Performance of Indian commercial banks (1995-2002): an application of data envelopment analysis and Malmquist productivity index

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Abstract

This paper investigates efficiency using data envelopment analysis (DEA) and productivity growth using Malmquist index in a sample of Indian commercial banks over the period 1995-2002. Using total deposits and operating expenses as input and loans and other earning assets as output in the DEA analysis we observe no significant growth in productivity during the sampled period. The rate of increase in technical efficiency though small is likely to be due to scale efficiency compared to managerial efficiency. In general, smaller banks are less efficient and highly DEA-efficient banks have a high equity to assets and high return to average equity ratios. There has been no growth in productivity in private sector banks where as the public sector banks appears to demonstrate a modest positive change through 1995-2002. Technological change in the public sector banks reveals a growth while the private sector banks experienced a negative growth of almost the same magnitude.

Key words: Indian banks, productivity change, DEA, Malmquist index
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1. Introduction

Examining banking performance has been a common practice among many banking and finance researchers for a number of years. The main reason for continued interest in this area of research is the ever changing banking business environment throughout the world. With the introduction of financial deregulation in many parts of the world, the effect of such deregulation on bank efficiency has become an important issue. Financial deregulation was first introduced in developed countries. Therefore, most studies on the effect of deregulation on bank productivity have been confined to the developed world. Non-availability of data is another reason for the dearth of literature on the impact of financial deregulation on the performance of the banking sector in developing countries. Many countries that adopted financial deregulation policies are now experiencing competitive banking practices. India is no exception and as an emerging market is becoming a competitive and important market not only for financial products but also for other products. Indian banking is a considerable component in Asian financial affairs and has not been subjected to substantial research compared to the countries in the developed world.

A few studies assessed Indian bank performance using the data envelopment analysis (DEA) technique- a nonparametric methodology to evaluate the relative efficiency of production units and can accommodate multiple inputs and outputs. For example, Bhattacharyya, Lovell and Sahay (1997) examined the productive efficiency of Indian commercial banks during 1986-1991 and reported a marginal increase in overall average performance after 1987 and the average efficiency of publicly owned banks is much higher than in the privately owned or foreign owned banks. Sathya (2001) compared productive efficiency of publicly owned, privately owned and foreign owned banks operational in India in the year 1997/1998 and reported that private sector commercial banks as a group is paradoxically lower than that of public sector and foreign banks. These studies differ from each other in at least two ways: (i) the time period captured in the analysis and (ii) the input-output variables used in the DEA model.[1] Shanmugam and Das (2004) on the other hand investigated the efficiency of Indian commercial banks during the reform period, 1992-1999 using a parametric methodology.[2] They observed that the state and foreign banks are more efficient than their counterparts namely, nationalised and privately owned domestic banks.

As efficient banking systems contribute in an extensive way for higher economic growth in any country, studies in this nature are very important for policy makers, industry leaders and many others who are reliant on the banking sector. This study fulfils a demanding gap in that case and attempts to examine the performance in commercial banks after implementing significant financial deregulation policies since 1980s. For this study, the chosen time period is 1995-2002 as the deregulation process began in India much later. The sample period 1995-2002 includes sub-periods that were favourable and unfavourable to banking institutions in India. Our aim is to examine if these changing conditions (i) have any impact on bank performance in general and (ii) impact differently on the banks with different characteristics and efficiency levels. Specifically, we will be interested in determining whether unfavourable conditions exacerbate the difference in efficiency between low and high performing financial institutions. We use the DEA technique to measure bank efficiency and the Malmquist index to assess productivity change.

Rest of the paper is as follows: Section2 examines the Indian commercial banking briefly; Section 3 discusses the methodology of the study; Section 4 details out variables and the data

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[1] See Sathya (2001) for a demonstration of the change in efficiency scores when inputs are changed.

[2] Parametric methods are used to estimate the frontier with an explicit functional form given. These types of frontier estimation methods fall under stochastic frontier estimation (SFE) methods. The SFE method largely depends on the industry under study as well as data availability. An advantage of using the SFE method is that it can handle stochastic noise. However, the requirement of *a priori* (explicit) specification of the production function and assumption of distributions for the error term without regard to the theory are considered as shortcomings in stochastic frontier methods.

used in the study; the results are discussed in Section 5 explains results; and Section 6 concludes the study.

2. Indian banking at a glance

The Indian financial system has been regulated for most of its existence. The main regulatory features were interest rate regulation, credit restrictions, equity market controls and foreign exchange controls. Though some restrictions are still in operation, regulations, which are affecting banks, are being relaxed after implementing the Narasimhan Committee Report (1991). The second phase of deregulation has been completed after the review report by the same Narasimhan Committee. The 1985 report of the committee to review the working of the monetary system and the 1987 report by Vaghul that examined the Indian money market activities are among the important reports, which contributed to the present deregulation in India.

It is important to note that none of the deregulatory measures implemented were strong enough to diminish the important role played by the largely inefficient public sector banks. While there are some improvements within the sector, the overall inefficiency remained the same (Verma Report, 1999). One of the stumbling blocks towards full deregulation may be the public sector banks which are not open for full scale competition. One significant reason why the Indian public sector banks are able to survive even while making losses is the stringent regulations imposed on general economic activities of the country. As a result of deregulation private sector institutions are growing rapidly however, major commercial banks and specialised institutions still remain within the public sector.

India has more than sixty-six thousand branches, of which sixty percent are in rural areas. This may be due to geographic factors, but is not necessarily a valid reason to justify having such a large number of branches. Of the 298 commercial banks in India, the regional rural banks account for sixty-six percent. The public sector banks account for approximately eighty percent of the total assets of the banking and financial institutions sector, while the private sector banks and foreign banks each account for eight percent of the total assets. Table 2 shows the current state of the largest ten commercial banks in India. In terms of the asset base the State Bank of India is the largest commercial bank in the country and ranks 158 in the world.

3. Methodology

The term ‘productive efficiency’ is commonly used to describe the level of performance of a production unit in terms of its utilisation of input resources in generating outputs. Koopmans (1951) defined technical efficiency as a feasible input/output vector where it is technologically impossible to increase any output without simultaneously reducing another output. This analogy holds for a reduction in any input or both a reduction in any input and an increase in any output. Farrell (1957) demonstrated that a production unit ‘overall efficiency’ is composed of two separate efficiency measures called ‘technical efficiency’ and ‘allocative efficiency’. Farrell measured technical inefficiency as the maximum equi-proportional reduction in all inputs consistent with equivalent production of observed output. A Farrell efficient unit however, may not be Koopmans efficient since even after Farrell efficiency is achieved, there may exist additional slack in individual inputs. Allocative efficiency is based on cost considerations namely input prices. The type of efficiency measured depends on the data availability and appropriate behavioural assumptions (Yin, 1999). When only quantities are available, technical efficiency can be calculated. When both, quantities and prices are available, economic efficiency can be calculated and decomposed into technical and allocative components.

3.1 Data envelopment analysis

Speaking broadly, the DEA technique defines an efficiency measure of a production unit by its position relative to the frontier of the best performance established mathematically by the ratio of weighted sum of outputs to weighted sum of inputs; see, for example, Norman and Stoker (1991) for a detail description of the DEA technique. The estimated frontier of the best performance is also referred to as efficient frontier or envelopment surface. The frontier of the best performance characterises the efficiency of production units and identifies inefficiencies based on known levels of attainment. Thus, a production unit attains 100% efficiency only when it is not found to be inefficient in using the inputs to generate the output when compared with other relevant production units.

The original formulation of the DEA model introduced by Charnes, Cooper and Rhodes (1978), denoted CCR hereafter, assume CRS and the production frontier is a piecewise linear envelopment surface.

Let us first define the following measures:

$S = \{1,...,s\}$ is the set of outputs considered in the analysis

$M = \{1,...m\}$ is the set of inputs considered in the analysis

y_{rj} = known positive output level of production unit j, $r \in S$

x_{ij} = known positive input level of production unit j, $i \in M$

n = total number of production units evaluated

An interpretation of the CCR model that estimates the proportional increase θ, in all outputs required to achieve efficiency in DMU 'k' is given by

$$\text{Min } \mu_k \tag{1}$$

subject to

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rk} / \mu_k \ , \ r = 1,2,...,s$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{ik} \ , \ i = 1,2,...,m$$

$$\lambda_j \geq 0 \ . \ j = 1,2,...,n$$

The variables in the CCR model are μ_k and λ_j. The sufficient condition for efficiency of DMU '*k*' is that the optimum value of μ_k is 1. Otherwise, it is labelled as inefficient compared to other DMUs in the sample. The constraints in the model ensure that relative technical efficiency of DMU '*k*', given by μ_k never exceeds 1. In the CRS model, the technical efficiency estimated with input and output orientation is the same. The optimal value of μ will be the Farrell (technical) efficiency. A DEA run involves solving the above model *n* times, once for each DMU analysed.

The measure of efficiency obtained from the solution to model (1) consists of two components: 'pure' technical efficiency and scale efficiency. Banker, Charnes and Cooper (1984) proposed the variable-returns-to-scale (VRS) version of the model (1), denoted as BCC hereafter. The BCC model is (1) together with the additional constraint

$$\sum_{j=1}^{n} \lambda_j = 1, \tag{2}$$

that captures returns to scale characteristics. Hence, the efficiency estimates obtained in the BCC model is net of the contribution of scale economies and therefore is referred to as 'pure' technical efficiency and also as the managerial efficiency.

The orientation of the model given in (1) is output augmentation since it provides information as to how much equi-proportional increase in output is necessary (while maintaining levels of input) for an inefficient unit to become DEA-efficient. Under CRS specification, input and output orientation provides identical DEA estimates. More over, the efficiency frontier estimated with input and output orientation DEA models is the same. Therefore, under VRS specification both types of orientation will produce the same set of efficient DMUs. Under VRS, the estimated efficiency of inefficient DMUs can differ between the orientations adopted.

A DEA run will produce a relative efficiency score, μ and a set of λ_j, $j = 1,2,...,n$ values for each production unit. In the DEA literature, the units evaluated are referred to as decision-making units (DMUs). The set of λ_j values of each unit defines a point on the envelopment surface[3] made up of a convex combination of the efficient units. Therefore, for an inefficient unit, the point so defined by the λ_j values becomes a role model that in turn establishes precedence for it to become efficient. The set of efficient production units {*j*: $\lambda_j > 0$ } is called the peer group of the designated unit, '*k*'.

The constraint given in (2) is referred to as the convexity constraint and accounts for VRS. BCC model measures technical efficiency only. Hence, the efficiency estimates obtained in the BCC model may be considered as "pure" technical efficiency estimates. When the convexity constraint is removed the resulting model represents the CRS situation. The relative efficiency score obtained for a designated unit under CRS is a measure of overall technical efficiency of the unit and is always at least as much as the corresponding value obtained under VRS. The relative efficiency score obtained under VRS is a measure of pure technical efficiency. The difference in overall and pure technical efficiencies is attributed to scale efficiency. A measure of scale efficiency is simply the ratio of overall and pure technical efficiencies.

3.2 Malmquist productivity index

Malmquist productivity index is defined using distance functions. Suppose the function that describes the technology of production is given as: $F(X,Y)=0$ where $X=(x_1,x_2,...,x_M)$ is the input vector and $Y=(y_1,y_2,...,y_S)$ is the output vector. Caves, Christensen and Diewert (1982) provided an alternative interpretation of production technology using the concept of 'distance function'. They defined the output distance function as $D_0(X,Y)=\underset{\mu}{Min}\left[\mu : F\left(X, Y/\mu\right)=0\right]$ where μ_Y is the minimum equi-proportional change in the output vector. The output distance

[3] Efficient units determine a piecewise linear envelopment surface. The entire mean variance frontier also may be generated by linear combinations of any frontier portfolios (Cass and Stiglitz, 1970).

function measures the maximum proportional change in output required to place (X,Y) on the efficiency frontier. If the evaluated production unit is efficient, $D_0(X,Y)=1$ otherwise, $D_0(X,Y)<1$. Distance function may also be computed with input orientation, reference technology in a certain time period and CRS or VRS specification. Let $D_0^t(CRS)$ and $D_0^t(VRS)$ denote the output distance function computed with period *t* technology and with CRS and VRS specification respectively. The distance function can be determined using the DEA methodology outlined in section 3.1.

Caves, Christensen and Diewert (1982) defines the output based Malmquist productivity index to compare performance of a production unit in time period *t* and *t+1* with reference to period *t* technology as

$$M_0^t(X_{t+1},Y_{t+1},X_t,Y_t)=\frac{D_0^t(X_{t+1},Y_{t+1})}{D_0^t(X_t,Y_t)}. \tag{3}$$

Alternatively we may define output based Malmquist productivity index with reference to period *t+1* technology as

$$M_0^{t+1}(X_{t+1},Y_{t+1},X_t,Y_t)=\frac{D_0^{t+1}(X_{t+1},Y_{t+1})}{D_0^{t+1}(X_t,Y_t)} \tag{4}$$

$M_0>1$ indicates higher productivity in period *t* than in period *t+1*.

Fare, Grosskopf, Norris and Zhang (1994) defines an index that incorporates Malmquist indices in both periods. This they suggest to avoid choice of the time period arbitrarily. Fare, Grosskopf, Norris and Zhang specifies the output based Malmquist productivity change index[4] as

$$M_0(X_{t+1},Y_{t+1},X_t,Y_t)=\left[\left(\frac{D_0^t(X_{t+1},Y_{t+1})}{D_0^t(X_t,Y_t)}\right)\left(\frac{D_0^{t+1}(X_{t+1},Y_{t+1})}{D_0^{t+1}(X_t,Y_t)}\right)\right]^{\frac{1}{2}} \tag{5}$$

[4] This is the geometric mean of output based Malmquist productivity indices with reference to period *t* and period *t+1* technology.

$$= \left(\frac{D_0^{t+1}(X_{t+1}, Y_{t+1})}{D_0^t(X_t, Y_t)} \right) \left[\left(\frac{D_0^t(X_{t+1}, Y_{t+1})}{D_0^{t+1}(X_{t+1}, Y_{t+1})} \right) \left(\frac{D_0^t(X_t, Y_t)}{D_0^{t+1}(X_t, Y_t)} \right) \right]^{\frac{1}{2}} \tag{6}$$

where $\frac{D_0^{t+1}(X_{t+1}, Y_{t+1})}{D_0^t(X_t, Y_t)}$ is the change in relative technical efficiency between periods *t* and *t+1*

and $\left[\left(\frac{D_0^t(X_{t+1}, Y_{t+1})}{D_0^{t+1}(X_{t+1}, Y_{t+1})} \right) \left(\frac{D_0^t(X_t, Y_t)}{D_0^{t+1}(X_t, Y_t)} \right) \right]^{\frac{1}{2}}$ captures the shift in technology (technological change) between the two time periods evaluated at (X_t, Y_t) and (X_{t+1}, Y_{t+1}).

Now, for each production unit, define five Malmquist indices for period *t+1* relative to period *t*:

Total factor productivity change index (TFPCI)

$$= \left(\frac{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})}{D_0^t(CRS)(X_t, Y_t)} \right) \left[\left(\frac{D_0^t(CRS)(X_{t+1}, Y_{t+1})}{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})} \right) \left(\frac{D_0^t(CRS)(X_t, Y_t)}{D_0^{t+1}(CRS)(X_t, Y_t)} \right) \right]^{\frac{1}{2}} \tag{7}$$

$$= (\text{Technical efficiency change index})(\text{Technological change index})$$

Technological change index (TCI) $= \left[\left(\frac{D_0^t(CRS)(X_{t+1}, Y_{t+1})}{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})} \right) \left(\frac{D_0^t(CRS)(X_t, Y_t)}{D_0^{t+1}(CRS)(X_t, Y_t)} \right) \right]^{\frac{1}{2}}$ (8)

Technical efficiency change index (TECI) = $\frac{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})}{D_0^t(CRS)(X_t, Y_t)}$ (9)

Pure technical efficiency change index (PTECI) = $\frac{D_0^{t+1}(VRS)(X_{t+1}, Y_{t+1})}{D_0^t(VRS)(X_t, Y_t)}$ (10)

Scale efficiency change index (SECI) = $\frac{\text{Technical efficiency change index}}{\text{Pure technical efficiency change index}}$

$$= \frac{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})}{D_0^t(CRS)(X_t, Y_t)} \div \frac{D_0^{t+1}(VRS)(X_{t+1}, Y_{t+1})}{D_0^t(VRS)(X_t, Y_t)} \tag{11}$$

A value of less than 1 in the index indicates a decline in efficiency, equal to 1 indicates stagnation and greater than 1 indicates a growth between period *t* and *t+1* from the perspective of period *t* technology.

4. Variables and data

Variable selection

The choice of the variable set in DEA is an empirical issue. Inclusion of many variables is not a viable option in DEA as the number of variables in the model increases, more and more production units become efficient. On the other hand, when relevant variables are omitted DEA underestimates efficiency and the effect of this is more severe than when irrelevant variables are included in the DEA model. Lack of a standard structured approach to variable selection in DEA makes the task of variable selection even more difficult.

Berger and Humphrey (1997) commented on the difficulty of variable selection in performance appraisal of banks using the DEA technique as: there is no 'perfect approach' on the explicit definition and measurement of banks' input and outputs. In choosing the variables, there are some restrictions on the type of variables since there is a need for comparable data and to minimise possible bias arising from different accounting practices even among the banks that are bounded by federal bank guidelines. Indian banks are no exception.

There are two common approaches to variable selection in bank performance appraisal in DEA: intermediation approach and production approach[5]. In the intermediation approach where the banks are considered as intermediaries, the role of deposits is considered as an input to the production process where as in the production approach where the banks are considered as service providers, the deposits are considered as an output involving the creation of value added for which customers bear an opportunity cost. Casu and Molineux (1999) argued that the

[5] Another approach is to treat financial products on their net contribution to the revenue of the bank. In this case a financial product may be classified as an input or an output depending on the net contribution.

intermediation approach may be superior for evaluating the importance of frontier efficiency to the profitability of financial institutions because minimisation of total costs is needed to maximise profits and not just minimisation of production costs alone. Besides, interest expenses often account for one-half to two-thirds of total costs that the production approach ignores. The intermediate approach accommodates interest expenses. The choice of the appropriate input-output variable selection approach could be based on the aim of the analysis as well. Grifell-Tatjé and Lovell (1997) argued that when the interest in the analysis is on bank productivity, the production approach is preferred to the other approaches as they essentially focus on bank profitability. The sets of input-output variables considered in some previous DEA studies of Indian bank efficiency are shown in Table 1. Following Casu and Molineux (1999) we specify two inputs: x_1= total deposits (customer and short term funding) and x_2= total operating expenses and two outputs: y_1= loans and y_2= other earning assets.

Sample data

The data for this study was obtained from the BankScope database. The sample period we consider is 1995-2002. The reason for our choice of this sample period is that significant impact of deregulation began to appear on Indian banking only in mid 90s. The database provided useable data on the input-output variables only on 40 banks over the sample period. The sample consists of seventeen public and twenty-three private banks. The names of the banks are given in Table 5.

Table 3 gives the minimum, median, maximum and the average of each input-output variable, for each year. The percentage change in the average from the average of the previous year is also shown in Table 3. It is apparent from the entries in Table 8 that the average loans grew steadily by about 8 percent from 1996 to 1988 and in 1999 the growth rate jumped to more 18 percent. The other earning assets average also increased from 1995 to 1999 by about 11 percent per annum and then the rate of increase dropped to below 3.5 percent in 2000 and appears to be growing since. The average total operating expenses in 1996 was below that of 1995. However after 1996 the average increased rapidly over the next four years to over 17 percent in 2000. The year 2001 witnessed a sharp decline in total operating expenses from the previous year but in 2002 the average increased by more than 15 percent. Customer and short term funding grew in each year with high percentage increases (over 15 percent) recorded in 1999 and 2002. Overall 2000 and 2001 appear to show some activity in the banking sector different from the other observed sample periods. Table 3 entries also reveal that the minimum of the input and output variables increased in each year from 1996 to 2001 and decreased in 2002. On further investigation of the data set we noted that the minimum values of the input-output variables in all years correspond to Ratnakar Bank and SBI Commercial and International Bank with 1995 being an exception.

5. Results and discussion

5.1 DEA efficiency

We computed the technical efficiency score with the CRS specification (Model given in (1)) and ‘pure’ technical efficiency with the VRS output orientation (BCC model outlined in Section 3.1) and VRS input orientation specification. The annual average, median, standard deviation (SD), first-quartile (Q1) and third-quartile (Q3) of DEA-efficiency distributions of all the banks and after separating them into two groups: private and public is reported in Table 4.

First, we discuss the results of both private and public banks combined. The results are reported in Panel C, Table 4. Under the CRS assumption, the average efficiency of the forty banks increased from 1995 through 1997 and declined there after until 1999. A slight improvement in average efficiency was observed in 2000 followed by a decrease in 2001 and an increase in 2002. The change in average efficiency under the VRS assumption is similar to those with the CRS assumption.

It should be noted here that the figures reported in Table 4 should not be compared across years as DEA measures relative efficiency and not absolute efficiency.[6] A higher value of average efficiency does not imply higher average performance compared to the performance with respect to a lower average efficiency. Overall, the technical efficiency of Indian commercial banks is approximately 0.92 where as the managerial efficiency is approximately 0.96. These values are high compared to the average efficiency reported in similar studies of banks in India and in other countries.[7] The differences in the estimated efficiency between studies can be due to many reasons: variation in (i) the best-practice frontier, (ii) the input-output variable set used in the DEA model, (iii) the time period captured in the analysis and (iv) characteristics of the sampled banks.[8]

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[6] DEA efficiency is measured relative to the observed best-practice frontier and therefore, the frontier can change from year to year.

[7] For example, Casu and Molyneux (1999) considered the same set of input-output variables as in this study and reported that the mean DEA efficiency of five European countries lies between 0.50 and 0.66. Bhattacharyya, Lovell and Sahay (1997) examined the productive efficiency of Indian commercial banks during 1986-1991 and reported that the annual average varied between 0.79 and 0.83, the average efficiency of publicly owned banks averaged between 0.82 and 0.90 and in the privately and foreign owned banks the average varied between 0.74 and 0.78 and 0.68 and 0.82 respectively. Sathya (2001) compared productive efficiency of banks operational in India in the year 1997/1998. Sathya (2001) considered two sets of input-output variables (see Table 1) thereby estimating the efficiency with two DEA models and reported that in one model the mean efficiency is 0.83 and in the other the mean efficiency is 0.62 highlighting the possibility of obtaining different efficiency estimates when alternative sets of inputs are used.

[8] Outliers can influence efficiency measurement in DEA. As far as we are aware no DEA study of the Indian banking sector discusses the results to the presence of outliers. Following previous studies (see, for example, Resti (1997) and Casu and Molyneux (1999)) a reduced sample for each year was obtained by eliminating the efficient banks when all the 40 banks were included in the analysis. When the efficient banks are removed the remaining banks form a new frontier. Having solved the DEA model again for each of the reduced samples we computed one-way correlations between the newly obtained relative efficiency scores and the corresponding relative efficiency scores obtained when all 40 banks were used. The correlation between relative efficiency scores obtained in the reduced sample and the relative efficiencies

The results in Panels A and B indicate that the technical efficiency of banks in the private and public sector in general are the same. Managerial efficiency of the public sector banks however is higher than their private sector counterparts. This is observed in the input and output orientation models.

We investigate the composition of the efficiency frontier next. Tables 5 and 6 show the banks that lie on the efficiency frontier under the CRS and VRS with output orientation assumption respectively. Table 5 displays a change in the composition of the efficiency frontier with the number of 100 percent efficient banks varying between five and ten with the number increasing in the last three years. In the years 1995-2000 the private sector banks dominated the CRS frontier. Thereafter, the distribution of the private and public sector banks that makes up the frontier is even. Fifty-percent of the banks have never been observed efficient compared to the others in the sample. Only five banks appeared efficient in at least four of the eight years observed.

On the other hand, Table 6 entries indicate that the best-practice VRS efficiency frontier is made up by more than thirty-five percent of the sampled banks.[9] In this case nine banks never made it to the frontier of which eight belongs to the private sector and one to the public sector. This clearly indicates the dominance of the VRS frontier by the public sector banks.[10] Further, eighteen banks of which ten belongs to the public sector are efficient in at least four of the eight sampled years and three banks namely, Bank of India, Ratnakar Bank Ltd and SBI Commercial & International Bank remained efficient in all years sampled.

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obtained in the original sample is considered as an indicator of the robustness of the results. Our results reveal that the DEA output is not sensitive to the presence of outliers.

[9] Bhattacharyya, Lovell and Sahay (1997) in their study of Indian commercial banks report that approximately ten percent of their sample is DEA-efficient.

[10] These nine banks that are not on the efficiency frontier in any sampled year under the VRS specification also are not on the CRS frontier in any year.

5.2 Technical efficiency versus performance indicators and size

In each year of study, we sorted the banks into four groups of equal size by their efficiency score and computed the average efficiency of the banks within each group. The groups are labelled as least efficient, low-medium efficient, medium-high efficient and most efficient. The averages are displayed in Figure 1. The curves shown in Figure 1 reveal that there is no distinguishable difference in average efficiency between the medium-high and most efficient banks. Hence these two groups are combined and referred to as highly efficient in the investigation of technical efficiency with two performance indicators: return on average equity (ROAE) and equity/total assets. The technical efficiency within four asset classes is also discussed in this section.

Return on average equity

As shown in Figure 2, the average ROAE of the banks in the least efficient group is higher than the medium efficiency group and in turn the average ROAE of the medium efficiency group is higher than the most efficient group in 1996 and 1997. This status started to change in 1988 such that in 2001 and 2002 the highest average ROAE is with the most efficient banks followed by the low-medium and the least efficient banks.

Equity/total assets

The second measure of performance considered is the ratio of equity to total assets. The results reported in Figure 3 reveals that this ratio with the most efficient banks remained the highest in all the sampled years except 1988 where the ratio of the medium banks was slightly higher. In general, medium to high efficiency banks always appear to maintain a high equity to assets ratio and the least efficient banks the lowest ratio with the exception in 1997.

Size

The average efficiency of banks in four groups where the groups are formed according to size of the bank as measured by total assets is presented in Figure 4. An analysis of efficiency by asset size reveals that in each year, the largest banks appear to be the most technically efficient. In general, the smaller banks appear to be less efficient than the others.[11]

5.3 Productivity change

In this section we discuss productivity change as measured by the Malmquist total factor productivity index and assign the change in total factor productivity to technical and/or technological change. We also attempt to attribute any change in technical efficiency to change in pure technical efficiency and/or scale efficiency change. The average annual values of TFPCI, TCI, TECI, PTECI and SECI for the year 1996 to 2002 are reported in Table 7. All the indices are relative to the previous year and therefore, there are no figures available for the year 1995.

The results in the analysis with all the banks reported in Panel C, Table 7 indicate that there was no significant growth in productivity (0.6 percent per year) during the sample period 1995 and 2002. Indian commercial banks experienced a 5.8 percent productivity growth in 1996 and in the following two years productivity declined by approximately 0.5 percent per year suggesting deterioration in bank performance in 1997 and 1998. One possibility for this deterioration could be the Asian financial crisis experienced throughout the region during this time period. In 1999 the commercial banking sector defied the negative trend in growth in previous years but only marginally to be followed by another two years of decline at approximately 1.4 percent per year. The percentage growth in productivity in 2002 was 1.5 percent.

Over the sample period the average annual rate of technical efficiency change is 1.7 percent where as the rate of technological change is -1.1 percent. Therefore, we infer that the average

[11] In an analysis of commercial US banks from 184-1998 reveals that the smallest institutions are the most efficient and the largest ones are the least efficient (Barr, Killgo, Siems and Zimmel, 19999).

increase in productivity, though modest, is due to the improvement in technical efficiency though the change is inconsistent over the seven year period such that a growth is observed in 1996, 1997, 2000 and 2002 where as in the rest of the years, technical efficiency declined from the previous year.

Pure technical efficiency -that measures performance only due to managerial activity- increased by a mere 0.1 percent per year. This low average is due to the large variation in the change in managerial efficiency through the years with the lowest decline at 1.8 percent in 2002 and the largest increase of 1.7 percent in 1997. Scale efficiency of the banks on the other hand grew on average by 1.6 percent per year. The observed rate of increase in technical efficiency therefore may be considered to be due to scale efficiency compared to managerial efficiency.

Private vs public banks

We repeated the above analysis for the private and public banks separately. The results in Panel A, Table 7 where the results of the private sector banks are given indicate that based on the averages for private banks there has been (ii) no growth in productivity and managerial efficiency, (ii) an annual growth rate of 1.6 percent in technical efficiency and (iii) a 1.6 percent per year negative growth in technological change. No growth in managerial efficiency indicates that the technical efficiency change in the private sector banks is entirely due to scale efficiency. Removal of various regulations since mid 1980s enabled private banks to progressively attain high levels of capacity utilisation. This might be one of the reasons for the lack of growth in managerial efficiency in the private sector banks during the sample time period.

The public sector banks indicate a picture different from the private sector banks. The results of the public sector banks are given in Panel B, Table 7. Here, in general there has been no change in technical, managerial and scale efficiency. There has been a 1.4 percent annual change in technical efficiency and this is fully reflected in the annual average TFP change which is 1.3 percent.

In terms of total factor productivity, we observe a small difference in the performance of the public and private sector banks. This difference is realised due to no TPF growth in private banks and a modest growth in public sector banks.[12] The modest growth in public sector banks indicates their slow response to deregulation.

6. Conclusion

The banking industry in India has been subjected to number of changes due to the deregulatory measures taken by the government and the industry. Changes in the national and international market environments, pressure applied by international organizations such as the IMF and the World Bank and the introduction of new technologies have forced authorities to relax controls making the banking industry more competitive and efficient. Beginning with deregulation policies introduced in mid 1990s to early 1990s, Indian banks have changed compared to the period before deregulation. It is obvious that changes are progressing well though slowly towards a more competitive banking industry in the region. For instance, increase in scale efficiency shows improvements within the banking industry due to deregulation. This would suggest that further steps need to be taken to improve efficiency in the banking industry substantially. As the public sector banks are dominating the market, it has become a difficult task for the private sector banks to change market and consumer attitudes swiftly. Further deregulation and more competition should be allowed within the banking sector for banks to become more efficient and productive.

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[12] Kumbakar and Sarkar (2003) report a larger difference in the TFP growth rates of the Indian private and public banks in the post-deregulation period compared to the pre-deregulation period. They used a generalized shadow cost function approach. In the literature however, it is argued that competition tends to narrow down the difference in performance of private and public banks (Caves and Christensen, 1980 and Borcherding, Pommerehne and Schneider , 1982).

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Table 1. Input-output variables used in previous studies

Study	Inputs	Outputs	Period
Bhattacharyya, Lovell and Sahay (1997)	Interest expense and operating expense	Advances, investments and deposits	1986 - 1991
Saha and Ravisankar (2000)[#]	No of branches, no of employees, establishment expenditure and non-establishment expenditure	Deposits, advances, investments, spread, total income, interest income, non-interest income and working funds	1991/92 to 1994/95
Sathya (2001) [Model A]	Interest expenses and non-interest expenses	Net interest income and non-interest income	1997/98
[Model B]	Deposits and number of staff members	Net interest income and non-interest income	

Notes: [#] Saha and Ravisankar (2000) selected the input and output variables based on the thrust areas of Indian banking in the post-nationalisation period. In the analysis they adopt a two-stage approach where in the first stage the DEA analysis is carried out taking one input and two outputs from among those in the respective lists.

Table 2. Indian commercial banking at a glance -2002

Name of the bank	Total assets (S$ '000)	Equity (S$ '000)	Net income (S$ '000)	Net interest margin (%)	Return on average assets (%)	Return on average equity (%)	Cost to income ratio (%)
State Bank of India	104,726,109	4,917,108	910,810	3.088	0.913	19.966	48.482
Punjab National Bank	18,529,586	950,082	192,517	4.197	1.128	22.127	45.711
ICICI Bank Limited	23,014,337	1,478,294	242,178	1.599	1.065	17.099	51.995
Canara Bank	17,509,794	963,247	223,995	2.945	1.279	23.254	45.121
Bank of Baroda	16,478,330	949,337	176,708	2.965	1.072	18.614	48.802
Bank of India#	16,114,988	744,643	178,969	2.895	1.162	26.653	44.819
Union Bank of India#	10,738,273	539,817	116,233	3.322	1.158	23.65	43.845
Central Bank of India#	12,009,498	509,770	64,252	3.738	0.557	13.822	62.308
UCO Bank#	7,342,604	253,554	43,636	2.911	0.643	18.727	58.162
HDFC Bank Ltd#	6,398,334	472,099	81,514	3.266	1.43	18.514	44.868

Notes: The figures are from the BankScope database. # indicates that the corresponding bank is in the sample.

Table 3. Some summary statistics of input and output variables used in DEA

Statistic	Year							
	1995	1996	1997	1998	1999	2000	2001	2002
No banks	40	40	40	40	40	40	40	40
Input variables								
Customer and short term funding (in thousands of US dollars)								
Median	795,593	952,047	1,081,766	1,229,308	1,598,486	1,752,036	1,895,854	2,064,937
Minimum	4,870	63,211	72,727	81,729	101,988	113,469	122,971	103,964
Maximum	8,514,486	9,308,215	10,353,443	11,181,446	11,379,387	11,471,409	12,921,787	14,401,792
Mean	1,532,201	1,677,898	1,840,073	2,053,523	2,379,641	2,539,428	2,788,377	3,228,367
% change	-	9.51	9.67	11.60	15.88	6.71	9.80	15.78
Total operating expense (in thousands of US dollars)								
Median	35,708	34,503	41,548	41,434	55,064	59,222	75,800	87,169
Minimum	2,246	1,320	2,737	2,915	3,928	4,260	3,719	4,946
Maximum	318,101	321,699	350,289	394,380	419,546	471,229	460,336	523,504
Mean	73,583	66,443	67,189	73,603	84,191	98,913	104,960	121,217
% change	-	-9.70	1.12	9.55	14.39	17.49	6.11	15.49
Output variables								
Loans (in thousands of US dollars)								
Median	414,768	504,266	558,953	634,771	805,491	922,779	87,169	1,152,414
Minimum	16,059	34,250	37,919	38,601	42,968	52,605	4,946	36,986
Maximum	4,542,907	5,106,341	5,574,866	5,737,505	6,033,586	6,898,186	523,504	8,965,975
Mean	747,214	796,358	861,038	934,708	1,111,312	1,231,867	121,217	1,656,310
% change	-	6.58	8.12	8.56	18.89	10.85	15.49	19.18
Other earning assets (in thousands of US dollars)								
Median	467,518	514,663	613,395	742,289	859,536	985,893	1,038,584	1,171,780
Minimum	16,673	31,011	36,848	44,465	57,730	54,972	73,482	71,838
Maximum	4,304,594	4,708,028	4,964,299	6,114,226	5,815,402	5,248,133	5,839,160	6,564,406
Mean	860,261	979,724	1,083,770	1,239,203	1,420,494	1,466,023	1,568,783	1,809,821
% change	-	13.89	10.62	14.34	14.63	3.21	7.01	15.36

Table 4. Estimated DEA efficiency

Year	Constant returns-to-scale					Variable returns-to-scale									
						Input orientation					Output orientation				
	Avg	Med	SD	Q1	Q3	Avg	Med	SD	Q1	Q3	Avg	Med	SD	Q1	Q3
Panel A: Private banks n = 23															
1995	0.8570	0.8330	0.1139	0.7620	1.0000	0.9277	0.9260	0.0716	0.8570	1.0000	0.9307	0.9280	0.0674	0.8690	1.0000
1996	0.9177	0.8980	0.0513	0.8765	0.9480	0.9488	0.9510	0.0477	0.9035	1.0000	0.9507	0.9530	0.0460	0.9070	1.0000
1997	0.9547	0.9580	0.0355	0.9340	0.9855	0.9663	0.9740	0.0328	0.9470	1.0000	0.9662	0.9740	0.0328	0.9460	1.0000
1998	0.9405	0.9460	0.0397	0.9175	0.9655	0.9560	0.9590	0.0405	0.9325	1.0000	0.9564	0.9610	0.0405	0.9345	1.0000
1999	0.9293	0.9170	0.0458	0.9070	0.9625	0.9463	0.9470	0.0464	0.9180	0.9955	0.9472	0.9490	0.0459	0.9180	0.9965
2000	0.9408	0.9390	0.0521	0.9160	0.9940	0.9589	0.9860	0.0508	0.9315	1.0000	0.9588	0.9850	0.0506	0.9305	1.0000
2001	0.9240	0.9230	0.0544	0.8850	0.9640	0.9424	0.9570	0.0542	0.8995	1.0000	0.9416	0.9550	0.0549	0.8985	1.0000
2002	0.9356	0.9410	0.0564	0.9135	0.9795	0.9495	0.9720	0.0556	0.9260	1.0000	0.9486	0.9710	0.0564	0.9255	1.0000
Avg	0.9249					0.9495					0.9500				
Panel B: Public banks n= 17															
1995	0.8251	0.8410	0.0927	0.7510	0.8950	0.9865	0.9960	0.0215	0.9810	1.0000	0.9872	0.9960	0.0208	0.9830	1.0000
1996	0.9158	0.9160	0.0406	0.8930	0.9400	0.9756	0.9990	0.0370	0.9700	1.0000	0.9764	0.9990	0.0362	0.9710	1.0000
1997	0.9524	0.9450	0.0310	0.9300	0.9810	0.9915	1.0000	0.0130	0.9820	1.0000	0.9918	1.0000	0.0127	0.9820	1.0000
1998	0.9469	0.9380	0.0404	0.9240	0.9890	0.9835	1.0000	0.0291	0.9880	1.0000	0.9842	1.0000	0.0277	0.9890	1.0000
1999	0.9252	0.9260	0.0390	0.8950	0.9510	0.9841	0.9980	0.0237	0.9740	1.0000	0.9856	0.9980	0.0205	0.9750	1.0000
2000	0.9343	0.9240	0.0481	0.8990	0.9780	0.9804	1.0000	0.0301	0.9710	1.0000	0.9825	1.0000	0.0258	0.9710	1.0000
2001	0.9410	0.9450	0.0539	0.8920	1.0000	0.9628	0.9830	0.0438	0.9360	1.0000	0.9652	0.9830	0.0405	0.9380	1.0000
2002	0.9551	0.9580	0.0423	0.9200	1.0000	0.9740	0.9960	0.0318	0.9430	1.0000	0.9749	0.9960	0.0311	0.9450	1.0000
Avg	0.9245					0.9798					0.9810				
Panel C: All banks n = 40															
1995	0.8435	0.8370	0.1054	0.7585	0.9180	0.9527	0.9865	0.0628	0.9125	1.0000	0.9547	0.9885	0.0595	0.9083	1.0000
1996	0.9169	0.9140	0.0465	0.8863	0.9400	0.9602	0.9855	0.0450	0.9108	1.0000	0.9616	0.9865	0.0435	0.9165	1.0000
1997	0.9537	0.9540	0.0333	0.9308	0.9835	0.9770	0.9855	0.0289	0.9620	1.0000	0.9771	0.9860	0.0289	0.9623	1.0000
1998	0.9432	0.9445	0.0396	0.9193	0.9680	0.9677	0.9835	0.0383	0.9448	1.0000	0.9682	0.9835	0.0379	0.9478	1.0000
1999	0.9275	0.9210	0.0426	0.9038	0.9585	0.9624	0.9730	0.0425	0.9320	1.0000	0.9635	0.9745	0.0416	0.9330	1.0000
2000	0.9380	0.9375	0.0499	0.9043	0.9825	0.9681	0.9935	0.0441	0.9473	1.0000	0.9689	0.9930	0.0431	0.9500	1.0000
2001	0.9312	0.9280	0.0542	0.8890	0.9985	0.9511	0.9625	0.0505	0.9058	1.0000	0.9516	0.9640	0.0501	0.9110	1.0000
2002	0.9439	0.9415	0.0512	0.9188	0.9963	0.9599	0.9745	0.0480	0.9378	1.0000	0.9598	0.9740	0.0486	0.9398	1.0000
Avg	0.9247					0.9624					0.9632				

Table 5. Composition of the production frontiers (1995-2002) with CRS specification

Bank	Type	1995	1996	1997	1998	1999	2000	2001	2002	Count
Federal Bank Ltd	Private			✓						1
ING Vysya Bank Ltd	Private	✓								1
Global Trust Bank Ltd	Private	✓								1
Indusind Bank Limited	Private	✓						✓		2
Bank of Punjab Ltd	Private	✓	✓							2
SBI Commercial & International Bank	Private		✓			✓				2
Jammu and Kashmir Bank Ltd	Private						✓	✓	✓	3
Karur Vysya Bank Ltd	Private						✓	✓	✓	3
Centurian Bank Ltd	Private	✓	✓	✓						3
Lakshmi Vilas Bank Ltd	Private						✓	✓	✓	3
Uti Bank	Private			✓	✓	✓	✓		✓	5
IDBI Bank Ltd	Private	✓	✓	✓	✓	✓				5
HDFC Bank Ltd	Private	✓		✓	✓	✓	✓	✓	✓	7
Punjab & Sind Bank	Private									
Karnataka Bank Ltd	Private									
South Indian Bank Ltd	Private									
Tamilnad Mercantile Bank Ltd	Private									
Catholic Syrian Bank Ltd	Private									
City Union Bank Ltd	Private									
Bharat Overseas Bank Ltd	Private									
Dhanalakshmi Bank Ltd	Private									
Lord Krishna Bank ltd	Private									
Ratnakar Bank Ltd	Private									
Bank of India	Public								✓	1
State Bank of Saurashtra	Public				✓					1
State Bank of Hyderabad	Public							✓	✓	2
State Bank of Mysore	Public							✓	✓	2
State Bank of Patiala	Public			✓			✓	✓		3
State Bank of Travancore	Public				✓		✓	✓	✓	4
State Bank of Bikaner and Jaipur	Public		✓	✓		✓	✓	✓	✓	6
Central Bank of India	Public									
Union Bank of India	Public									
Indian Overseas Bank	Public									
UCO Bank	Public									
Syndicate Bank	Public									
Oriental Bank of Commerce Ltd	Public									
Bank of Maharashtra	Public									
United Bank of India	Public									
Dena Bank	Public									
State Bank of Indore	Public									
Number of banks	n = 40	7	5	7	5	5	8	10	10	

Notes: The banks corresponding to the shaded regions have not been efficient in any year in the sample period (1995-2002) compared to the other banks in the sample.

Table 6. Composition of the production frontiers (1995-2002) with VRS specification (output orientation)

Bank	Type	1995	1996	1997	1998	1999	2000	2001	2002	Count
ING Vysya Bank Ltd	Private	✔								1
Global Trust Bank Ltd	Private	✔								1
City Union Bank Ltd	Private									1
Bank of Punjab Ltd	Private	✔	✔							2
Lakshmi Vilas Bank Ltd	Private						✔		✔	2
Indusind Bank Limited	Private	✔					✔	✔		3
Karur Vysya Bank Ltd	Private						✔	✔	✔	3
Jammu and Kashmir Bank Ltd	Private				✔		✔	✔	✔	4
Centurian Bank Ltd	Private	✔	✔	✔				✔		4
Federal Bank Ltd	Private		✔	✔	✔	✔	✔			5
IDBI Bank Ltd	Private	✔	✔	✔	✔	✔				5
Uti Bank	Private		✔	✔	✔	✔	✔		✔	6
HDFC Bank Ltd	Private	✔		✔	✔	✔	✔	✔	✔	7
Ratnakar Bank Ltd	Private	✔	✔	✔	✔	✔	✔	✔	✔	8
SBI Commercial & International Bank	Private	✔	✔	✔	✔	✔	✔	✔	✔	8
Punjab & Sind Bank	Private									
Karnataka Bank Ltd	Private									
South Indian Bank Ltd	Private									
Tamilnad Mercantile Bank Ltd	Private									
Catholic Syrian Bank Ltd	Private									
Bharat Overseas Bank Ltd	Private									
Dhanalakshmi Bank Ltd	Private									
Lord Krishna Bank ltd	Private									
Bank of Maharashtra	Public	✔								1
Dena Bank	Public				✔					1
State Bank of Saurashtra	Public				✔					1
Syndicate Bank	Public	✔				✔				2
State Bank of Mysore	Public							✔	✔	2
Indian Overseas Bank	Public	✔	✔	✔						3
Union Bank of India	Public		✔	✔	✔		✔		✔	5
UCO Bank	Public	✔	✔	✔	✔		✔			5
United Bank of India	Public		✔	✔	✔	✔	✔			5
State Bank of Patiala	Public			✔		✔	✔	✔	✔	5
State Bank of Travancore	Public				✔	✔	✔	✔	✔	5
State Bank of Hyderabad	Public	✔		✔	✔		✔	✔	✔	6
Central Bank of India	Public		✔	✔	✔	✔	✔	✔	✔	7
Oriental Bank of Commerce Ltd	Public	✔	✔	✔	✔	✔	✔	✔		7
State Bank of Bikaner and Jaipur	Public	✔	✔	✔		✔	✔	✔	✔	7
Bank of India	Public	✔	✔	✔	✔	✔	✔	✔	✔	8
State Bank of Indore	Public									
Number of banks	n = 40	17	15	17	17	14	20	15	15	

Note: The banks corresponding to the shaded regions have not been efficient in any year in the sample period (1995-2002) compared to the other banks in the sample.

Table 7. Malmquist indices (annual means) [output oriented]

Year	Technical efficiency change	Technological change	Pure technical efficiency change	Scale efficiency change	Total factor productivity change
Panel A: Private banks					
1996	1.110	0.924	1.024	1.084	1.026
1997	1.032	0.955	1.007	1.025	0.986
1998	0.980	1.014	0.985	0.995	0.994
1999	0.996	1.018	1.008	0.988	1.014
2000	1.018	0.969	1.001	1.017	0.986
2001	0.989	0.992	0.988	1.001	0.981
2002	0.990	1.024	0.994	0.996	1.014
Geometric mean	1.016	0.984	1.001	1.015	1.000
Panel B: Public banks					
1996	0.997	1.069	0.993	1.005	1.066
1997	1.014	0.999	1.014	1.000	1.012
1998	0.989	1.005	0.991	0.998	0.994
1999	0.989	1.024	1.001	0.988	1.013
2000	0.995	0.979	1.000	0.995	0.974
2001	0.996	1.023	0.991	1.004	1.019
2002	1.010	1.003	1.005	1.006	1.013
Geometric mean	0.999	1.014	0.999	0.999	1.013
Panel C: All banks					
1996	1.094	0.967	1.008	1.085	1.058
1997	1.041	0.956	1.017	1.024	0.995
1998	0.989	1.007	0.991	0.998	0.995
1999	0.983	1.026	0.995	0.988	1.009
2000	1.011	0.976	1.006	1.005	0.987
2001	0.992	0.994	0.982	1.011	0.986
2002	1.014	1.001	1.009	1.005	1.015
Geometric mean	1.017	0.989	1.001	1.016	1.006

Note: All indices are relative to the previous year and therefore, no figures for 1995.

Figure 1.Average efficiency by efficiency level (VRS-input oriented)

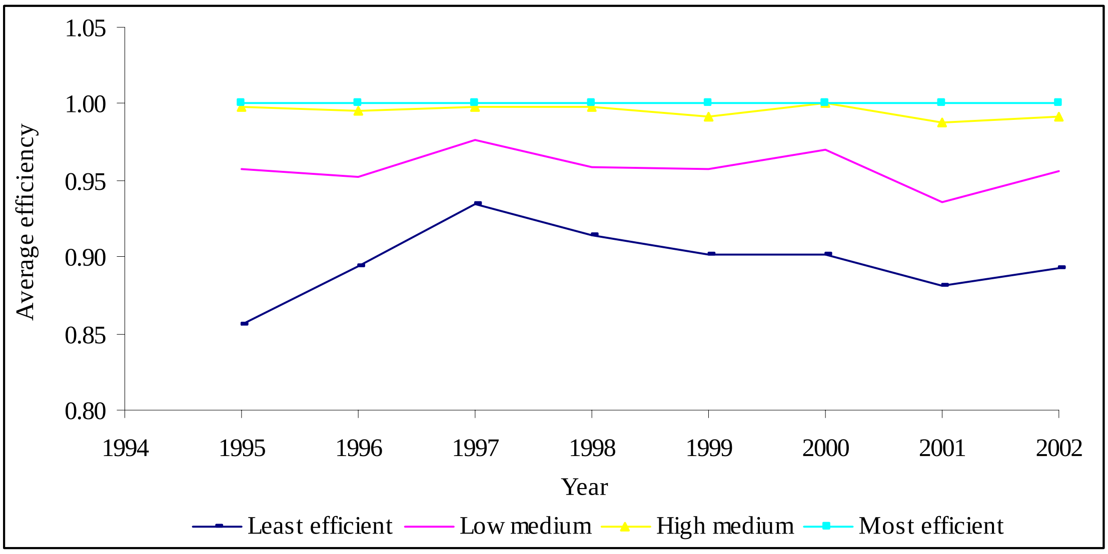

Figure 2. ROAE by efficiency level (VRS-input oriented)

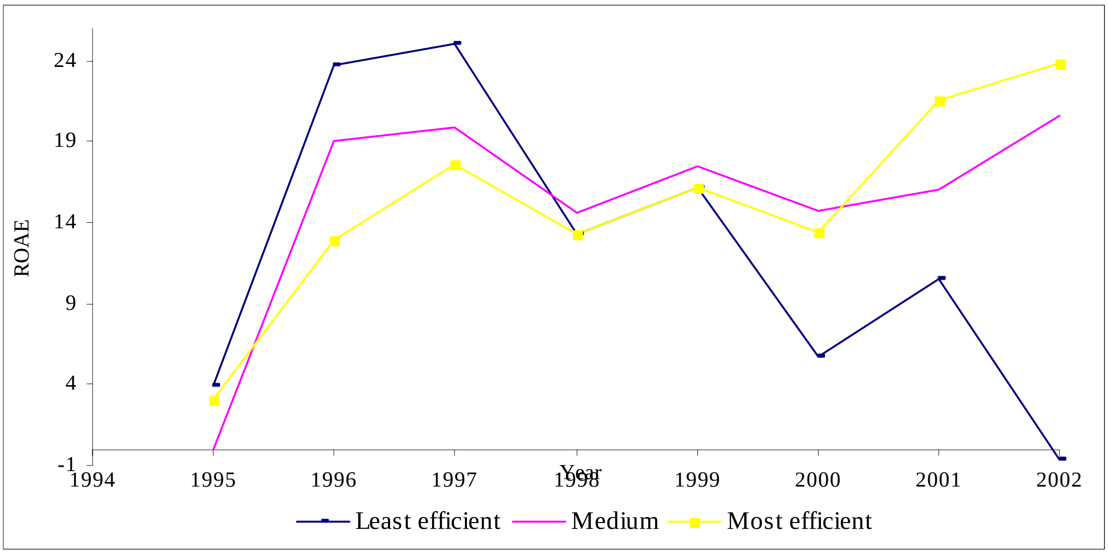

Figure 3. Equity/total assets by efficiency level (VRS-input oriented)

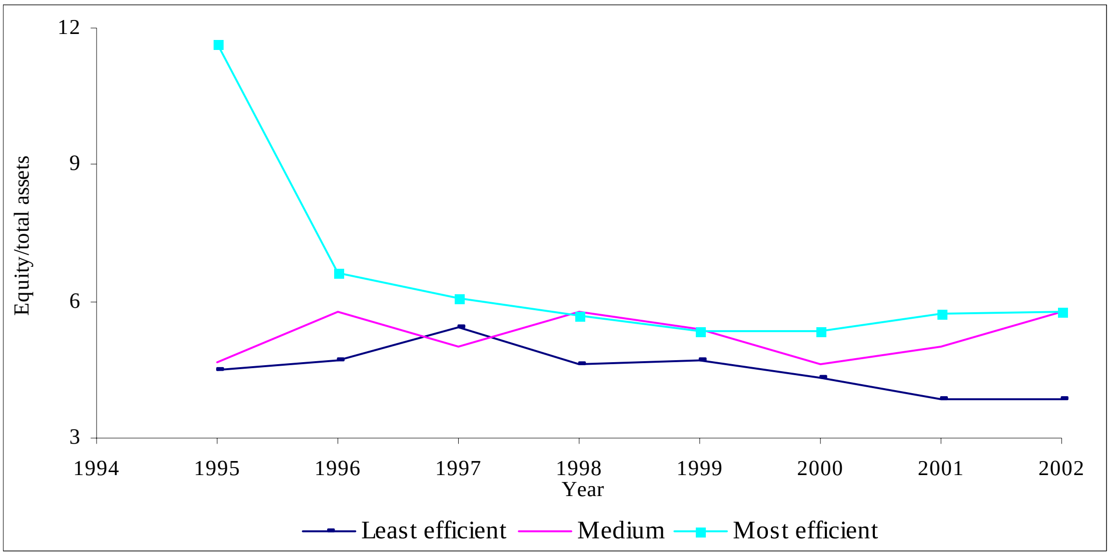

Figure 4. Average efficiency by size (VRS-input oriented)