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# Productive Performance Evaluation of the Banking Sector in India Using Data Envelopment Analysis

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***Abstract***—This paper attempts to examine, using data envelopment analysis, the productivity performance trends of the Indian commercial banks for the period: 1997-98 – 2004-05. Our broad empirical findings are indicative in many ways. First, the increasing average annual trends in technical efficiency for all ownership groups indicate an affirmative gesture about the effect of the reform process on the performance of the Indian banking sector. Second, the higher cost efficiency accrual of private banks over nationalized banks indicate that nationalized banks, though old, do not reflect their learning experience in their cost minimizing behavior due to X-inefficiency factors arising from government ownership. This finding also highlights the possible stronger disciplining role played by the capital market indicating a strong link between market for corporate control and efficiency of private enterprise assumed by property right hypothesis. And, finally, concerning the scale elasticity behavior, the technology and market-based results differ significantly supporting the empirical distinction between returns to scale and economies of scale, often used interchangeably in the literature.

***Keywords***—Banks, Efficiency, Scale elasticity, Data envelopment analysis

## 1. INTRODUCTION

There is a widely held general belief that competition, a driving force behind numerous important policy changes, exerts downward pressure on costs, reduces slacks, provides incentives for the efficient organization of production, and even drives innovation forward. However, the empirical evidence in its favor is mix. We in this paper analyze productivity performance of banking sector in India, looking particularly at the impact of competition on both the level and growth of productivity performance. Productivity performance is measured here through efficiency and scale economies, as these two are perceived to be the two most important key issues in the banking literature.

For a growing economy like India the faster growth of the industrial sector critically depends on an efficient and liberal market-oriented financial policies, and hence the Indian banking sector is selected for empirical illustration. The Indian financial sector, which had been operating in a closed and regulated environment, underwent a radical change during the nineties. To induce efficiency and competition into the system, Reserve Bank of India (RBI) initiated in 1992 a number of reforms such as entry deregulation, branch delicensing, deregulation of interest rates, and allowing public sector banks to raise up to 49% of their equity in the capital market, which all gave rise to the heightened competitive pressure in the banking industry. These changes came in the form of greater use of automatic teller machines and internet banking, huge increase in housing and consumer credit, stronger and more transparent balance sheets and product diversification. A significant intent of these policies is to have a radical transformation in the operating landscape of the Indian banks. In this scenario we believe that banks in India are in the pursuit of enlarging their size using available scale economies in order to enhance their asset base and profit so as to meet with the global standard.

Also important is to examine the issues of efficiency and scale elasticity behavior of banking sector across the entire spectrum of ownership groups that might yield valuable information concerning productivity differentials across ownership groups. This will enable us to verifying the issue of economic linkage of ownership vis-à-vis performance in the light of property right hypothesis (Alchian (1965) and de Alessi (1980)) and public choice theory (Nickskamen (1971) and Levy (1987)). As per property right hypothesis, private enterprises should perform more efficiently and more profitably than public enterprises, i.e., there is a strong link between the market for corporate control and efficiency of private enterprise, which precisely holds for developed countries where capital market functions well. However, in the absence of well-functioning capital markets in developing country, the

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Indian banking industry could provide a test for performance differential across the entire ownership groups arising from studying efficiency and scale economies behavior so as to examine whether reforms process are working. Against this backdrop, it is of interest to examine the efficiency and scale elasticity behavior of commercial banks having a minimum level of retail presence in India with respect to ownership in the light of financial sector reforms.

We have used the nonparametric approach called data envelopment analysis (DEA) for the simple reason that it does not require specification of arbitrary functional forms, and it has the natural advantage of eliminating the effects of all productive and scale inefficiencies prior to calculating scale economies. Applications of DEA in banking sector in developed countries are enormous, but, in developing countries, are modest[1]. Several authors[2] have compared the efficiency of the Indian banks with that of those in other countries. Previously though, Tyagarajan (1975), Subramanyam (1993) and Rangarajan and Mampillly (1972) have examined various issues relating to the performance of banks in India, none of these studies have examined the efficiency of banks' service provision. Bhattacharyya et al. (1997) used DEA methodology to study the consequences of liberalization on the performance of the banking sector in India. This study considered 70 banks for the period 1986 to 1991. Hence, no estimates were available after the reform initiation period. Moreover, during that period the Indian private sector banks were yet to establish themselves entirely whereas the public sector banks were well recognized. Hence, it is expected that the public sector banks were outperforming the rest during that regime.

Rammohan and Ray (2004) used DEA technique to compare the revenue efficiencies of the public, private and foreign sector banks in India during the period 1992-2000. Using operational data on inputs (deposits and operating cost) and outputs (loans, investments and other income), they found significant difference in performance between the public and private sector, whereas between the public sector and foreign banks, the results were comparable. Sathey (2003) analyzed using DEA the efficiency of Indian banking sector in the year 1997-98 using both the financial and operational models of the intermediation approach. Das et al. (2004) used the operational side of the intermediation approach to examine the effects of liberalization on the efficiency of banks for the period: 1997-98 – 2002-03. The problem with their approach is that they considered constructing annual DEA frontiers to analyze various efficiency changes over time where the information on trends in performance would not be available, since the benchmarks would likely change from year to year. This problem would have been overcome, had they used the panel data to construct a 'grand frontier', which Bhattacharyya et al. (1997) had used in their study.

However, the research efforts in these studies have failed to throw light on one important issue, i.e., scale elasticity, and its linkage with cost efficiency. There is no such study, to our knowledge, that employed DEA in evaluating the productive performance in terms of technical efficiency, cost efficiency and scale elasticity for the banking sector in India. This present study, using the panel data, utilizes the different variants of DEA models to evaluate the same for the period: 1997-98 – 2004-05.

The rest of the paper proceeds as follows: Section 2 not only discusses the current state of the Indian banking sector describing how it has altered in the recent past, but also puts the main arguments highlighting especially the question of efficiency. Section 3 deals with the DEA methodology wherein the detailed computational procedures for efficiency, returns to scale, and economies of scale are elaborated. The data concerning the selection of inputs and outputs, and their sources are provided in Section 4. Section 5 presents the results of the empirical analysis, and Section 6 concludes.

## 2. AN OVERVIEW OF INDIAN BANKING SYSTEM

The banking sector in India is broadly divided into two groups: commercial banks and co-operative banks. On the basis of ownership mold, commercial banks are grouped into three categories - state owned or public sector banks (PSBs), private banks under Indian ownership and foreign banks. There are 27 PSBs, which all account for 80 per cent of commercial banking asset.

At the top of the banking system is the Reserve Bank of India (RBI). RBI is the central bank of the country entrusted with monetary stability, management of currency and supervision of financial as well as payments system. Established in 1935, its functions and focus have evolved in response to the changing economic environment. Its history is intrinsically interwoven with the economic and financial history of the country.

The financial structure in India in 1950s was convincingly liberal. It had restricted control on interest rates and had low statutory preemption on funds. The All–India Rural Survey Committee observed that out of total borrowings of Rs.750 billion for cultivators in 1951-52, both agriculturalist and professional money lenders accounted for 24.9% and 44.8%, respectively. Hence, it shows unequal distribution of bank credit, which ascertains the lack of ability of the market to efficiently allocate resources. In retort, to ensure adequate flow of credit into indisputably productive activities in conformance with the planned priorities, the Government tightened its control over the credit allocation process.

[1]Leightner and Lovell (1998), Shyu (1998), Gilbert and Wilson (1998) and Hao et al. (2001) are the few authors who have carried out studies related to the Asian banking sector.

[2]For example, see Bhattacharyya et al. (1997), Chatterjee (1997) and Saha and Ravishankar (2000).

Some further measures, viz., control of lending rates, raising liquidity requirements and establishment of a system of development banks for serving the assorted segments of industry and agriculture, were also introduced. This process ended up in nationalization of 14 largest commercial banks in 1969 and subsequently six more in 1980, and in 1993 it leads to the merger of two banks. Reforms in India in mid-1991 heralded a new era in the economic history of our country. Certain reforms in the financial sector were put through even before the onset of economic reforms in 1991. These measures were taken in 1985 based on the report of Sukhmoy Chakravarthi, an expert committee constituted by RBI.

This Committee initiated the process of financial sector reforms in the country. This was followed by the report of the working group headed by Mr. N. Vaghul in 1985. This is in the form of a follow-up report of the earlier Sukhmoy Chakravarthi Committee Report. After the introduction of economic reforms in 1991, the recommendations of the Narasimhan Committee in 1997 provided the impetus for further initiatives. A second report submitted by Mr. Narasimhan in 1987 signaled the need for the 2nd phase of financial and banking sector reforms.

The main objectives of the financial sector reforms were to widen, deepen and integrate the different segments of financial sector, viz., the money market, debt market and foreign exchange market. The Sukkmoy Chakravarthi Committee made several recommendations for the development of money and government securities markets. The noteworthy developments in the financial system include, among others, restricting the call, notice, term money market as a pure inter-bank market with additional access only to primary dealers, phasing out non-bank participants by granting permission to operate in repo market, smoothening the maturity structure of debt, improving the liquidity of government securities, phased reduction in SLR requirements from an effective 37.4 per cent in March 1992 to a little over 28 per cent in March 1996, activating the Repo market by allowing repos/reverse repos transactions in all government securities.

Non performing assets (NPA) has not only affected the profitability, liquidity and competitive functioning of PSBs, but also the psychology of bankers in respect of their disposition towards credit delivery and credit expansion. Between 01.04.93 to 31.03.2001 Commercial banks incurred a total amount of Rs.31251 crores towards provisioning NPA. This has brought Net NPA to 6.2% of net advances. To this extent the problem is contained, but at a cost. This costly remedy is made at the sacrifice of building healthy reserves for future capital adequacy. NPA is not merely non-remunerative but also cost absorbing and profit eroding.

In the context of intense competition, the weak banks are at disadvantage for leveraging the rate of interest in the deregulated market and securing remunerative business growth. This is the margin between cost of resources employed and return there from. When interest rates were directed by RBI, there was no option for banks. But, today, in the deregulated market, banks decide on their lending and borrowing rates. In the competitive money and capital markets, the inability to offer competitive market rates adds to the disadvantage of marketing and building new business. In the face of the deregulated banking industry, an ideal competitive working will be reached when the banks are able to earn adequate amount of non-interest income to cover their entire operating expenses. In this case, the spread factor i.e. the difference between the gross interest income and interest cost will constitute its operating profits. Theoretically, even if the bank keeps 0% spread, it will still break even in terms of operating profit and not return on operating loss. The net profit is the amount of the operating profit minus the amount of provisions to be made including for taxation. On account of the burden of heavy NPA, many nationalized banks have little option, and they are unable to lower lending rates competitively, as a wider spread is necessitated to cover cost of NPA in the face of lower income from off balance sheet business yielding non-interest income.

NPA affects the liquidity of nationalized banks even though they (except Indian Bank) are able to meet norms of capital adequacy. The fact that their net NPA on the average is as much as 7%, is a potential threat for them. RBI has indicated the ideal position as Zero percent Net NPA. Even granting 3% net NPA within limits of tolerance the nationalized banks are holding an uncomfortable burden at 7.1% as on March 2001. They have not been able to build additional capital needed for business expansion through internal generations or by tapping the equity market, but have resorted to II-Tier capital in the debt market or looking forward towards capital to be granted by Government of India. Banks in the process of financial intermediation are confronted with various kinds of financial and non-financial risks. These risks are highly interdependent, and events that affect one area of risk can have ramifications for a range of other risk categories. It therefore becomes very essential for the top management to attach considerable importance to improve the ability to identify, measure, monitor and control the overall level of risks undertaken.

Decades before the reforms, the exercise of risk assessment and risk management were never seriously considered, as banks were operating in a captive economy. Since 1998 RBI has been giving serious attention towards evolving suitable and comprehensive models for risk-management, and to integrate this new discipline in the working systems of banks to enhance operational efficiency. In this circumstance, efficiency assumes decisive importance aligned with setting of competitive viability and improved performance in future.

## 3. METHODOLOGY

We deal with $n$ banks; each bank uses $m$ inputs to produce s outputs. For each bank $o$ ($o$ = 1, 2, …, $n$), we denote, respectively, the input and output vectors by $x_o \in R^m$ and $y_o \in R^s$. The corresponding input/output matrices are defined by $X = (x_1, x_2, \ldots, x_n) \in R^{m \times n}$ and $Y = (y_1, y_2, \ldots, y_n) \in R^{s \times n}$. Let the input and output price vectors be, respectively, $w_o \in R^m$ and $p_o \in R^s$., and the corresponding input and output price matrices are defined, respectively, by $C = (w_1, w_2, \ldots, w_n) \in R^{m \times n}$ and $P = (p_1, p_2, \ldots, p_n) \in R^{s \times n}$.

The technology ($T$) is defined as the set of all feasible input-output vectors, i.e., $T \equiv \{(x, y): x \text{ can produce } y\}$. The standard neoclassical characterization of technology involving multiple inputs and outputs is the transformation function $\psi(x, y)$, which exhibits the following properties:

$$\psi(x, y) = 0, \ \frac{\partial \psi(x, y)}{\partial y_r} < 0 \ (\forall r) \ and \ \frac{\partial \psi(x, y)}{\partial x_i} > 0 \ (\forall i)$$

Alternatively, $T$ can be described by its input set $L(y)$ or output set $P(x)$, defined, respectively, as $L(y) \equiv \{x: (x, y) \in T\}$ for all $y$, and $P(x) \equiv \{y: (x, y) \in T\}$ for all $x$.

$T$ can also be represented by the input/output distance functions (which are due to Shephard (1970)), defined, respectively, as $D_i(x, y) \equiv \sup \{\theta: \theta x \in L(y), \theta > 0\}$ and $D_o(x, y) \equiv \inf\{\delta: y/\delta \in P(x), \delta > 0\}$.

### 3.1 Efficiency

The input technical efficiency ($TE_i$), defined as the ratio of minimum input $\theta x$ to actual input $x$, is nothing but $D_i(x, y)$ itself. Similarly, the output technical efficiency ($TE_o$), defined as the ratio of actual output $y$ to potential output $y/\delta$, is nothing but $D_o(x, y)$ itself. The corresponding price measures of efficiency are, respectively, the cost and revenue efficiency. Cost efficiency (CE) is defined as the ratio of actual cost ($w.x$) to $C(y, w)$ where $C(y, w) = \min_x\{w.x: x \in L(y)\}$ is the minimum cost of producing $y$, given the input price vector $w$. Revenue Efficiency (RE) can be analogously defined as the ratio of actual revenue ($p.y$) to $R(x; p)$ where $R(x; p) = \max_y\{p.y: y \in P(x)\}$ is the maximum revenue of selling $y$, given the output price vector $p$. For various concepts of efficiency and their best treatments in economics, see among others, Färe et al. (1985), Sengupta (2000, 2003) and Ray (2004).

### 3.2 Scale elasticity

#### 3.2.1 Scale elasticity in primal form

The returns to scale (RTS)/scale elasticity (SE) in production is defined as the ratio of the maximum proportional ($\beta$) expansion of outputs to a given proportional ($\alpha$) expansion of inputs. So, on differentiation of $\psi(\alpha x, \beta y) = 0$ with respect to scaling factor $\alpha$, and then equating it with zero yields the following local $SE$ measure $\rho_p$:

$$\rho_p(x, y) \equiv -\sum_{i=1}^{m} x_i \frac{\partial \psi}{\partial x_i} \Bigg/ \sum_{r=1}^{s} y_r \frac{\partial \psi}{\partial y_r} \tag{1}$$

See Hanoch (1970), Starrett (1977), Panzar and Willig (1977) and Baumol et al. (1982) for the detailed discussions.

In the case of single input and output technology, $\rho_p$ is simply expressed as the ratio of marginal product (MP) to average product (AP), i.e., $\rho_p(x, y) \equiv MP/AP = (dy/dx)/(y/x)$

Färe et al. (1988) redefine $\psi(x, y)$ in terms of $D_i(x, y)$ as $\psi(x, y) = D_i(x, y) - 1 = 0$, which yields the following measure of SE (Färe et al. (1986)):

$$\rho_{p(i)}(x, y) = D_i(x, y) \Bigg/ \sum_{r=1}^{s} \frac{\partial D_i(x, y)}{\partial y_r} y_r \tag{2}$$

Analogously, they define scale elasticity in terms of output distance function as

$$\rho_{p(o)}(x, y) = \sum_{i=1}^{m} \frac{\partial D_o(x, y)}{\partial x_i} x_i \Bigg/ D_o(x, y) \tag{3}$$

(Local) RTS is increasing, constant and decreasing if $\rho(x, y) > 1$, $\rho(x, y) = 1$ and $\rho(x, y) < 1$ respectively (we omit subscripts here to mean any of these three scale elasticity).

#### 3.2.2 Scale elasticity in dual form

Following Panzar and Willig (1977), the dual measure of SE in cost, $\rho_c(w, y)$ is defined as

$$\rho_c(y;\ w) = C(y; w) \Bigg/ \sum_{r=1}^{s} y_r \frac{\partial C(y; w)}{\partial y_r} \tag{4}$$

In the case of single output, $\rho_c$ can be expressed as the ratio of average cost (AC) to marginal cost (MC). Economies of scale exist if $\rho_c > 1$, diseconomies of scale exist if $\rho_c < 1$, and there is neither economies nor diseconomies if $\rho_c = 1$. However, the duality relationship between $C(y, w)$ and $D_i(x, y)$ suggests that SE in both production and cost environments are the same, i.e.,

$$\begin{aligned} \rho_c(y;\ w) &= C(y; w) \Bigg/ \sum_{r=1}^{s} y_r \frac{\partial C(y; w)}{\partial y_r} \\ &= \rho_{p(i)}(x, y) = D_i(x, y) \Bigg/ \sum_{r=1}^{s} \frac{\partial D_i(x, y)}{\partial y_r} y_r \end{aligned} \tag{5}$$

Similarly, the duality relationship between $R(x; p)$ and $D_o(x, y)$ says that SE in both revenue and production environment are the same, i.e.,

$$\begin{aligned} \rho_r(x;\ p) &= \sum_{i=1}^{m} \frac{\partial R(x;\ p)}{\partial x_i} x_i \Bigg/ R(x;\ p) = \rho_{p(o)}(x, y) \\ &= \sum_{i=1}^{m} \frac{\partial D_o(x, y)}{\partial x_i} x_i \Bigg/ D_o(x, y) \end{aligned} \tag{6}$$

See Färe and Primont (1995) for proof of these two duality theorems.

### 3.3 DEA models to evaluating efficiency[3] and SE

#### 3.3.1 Scale elasticity in primal measure

The dual of the input-oriented Banker, Charnes and Cooper (BCC) model (Banker et al, 1984), which is based on the assumption of variable returns to scale (VRS), is used for obtaining SE in production of bank '*o*' as follows:

$$\begin{aligned} D_i(x_o, y_o) &= \max \sum_{i=1}^{m} u_r y_{ro} + u_o \\ s.t.\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_o \le 0,\ (\forall j), \\ & \sum_{r=1}^{s} v_i x_{io} = 1,\ u_r,\ v_i\ \ge\ 0, \text{ and } u_o:\ \text{free} \end{aligned} \tag{7}$$

If the bank '*o*' is efficient, then it holds that

$$D_i(x_o, y_o) = \sum_{r=1}^{s} u_r^* y_{ro} + u_o^* = 1 \tag{8}$$

On differentiation of $D_i(x_o, y_o)$ with respect to $y_{ro}$ yields

$$\frac{\partial D_i(x_o, y_o)}{\partial y_{ro}} = u_r^* \tag{9}$$

Now, using (2) SE[4] of bank '*o*' in production, $\rho_{i(p)}$ can be obtained as:

$$\begin{aligned} \rho_{p(i)} &= D_i(x_o, y_o) \Big/ \sum_{r=1}^{s} \frac{\partial D_i(x_o, y_o)}{\partial y_{ro}} y_{ro} \\ &= D_i(x_o, y_o) \Big/ \sum_{r=1}^{s} u_r^* y_{ro} = 1/(1 - u_o^*) \end{aligned} \tag{10}$$

However, if bank '*o*' is inefficient, then $\rho_{p(i)}$ equals $(D_i(x_o, y_o)/(D_i(x_o, y_o) - u_o^*))$. RTS is increasing, constant and decreasing if $u_o^* > 0$, $u_o^* = 0$ and $u_o^* < 0$, respectively. However, when model (7) suffers from the problem of multiple optima, one can then compute lower and upper bounds of $\rho_{p(i)}$ to arrive at average SE. See Sueyoshi (1997, 1999) for the details.

#### 3.3.2 Scale elasticity in dual measures: Cost and revenue DEA models

The following dual of the VRS [Cost] DEA model:

$$\begin{aligned} C(w; y) &= \max \sum_{r=1}^{s} u_r y_{ro} + \omega_o \\ s.t.\ & -\sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} u_r y_{rj} + \omega_o \le 0,\ (\forall j), \\ & v_i \le w_i,\ (\forall i),\ u_r,\ v_i\ \ge\ 0,\ (\forall r,\ i),\ \omega_o:\ \text{free} \end{aligned} \tag{11}$$

to compute SE of bank '*o*' in cost environment as follows:
If the bank '*o*' is efficient, then it holds that

$$C(y; w)\ =\ \sum_{r=1}^{s} u_r^* y_{ro} + \omega_o^* \tag{12}$$

Then, using (4) SE of bank '*o*' can be obtained as

$$\rho_c(y; w) = C(y; w) \Big/ \sum_{r=1}^{s} u_r^* y_{ro} = 1 \Big/ \left[1 - (\omega_o^* / C(y; w))\right] \tag{13}$$

Bank '*o*' exhibits economies of scale/no economies/ diseconomies of scale when $\omega_o^*$ is greater than/equal to/less than zero, respectively. See Sueyoshi (1997, 1999) for the case of multiple optimal solutions.

The following dual of the VRS [Revenue] DEA model:

$$\begin{aligned} R(x_o; p_o) &= \min \sum_{i=1}^{m} v_i x_{io} + \delta_o \\ s.t.\ & \sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} + \delta_o \ge 0,\ (\forall j), \\ & u_r \ge p_r,\ (\forall r),\ u_r,\ v_i\ \ge\ 0,\ (\forall r,\ i),\ \delta_o:\ \text{free} \end{aligned} \tag{14}$$

to compute SE of bank '*o*' in revenue environment as follows:
The objective function of (14) can be expressed as

$$R(x_o; p_o)\ =\ \sum_{i=1}^{m} v_i^* x_{io} + \delta_o^* \tag{15}$$

Then, using (6) SE for bank '*o*' in revenue environment can be obtained as

$$\begin{aligned} \rho_r(x_o; p_o) &= \sum_{i=1}^{m} v_i^* x_{io} \Big/ R(x_o; p_o) = \\ (R(x_o; p_o) - \delta_o^*) \big/ R(x_o; p_o) &= 1 - (\delta_o^* \big/ R(x_o; p_o)) \end{aligned} \tag{16}$$

### 3.4 Alternative measures of scale elasticity

The above [Cost] and [Revenue] DEA models suffer from two problems: 1) SE in production ($\rho_{p(i)}/\rho_{p(o)}$) does not differ from its dual counterpart, i.e., cost/revenue

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[3]Due to lack of space, we are excluding here the discussion on standard DEA models, viz., BCC and Cost efficiency models for technical and cost efficiency measurements. Refer to Cooper et al. (2000) for their detailed discussion.

[4]Several authors (Färe et al. (1988), Førsund (1996), Fukuyama (2001), Sueyoshi (1997, 1999)) have derived this same scale elasticity formula in (10) in different ways. Tone and Sahoo (2004) have employed this approach to measure SE in production in the presence of congestion.

elasticity ($\rho_c/\rho_r$), thus giving the illusion that RTS and economies of scale are the one and the same[5]; and 2) this cost/revenue model declares a cost/revenue inefficient DMU as efficient.

Note that in [Cost] DEA model where input prices are held constant, the cost structure is based on its underlying technology $L(y)$ where increasing returns to scale implies economies of scale. Similarly, in [Revenue] DEA model where output prices are held constant, the revenue structure is entirely determined from its underlying technology $P(x)$ where both production and revenue elasticities are the same. However, since the input/output market is typically imperfect, these two concepts can no longer be the same[6]. See Sahoo et al. (1999) and Tone and Sahoo (2003) for the historical distinction between these two concepts, and Tone and Sahoo (2005, 2006) for empirical measurements..

Concerning the evaluation of CE, Tone (2002) points out that if any firms, $A$ and $B$ have the same amount of inputs and outputs, i.e., $x_A = x_B$ and $y_A = y_B$, and the unit input price of firm $A$ is twice that of firm $B$ for each input, i.e., $w_A = 2w_B$, then both firms exhibit the same CE. Similarly, concerning RE evaluation, if any two firms, $A$ and $B$, have the same amount of inputs and outputs, i.e., $x_A = x_B$ and $y_A = y_B$, and the unit output price of firm $A$ is twice that of bank $B$ for each output, i.e., $p_A = 2p_B$, then both firms exhibit the same RE.

It is thus imperative to recognize that other than technological factors, banks' cost/revenue structures are influenced by pecuniary factors as well, thus aiming atreducing/increasing cost/revenue without which scale elasticity information based on [Cost]/[Revenue] DEA models are potentially misleading. In the light of imperfect input/output markets where non-linear scale line is increasingly common, we therefore argue to consider alternative models to estimate scale elasticity, which can provide important insights concerning scale economies behavior not only to managers when making operational decisions, but also to policy makers debating on regulatory issues.

### 3.4.1 Scale elasticity in cost environment

We discuss the empirical evaluation of SE of bank '*o*' whose input and output considered are, respectively, total cost ($c_o$) and $y_o = (y_{1o}, y_{2o}, ..., y_{5o})$. Here, $c_o = \sum_{i=1}^{m} w_{ij} x_{ij}$. One needs first to run the following output-oriented linear programming (LP):

$$\theta^* = \max\ \theta$$

$$s.t.\ \sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ = \theta\, y_{ro},\ (\forall r),\ \sum_{j=1}^{n} c_j\lambda_j + s^- = c_o, \qquad (17)$$

$$\sum_{j=1}^{n}\lambda_j = 1,\ \lambda_j \ge 0$$

If the bank '*o*' is efficient, then $\theta^* = 1$, then the minimum cost $(c_o^*)$ for producing output vector $y_o$, is obtained from the following LP:

$$c_o^* = \min\ \sum_{j=1}^{n} c_j\lambda_j$$

$$s.t.\ \sum_{j=1}^{n} y_{rj}\lambda_j \ge y_{ro},\ (\forall r),\ \sum_{j=1}^{n}\lambda_j = 1,\ \lambda_j \ge 0 \qquad (18)$$

Let the optimal solutions be $c_o^*$ and $\lambda_j^*$. The dual of (18) can be expressed as

$$\max\ \sum_{r=1}^{s} u_r y_{ro} + \sigma_o\ \ s.t.\ \sum_{r=1}^{s} u_r y_{rj} + \sigma_o \le c_j,\ (\forall j),$$
$$u_r \ge 0\ (\forall r) \text{ and } \sigma_o:\ \text{free} \qquad (19)$$

Let the optimal solution of (19) be $u_r^*$ $(\forall r)$ and $\sigma_o^*$. At the optimum, the objective function values of (18) and (19) are same. That is,

$$c_o^* = \sum_{r=1}^{s} u_r^* y_{ro} + \sigma_o^* \qquad (20)$$

Using formula (4), SE of bank '*o*' can be obtained as

$$\rho_{c(N)} = c_o^* \Big/ \sum_{r=1}^{s} y_r(\partial c_o^* / \partial y_{ro}) = c_o^* \Big/ \sum_{r=1}^{s} u_r^* y_{ro}$$
$$= c_o^* \big/ (c_o^* - \sigma_o^*) = 1 \big/ (1 - (\sigma_o^* / c_o^*)) \qquad (21)$$

Bank '*o*' exhibits economies of scale/no economies/ diseconomies of scale if $\sigma_o^*$ is greater than/equal to/ less than zero, respectively.

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[5]RTS and economies of scale are the same under two conditions: 1) input/output prices are exogenous, and 2) technology structure is homothetic.

[6]When input market is imperfect where input demand is inversely related to its price, the production and cost elasticities are different, i.e., $\rho_c = \frac{dy/y}{(1-|\varepsilon_w|)(dw/w)} = \frac{dy/y}{(1-(1/|\varepsilon_w|))(dx/x)} = \frac{|\varepsilon_w|}{(1-|\varepsilon_w|)}\rho_p$ where $\varepsilon_w$ is input price elasticity of demand. Similarly, when output market is imperfect where output demand is inversely related to its price, production and revenue elasticities are different, i.e., $\rho_r = \frac{dr/r}{dx/x} = \frac{d(py)/py}{dx/x} = \left(1 - \frac{1}{|\varepsilon_p|}\right)\rho_p$, where $\varepsilon_p$ is the output price elasticity of demand.

However, if bank '*o*' is inefficient (i.e., $\theta^* < 1$ in (17)), then one first needs to find out the following projections:

$$y_{ro} \to \theta^* y_{ro} + s_r^{+*} \ (\forall r), \ and \ c_o \to c_o - s^{-*} \quad (22)$$

Using these projected data, one needs to run the model (19) to compute $\rho_c(N)$. However, in case of multiple optima, one can compute lower and upper bounds of $\rho_c(N)$ to arrive at average SE. For details on this cost DEA model, see Tone and Sahoo (2005, 2006).

### 3.4.2 Scale elasticity in revenue environment

Each bank '*o*' ($o$ = 1, 2, …, $n$) is associated here with revenue ($r_o$) with input vector $x_o = (x_{1o}, x_{2o}, ..., x_{mo})$ where $r_o = \sum_{r=1}^{s} p_{ro} y_{ro}$ The maximum revenue of bank '*o*' can be obtained from the following LP:

$$\begin{aligned} r_o^* &= \max \sum_{j=1}^{n} r_j \lambda_j \\ s.t. &\sum_{j=1}^{n} x_{ij} \lambda_j \le x_{io}, \ (\forall i), \ \sum_{j=1}^{n} \lambda_j = 1, \ \lambda_j \ge 0 \end{aligned} \quad (23)$$

Let the optimal solutions be $r_o^*$ and $\lambda_j^*$. The dual of (23) can be expressed as:

$$\begin{aligned} &\min \sum_{i=1}^{m} v_i x_{io} + \psi_o \\ &s.t. \sum_{i=1}^{m} v_i x_{ij} + \psi_o \ge r_j, \ (\forall j), \ (\forall i) \text{ and } \psi_o : \text{ free} \end{aligned} \quad (24)$$

which can be used to calculate SE. Let the optimal solution to model (24) be $v_i^*$ and $\psi_o^*$. At the optimum, the objective function values of (23) and (24) are same. That is,

$$r_o^* = \sum_{i=1}^{m} v_i^* x_{io} + \psi_o^* \quad (25)$$

Using formula (6), SE of bank '*o*' can be obtained as

$$\begin{aligned} \rho_{r(N)} &= \sum_{i=1}^{m} \frac{\partial r_o^*}{\partial x_i} x_i \Big/ r_o^* = \sum_{i=1}^{m} v_i^* x_{io} \Big/ r_o^* \\ &= (r_o^* - \psi_o^*) \big/ r_o^* = 1 - (\psi_o^* \big/ r_o^*) \end{aligned} \quad (26)$$

Bank '*o*' exhibits economies of scale/no economies/ diseconomies of scale if $\psi_o^*$ is less than/equal to/greater than zero, respectively. However, in case of multiple optima, one can, in the spirit of Tone and Sahoo (2005, 2006), compute the lower and upper bounds of $\rho_{r(N)}$ to arrive at average SE.

### 3.4.3 Scale elasticity in cost-revenue environment

One can use a DEA model in which each bank '*o*' is associated with one input, i.e., ($c_o$) and one output i.e., ($r_o$) where $c_o = \sum_{i=1}^{m} w_{ij} x_{ij}$ and $r_o = \sum_{r=1}^{s} p_{ro} y_{ro}$ for all $o$. The maximum revenue of bank '*o*' can be obtained from the following LP:

$$\begin{aligned} r_o^* &= \max \sum_{j=1}^{n} r_j \lambda_j \\ s.t. &\sum_{j=1}^{n} c_j \lambda_j \le c_o, \ \sum_{j=1}^{n} \lambda_j = 1, \ \lambda_j \ge 0 \end{aligned} \quad (27)$$

The scale elasticity in cost-revenue environment can be obtained from the dual of (34), which is given below:

$$\begin{aligned} &\min \ vc_o + \xi_o \\ &s.t. \ vc_j + \xi_o \ge r_j, \ (\forall j), \text{ and } \xi_o : \text{free} \end{aligned} \quad (28)$$

Let the optimal solution to (28) be $v^*$ and $\xi_o^*$. At the optimum, the objective function values of models (27) and (28) are same. That is,

$$r_o^* = v^* c_o + \xi_o^* \quad (29)$$

So, from (29) SE of bank '*o*' can be obtained as:

$$\begin{aligned} \rho_{cr} &= (dr_o^* / dc_o) \big/ (r_o^* / c_o) = v^* c_o \big/ r_o^* \\ &= (r_o^* - \xi_o^*) \big/ r_o^* = 1 - (\xi_o^* \big/ r_o^*) \end{aligned} \quad (30)$$

Bank '*o*' exhibits economies of scale/no economies/diseconomies of scale if $\xi_o^*$ is less than/equal to/greater than zero, respectively. In case of multiple optima, in the spirit of Tone and Sahoo (2005, 2006), one can compute the lower and upper bounds of $\rho_{cr(N)}$ so as to arrive at average SE.

Note that in case of single input and single output, *SE* in cost-revenue vis-à-vis production environment can be related as:

$$\begin{aligned} \rho_{cr} &= (dr/r)/(dc/c) \\ &= \left( \left[ 1 - \left( 1/|\varepsilon_p| \right) \right] \Big/ \left[ 1 - \left( 1/|\varepsilon_w| \right) \right] \right) \rho_p \end{aligned} \quad (31)$$

and, in case of multiple input and output, the above relationship can be expressed as

$$\begin{aligned} \rho_{cr} &= \frac{dr/r}{dc/c} = \frac{d\left( \sum_{r=1}^{s} p_r y_r \right) \Big/ \sum_{r=1}^{s} p_r y_r}{d\left( \sum_{i=1}^{m} w_i x_i \right) \Big/ \sum_{i=1}^{m} w_i x_i} \\ &= \frac{\sum_{r=1}^{s} \left[ 1 - (1/|\varepsilon_{p_r}|) \right] (dy_r / y_r) s_r}{\sum_{i=1}^{m} \left[ 1 - (1/|\varepsilon_{w_i}|) \right] (dx_i / x_i) s_i} \end{aligned} \quad (32)$$

where $s_r$ and $s_i$ are, respectively, the *r*th output's revenue share and ith input's cost share, i.e., $s_r = p_r y_r / \sum_{r=1}^{s} p_r y_r$ and $s_i = w_i x_i / \sum_{i=1}^{m} w_i x_i$ .

## 4. THE INDIAN COMMERCIAL BANK DATA

There has been debate concerning what banks produce (outputs) and what resources (inputs) banks consume in that process. In the literature, there are two approaches: production approach and intermediation approach, to measure bank efficiency. In the former, Ferrier and Lovell (1990) use capital, labor and other non-financial inputs to provide deposits and advances. In the latter, however, a bank is treated as a producer of intermediation services - by transforming risk and maturity profile of funds received from depositors to investment or loan portfolio of different risk and maturity profile. Banks also provide services for which specific charges are levied, money value of non-interest income is considered another output variable. To sum up, banks in general are considered to have three outputs: Investments (I), performing loan assets (PLA) and non-interest income (NonII), and three inputs: borrowed funds (BF), labor (L) and fixed assets (FA). See Berger and Mester (1997) for a comprehensive discussion of these two approaches.

Besides being profit driven, banks are also forced to take up economic and social responsibilities like safety of customers, financing much needed public sector expenditure in various social and economic services, and this study, therefore, adopted the intermediation approach. More importantly, the essence of taking PLA, as an output measure is more realizable in Indian context, because only earning asset contributes to revenue of bank and not total loan. This approach is effective in analyzing management's success. Coates (1990) also provides a comprehensive description of the objectives of the Indian banking system for which production approach seems to be inappropriate. All the monetary values of inputs and outputs have been deflated using wholesale price index deflator with base 1993-94.

Concerning the prices of inputs and outputs, the unit prices of the inputs: 'borrowed funds', 'labor' and 'fixed assets' are, respectively, the 'average interest paid per rupee of borrowed funds', [(*w*) *BF*], 'average staff cost', [(*w*) *L*], and 'non-labor operational cost per rupee amount of fixed asset', [(*w*) *FA*]; and outputs: 'investments', 'performing loan assets' and 'non-interest income' are, respectively, the 'average interest earned on per rupee unit of investment', [(*p*) *I*], 'average interest earned on per rupee unit of performing loan assets', [(*p*) *PLA*], and 'non-interest fee-based income on per rupee of working funds, [(*p*) *NonII*]. The input and output data as well as their prices have been taken from the various sections of 'Statistical Tables Relating to Banks in India', Reserve bank of India and from Indian Banking Association publications. The relevant data are downloaded from http://www.rbi.org.in/rbi-sourcefiles/annualdata/bs_annualdata.aspx.

Our study covers eight years commencing from the financial year 1997-98. This is the year in which competition intensifies in the banking industry with a total of around 100 banks, a shift from around 80 banks in the preceding years[7]. The Regional Rural Banks have their operations limited to a few contiguous districts and mostly serve credit to local farmers and a few small-scale enterprises. Because these banks operate for some special purpose, and provide service to a small target group, they have been excluded from our study to avoid inconsistencies. Since data are not available for all the banks for all the years, we have considered a balanced panel data on 81 banks (26 nationalized banks (NB), 29 Indian private banks, *PB*(*I*) and 26 foreign banks, *PB*(*F*)) over a period of eight years: 1997-98 – 2004-05. In the spirit of Bhattacharyya et al. (1997), each bank's annual performance is treated here a distinct bank. So, we have in total 648 (= 81 * 8) commercial banks in our sample period to construct a single 'grand frontier,' which provides a benchmark against which to calculate the efficiency of each bank in each year[8].

## 5. RESULT AND DISCUSSION

The analysis of efficiency on the input-side[9] is becoming increasingly common in DEA applications for a variety of reasons. First, real world managers are never given a bundle of inputs and told to produce the maximum output from it. Instead they are given output targets and told to produce it most efficiently. Second, profitability in any business hinges on the efficiency of operations. But if the business involves a commodity, then what depends on efficient operations is survival. When prices are beyond companies' control, what remain are costs. This reflects the companies' emphasis on the input dimensions of policies. On a tentative basis, it has been suggested in the literature that

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[7]It would have been interesting to examine productivity performance variations of banks just after the financial liberalization was introduced in 1991. However, the unavailability of data on unit prices of inputs of banks up to 1996, which are required to estimate cost efficiency and scale elasticity, forced us to conduct this study starting with the year 1997-98.

[8]This approach has some advantage in terms of yielding information on trends in performance, which would not have been available, had we used DEA to calculate annual frontiers (which Das et al. (2004) have used in their study), since the benchmarks would likely change from year to year. However, a Malmquist productivity index is another approach to study productivity change, which can be taken up as an extension of this study.

[9]Bhattacharyya et al. (1997) have, however, considered in their study the output orientation where each bank seeks to maximize its service provision (advances, investments and deposits), given the resources at its disposal.

costs (or inputs) are generally more predictable than outputs, giving cost targets a greater credibility than those for outputs. Sengupta (1987) has argued that: "…… data variations may arise in practical situations …… when the output measures have large and uncertain measurement errors which are much more significant than in the input measures (p.2, 290). For example in school efficiency studies, the input costs, such as teachers' salaries, administrative expenses, etc., may have low measurement errors whereas the performance test scores of students may contain large errors of measurement of true student quality". This argument is most compelling where measurement errors are large relative to true random fluctuations in the production process. Note that the assumption of variable returns to scale is maintained since our DEA results do not support the assumption of constant returns to scale.

Following Sengupta (1988), we have used the step-wise DEA approach where aggregated metrics in the first step were disaggregated into productivity-significant determinant factors to give a robust DEA productivity metric in step 2. Because inputs and outputs used in DEA should satisfy the condition that greater quantities of the selected inputs provide increased output, an isotonicity test between inputs and outputs at step 1 was conducted. If positive intercorrelations between inputs and outputs were found (Pearson correlations, $\alpha$ = 0.05), the isotonicity test was passed. In step 1 BCC efficiency scores obtained from composite (aggregated) output ($y$) and input ($x$)[10] were correlated with disaggregated inputs/outputs, correlations between BCC scores and I ($p$ = 0.382, $\alpha$ = 0.000), PLA ($p$ = 0.516, $\alpha$ = 0.000), NonII ($p$ = 0.364, $\alpha$ = 0.000), BF ($p$ = −0.289, $\alpha$ = 0.000), FA ($p$ = −0.383, $\alpha$ = 0.000), and L ($p$ = −0.285, $\alpha$ = 0.000) revealed that all the outputs and inputs can significantly enhance and determine the productivity levels. Thus, in constructing DEA model at step 2, all the three outputs and three inputs were used, and this model can be considered a robust productivity metric.

Table 1 exhibits the descriptive statistics of all the three output and three input variables, and their respective unit prices where average NonII and FA values are more less constant over all the eight years. All the variables are measured in crores of rupees. (1 crore = 10 million). Both composite output and input as well as their significant constituents have grown fairly steadily over years (excepting for the year 1998-99). This trend holds true for cost and revenue figures as well. Also evident is the steadily increasing variations in output and input variables, as reflected in their SD scores, being more than their means.

We first present our discussion concerning average annual trends in productivity performance behavior of banks, first, in terms of efficiency, and then, in term of scale elasticity with respect to ownership groups.

## 5.1 Efficiency

### 5.1.1 Technical efficiency

Three types efficiency are computed: technical efficiency (TE) from model (7), cost efficiency from model (11) and new cost efficiency (NCE) from the input-oriented version of model (17). The annual average TE trends with respect to ownership are exhibited in Figure 1.

It is seen that deregulation is yielding a remarkable increase in annual average trend performance for all the ownership groups. *PB*(*F*) group consistently remained high and above *NB* and *PB*(*I*) groups over the entire sample period. However, on comparison of *NB* with *PB*(*I*) reveals that the former outperforms the latter[11]. It is noteworthy that that TE performance trends of both *NB* and *PB*(*F*) remained above the grand average (shown in dotted line) whereas *PB*(*I*) remained below it. Also seen is that the variation in trend performance of each ownership group remains more or less the same, reflecting their similar familiarity with the regulatory system in terms of dependence on wholesale or corporate resources, inter-bank market borrowings, refinance of assets, etc.

On seeing the banks on the 'grand frontier' reveals that a total of 70 banks, approximately 11% of the sample, are rated being technically efficient. See Table 2. Of these 70 best banks, 45 (2 + 3 + 18 + 22) come from the last four years and 25 (8 + 6 + 6 + 5) come from first four years of the sample period, which justifies for their increasing performance trends. On the distribution of 70 best banks with respect to ownership, we find 39 foreign banks, 19 nationalized banks and 12 private banks, which clearly indicate that with the deregulation of the banking sector in India, foreign banks are not only found playing an active role in Indian financial market but also setting performance standards.

Adopting and practicing latest technologies may be one of the reasons for each bank group exhibiting increasing TE trend. The improvement in TE for all the ownership groups may be due to the intense competition. Leibenstein (1966) maintains that exposure to competition will generate improvement in efficiency (i.e., X-efficiency or technical efficiency). He argues that enterprises exposed to competition respond by eliminating internal inefficiency, and seek out opportunities for innovation. To Stigler

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[10]Here $y=\sum_{r=1}^{3} s_r y_r$ and $x=\sum_{i=1}^{3} s_i y_i$ where $s_r$ and $s_i$ are, respectively, the $r$th output's revenue share and $i$th input's cost share, i.e., $s_r = p_r y_r / \sum_{r=1}^{s} p_r y_r$ and $s_i = w_i x_i / \sum_{i=1}^{m} w_i x_i$.

[11]The differences in TE performance among all possible ownership groups are statistically tested with the help of rank-sum-test developed by Wilcoxon-Mann-Whitney. We find the $t$-values significant at 1% level between *NB* and *PB*(*I*) ($t$ = 10.349), between *NB* and *PB*(*F*) ($t$ = 11.171) and *PB*(*I*) and *PB*(*F*) ($t$ = 31.846). However, TE difference between nationalized banks, and private and foreign banks as a whole turns out to be insignificant ($t$ = −0.002).

Table 1. Summary statistics for Indian banks: 1997-98 – 2004-05

| | | 1997–98 | 1998–99 | 1999–00 | 2000–01 | 2001–02 | 2002–03 | 2003–04 | 2004–05 |
|---|---|---|---|---|---|---|---|---|---|
| (*O*) *II* | Mean | 20.615 | 23.891 | 28.404 | 32.756 | 37.102 | 43.173 | 53.414 | 53.884 |
| | SD | 45.647 | 51.241 | 61.410 | 72.643 | 89.516 | 111.576 | 142.663 | 143.917 |
| (*O*)*PLA* | Mean | 66.392 | 149.415 | 75.348 | 83.679 | 89.630 | 97.734 | 109.363 | 110.324 |
| | SD | 149.105 | 701.636 | 185.142 | 210.525 | 219.883 | 230.052 | 243.612 | 245.753 |
| (*O*) *NonII* | Mean | 0.891 | 1.060 | 1.059 | 1.241 | 1.268 | 1.336 | 1.458 | 1.471 |
| | SD | 2.371 | 2.464 | 2.683 | 2.770 | 2.954 | 3.163 | 3.440 | 3.470 |
| *Y* | Mean | 43.446 | 86.554 | 51.820 | 58.133 | 63.287 | 70.371 | 81.290 | 82.005 |
| | SD | 96.587 | 357.338 | 122.928 | 141.219 | 154.441 | 170.258 | 191.446 | 193.128 |
| (*I*) *BF* | Mean | 2.067 | 2.184 | 3.268 | 3.522 | 4.077 | 5.657 | 9.770 | 9.856 |
| | SD | 6.211 | 6.969 | 7.874 | 7.687 | 9.099 | 12.704 | 23.339 | 23.544 |
| (*I*) *FA* | Mean | 0.595 | 1.070 | 1.181 | 1.198 | 1.204 | 1.255 | 1.419 | 1.432 |
| | SD | 1.531 | 1.753 | 2.099 | 2.164 | 2.133 | 2.146 | 2.425 | 2.446 |
| (*I*) *L* | Mean | 11530 | 11359 | 11301 | 11419 | 10754 | 10501 | 11046 | 11143 |
| | SD | 29688 | 29417 | 28929 | 28843 | 27627 | 26668 | 27451 | 27692 |
| *X* | Mean | 2465.603 | 2348.595 | 2346.146 | 2305.229 | 2425.808 | 2628.666 | 3063.996 | 3090.951 |
| | SD | 6939.791 | 6829.633 | 6467.732 | 6130.776 | 6513.525 | 6972.524 | 8053.851 | 8124.636 |
| (*P*) *I* | Mean | 0.392 | 0.327 | 0.302 | 0.280 | 0.263 | 0.262 | 0.275 | 0.277 |
| | SD | 0.203 | 0.124 | 0.135 | 0.113 | 0.089 | 0.105 | 0.145 | 0.146 |
| (*P*) *PLA* | Mean | 0.101 | 0.105 | 0.106 | 0.104 | 0.102 | 0.101 | 0.103 | 0.104 |
| | SD | 0.024 | 0.023 | 0.016 | 0.015 | 0.013 | 0.018 | 0.033 | 0.033 |
| (*P*) *NonII* | Mean | 0.018 | 0.023 | 0.017 | 0.022 | 0.019 | 0.019 | 0.021 | 0.021 |
| | SD | 0.014 | 0.019 | 0.018 | 0.025 | 0.023 | 0.027 | 0.041 | 0.041 |
| (*C*) *BF* | Mean | 4.939 | 5.573 | 8.606 | 8.682 | 6.348 | 9.872 | 23.957 | 24.168 |
| | SD | 7.390 | 8.502 | 24.753 | 33.110 | 10.721 | 20.483 | 72.793 | 73.433 |
| (*C*) *FA* | Mean | 1.420 | 1.522 | 1.889 | 1.629 | 1.436 | 1.529 | 1.813 | 1.829 |
| | SD | 3.155 | 3.803 | 5.255 | 4.174 | 2.614 | 2.847 | 3.621 | 3.653 |
| (*C*) *L* | Mean | 0.0001 | 0.0007 | 0.0005 | 0.0005 | 0.0008 | 0.0042 | 0.0041 | 0.0046 |
| | SD | 0.0002 | 0.0037 | 0.0027 | 0.0016 | 0.0030 | 0.0228 | 0.0182 | 0.0212 |
| REVENUE | Mean | 12.202 | 13.008 | 14.659 | 15.779 | 17.367 | 19.285 | 22.091 | 22.481 |
| | SD | 28.137 | 28.807 | 32.674 | 35.236 | 380847 | 42.878 | 48.416 | 49.271 |
| COST | Mean | 5.733 | 7.041 | 7.162 | 7.568 | 8.365 | 9.801 | 11.160 | 11.427 |
| | SD | 13.393 | 15.921 | 15.962 | 17.138 | 19.371 | 22.250 | 25.792 | 26.295 |

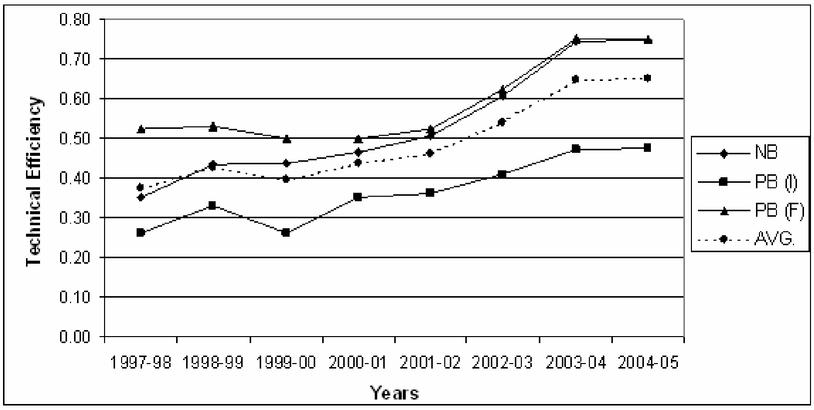


Figure 1. TE w.r.t. ownership over time.

(1976), this X-efficiency gain is nothing but an increase in the intensity of labor or, equivalently, a reduction in on-the-job leisure. Ganley and Grahl (1988) pointed out that, where labor productivity has increased due to such competition, there is evidence of increased work intensity. A closer look at our data set reveals that labor productivity shows an increasing trend (*NB*: from 0.004 to 0.008, *PB*(*I*): from 0.014 to 0.089, and *PB*(*F*): from 0.122 to 0.241 over the period), confirming the above-mentioned claim of increased work intensity.

**5.1.2 Cost/New cost efficiency**

The average annual trends in CE behavior with respect to each ownership group are all exhibited in Figure 2. Here, banks on each ownership group show increasing cost

Table 2. TE Frontier banks by ownership from and by year

| Banks | Ownership | Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1997-98 | 1998-99 | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 2003-04 | 2004-05 |
| State Banks of Indian | Public | X | | | X | X | X | | X |
| State Banks of Bikaner & Jaipur | Public | | | | | | | | X |
| State Banks of Hyderabad | Public | | | | | | | X | X |
| State Banks of Mysore | Public | | | | | | | | X |
| State Banks of Patiala | Public | | | | | | | X | X |
| Bank of Baroda | Public | | | X | | | | | |
| Canar of Bank | Public | | | | | | | | X |
| Indian Overseas Bank | Public | | | | | | | | X |
| Punjab National Bank | Public | | X | X | | | | | X |
| Andhra Bank | Public | | X | | | | | | |
| Oriental Bank of Commerce | Public | | | | | | | | X |
| Indusind Bank | Private | | X | | | | | | |
| Benares State Bank | Private | | | | | | | X | |
| Karur Vysya Bank | Private | | | | | | | X | X |
| Global Trust Bank | Private | | | | | | | X | X |
| Lord Krishna Bank | Private | | | | | | | X | X |
| Jammu & Kashmir Bank | Private | | | | X | | | | |
| Ratnakar Bank | Private | | | | | | | X | X |
| Nainital Bank | Private | | | | X | | | | |
| Chase Manhattan Bank | Foreign | | X | | | | | X | X |
| Chinatrust Commercial Bank | Foreign | X | | | | | | X | |
| ABN Amro Bank | Foreign | | | | | | | X | X |
| Bank of Tokyo | Foreign | | | X | | | | X | X |
| DBS Bank | Foreign | X | | | | | | X | |
| Citibank | Foreign | X | | X | | | | | X |
| Commerzbank | Foreign | | | | | | | X | X |
| Abu−Dhabi Commercial Bank | Foreign | | | | | | | X | X |
| Credit Lyonnais | Foreign | X | | X | | | | X | X |
| Bank of Ceylon | Foreign | X | | X | | | | | |
| Bank of International Indonesia | Foreign | | | | X | | | X | |
| State Bank of Mauritius | Foreign | X | X | | X | X | X | X | |
| Standard Chartered Bank | Foreign | | X | | | | X | X | X |
| HongKong & Shanghai Bank | Foreign | X | | | | | | | X |

efficiency accrual, and the performances of nationalized banks are outstanding followed by foreign banks and private banks. The differences in CE among all ownership groups are also confirmed from significant Wilcoxon-Mann-Whitney *t*-test values found between *NB* and *PB*(*I*) ($t$ = 3.971), *NB* and *PB*(*F*) ($t$ = 21.641) and *PB*(*I*) and *PB*(*F*) ($t$ = 28.584). However, CE difference between *NB*, and *PB*(*I* + *F*) was found insignificant ($t$ = −0.003).

Note that these results may not be reliable for, as discussed earlier, the cost DEA model (11) suffers from some fundamental shortcomings, and therefore, we present the average annual trends in new cost efficiency in Figure 3.

Foreign banks are found the best, and private banks the worst. This is also seen from the distribution of cost frontier banks (see Table 3) where out of 19 cost efficient banks (approximately 3% of the sample), nine are *PB*(*F*), eight are *NB* and only two are *PB*(*I*). On further statistical Wilcoxon-Mann-Whitney test reveals that $t$ = 14.502 between *NB* and *PB*(*I*), $t$ = 7.253 between *NB* and *PB*(*F*) and $t$ = 31.301 between *PB*(*I*) and *PB*(*F*). However, differences in cost performance between *NB*, and private and foreign banks as a group, are not statistically significant ($t$ = −0.0004).

The main reason for the foreign banks found superior over the rest is the use of the relatively fewer number of employees implying higher work intensity. However, in spite of the facts that nationalized banks are the oldest banks with strong asset base, their cost performances are at stake. This might be due to the possibility that with the emergence of new private and foreign banks, the older banks have devised a market responsive product-mix concerning saving and invest plans offering attractive returns, and they are going through the process of overhauling with significant decentralization in the management and organizational structure, causing huge loss in allocative efficiency.

Note that we have used a mixed evaluation of banks in three ownership groups where each bank is evaluated on both inter and within group bases. However, following Cooper et al. (2000), a sharper discrimination between any two groups can be obtained when each bank from a particular group, *NB* (say) is evaluated with respect to all the banks in the other group, *PB*(*I*)/*PB*(*F*)/*PB*(*I* + *F*) where *PB*(*I* + *F*) represents all the private and foreign banks. For example, to measure TE of banks '*o*' ($o \in NB$) in *PB*(*I*), we formulate the following LP:

$$\min\ \theta$$
$$s.t.\ \sum_{j\in PB(I)} x_j\lambda_j \le \theta x_o,\ \sum_{j\in PB(I)} y_j\lambda_j \ge y_o,$$
$$\sum_{j\in PB(I)} \lambda_j = 1,\ \lambda_j \ge 0\ (\forall j \in PB(I))$$

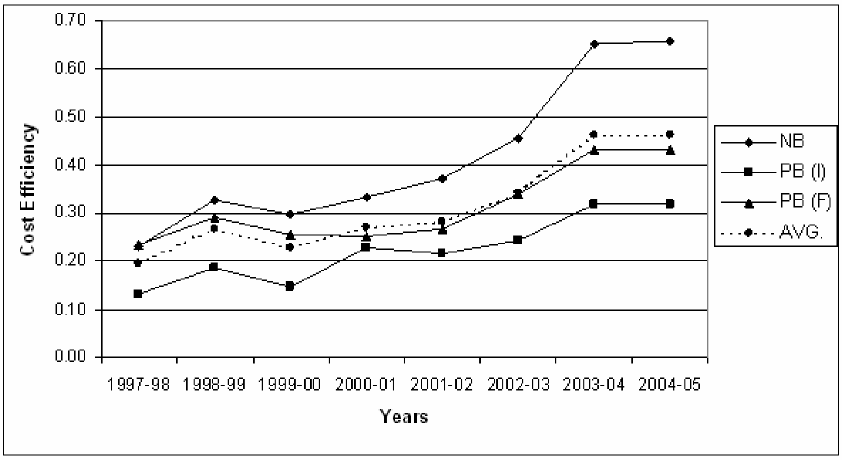


Figure 2. CE w.r.t. ownership over time.

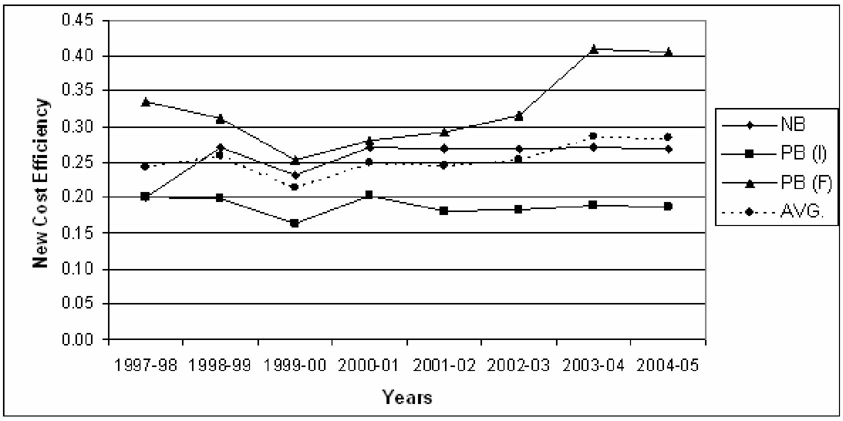


Figure 3. New CE w.r.t. ownership over time.

Table 3. NCE Frontier banks by ownership from and by year

| Banks | Ownership | Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1997–98 | 1998–99 | 1999–00 | 2000–01 | 2001–02 | 2002–03 | 2003–04 | 2004–05 |
| State Banks of Indian | Public | | X | X | X | X | X | X | X |
| Andhra Bank | Public | | X | | | | | | |
| Lord Krishna Bank | Private | | | | | | | X | X |
| Chase Manhattan Bank | Foreign | X | | | | | | | |
| Bank of Tokyo | Foreign | | | | | | | X | X |
| Citibank | Foreign | | | | | | | X | X |
| Abu–Dhabi Commercial Bank | Foreign | | | | | | | X | X |
| Standard Chartered Bank | Foreign | | | | | | | X | |

Table 4. Bilateral comparisons among ownership groups

| | Technical Efficiency | | | New Cost Efficiency | | |
|---|---|---|---|---|---|---|
| Rank Sum | *NB* | *PB*(*I*) | Test Stat. (*t*) | *NB* | *PB*(*I*) | Test Stat. (*t*) |
| | 44829 | 52191 | −0.7772 | 55666 | 41354 | 7.3606 |
| Rank Sum | *NB* | *PB*(*F*) | Test Stat. (*t*) | *NB* | *PB*(*F*) | Test Stat. (*t*) |
| | 55737 | 30999 | 10.0877 | 63667 | 23069 | 16.5552 |
| Rank Sum | *NB* | *PB*(*I* + *F*) | Test Stat. (*t*) | *NB* | *PB*(*I* + *F*) | Test Stat. (*t*) |
| | 92028 | 118248 | 11.0266 | 111686 | 98590 | 19.8625 |
| Rank Sum | *NB* | *PB*(*F*) | Test Stat. (*t*) | *NB* | *PB*(*F*) | Test Stat. (*t*) |
| | 64216 | 32804 | 9.8071 | 72253 | 24767 | 15.8422 |

We test against the null hypothesis that the two ownership groups have the same distribution of efficiency scores. The results of these bilateral comparisons concerning TE and CE across all ownership groups are all exhibited in Figure 4(a)-4(d) and Figure 5(a)-5(d), respectively.

Concerning the TE comparison, excepting the case between nationalized and private banks, the picture is quite clear-cut. Foreign banks are seen outperforming over both the nationalized banks and private banks, and private and foreign banks as a group outperforming over the nationalized banks. And, as regards the new cost efficiency comparisons, we find private banks scoring over the nationalized banks, private and foreign banks as a group outperforming over the nationalized banks, and foreign banks scoring over both nationalized and private banks. These visual findings are further confirmed through statistical Wilcoxon-Mann-Whitney test statistics exhibited in Table 4. Excepting the case between *NB* and *PB*(*I*), we reject throughout the null hypothesis that TE/NCE scores of any possible two groups belongs to the same distribution at the 1% level of significance.

The finding of higher cost efficiency of private banks over nationalized banks clearly highlights the possible disciplining role increasingly played by the capital market in improving the weak relationship between market for corporate control and efficiency of private enterprise assumed by the property right hypothesis. Even though institutional conditions are favorable, the lesser cost-efficiency growth can be understandable because of X-inefficiency factors arising from government ownership[12], which might be argued to be leading to diminishing return to income, reduction in interest spread, and the presence of scale economies due to fixed cost.

Now let us turn to discuss the scale elasticity issue across ownership groups.

## 5.2 Scale elasticity

The lower and upper bounds of SE estimates of banks over the years are computed using BCC (eqn.10), COST (eqn.21), REVENUE (eqn.26) and COST-REVENUE (eqn.30) DEA models, and the distribution of returns to scale exhibited below in Table 5 is uneven indicating that policy prescription concerning whether to expand or contract business operations depends upon the very objective of the bank. Also evident is the distinction between RTS (in production environment) and economies of scale (in price environment) from the number of banks operating in IRS column.

The annual average SE estimates for all the banks with respect to ownership over time in all environments are all exhibited in Figures 6, 7, 8 and 9.

In all the models, one could clearly see that SE estimates of foreign banks are higher, followed by those of private and nationalized banks, respectively, and foreign banks mostly exhibit IRS/economies of scale whereas nationalized banks exhibit DRS/diseconomies of scale as their average SE scores are mostly above unity and less than unity respectively. This result is not at all surprising because of the RBI's branching policy. As Bhattacharyya et al. (1997) pointed out, under the RBI's branching policy, Indian banks are required to open branches but are not allowed to close unprofitable branches, and this policy prevents banks from optimizing their resources across the branch network because banks have neither control over the location of branches nor the ability to close loss-making branches. However, foreign banks are mostly young, and tend to have smaller branch networks, since they have not yet fully expanded their business and have not been forced by regulators to expand branch networks beyond their optimal size. However, the SE nature for private banks is mix, supporting both economies and diseconomies of scale. This might be due that Indian private banks of two types: old and new, the former follows the tradition of *NB* whereas the latter with *PB*(*F*).

[12]Government officials are in general more inclined to pursue their own interests, or interest of pressure group, rather than interests of public. Frequently changing objectives of nationalized banks arising from government's attempts to accommodate diverse interest groups creates hindrances in their growth.

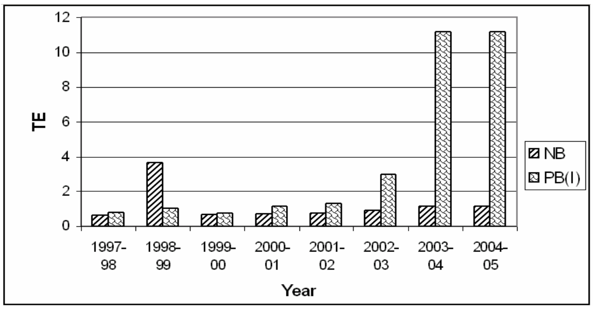


Figure 4(a). *NB* vis-a-vis *PB*(*I*).

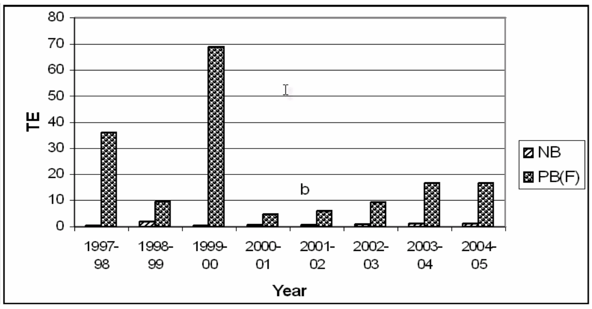


Figure 4(b). *NB* vis-a-vis *PB*(*F*).

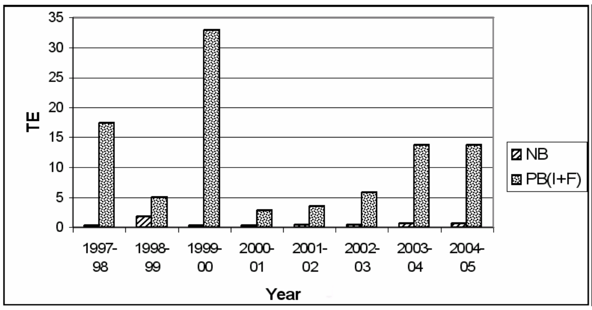


Figure 4(c). *NB* vis-a-vis *PB*(*I* + *F*).

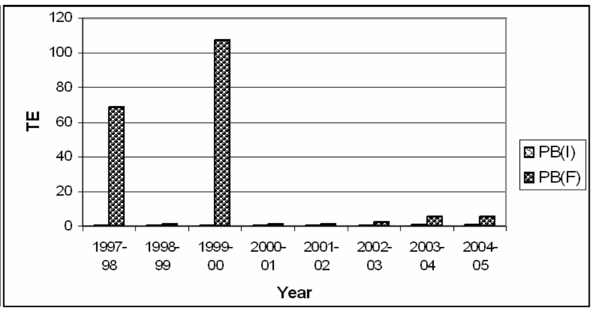


Figure 4(d). *PB*(*I*) vis-a-vis *PB*(*F*).

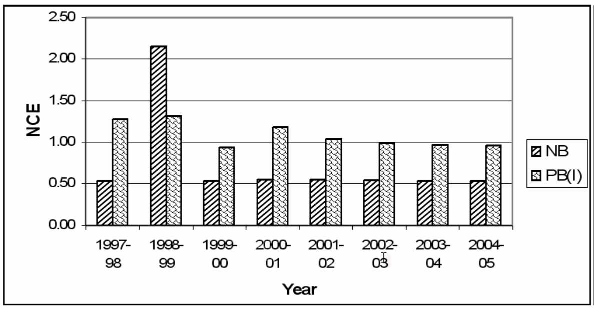


Figure 5(a). *NB* vis-a-vis *PB*(*I*).

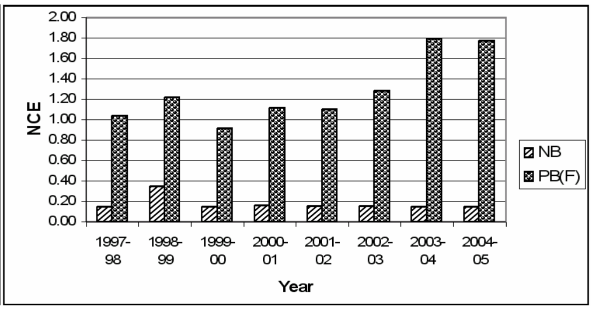


Figure 5(b). *NB* vis-a-vis *PB*(*F*).

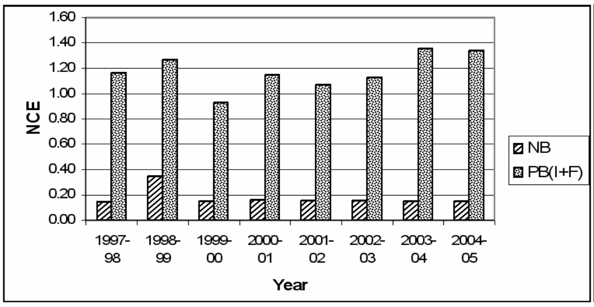


Figure 5(c). *NB* vis-a-vis *PB*(*I* + *F*).

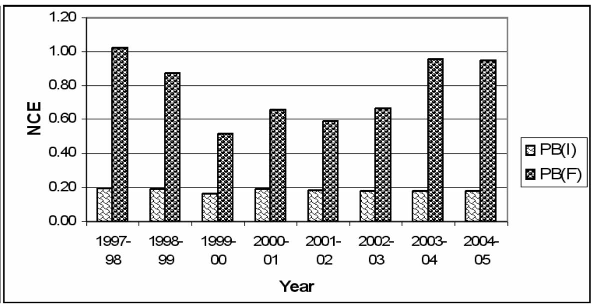


Figure 5(d). *PB*(*I*) vis-a-vis *PB*(*F*).

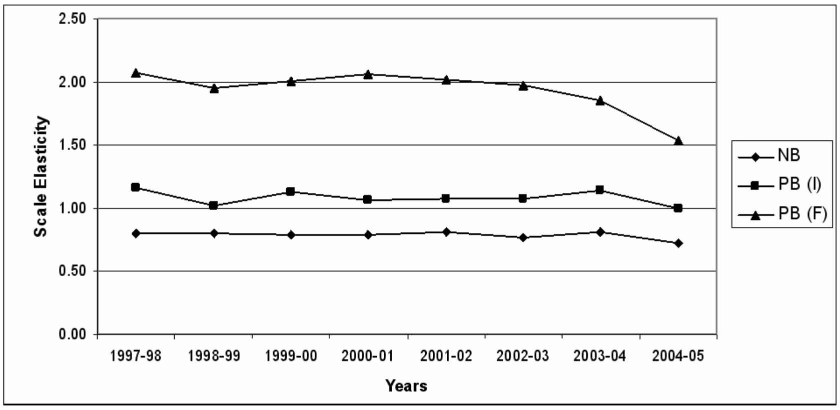


Figure 6. *SE* in production environment.

Table 5. Distribution of RTS

| Models | IRS/Economies of scale | CRS/No economies | DRS/ Diseconomies of scale |
|---|---|---|---|
| BCC | 267(IRS) | 31(CRS) | 350(DRS) |
| *NB* | 6 | 6 | 196 |
| *PB(I)* | 117 | 8 | 107 |
| *PB(F)* | 144 | 17 | 47 |
| COST | 395(economies of scale) | 3(no economies) | 250(diseconomies of scale) |
| *NB* | 21 | 1 | 146 |
| *PB(I)* | 214 | 0 | 18 |
| *PB(F)* | 160 | 2 | 46 |
| REVENUE | 290(economies of scale) | 28(no economies) | 330(diseconomies of scale) |
| *NB* | 19 | 10 | 179 |
| *PB(I)* | 118 | 3 | 111 |
| *PB(F)* | 153 | 15 | 40 |
| COST−REVENUE | 303(economies of scale) | 1(no economies) | 344(diseconomies of scale) |
| *NB* | 2 | 0 | 206 |
| *PB(I)* | 114 | 0 | 88 |
| *PB(F)* | 157 | 1 | 50 |

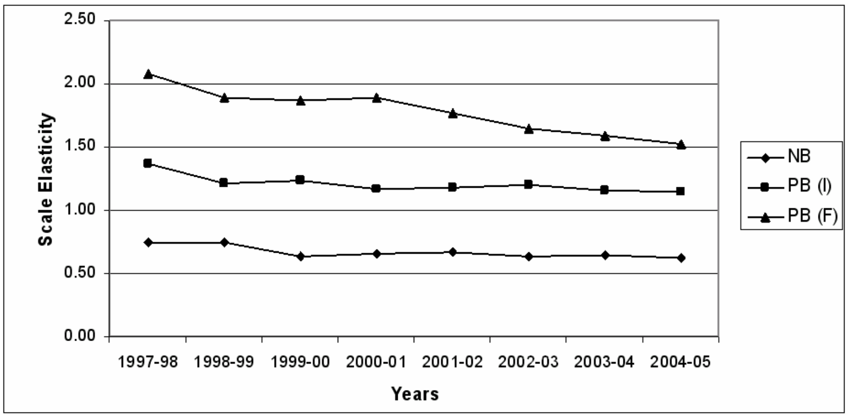


Figure 7. SE in Cost environment.

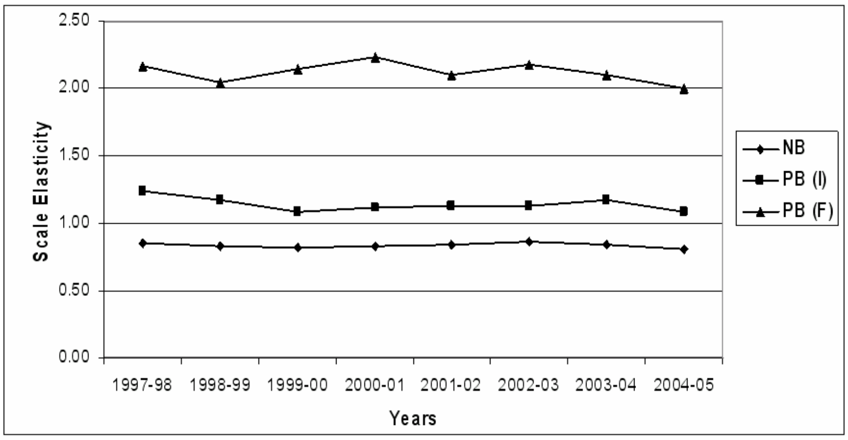


Figure 8. SE in revenue environment.

Note that the conflicting signals concerning scale economies behavior of banks obtained from both production and price-based DEA models are simply due to the very nature of their underlying objectives pertaining whether to minimize inputs (BCC model), or to minimize cost (COST model), or to maximize revenue (REVENUE model), or doing both, i.e., minimizing cost and maximizing revenue (COST-REVENUE model).

## 6. CONCLUDING REMARKS

This paper empirically estimates the productivity

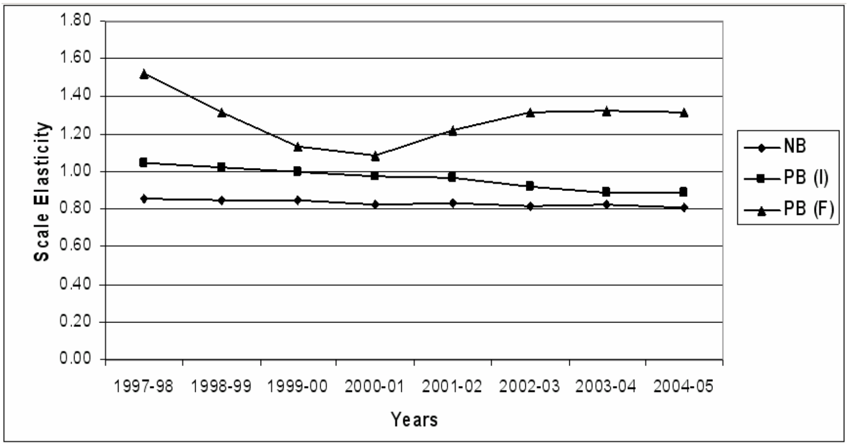


Figure 9. SE in Cost-revenue environment.

performance in terms of technical efficiency, cost efficiency and scale elasticity of the banking sector for the period: 1997-98 – 2004-05. Our broad empirical results are indicative in many ways: first, the average annual trends in TE for all ownership groups have improved, indicating an affirmative gesture about the effect of the reform process on the performance of the Indian banking sector, second, foreign banks have a leading edge over both the nationalized banks in both operational and price measures of performance, which indicates that foreign banks are mostly strongly exposed to international markets, and are more sensitive to competitive pressures from outside the country, third, the higher cost efficiency accrual of private banks over the nationalized banks indicate that the nationalized banks though old, do not reflect their learning experience in their cost minimizing behavior due to X-inefficiency factors arising from government ownership. This finding also highlights the possible stronger disciplining role played by the capital market indicating a strong link between market for corporate control and efficiency of private enterprise assumed by property right hypothesis. And, finally, concerning the scale elasticity behavior, the technology- and market-based results differ significantly supporting the empirical distinction between returns to scale and economies of scale, which are most often used interchangeably in the literature.

This study points to avenues for future research in two ways: first, one can use both quadratic and dynamic cost frontier DEA models proposed by Sengupta (2003) to study efficiency and technical changes over time, and second, one can use Malmquist productivity index approach to measure and analyze productivity change and its components such as pure efficiency change, scale efficiency change and technical change over time.

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