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Productivity growth and efficiency change in Indian banking

Technology effect vs catch-up effect

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Abstract

Purpose – The purpose of this paper is to understand the influence of technology change in the banking sector by employing data envelopment analysis (DEA) and also to determine the change in total factor productivity (TFP) and its components, namely technical change and technical efficiency change.

Design/methodology/approach – The DEA method has been used to assess the efficiency of the entire banking sector and the bank groups. The purpose has been to investigate TFP change and its components' (obtained using Malmquist index) influence on the growth in the banking sector as well as in the four bank groups. In doing so, for each bank group the levels of technical efficiency, technical efficiency change, efficiency change and TFP change have been estimated. Further investigation has been done to determine if significant differences in these exist between the different bank groups in terms of size, time period and ownership. The determinants of productivity have been assessed.

Findings – The TFP growth over the entire period (1995-2006) was driven by technical change as compared to efficiency change, showing that technology and innovation had a greater impact than efficiency change, or the catch-up effect. The fixed effects estimates of the determinants of TFP change and its components show that size, ownership and time period exert significant effect on technical change.

Practical implications – The results of the analysis presented in this paper suggest that policies that result in efficiency change are likely to have little impact on the future prospects of the banking sector relative to policies that foster the adoption of the latest technologies. This has exactly been the focus of Reserve Bank of India and though some banks may consider it as an imposition of technology, the result of this requirement appears to be positive as is apparent from this paper's analysis.

Originality/value – The value of this paper comes from the empirical testing that in the Indian banking sector growth in the more recent period came from technology change or frontier shifts as compared to efficiency change. Also, growth is larger due to frontier shifts than due to efficiency change. This endorses Lucas' findings regarding the focus on the positive impacts of deregulation and competition in the Indian banking sector.

Keywords India, Banking, Productivity rate, Communication technologies, Process management
Paper type Research paper

Journal of Advances in Management Research
Vol. 7 No. 2, 2010
pp. 194-218

0972-7981
DOI 10.1108/09727981011084995

1. Introduction

Since the mid-1990s, efficiency has been used as an important metric to judge the health of the Indian banking sector[1]. The measurement of efficiency serves several

purposes. It helps individual banks to benchmark their relative efficiency against the "best practice" bank(s). It helps to evaluate the impact of various policy measures in the light of financial reforms, the first phase of which was claimed to be capital infusing and the second phase competition/efficiency oriented (Reddy, 2004).

Productivity growth too has been a subject of great interest and concern for development economists and policy makers. The concept of productivity growth as well as its measurement gained importance when it was realized that economic growth based on expansion of inputs, rather than growth in output per unit of input, is inevitably subject to diminishing returns.

Historically, although productivity growth has been regarded as a principal contributor to economic growth, the credit for popularizing growth accounting exercises in empirical literature goes to Solow (1957). Using a growth accounting framework, Solow separated growth originating from increased application of factor inputs and that which is due to residual factors, which was designated as productivity. Since then, considerable research has been undertaken on the measurement, determinants and consequences of factor productivity. This has led to newer and better data generation, better analytical techniques and also analysis of causal factors that can help explain productivity.

The concepts of efficiency and productivity are often used interchangeably. It is however important to understand the subtle difference between the two. In the case of a firm or a production unit producing one output using single input, productivity refers to the ratio of its output to its input. In a multi input-output case, the outputs appearing in the numerator are aggregated in some "economically sensible manner", and so are the inputs in the denominator so that the overall productivity remains the ratio of two scalars. Available evidence from literature indicates that changes in productivity can occur due to three reasons, namely technical change or changes in efficiency, or differences in the setup in which production occurs. This clearly implies that efficiency is only one component of productivity change of a firm.

This paper makes an attempt to evaluate the total factor productivity (TFP) growth in the banking sector, over the period 1995-2006. The popular non-parametric method namely data envelopment analysis (DEA) has been used for the purpose. The measures of productivity growth are computed across the various bank types, namely public sector banks (PSBs), old private banks (OPBs), new private banks (NPBs) and foreign banks (FBs).It is important to study the same in the context of understanding the productivity of the banking sector because several Reserve Bank of India (RBI) reports have indicated that some bank groups have become more efficient in terms of operational efficiency since 1996[2]. Most studies on efficiency of banking in India have done so through financial ratios. Rishi and Saxena (2004) have discussed how the growth in output in the post-reform period, particularly among the early adopters of technology (NPBs and FBs) is related to the growth in profit per employee (PPE) and business per employee (BPE) (partial productivity).

Given the importance of the banking sector and the growing evidence of its increased efficiency, this TFP growth study will allow identification of growth due to productivity and also the sources of growth. This will be done by decomposing the growth into two distinct changes, namely, the catching up effect and the identification of innovation, apart from understanding the change in technical efficiency over the period of consideration. The question therefore arises as to why TFP growth should be decomposed into technological change and efficiency change? The decomposition

helps to determine what kinds of policies are better suited to improve the growth prospects of the banking sector.

There are two mechanisms through which a firm can grow. On the one hand, the firm could get closer to its production possibilities frontier thereby improving its allocative efficiency. In this case, a bank reorganizes its inputs given the available technology. On the other hand, the bank can grow by adopting state-of-the-art technology and consequently shift its production frontier. This is referred to as growth by technological change. Apart from isolating the dominant effect on growth, this paper will help understand whether resource reallocation or access to technology will lead to faster growth. We have also attempted to assess the influence of select variables on productivity and efficiency change using panel data models.

The remainder of this paper is organized as follows. Section 2 gives a selected literature review and section 3 describes the DEA methodology for measuring efficiency and its decomposition. Section 4 provides a discussion on the inputs and outputs and compares them with previous studies. Section 5 discusses the empirical results, section 6 the determinants of productivity, section 7 presents the managerial implications of research and section 8 the summary and conclusions.

2. Literature review

There is rich literature, mostly with regard to developed countries, on assessing bank performance using measures of efficiency and productivity across. Various methodologies have been used and different conclusions reached. Fare *et al.* (1994) discuss in their paper how the USA in the 1980s maintained a higher growth among its industrial peer countries due to technical change rather than efficiency change. There are also many good surveys/articles of the efficiency and productivity literature related to banking.

Berger and Humphrey (1997) document a country-wise and methodology-wise review of studies on bank efficiency. More recently, Alam (2001) and Berger and Mester (2003) provided updated reviews. These two studies contain an exhaustive list of methodologies applied in various studies. They form the basis for selection of inputs/outputs as well as the methodology in this paper.

Outside of the USA, Berg *et al.* (1992) used the Malmquist index (Malmquist, 1953) to analyze the performance of Norwegian banks between 1980 and 1989. They identified productivity regress before deregulation and progress post-deregulation. The productivity change was mainly attributed to relative efficiency gains rather than frontier shifts. In continuation, Berg *et al.* (1993) extended the study to the Finnish and Swedish banking sectors using data for a single year. This yielded similar results as their earlier study. Elyasiani and Mehdian (1995) worked on US data and selected 1979 and 1986 as proxies for pre- and post-deregulation. They found that for large banks technical efficiency declined and technology regressed. Their study grouped banks according to their size. In contrast, this paper involves a comparison of various bank groups according to their ownership structure. Most studies (including the RBI) relating to banks in India group banks according to ownership structure. This seems the case because the characteristics of bank groups in terms of their origin, objectives, etc., have been similar historically. Wheelock and Wilson (1999) decomposed TFP growth in banks in the USA during the period 1984 to 1993. They found that technical efficiency dropped but considerable technology progress happened in the ten-year period. This varied according to bank size. Alam (2001) found sustained productivity progress post-1985 in the US banking sector. The productivity increase was primarily

attributed to technological changes. The common question addressed in most studies has been whether there has been productivity growth due to deregulation and whether this growth could be attributed to technical efficiency change or technical change. Most countries found convergence or catching up preceding the frontier shift. This paper will address the same question in the context of India.

Indian studies on bank efficiency and productivity have been evolving since the 1990s. Only a few papers have estimated TFP growth in Indian banking, which is the growth of output relative to input usage. Results from such studies are varied and often contrasting:

- technical change is the main contributor to TFP growth (Subramanyam, 1993);
- deregulation has led to improvement in TFP growth (Bhattacharyya *et al.*, 1997); and
- there is no significant impact of deregulation on TFP growth (Kumbhakar and Sarkar, 2003).

Reddy (2005) discussed TFP growth in Indian banking by decomposing it into technology change and efficiency change in the period 1995 to 2006. Overall, he found that TFP was stagnant over the time period, technology change was declining at the same time that efficiency change was improving. Among the bank groups, PSBs performed the best followed by the OPBs, FBs and the NPBs. Ram Mohan and Ray (2004) estimated TFP growth for all Indian banks using DEA and concluded that differences among productivity levels of different bank groups were insignificant.

The studies in India relating to efficiency in banking are based on financial ratios. They examine the effect of performance and competition in banking across various bank groups or banks based on size. Some of the pertinent literature is discussed here. Sarkar *et al.* (1998) studied performance in terms of financial ratios of efficiency and profitability and concluded that private banks are not unambiguously superior to public banks. Sarkar and Bhaumik (1998) studied bank competition in Indian states during 1980 to 1998. They found that competition from FBs has been very small compared to the established presence of PSBs. Das (1999) performed a sequential decomposition model for profitability analysis of PSBs and found a convergence in bank-wise profitability in the post-reform period. Koeva (2003) examined a variety of financial indicators of banks and concluded that ownership had a significant effect on some of the performance indicators and deregulation had led to lower intermediation costs and profitability. More recently, Bhaumik and Dimova (2004) studied performance in terms of return on assets of all banks and concluded that by 2000 competition had helped PSBs to reduce the gap in performance between them and private banks. Das (1997) estimated efficiency for PSBs and found that they had improved their allocative efficiency significantly in the post-reform period, but there was a fall in scale efficiency. Das *et al.* (2005) discussed liberalization, ownership with respect to revenue efficiency and profit efficiency in Indian banking. They found that the median efficiency scores of bigger banks, and in particular Indian banks, had improved in the post-reform period. However, the above studies have not decomposed growth into technical efficiency change and technical change, since technology had not taken center stage in those periods of study.

The two studies by Subramanyam (1993) and Reddy (2005) decomposed TFP growth into technical efficiency change and technical change. The former studied the question of what contributed to TFP growth before 1991, and also examined Indian banking before liberalization. The latter pursued the same question, but with a different choice of inputs

and outputs, using the production approach (PA). The choice of inputs/outputs has always been a contentious issue in banking. In this work, the intermediation approach (IA) is used to address the issues of efficiency and productivity in the Indian banking sector. A more detailed discussion is presented in section 4.

Specifically, the present study will examine TFP change during the period 1995-2006, year wise, examine it with reference to various inputs to determine if TFP change was due to efficiency change (catching up effect), technical change (innovation) or input driven (high input investment). The study will be conducted on the entire banking sector, the four distinct bank groups, namely PSBs, OPBs, NPBs and FBs as well as at the individual bank level. The four bank groups are treated as homogenous units with similar characteristics for aggregation over time. Panel data models are used to assess the influence of select variables on productivity and efficiency change.

3. Methodology

The concept of technical efficiency is as old as neoclassical economics, but the interest in its measurement is not. The question arises as to why should one measure technical efficiency at all. There are two principal supporting arguments. The first, and the most compelling reason, lies in the recognition that a gap exists between the theoretical assumptions of full technical efficiency and the empirical reality. Leibenstein (1966) drew attention to this in the 60s. Second, on *a priori* reasoning, there is a high probability that, where technical inefficiency exists, it will exert an influence on allocative efficiency and there will be a cumulative negative effect on economic efficiency (Bauer, 1990; Kalirajan and Shand, 1999). Following this logic, technical efficiency becomes central to the achievement of high levels of economic performance at the firm level, as does its measurement.

Technical efficiency is concerned with how closely the production unit operates to the frontier of the production possibility set. The historical roots of a rigorous approach to efficiency measurement can be traced to the works of Koopmans (1951), Debreu (1951) and Farrell (1957). These authors used the concepts of isoquant frontiers and production functions to define relative technical efficiency as the firm's (any unit of observation) "distance" from a production frontier built with observed data from input-output combinations. Koopmans provides a definition of efficiency while Debreu and Farrell provide a measure of efficiency (Knox and Lovell, 1993).

A variety of theoretical approaches, parametric and non-parametric, have been developed to investigate the failure of producers to achieve the same level of efficiency (for a detailed survey on such methodologies see Kalirajan and Shand, 1999). In parametric models, one specifies an explicit functional form for the frontier and econometrically estimates the parameters using sample data for inputs and outputs, and hence the accuracy of the derived technical efficiency estimates is sensitive to the nature of the functional form specified. In contrast, the method of DEA introduced by Charnes, Cooper and Rhodes (CCR) (1978) and further generalized by Banker, Charnes and Copper (BCC) (1984) offers a non-parametric alternative to parametric frontier production function analysis. The method has the advantage that it is parameter free, and includes observed input-output data without requiring a priori specification of functional forms. A production frontier is empirically constructed using linear programming methods from observed input-output data of sample firms. Efficiency of firms is then measured in terms of how far they are from the frontier.

DEA was developed initially to evaluate the efficiency of public sector and non-profit organizations. Sherman and Gold (1985) were the first to apply DEA to banking. DEA calculates the relative efficiency scores of various decision-making units (DMUs)

in the particular sample. The DMUs could be banks or branches of banks. The DEA measure compares each of the banks/branches in that sample with the best practice in the sample. It tells the user which of the DMUs in the sample are efficient and which are not. The ability of DEA to identify possible peers or role models as well as simple efficiency scores gives it an edge over other methods. As an efficient frontier technique, DEA identifies the inefficiency in a particular DMU by comparing it to similar DMUs regarded as efficient, rather than trying to associate a DMU's performance with statistical averages that may not be applicable to that DMU.

Methodologically, the characteristics of DEA can be described through the original model. Consider N units (each is called a DMU) that convert I inputs into J outputs, where I can be larger, equal or smaller than J. To measure the efficiency of this conversion process for a DMU, CCR (1978) proposed the use of the maximum of a ratio of weighted outputs to weighted inputs for that unit, subject to the condition that the similar ratios for all other DMUs be less than or equal to 1. That is:

$$Max\, e^0 = \frac{\sum_{j=1}^{J} u_j^0 y_j^0}{\sum_{i=1}^{I} v_i^0 x_i^0} \tag{1}$$

Subject to:

$$\frac{\sum_{j=1}^{J} u_j^0 y_j^n}{\sum_{i=1}^{I} v_i^0 x_i^n} \leq 1;\ n = 1, \ldots\ldots, N$$

$$v_i^0, u_j^0 \geq 0; i = 1, \ldots\ldots, I; j = 1, \ldots\ldots, J$$

where y_j^n, x_i^n are positive known outputs and inputs of the nth DMU and v_i^0, u_j^0 are the variable weights to be determined by solving problem (1) above.

The DMU being measured is indicated by the index 0, which is referred to as the base DMU. The maximum of the objective function e^0 given by problem (1) is the DEA efficiency score assigned to DMU^0. Since every DMU can be DMU^0, this optimization problem is well defined for every DMU. If the efficiency score $e^0 = 1$, then DMU^0 satisfies the necessary condition to be DEA efficient; otherwise it is DEA inefficient.

It is difficult to solve problem (1) as stated, because the objective function is non-linear and fractional. CCR (1978), however, transformed the above non-linear programming problem into a linear one as follows:

$$Max\, h^0 = \sum_{j=1}^{J} u_j^0 y_j^0 \tag{2}$$

Subject to:

$$\sum_{i=1}^{I} v_i^0 x_i^0 = 1, \quad \text{and} \quad \sum_{j=1}^{J} u_j^0 y_j^n - \sum_{i=1}^{I} v_i^0 x_i^n \leq 0;$$

$$n = 1, \ldots\ldots, N;\ v_i^0 \geq \mu;\ u_j^0 \geq \mu;\ i = 1, \ldots\ldots, I;\ j = 1, \ldots\ldots, J$$

The variables defined in problem (2) are the same as those defined in problem (1). An arbitrarily small positive number, μ is introduced in problem (2) to ensure that all of the known inputs and outputs have positive weight values and that the optimal objective function of the dual problem to problem (2) is not affected by the values assigned to the dual slack variables in computing the DEA efficiency score for each DMU. The condition $h^0 = 1$ ensures that the base DMU^0 is DEA efficient; otherwise it is DEA inefficient, with respect to all other DMUs. A complete DEA model involves the solution of N such problems, each for a base DMU, yielding N different (v_i^n, u_j^n) weight sets. In each program, the constraints are held constant while the ratio to be maximized is changed. Finally, these DEA problems are solved using the computer software developed by Coelli (1996). The Malmquist index (Malmquist, 1953) is frequently used to evaluate technological change or technical change (used interchangeably) and technical efficiency change.

The concept of the Malmquist index can be understood by considering a single input and single output production process. An output-efficient firm is one which cannot increase its output unless it also increases one or more of its inputs; such a firm has an efficiency score (or, Malmquist index) of 1. Conversely, an output-inefficient firm has an efficiency score less than 1. Figure 1 is illustrative of a single-input (x), single-output (y) production scenario. The bold rays from the origin, labeled T_t and T_{t+1}, represent the boundaries of technology at time t and $t + 1$, respectively, under the assumption of constant returns to scale (CRS).

Since T_{t+1} is above T_t, technological progress has occurred between time t and $t + 1$. Consider the case of firm "n" represented as (x_{nt}, y_{nt}) at time t. Since it is completely interior to the T_t frontier, this firm is inefficient and its output inefficiency is measured as the ratio 0a/0b. Similarly, the same firm at $t + 1$, represented as $(x_{n,t+1}, y_{n,t+1})$ is inefficient with respect to the T_{t+1} frontier and its inefficiency score is given by 0e/0f.

DEA is used to define the boundary of the technology and obtain the efficiency score for each bank in each time period. It does so by creating an envelope of observed production points (CCR, 1978). DEA provides for flexible piece wise linear approximations to model the best-practice reference technology. One advantage of programming methods over econometric models is that they do not require an assumption of cost minimization or

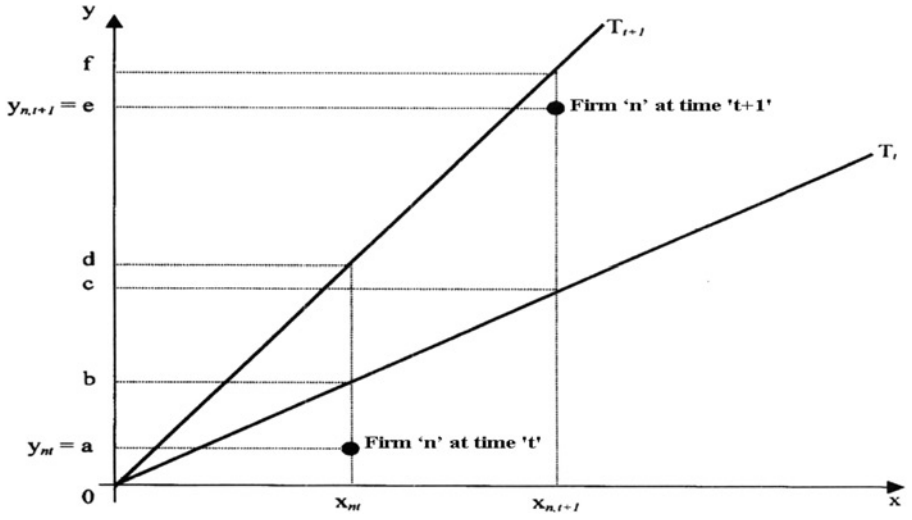

Figure 1.
Single-input (x), single-output (y) production technology

profit maximization. In addition, linear programming methods are non-parametric and thus do not require a priori specification of a production function. Finally, these methods do not smooth effects and, therefore, allow for greater flexibility since substantial annual variations in efficiency can occur if they exist in the data. The DEA methodology using the Malmquist index is used in this analysis for it offers the advantage of handling multiple inputs and outputs, a unique feature of the banking sector.

The Malmquist index procedure is used to identify productivity dynamics. It can account for changes in both technical efficiency (catching up) and changes in frontier technology (innovation). In a study of industrialized countries, Fare *et al.* (1994) note that this decomposition allows for a more comprehensive measure of productivity growth convergence since earlier endeavors failed to distinguish between these two components. The decomposition can be illustrated by referring back to Figure 1. For firm "n" the decomposition is:

$$\text{Malmquist Index} = \left(\frac{Oe}{Of}\right)\left(\frac{Ob}{Oa}\right) * \left(\frac{Of}{Oc}\right)\left(\frac{Od}{Ob}\right)^{1/2} = E_{t+1} * A_{t+1} \tag{3}$$

This index captures the dynamics of productivity change by incorporating data from two adjacent periods: E_{t+1} reflects changes in relative efficiency while A_{t+1} reflects changes in technology between t and $t + 1$. For the index and its components, values below 1 indicate productivity decline (regress) while values above 1 indicate growth (progress). For the firm n, both components exceed 1. In terms of relative technical efficiency, the firm moved closer to the relevant contemporaneous frontier indicating that production for this firm is converging to the frontier (i.e. $E_{t+1} > 1$). In terms of technology shifts, the frontier, as measured at input levels x_t and x_{t+1} moved out between periods t and $t + 1$ (i.e. $A_{t+1} > 1$).

Before proceeding with the analysis, a comparison of the various inputs and outputs used in the banking sector is made in the following section. This comparison is presented to enable a better understanding of the contentious issue of inputs and outputs of the banking sector. The definitions of inputs and outputs used in this paper are based on the discussions that follow.

4. Specification of outputs and inputs

A definition of banking inputs and outputs is necessary in order to analyze the efficiency of the banking sector. Economists are divided over the conceptual issue of the correct definitions of outputs and inputs in the industry.

Broadly speaking, the literature identifies five approaches to the input and output specifications (see Table I). Three of the approaches, the production approach (PA), the intermediation approach (IA) and the asset approach (AA) are related to some functions carried out by banks. According to the PA, banks are mainly considered as producers of deposit accounts and loan services; the number of accounts serviced or transactions processed are measures of outputs. Inputs include capital and labor, but do not include interest costs. According to the IA, banks are viewed as intermediates, which transform and transfer financial resources from units in surplus to units in deficit. This approach is particularly appropriate for banks where more activities consist of turning large deposits and funds purchased from other financial institutions into loans and financial investments. A variant of the IA is the AA, which focuses on recent developments in the theory of intermediation. Outputs are strictly defined by

Table I.
Input–output measures

Authors	Inputs	Outputs	Approach
Sherman and Gold (1985)	Labor, capital (rent paid to each branch), cost of supplies	Number of transactions	PA
Rangan *et al.* (1988)	Labor (employees), capital, purchased funds	Loans, deposits (demand and time)	IA
Aly *et al.* (1990)	Labor (employees), capital, loanable funds	Loans (real estate, comm. Ind., consumer, other), demand deposits	IA
Charnes *et al.* (1990)	Total operating expense, total non-interest expense, provision for loan losses, actual loan losses	Total operating income, total interest income, total non-interest income and total net loans	IA
Elyasiani and Mehdian (1990, 1992)	CD, time and saving deposits, demand deposits, capital, labor	Investments, loans (real estate, ind., commer, comer.)	AA
Ferrier and Lovell (1990)	Labor, expenditure on materials, occupancy costs and expenditure on furniture and equipments	Number of deposit, accounts (demand, time), number of loans (real, estate, comm., inst.)	PA
Berger and Humphrey (1991)	Labor, purchased funds, capital	Deposits (demand, retail, saving), loans (real estate, comm., ind., installment)	IA
Olivei (1992)	Labor, non-interest expense, depreciation, interest expenses	Loans, deposits, non-interest income	VAA
Yue (1992)	Interest expenses, non-interest-expenses, deposits	Interest income, non-interest income, total loans	IA
Resti (1997)	Capital, labor, purchased funds	Loans, deposits (current and saving), net loans to banks	VAA
English *et al.* (1993)	Deposits, labor, purchased funds	Loans, investments	AA
Berg *et al.* (1993)	Labor, capital	Loans deposits, Services (number of branches)	VAA
Das (1997)	Deposits, borrowings, no. of employees	Net interest margin, commission, brokerage, exchange	IA
Bhattacharyya *et al.* (1997)	Interest expense, operating expense	Advances, investments, deposits	IA
Sathye (1999)	Interest expenses, Non-interest expenses	Net interest income, non-interest income	IA
Bhattacharyya *et al.* (1999)	Labor, physical, capital	Fixed deposit, saving deposit, current deposit, investment loans and advances, number of branches	VAA
Mukherjee *et al.* (2001)	Transaction deposits, non-transaction deposits, equity, labor, capital	Consumer loans, real estate loans, investment, total non-interest income	IA
Ram Mohan and Ray (2004)	Deposits, operating costs	Loans, investments, other income	IA
Shanmugam and Das (2004)	Deposits, borrowings, labor, fixed assets	Net interest margin, non-interest margin, credit, investment	IA

assets and mainly by the production of loans, in which banks have advantages over other financial institutions. The main shortcoming of the IA and AA is that they do not take into account most of the services provided by banks.

The remaining two approaches are not related to macro economic functions carried out by banks. Under the user cost approach (UCA), the net contribution to bank revenue determines the nature of inputs and outputs. In the value-added approach (VAA), the identification of inputs or outputs is based on the share of value added. Items of the balance sheet with a substantial share of value added are considered as important outputs. In general, the UCA approach is less frequently used due to difficulty in collecting data. The PA approach seems to be apt when the relative efficiency of a branch is considered. The VAA approach has been implemented to measure changes in banking technology over time (Berger and Humphrey, 1991). IA and AA are the most widely used as can be seen from various bank studies as reported in Table I. The table reports a summary of definitions of various outputs and inputs used in some recent studies, which have followed non-parametric approaches.

There is considerable debate in the literature over what banks produce (output) and what resources they use in the process (inputs). Most studies use either the production or the IA. The Indian commercial banks have multiple goals. Coates (1990) comprehensively discussed the objectives of the Indian banking system, for which the PA would be inappropriate. The PA considers that banks use capital, labor and other non-financial inputs to provide services for account holders (Ferrier and Lovell, 1990). In the latter, banks are intermediating funds between savers and investors and incur interest expense and other operating expenses to provide revenue-generating services. Therefore investments, advances and deposits are treated as outputs.

The inputs and outputs of the banks used in the present study conform to the belief that presently the Indian commercial banks' objective is profit-orientation, with the regulatory agency (RBI) trying to foster economic growth (through its policies) while preserving the safety and soundness of the banking system (through adherence to Basel II norms). The study considers two outputs:

(1) net interest margin, (interest earned minus interest paid, this reflects the gain in the financial intermediation process); and

(2) non-interest income (commission, brokerage, reflecting revenues from other services).

The two outputs would reflect the profit goal of the banks. The inputs used are deposits, borrowings, labor (in numbers) and fixed assets (Shanmugam and Das, 2004).

The present research uses a time series of cross-sectional data. The data on inputs and outputs are obtained from RBI's *Statistical Tables* (various issues) relating to banks in India. Labor-related data are obtained from the Indian Banks Association (IBA) bulletins (various issues). The period of analysis is 1995 to 2006. A total of 64 banks operating in India are considered – 27 PSBs, 16 OPBs, 16 FBs and five NPBs. Only these 64 banks are considered as DEA entails an analysis of only a balanced panel and the period of analysis is 1995-2006, a 11-year period in which the numbers of banks have reduced due to mergers.

5. Empirical results

In using the IA, some authors use investments and credit as outputs. Hence, it will be worthwhile to look at the trends. Figure 2 shows the growth in the outputs of the banking sector in terms of investments, credit, interest margin and other income. Overall

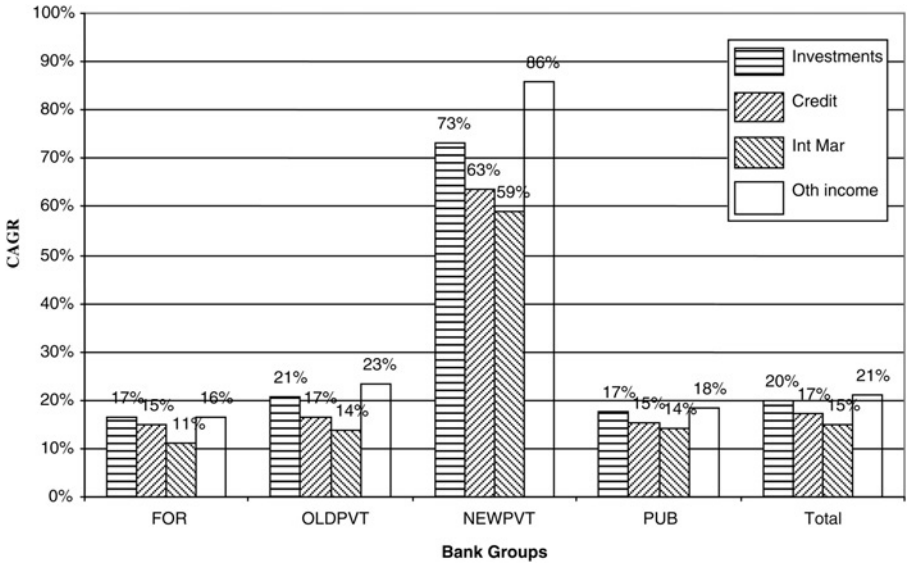

Figure 2.
Growth in outputs by bank ownership (CAGR 1995-2006)

the growth in all indicators has been very high, and seems to suggest that investments have paid off or the banking sector's productivity has increased. A 20 percent CAGR in the case of investments against a 17 percent growth in credit speaks volumes about risk aversion and lazy banking. The 15 percent growth in interest margin is more a result of returns on the banks' investments than their advances. Overall, there has been profitability in the banking sector, but that needs investigation in the light of understanding whether it is capital accumulation driven or productivity driven.

The compounded growth in output (Figure 2) in the post-reform era, particularly among the early adopters of technology (NPBs and FBs), has been significantly higher than the other bank groups. It is interesting to find out what has contributed to this sustained increase in output. This study addresses the question of whether the output increase in the period of consideration (1995-2006) is due to the banks' better investments in technology and the consequent increase in technical efficiency change or efficient use of existing inputs and technology.

Given the importance of productivity growth, labor productivity trends are closely monitored by economists and policy makers and are often used as a measure of productivity (Ray, 2002). Figures 3 and 4 report median BPE and median PPE. Rishi and Saxena (2004) have used these among other indicators to show how the rising labor productivity in foreign and NPBs after 1997 indicates their very efficient use of recourses, particularly labor, as well as their efficient technology deployment as compared to PSBs (both the state bank group and other nationalized banks). Their empirical analysis demonstrates the superior performance of the early adopters of technology (NPBs and FBs) as compared to the late or passive adopters (PSBs). Figures 3 and 4 show very high variations in labor productivity trends among the different bank groups. The labor productivity of PSBs has been increasing but is very low in comparison with that of the NPBs and FBs.

BPE and PPE are only partial productivity figures like output per worker and fail to incorporate the contribution from capital and other inputs. According to Farrell (1957), labor productivity is a blatantly unsatisfactory measure and may indeed have

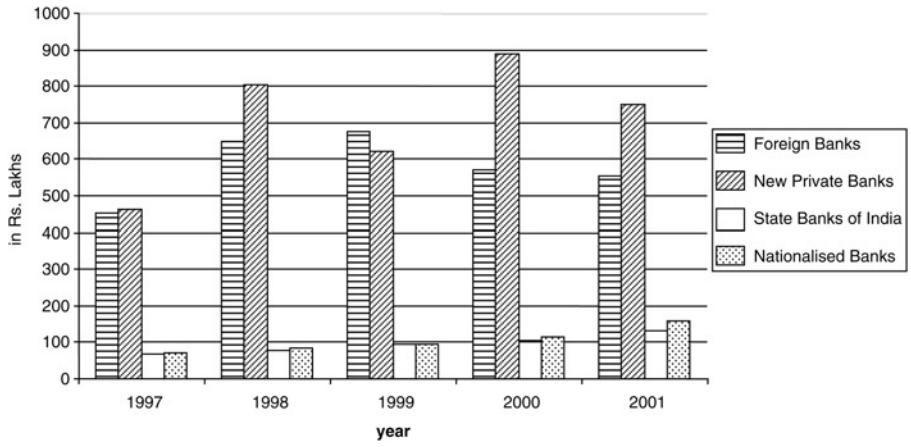

Figure 3.
Median business per employee by bank ownership (1997-2001)

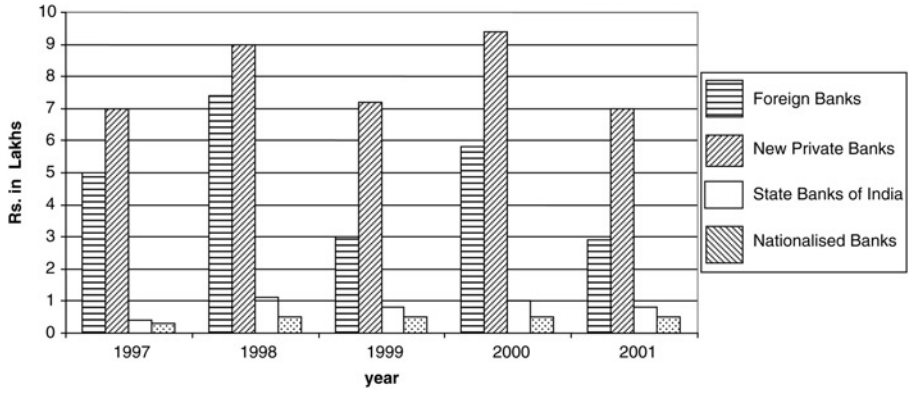

Figure 4.
Median profit per employee by bank ownership (1997-2001)

unfortunate effects on economic policy. It is also argued that a rapid growth in a partial factor productivity measure could be due to a rapid growth in an omitted input category and thus could be quite misleading (Diewert, 2003). Similarly, these measures are incapable of identifying the causal factors accounting for observed productivity growth. This problem can be resolved by analyzing TFP growth, which encompasses the effect not only of technical progress but also of better utilization of capacities, learning-by-doing and improved skills of labor (Ahluwalia, 1991). Both CRS and variable returns to scale (VRS) gave the same results. Hence an assumption of CRS or VRS is not needed.

Table II shows the TFP growth using the Malmquist productivity index over a period of time. Unlike the measure of labor productivity, which shows a steady increase, this growth rate shows ups and downs. There was a decline in TFP growth in the banking industry in the years 1995-1996 and 1999-2000. The decrease in TFP in 1995-1996 (−2.9 percent) can be attributed to the very high increase in inputs in that period. Even in the year 1999-2000 (−1.7 percent), the negative TFP growth could be attributed to RBI's directive to attain 100 percent computerization by 2000 (Reserve Bank of India, 1999) which necessitated high input costs. The banks probably hoped to reap the benefits of investment in fixed assets and their borrowings over a period of time. The period

Year	TFP growth
1995-1996	−2.9
1996-1997	9.1
1997-1998	3.5
1998-1999	3.5
1999-2000	−1.7
2000-2001	8.4
2001-2002	1.5
2002-2003	10.2
2003-2004	8.6
2004-2005	9.4
2005-2006	6.2
1995-2000	*2.30*
2001-2006	*7.38*
1995-2006	*5.07*

Table II. Total factor productivity growth

Source: Author's computation using Malmquist index determined using data from RBI and IBA

1995-2000 registered a growth of 2.30 percent. The period 2001-2006 however showed a robust growth rate of about 7.38 percent. Overall the entire period registered a positive growth rate of 5.07 percent.

An important factor contributing to the productivity growth (decline) is improvement (deterioration) in the level of technical efficiency. If a bank is more efficient over time, its average productivity increases. Appendix 1 reports on the levels of average technical efficiency for all banks for four years, namely 1995, 1999, 2003 and 2006. The technical efficiency in four time periods has been calculated to examine if the efficiency has changed over a period of time for all banks as a whole as well as for individual banks. The table shows that technical efficiency has been high since 1995 ranging from 0.91 to 0.98 (1995-2006) implying that about 91-98 percent (geometric mean of all banks) of the potential output is being produced using the same input quantities. The table also shows that the technical efficiencies of individual banks have improved over the period. In 1995, there were only 23 banks defining the frontier, predominantly FBs. In 1999, there were 40 banks on the frontier and many among them were NPBs, OPBs and PSBs. The number of banks on the frontier only marginally improved to 46 in 2003 and to 51 in 2006. This only shows that banks are constantly trying to keep up with technically efficient banks.

Next, the Malmquist productivity index and its components are analyzed. The productivity growth change and its components are discussed below. Table III below reports geometric means of the Malmquist productivity change index along with its components averaged over the period 1995-2006 and its two sub-periods 1995-2000 and 2001-2006. The purpose is to provide a quick glance on the central tendency of productivity change in the banking sector as well as the PSBs, OPBs, NPBs and FBs in the post-liberalization era.

The period 1995-2006 is divided into two sub-periods, 1995-2000 and 2001-2006. This is for two reasons. First, the division enables understanding the effect of the Reserve Bank of India (1999), which directed banks to achieve 100 percent computerization by 2000. Second, this division will show us which component of the TFP change was dominant in the two periods. Research has shown that in many studies (Berg *et al.*, 1992; Wheelock and Wilson, 1999) the efficiency effect precedes the technical effect. It would be worthwhile to test whether similar patterns holds for India.

The numbers in Table III are to be interpreted in the following manner. The ΔTFP of 1.023 implies there has been a productivity increase of 2.3 percent while against $\Delta T = 0.970$ implies that there is a productivity regress of 3 percent. If the number is 1 then there is no productivity change.

The annual average growth rate in TFP has been 5.1 percent in the entire banking sector in 1995-2006. Technical change has contributed to the tune of 4.3 percent per annum while efficiency change (catching up effect) has been just about 0.6 percent per annum on an average, showing that innovation and technological progress have had a larger effect on the TFP change over the entire period. When the different bank groups are examined closely, it can be noticed that the TFP increase for PSBs (10.7 percent) and the OPBs (5.7 percent) have occurred primarily because of progress in technical change. The TFP growth in NPBs has been only 1.1 percent primarily due to technical regress. FBs have shown a small positive growth arising from technical progress.

In the period 1995-2001, TFP increased by only 2.3 percent and the same was due to efficiency progress. While efficiency gains were positive in this period showing convergence, technical regress occurred in OPBs, NPBs and FBs, but not PSBs.

In the period 2001-2006, TFP increased by 7.4 percent primarily on account of technical progress. Almost the entire TFP change came from technical gains which were led primarily by a 6.4 percent technical progress or a frontier shift. A closer look at the various banking groups reveals that the NPBs had a technical progress of 16.1 percent followed by OPBs of 14 and 10 percent by both the PSBs as well as FBs. Essentially during this period, the banking groups' innovation and frontier shifts caused productivity gains, and efficiency changes had very little effect on productivity increase among the various banking groups. As can be seen, most of the TFP change in all the banking groups has come about because of technical change. Hence, this positive TFP growth can only be attributed to technical progress while efficiency has remained almost unchanged. This suggests that the change in technical efficiency has outweighed change in efficiency, i.e. innovation in the last 11 years has impacted growth of the banking sector more than the catch-up effect.

Figure 5 shows the technical efficiency changes on a year-on-year basis. The efficiency change has been above 1 among all bank groups in the initial period (1995-2000) and below or equal to one in the latter period (2001-2006). This means that efficiency gains existed in the initial period.

Figure 6 shows technical changes over the entire period. It can be seen that technical changes were less than 1 in the first period and more than 1 in the second period. Examining Figures 5 and 6 together, it can be concluded that efficiency gains were

	1995-2000			2001-2006			1995-2006		
Bank type	ΔE	ΔT	ΔTFP	ΔE	ΔT	ΔTFP	ΔE	ΔT	ΔTFP
Banking sector	*1.050*	*0.970*	*1.023*	*1.012*	*1.064*	*1.074*	*1.006*	*1.043*	*1.051*
PSBs	1.040	1.000	1.110	1.010	1.100	1.100	1.000	1.107	1.100
OPBs	1.000	0.980	0.980	1.000	1.140	1.140	1.001	1.057	1.058
NPBs	1.000	0.990	0.990	1.000	1.161	1.160	1.000	1.011	1.011
FBs	1.010	0.890	0.980	0.990	1.10	1.11	1.000	1.004	1.004

Note: ΔE, ΔT and ΔTFP denote the change in efficiency change, technical change and TFP change, respectively

Source: Author's computation using Malmquist index determined using data from RBI and IBA

Table III. Malmquist productivity growth and its components in Indian banks by ownership (1995-2006)

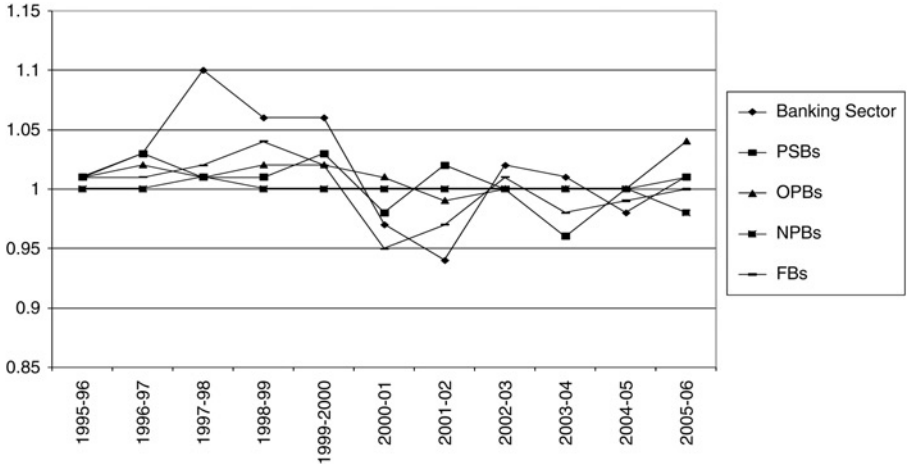

Figure 5.
Technical efficiency changes in bank groups in India (1995-2006)

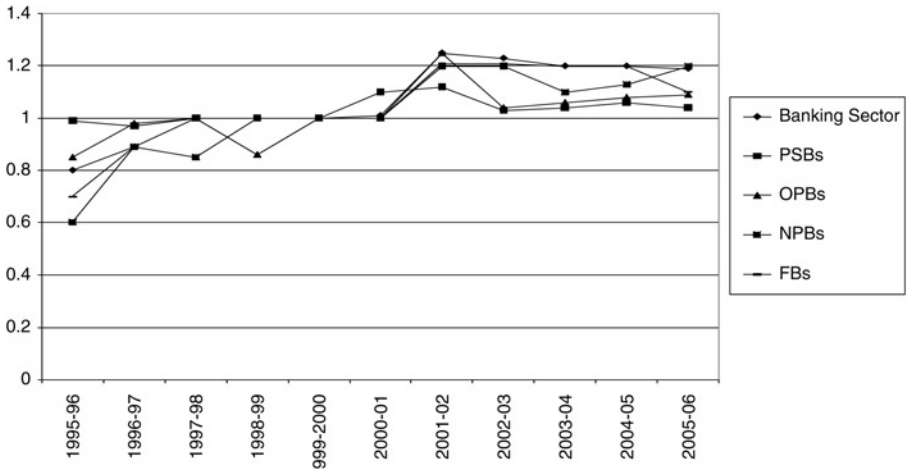

Figure 6.
Technical change in bank groups in India (1995-2006)

dominant in the first period while technical gains dominated the second period. Also, efficiency increase preceded technical progress, i.e. the catch-up effect preceded the technology effect.

Figures 6 and 7 show how technical change and TFP change almost mirror one another, showing that almost all changes in productivity were due to technological advances rather than diffusion of technology in the entire period and the two sub-periods.

When Table III and Figure 8 are compared across bank groups it can be seen that in the case of NPBs the CAGR of all their inputs has been very high. While all other banking groups have had a negative growth in labor force, only the NPBs have had a phenomenal labor addition of about 50 percent per annum. This again suggests that their output growth could just be factor input driven given the fact that their efficiency levels have not been very high.

On comparing these results with those of Subramanyam (1993), it is found that most of the TFP growth can be attributed to technical change. However, his work pertains to the time period before liberalization. He too used the IA to define inputs/outputs. Reddy (2005)

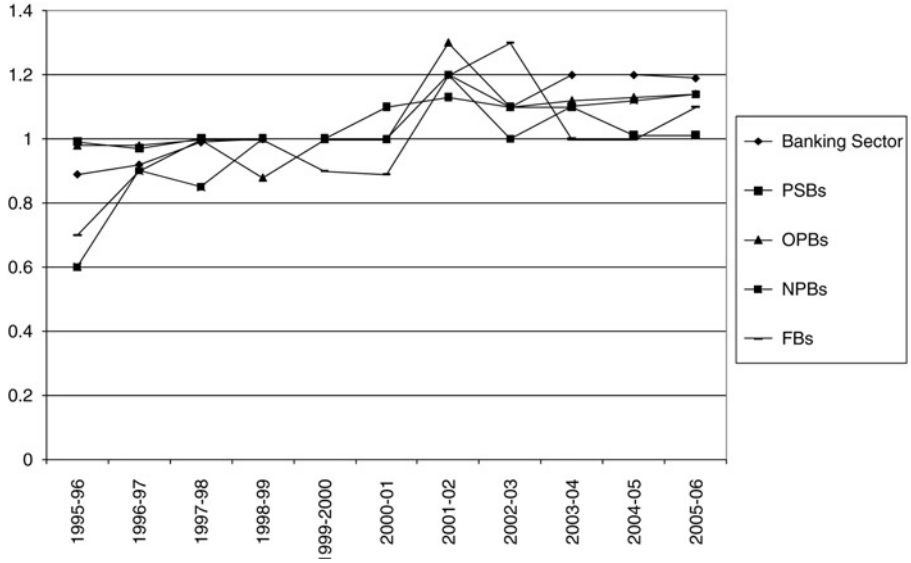

Figure 7.
TFP changes in bank groups in India (1995-2006)

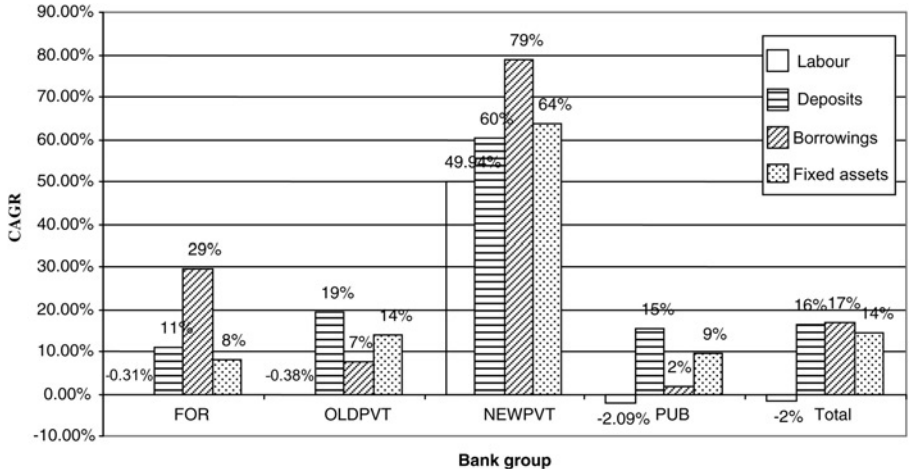

Figure 8.
Inputs growth in bank groups in India (CAGR 1995-2006)

found TFP growth stagnant during 1996-2002, and found more technical regress than efficiency gains. However, he also found that PSBs and OPBs had higher TFP growth compared to NPBs and FBs. He found the catch-up effect playing a larger role than the innovation effect. This can be attributed to his time period of study. In this analysis too, the catch-up effect was dominant in 1995-2000. Comparing these results with some international studies, it is found that Berg *et al.* (1992) noted that in Norwegian banks TFP grew due to relative efficiency gains rather than frontier shifts post-deregulation. However, studies by Wheelock and Wilson (1999) and Alam (2001) relating to the US economy observed that TFP growth was due to technology change or frontier shifts.

The dominance and hence superiority of technical change over efficiency change in driving productivity in Indian banks is in line with the results from US banks (Mukherjee *et al.*, 2001), Spanish Banks (Grifell-Tatjé and Lovell, 1997), and Korean

banks (Gilbert and Wilson, 1998), where the productivity growth was found to be driven mostly by technical progress rather than efficiency increase. Apparently, financial liberalization has the potential to foster innovation in banking. Domestic banks in India responded to these changes by imitating the same products and services such as extending customer credit and starting to use high technology including establishing ATM networks, associating with the SWIFT system and using online computer systems.

In the preceding analysis, it is found that though productivity growth in the period 1995-2006 was basically aided by technical progress, productivity growth during the period 1995-2000 mainly resulted from "imitation" efforts of the inefficient banks to catch-up with the best practice banks. In the period 2000-2006, it can be observed that productivity growth was more due to "innovation" or outward shifts of the production frontier by the leading banks. That is, the efficiency gap between the worst and best-practice banks tended to narrow in the liberalized environment.

The analysis thus far has shed light on the TFP growth in the Indian banking sector and the sources of growth. It would be useful to examine the factors that determine TFP growth. This is taken up in the following section.

6. Productivity and efficiency determinants

In this section, the variation in TFP growth and its components among various bank groups is examined across time. What are the possible factors that can explain this variation? An insight can be had from a number of studies. Significant differences among the bank groups and their sources are identified. Beim and Calomiris (2001) suggest that according to the property rights theory[3], agency cost theory[4] and contract theory[5] publicly owned firms would perform less efficiently and less profitably than private firms. According to them private ownership of the means of production is the single credible form for higher productive efficiency. The goal of a successful private firm is to maximize shareholder value, which is closely connected to the efficient use of resources. However, public firms have various goals that are usually conflicting and rarely related to the efficient use of resources. They seem to focus on employment, promote regional development and reward loyalists. In India too, PSBs have development as their goal and CEOs are appointed by the government. It would therefore be useful to analyze the significant differences that exist among the different bank groups in terms of their size, time, and ownership.

The five series of cross-sectional data that we have permit the use of panel regression models. Panel data consist of observations on the same cross-sectional or individual units over several time periods. There are several advantages to using panel data. First, they increase the sample size considerably. Second, by studying repeated cross-sectional observations, panel data are better suited to study the dynamics of change. Third, panel data enable us to study more complicated behavior models. Despite their advantages, the problems of hetroscedasticity (in cross-sectional data) and auto correlation (in time series data) inherent in panel data must be carefully addressed. The two most prominent techniques used in panel data analysis are the fixed effect (FE) model and the random effect (RE) model. The familiar Hausman specification test can be used to decide between the FE and the RE models. Given a model and data in which fixed effects estimation would be appropriate, the Hausman test is employed to determine if random effects estimation would be almost as good. In the case of fixed effects, the Hausman test is employed for testing the following hypotheses:

H_0. Random effects would be consistent and efficient, vs

H_1. Random effects would be inconsistent.

The result of the test is a vector of dimension k that will be distributed as chi-square with "k" degrees of freedom. If the Hausman test statistic is large, one must use the FE model. If the statistic is small, the RE can be used.

The system of equations for the panel regression for each bank i= 1,2. . .n; n = 64 is given below:

$$\text{TFP growth} = b_0 + b_1\ \text{Ownership}_{\text{PSBs}} + b_2\ \text{Ownership}_{\text{OPBs}} + b_3\ \text{Ownership}_{\text{FBs}} + b_4\ \text{Time Period} + b_5\ \text{Size} + \varepsilon_1$$

$$\text{Technical change} = c_0 + c_1\ \text{Ownership}_{\text{PSBs}} + c_2\ \text{Ownership}_{\text{OPBs}} + c_3\ \text{Ownership}_{\text{FBs}} + c_4\ \text{Time Period} + c_5\ \text{Size} + \varepsilon_2$$

$$\text{Efficiency change} = d_0 + d_1\ \text{Ownership}_{\text{PSBs}} + d_2\ \text{Ownership}_{\text{OPBs}} + d_3\ \text{Ownership}_{\text{FBs}} + d_4\ \text{Time period} + d_5\ \text{Size} + \varepsilon_3$$

where b_is, c_is, and d_is are the parameters estimated by the panel regression model. ε_1, ε_2, and ε_3 are the normally distributed random error with mean "0" and variance σ_i^2. The Hausman test statistic obtained from the panel regression results is equal to 550.56, which is very high. This suggests that FE is preferred to the RE model. Hence, the FE model is used and the results are tabulated in Table IV.

The separate dependent variables in the respective regression models are the productivity measures, namely TFP change, technical change and efficiency change. The independent variables are Ownership (PSBs, OPBs, FBs, NPBs), Time Period and Size.

Ownership is introduced as a dummy variable (NPBs are used as the base group). Time Period is also a dummy variable that takes the value 1 if the observation belongs to 1995-2000 and 0 if it belongs to 2000-2006. This helps to make meaningful comparisons among bank groups across the two periods. As mentioned earlier, several studies have used two approximately equal periods for their analysis. The reason for splitting in the year 2000 has been given earlier. The Time Period dummy variable enables examination of significant changes in the performance of the banks between period 1 (1995-2000) and period 2 (2000-2006). As commonly adopted, size is measured by taking the log of the total assets of banks.

Observations, inferences and conclusions

Table IV shows that:

	TFP growth	Technical change	Efficiency change
Intercept	849.9162*	−6.24E + 13*	−4.44E + 11*
PSBs (b_1, c_1, d_1)	−648.4490*	5.16E + 12*	1.08E + 11*
OPBs (b_2, c_2, d_2)	−614.8242*	1.28E + 12	−2.27E + 10
FBs (b_3, c_3, d_3)	6.553093	2.09E + 12	−9.86E + 09
Time period dummy (b_4, c_4, d_4)	−155.3992*	−2.37E + 12*	−7.71E + 10*
Size (b_5, c_5, d_5)	−0.079133*	2.48E + 12*	2.05E + 10*
N	484	552	552
R^2	*0.582249*	*0.298684*	*0.212270*

Note: *Indicates significance at 5 percent level for the coefficient of the independent variables
Source: Author's computation with LIMDEP software using data from RBI

Table IV.
Fixed effects estimates of TFP change and its components

- PSBs had significant productivity, technology and efficiency improvements in comparison to the NPBs, which form the base group whereas OPBs experienced significant productivity changes only.
- FBs did not exhibit significant changes in any of the productivity measures.
- The dummy variable for Time Period indicates that there are significant differences between the two periods. TFP change and its components are significantly lower in the former period compared to the latter period.
- Bank size has a significant positive effect on technical change and efficiency change. A positive association between technical change and efficiency change with size indicates that larger banks have increased efficiency, implying that an increase in size increases technical change and efficiency change.
- There is a negative association between size and TFP change. This implies that smaller banks could be more productive. In other words, TFP gains do not yield any comparative advantage to larger banks.

A recent paper by Das and Ghosh (2006) discusses the financial deregulation and efficiency in Indian banks in the post-reform period. Their period of discussion is 1992-2002. The time period is different and we use the IA. It may be pertinent to note that this research as well as the paper by Das and Ghosh (2006) find that size does matter. There is a negative association between size and TFP change according to the preceding analysis. In other words, TFP gains do not yield any comparative advantage to larger banks.

7. Managerial implication of research

Earlier studies that used the decomposition model found that TFP grew in most economies only after deregulation and after the infusion of competition. The reasons for such TFP growth in those economies included both the catch-up effect and the innovation effect. The dominance of any one of these two effects appears to be linked to the timing of deregulation and the corresponding state of the banking sector in a country. As Parente and Prescott (2004) present in their essay on the theory of the evolution of international income levels:

> Countries reach their critical levels of efficiency at different dates not because they have access to different stocks of knowledge but rather because they differ in the amount of society-imposed constraints on the technology choices of the citizens.

Elimination of these constraints relating to the use of technology is critical according to them for countries to grow and become rich. Lucas (2003) observed that redistribution of resources should be driven more by market forces than by government intervention. To quote him: "Of the tendencies that are harmful to sound economics, the most seductive, and in my opinion the most poisonous, is to focus on the questions of distribution." According to him, growth results only from understanding the potential to increase production rather than finding ways to distribute current production. The growth success of countries with policies of open trade is not only because of their moving towards an efficient scale or catching up but more because of technology transfer, serious international competition and learning-by-doing. The lesson we can take away from the above two studies in the context of this paper is that major increases in growth in the Indian banking sector in the more recent period came from technology change or frontier shifts as compared to efficiency change. Also, growth is larger due to frontier shifts than

due to efficiency change. This endorses Lucas (2003) in regards the focus on the positive impacts of deregulation and competition in the Indian banking sector.

The question therefore is what kinds of policies are better served to improve the growth prospects of the banking sector? The results of the analysis presented in this paper suggest that policies that result in efficiency change are likely to have little impact on the future prospects of the banking sector relative to policies that foster the adoption of the latest technologies. This is exactly the focus of RBI. Though some banks may complain about the imposition of technology, the result of this obligation is very positively clear from the analysis done here.

8. Summary and conclusions

In this paper, DEA method has been used to assess the efficiency of the entire banking sector and the bank groups. The purpose has been to investigate TFP change and its components' (obtained using Malmquist index) influence on the growth in the banking sector as well as in the four bank groups. In doing so, for each bank group the levels of technical efficiency, technical efficiency change, efficiency change and TFP change have been estimated. Further investigation has been done to determine if significant differences in these exist between the different bank groups in terms of size, Time Period and ownership. The determinants of productivity have been assessed.

The TFP growth of about 5 percent over the entire period (1995-2006) was almost dominated by technical change as compared to efficiency change, showing that technology and innovation had a greater impact than efficiency change, or the catch-up effect, on the growth of the banking sector during this period. The catch-up effect did not seem to regress on the whole set of banks or for any of the bank groups, showing that existing technology was efficiently used. However, a great increase in the utilization of existing technology was not apparent. Hence, it can be concluded that most of the growth was driven by new technology. The simultaneous increase of both outputs and inputs, keeping in mind the above observations, reveal that the outputs were driven more by the inputs or factor inputs, than by efficiency changes associated with any given level of input.

Notes

1. This is apparent from the following statement by Dr Bimal Jalan, the former Governor of RBI: "Inefficiency in the use of resources, tolerance of waste and slothfulness also contributes to low productivity as often reflected in high spreads. The important challenge of managing transformation would, for the Banking Sector, mean moving from high cost, low productivity and high spread to being more efficient, productive and competitive" (Jalan 2002).
2. The ten select financial indicators as brought out by RBI are CRAR-Tier I, CRAR-Tier II, CRAR-Total, Net NPAs/Net Advances, Interest Income/Working Fund, Non-Interest Income/Working Fund, Operating Profit/Working Fund, Return on Assets, Business per employee, Profit per employee.
3. Demsetz (1967) considers that one of the main "function[s] of property rights is that of guiding incentives to achieve a greater internalization of externalities" (Beim and Calomiris, 2001, p. 348).
4. Agency costs are a type of *transaction cost*, reflecting the fact that without incurring costs, it is impossible for principals to ensure agents will act in the principals' interest. (Jensen and Meckling, 1976).
5. In economics, contract theory studies how economic actors can and do construct contractual arrangements, generally in the presence of asymmetric information (Bolton and Mathias, 2005).

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Appendix

Technical efficiency	Bank type	1995	1999	2003	2006
ING Vysya Bank	FOR	0.779	0.788	0.931	0.98
ABN Amro Bank	FOR	1	1	1	1
Abu-Dhabi Commercial Bank	FOR	1	1	1	1
Bank of America	FOR	1	1	1	1
Bank of Bahrain & Kuwait	FOR	0.999	0.996	0.929	0.98
Barclays Bank	FOR	1	1	1	1
Bank of Tokyo	FOR	1	1	1	1
BNP Paribas	FOR	1	1	0.933	1
Chase Manhattan Bank	FOR	1	1	1	1
Citibank	FOR	1	1	1	1
DBS Bank	FOR	1	1	1	1
Hongkong & Shanghai Bank	FOR	0.948	0.904	1	1
Deutsche Bank	FOR	1	1	1	1
Mashreq Bank	FOR	1	1	1	1
Oman International Bank	FOR	0.994	0.943	0.591	0.68
State Bank of Mauritius	FOR	0.951	1	1	1
Standard Chartered Bank	FOR	0.935	0.955	1	1
Centurion Bank	NEWPVT	1	0.889	1	1
Development Credit Bank	NEWPVT	1	0.923	0.991	0.99
HDFC Bank	NEWPVT	0.676	1	1	1
Indusind Bank	NEWPVT	0.943	1	1	1
ICICI Bank	NEWPVT	0.88	1	1	1
UTI Bank	NEWPVT	1	1	1	1
Bank of Rajasthan	OLDPVT	0.969	0.955	0.981	0.985
Baharat Overseas Bank	OLDPVT	0.801	0.894	0.88	0.9
Catholic Syrian Bank	OLDPVT	0.835	0.798	1	1
City Union Bank	OLDPVT	0.803	0.997	0.967	0.98
Dhanalakshmi Bank	OLDPVT	0.91	0.894	1	1
Federal Bank	OLDPVT	0.879	1	0.988	0.99
Jammu & Kashmir Bank	OLDPVT	0.938	1	1	1
Karur Vysya Bank	OLDPVT	0.775	0.909	0.802	0.88

(*continued*)

Table AI.
Technical efficiency (using Malmquist index)

Technical efficiency	Bank type	1995	1999	2003	2006
Lakshmi Vilas Bank	OLDPVT	0.863	0.999	1	1
Karnataka Bank	OLDPVT	0.89	0.881	1	1
Lord krishna bank	OLDPVT	0.845	0.971	1	1
Ratnakar Bank	OLDPVT	0.731	0.951	1	1
Nainital Bank	OLDPVT	0.877	1	1	1
Tamilnad Mercantile Bank	OLDPVT	0.784	0.904	1	1
South Indian Bank	OLDPVT	0.963	0.943	0.981	0.98
United Western Bank	OLDPVT	0.767	0.881	0.439	0.77
State Bank of India	PUB	1	0.88	0.957	1
State Bank of Bikaner & Jaipur	PUB	0.952	0.975	1	1
State Bank of Hyderabad	PUB	0.893	1	1	1
State Bank of Indore	PUB	0.907	1	1	1
State Bank of Mysore	PUB	1	1	1	1
State Bank of Patiala	PUB	1	1	1	1
State Bank of Saurashtra	PUB	0.918	1	0.907	0.98
State Bank of Travancore	PUB	0.992	1	1	1
Allahabad Bank	PUB	0.866	1	1	1
Andhra Bank	PUB	0.903	1	0.951	1
Bank of Baroda	PUB	0.842	0.951	0.978	0.99
Bank of India	PUB	0.836	0.91	1	1
Bank of Maharastra	PUB	0.986	0.92	0.922	0.98
Canara Bank	PUB	0.928	0.867	1	1
Central Bank of India	PUB	0.86	1	1	1
Corporation Bank	PUB	1	1	0.991	1
Dena Bank	PUB	0.901	0.965	1	1
Indian Bank	PUB	0.877	0.836	0.933	1
Indian Overseas Bank	PUB	0.907	0.871	0.966	1
Oriental Bank of Commerce	PUB	1	1	1	1
Punjab & Sind Bank	PUB	0.906	0.849	1	1
Punjab National Bank	PUB	0.923	1	1	1
Syndicate Bank	PUB	0.896	1	1	1
UCO Bank	PUB	0.921	0.918	0.878	0.96
Union Bank of India	PUB	1	1	1	1
United Bank of India	PUB	0.896	1	1	1
Vijaya Bank	PUB	0.836	0.811	0.955	1
Geometric mean		*0.919*	*0.96*	*0.965*	*0.98366*
No. of banks on frontier = 1		23	40	47	51

Table AI.

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