2	State Bank of Hyderabad	1 (0.17) 39 (0.24) 50 (0.59)
3	State Bank of India	12
4	State Bank of Indore	1 (0.39) 18 (0.06) 39 (0.30) 47 (0.26)
5	State Bank of Mysore	1 (0.79) 37 (0.00) 47 (0.18) 50 (0.02)
6	State Bank of Patiala	1 (0.66) 14 (0.01) 18 (0.08) 50 (0.24)
7	State Bank of Sourashtra	1 (0.04) 39 (0.85) 47 (0.11)
8	State Bank of Travancore	1 (0.91) 14 (0.00) 18 (0.08) 37 (0.00)
9	Allahabad Bank	1 (0.92) 3 (0.05) 37 (0.04)
10	Andhra Bank	1 (0.37) 39 (0.12) 50 (0.51)
11	Bank of Baroda	1 (0.73) 3 (0.11) 37 (0.17)
12	Bank of India	1 (0.71) 3 (0.10) 37 (0.19)
13	Bank of Maharashtra	1 (0.99) 3 (0.01)
14	Canara Bank	3
15	Central Bank of India	1 (0.90) 3 (0.10)
16	Corporation Bank	1 (0.81) 14 (0.01) 18 (0.13) 37 (0.01) 50(0.04)
17	Dena Bank	1 (0.81) 37 (0.02) 47 (0.17)
18	IDBI Ltd	12
19	Indian Bank	1 (0.71) 36 (0.28) 37 (0.01)
20	Indian Overseas Bank	1 (0.88) 3 (0.04) 37 (0.09)

21	Oriental Bank of Commerce	1 (0.87) 3 (0.00) 37 (0.13)
22	Pun jab &sind Bank	1 (0.62) 36 (0.00) 47 (0.38)
23	Punjab National Bank	1 (0.76) 3 (0.24)
24	Syndicate Bank	1 (0.87) 3 (0.07) 37 (0.06)
25	UCO Bank	1 (0.91) 3 (0.07) 37 (0.02)
26	Union Bank of India	1 (0.82) 3 (0.08) 37 (0.10)
27	United Bank of India	1 (0.99) 3 (0.01)
28	Vijaya Bank	1 (0.85) 18 (0.11) 47 (0.04)
29	Bank of Rajasthan	1 (0.20) 36 (0.03) 47 (0.77)
30	Catholic Syrian Bank	1 (0.23) 47 (0.77)
31	Centurion Bank of Punjab	1 (0.46) 36 (0.16) 47 (0.38)
32	City Union Bank	1 (0.15) 47 (0.85)
33	Development Credit Bank	1 (0.13) 37 (0.01) 47 (0.87)
34	Dhanalakshmi Bank	1 (0.11) 47 (0.89)
35	Federal Bank	1 (0.44) 18 (0.05) 37 (0.01) 47 (0.49)
36	HDFC Bank	4
37	ICICI Bank	19
38	IndusInd Bank	1 (0.11) 18 (0.07) 37 (0.02) 47 (0.80)
39	ING Vysya Bank	5
40	Jammu &Kashmir Bank	1 (0.51) 18 (0.10) 47 (0.38)
41	Karnataka Bank	1 (0.35) 18 (0.02) 37 (0.00) 47 (0.62)
42	KarurVysya Bank	1 (0.26) 18 (0.02) 47 (0.72)
43	Kotak Mahindra Bank	1 (0.39) 37 (0.02) 47 (0.58) 50 (0.01)
44	Laksmi Vilas Bank	1 (0.16) 18 (0.00) 47 (0.84)
45	Nainital Bank	1 (0.00) 39 (0.04) 47 (0.96)
46	Ratnakar Bank	1 (0.04) 47 (0.96)
47	SBI Comm.&Intl Bank	23
48	South Indian Bank	1 (0.31) 18 (0.02) 47 (0.67)
49	Tamilnad Mercantile Bank	1 (0.17) 37 (0.00) 47 (0.82)
50	UTI Bank	6

All the input and output slacks vanish for the State Bank of Bikaner and Jaipur, State Bank of India, Canara Bank, IDBI Ltd, HDFC Bank, ICICI Bank, ING Vysya Bank, SBI Comm. & Intl and UTI Bank, as such these attained slack based efficiency score. State Bank of Indore emerged to be additive inefficient. Its input and output slacks are respectively,

Input (1) 0
Input (2) 1107238.49
NPA 0
Output (1) 0
Output (2) 4570.85

Input Targets:

	Actual	Target
Number of Employees	6517	6517
Total assets	2452680	1345442 (0.5486)
Non-performing assets (Bad output)	294	294

Output Targets

	Actual	Target
Advances	1535138	1535138
Non-interest income	21550	26120.85 (12.21)

The State Bank of Indore saw its employees fully productive, and to produce its good outputs, had this been efficient it could have involved only 54 percent of its assets that it uses currently. In its efforts it cannot reduce NPA while one of other inputs can be reduced and one of good outputs is further augmented, if best practices are implemented.

For State Bank of Indore bench mark technology is provided by State Bank of Bikaner and Jaipur, IDBI Ltd, ING Vysya Bank and SBI Comm.& Intl. Bank, the most dominating peer being State Bank of Bikaner and Jaipur.

Positive slacks of non-performing assets (NPA) are noticed in 24 commercial banks out of fifty. For example, Allahabad Bank is found to be inefficient, since some of its input and output slacks emerged to be positive. In an effort to become slack based efficient, Allahabad Bank should reduce its NPA by 65.7 lakhs, which is 6 percent of its outstanding NPA.

Table 3

S.No.	*Commercial Bank*	*Gross NPA reduction (in Lakhs)*	*Best practice NPA*	*% Rate of reduction of NPA*
1	Allahabad Bank	65.7	1028.3	6.08
2	Bank of Maharashtra	284.97	535.03	34.75
3	Central Bank of India	1167.89	1404.11	45.40
4	Dena Bank	298.9	445.10	40.17
5	Oriental Bank	496.13	623.87	34.12
6	Punjab National Bank	638.52	2752.48	18.82
7	Syndicate Bank	256.28	1303.72	16.42
8	UCO Bank	278.66	1227.34	18.50
9	Union Bank of India	305.18	1567.82	16.29
10	United Bank of India	304.94	512.88	37.32
11	Vijaya Bank	36.85	527.15	6.53
12	Catholic Syrian Bank	13.52	115.48	10.48
13	City Union Bank	7.2	79.8	8.27
14	Development Credit Bank	47.12	98.08	32.82
15	Dhanalakhsmi Bank	35.05	68.95	36.51
16	Federal Bank	126.23	324.77	27.99
17	IndusInd Bank	108.55	234.77	27.99
18	Jammu and Kashmir Bank	133.62	368.38	26.62
19	Karnataka Bank	174.6	212.4	45.17
20	KarurVysya Bank	45.88	157.12	22.60
21	Lakshmi Vilas Bank	46.91	84.08	35.84
22	Ratnakar Bank	9.32	28.68	24.53
23	South Indian Bank	143.78	177.22	44.77
24	Tamilnad Mercantile Bank	89.7	101.3	46.96

The slacks of NPA measure gross NPA reduction, if the corresponding commercial bank implements best practices. Best practice NPA measures the target NPA. Rate of reduction of NPA measures reduction of NPA relative to gross NPA. These values suggest the degree of potency of a commercial bank in reducing NPA.

Potential rate of NPA reduction varied between 6.08 percent and 46.96 percent. $6.08 \leq R \leq 46.96$, where R stands for potential rate of reduction of NPA, the least and largest rates correspond in percentages to Allahabad Bank and Tamilnad Mercantile Bank respectively.

5. Conclusions

The chief advantage of additive model over other oriented DEA methods is that in the additive model, the rates of reduction of inputs vary from input to input and the rates of augmentation of outputs change from output to output. Also the method simultaneously seeks reduction of inputs and augmentation of outputs.

Implementing best practices, large potentials to recover NPA are found in Tamilnad Mercantile Bank (46.96%), Central Bank of India (45.40), Karnataka Bank (45.17), South Indian

Bank (44.77), Dena Bank (40.17), United Bank of India (37.32), Dhanalakshmi Bank (36.51), Lakshmi Vilas Bank (35.84), Bank of Maharashtra (34.75), Oriental Bank (34.12), Development Credit Bank (32.82), IndusInd Bank (31.65), Federal Bank (27.99), Jammu and Kashmir Bank (26.62), Ratnakar Bank (24.53) and KarurVysya Bank (22.60).

For NPA-zero-slack commercial banks, best practices do not lead to recovery of NPA.

Notes:

1. In efficiency evaluation if desirable and undesirable outputs are produced, bad outputs are often ignored. When this happens the output technical efficiency is exaggerated.
2. Weak disposability refers to; proportional reduction of desirable and undesirable outputs is globally possible. The production possibility set under weak disposability assumption is,

$$(x, u_b, u): \sum_{j=1}^{n} \lambda_j x_{ij} \le x_{i0}, \quad \sum_{j=1}^{n} \lambda_j (\mu u_{bj}) = u_{b0},$$

$$\sum_{j=1}^{n} \lambda_j (\mu u_{rj}) \ge u_{r0}, \quad \sum_{j=1}^{n} \lambda_j = 1,$$

$$\left\{ \begin{array}{l} i = 1,2,\ldots\ldots\ldots\ldots m;\ r = 1,2,\ldots\ldots\ldots\ldots s. \\ 0 \le \mu \le 1 \end{array} \right\}$$

At some level of μ reduction of undesirable outputs is not possible since good outputs are to be produced at a level to survive the competition.

3. Charnes, Cooper, and Rhodes proposed the multiplier problem, also referred to production model under linear homogeneous technology; the dual of their problem is called the envelopment problem.
4. The frontier points of the production possibility set can be divided into efficient and weak efficient subsets which are disjoint. Radial measures compare an observed performance, sometimes with the performance of a point that belonged to weak efficient subset. The additive or slack based efficiency models compare an observed performance with efficient performance that belonged to the Pareto-Koopman efficient points.
5. The slack based efficiency problem appears to be a fractional programming problem. Employing Charnes-Cooper transformation, transforming the input and output slacks suitably, it can be reduced into a linear programming problem.
6. It one output is a multiple of another output one of them shall be retained in the output list of DEA.

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