Int Rev Econ (2009) 56:47–84
DOI 10.1007/s12232-008-0057-2

Did efficiency of Indian public sector banks converge with banking reforms?

Sunil Kumar · Rachita Gulati

Published online: 15 November 2008

Abstract This paper examines the issue of convergence of efficiency levels among Indian public sector banks (PSBs) during the post-reforms period spanning from 1992/1993 to 2005/2006. The empirical results indicate that the majority of PSBs have observed an ascent in technical efficiency during the post-reforms years. Further, the inefficient PSBs have been noted to be catching up with the efficient ones. That is, the banks with low level of efficiency at the beginning of the period are growing more rapidly than the highly efficient banks. In sum, the study confirms a presence of convergence phenomenon in the Indian public sector banking industry.

Keywords Data envelopment analysis · Public sector banks · Technical efficiency · σ-Convergence · β-Convergence

JEL Classifications G21 · G15

1 Introduction

In the 1970s and 1980s, the Indian banking sector was marked by a high degree of regulation and the parameters like business growth and branch network were the major performance criteria. The government set limits on interest rates, increased cash and statutory liquidity requirements, increased priority sector lending requirements to channel funds at below-market rates to the sectors favored by

S. Kumar (✉) · R. Gulati
Punjab School of Economics, Guru Nanak Dev University,
Amritsar 143005, Punjab, India
e-mail: sunil12eco@yahoo.com

R. Gulati
e-mail: rachita1302@yahoo.co.in

government, and nationalized banks to ensure that these policies were implemented and to allay concerns about bankruptcies and insider lending (Hanson 2005). In this highly regulated and controlled environment, Indian banks, especially public sector banks (PSBs), lost versatility in their operations and consequently, experienced a fall in profitability, operating efficiency and productivity. As a result, the banking system became virtually bankrupt and ill suited to the task of allocating credit and performing ordinary banking business (Joshi and Little 1996).[1] Overall, the state of the banking sector in India could be described as a classic example of 'financial repression' à la Mackinnon and Shaw (Mohan 2007).

For getting rid of this distressed banking system, the policy makers[2] felt a need of reform measures to improve the health of the Indian banking system. Consequently, the first phase of banking reforms was set in motion in the year 1992 on the basis of the recommendations of the Committee on the Financial System (1991).[3] The key objective of the reforms was to transform the operating environment of the industry from a highly regulated system to a more market-oriented one with a view to increasing competitiveness and efficiency (Sarkar 2004). Nevertheless, it is significant to note that the main focus of the reforms process was to increase the profitability and efficiency of the then 28 PSBs that controlled about 90% of all deposits, assets, and credit (Shirai 2002). The reforms process heralded the beginning of implementing prudential norms consisting of capital adequacy ratio, asset classification and income recognition and provisioning, and the deregulation of the operating environment (Agarwal 2000). In order to impart more vitality and autonomy to banks in their operations, the policy makers successfully adopted the route of partial privatization of PSBs, interest rate deregulation, relaxing entry norms for domestic private and foreign banks, and removal of 'financial repression' through reduction in statutory pre-emptions. This phase of banking reforms produced some favorable outcomes as reflected by the fact that most of the banks had achieved the international standards of the capital adequacy norm of 8% of the risk-weighted assets, had earned operating profits and, had reduced significantly the proportion of non-performing assets (NPAs) to the total assets (Sarma 1995).

The success of the first phase of banking reforms catalyzed the move towards the next phase in the year 1998. The recommendations of the Committee on the Banking

[1] For supporting their observation, the authors cited that "The profitability of banks was extremely low in spite of rapid growth of deposits. The average return on assets in the second half of the 1980s was about 0.15%, an extraordinary low figure by world standards. Return on equity was higher (about 9.5%) but that was simply a reflection of the low capitalization of Indian banks. Capital and reserves averaged about 1.5% of assets, compared to 4–6% in other Asian countries. The true picture was even worse because these figures were not based on applying the correct income recognition and provisioning criteria….The banking system had become extremely fragile as a result of the large overhang of non-performing assets (NPAs). Under proper accounting procedures, the latter result in lower income, high provisions, lower net profits, and erosion of capital and net worth".

[2] In India, the policy makers that have been entrusted with the task of formulating the policies for the banking sector comprise the Reserve Bank of India (Central Bank), Ministry of Finance, and related Government and financial sector regulatory entities.

[3] This committee is popularly known as Narasimham Committee I, named after its chairman M. Narasimham.

Sector Reforms (1998)[4] provide the blueprint of the second phase of banking reforms. The key focus of this phase has been on strengthening the foundations of the banking system as well as on issues like upgradation of technology and human resource development (Bhaumik and Mukherjee 2001). This phase laid stress on strengthening the system safeguards and improving the structural environment. The basic tenet of reform measures in this phase was to usher the transparency in financial statements, diversification of ownership and strong corporate governance practices to mitigate the prospects of systemic risks in the banking sector. In view of that, the prudential norms have been made more stringent and tighter to bring these at par with international standards. On the whole, the thrust of the banking reforms program since 1992 was on (1) the promotion of efficiency through competition and market orientation; and (2) strengthening the shock absorptive capacity of the system through adoption of prudential norms and tightening of supervision.

With the completion of about 16 years of banking reforms process, it seems pertinent to take stock of the impact of reform measures on the efficiency of PSBs, a most significant constituent of the Indian banking system.[5] A theoretical proposition appears in the banking literature that a deregulatory process increases competitive forces in the financial system so that 'banks not allocating their resources efficiently would perish unless they could become like their efficient competitors by producing more output with exiting inputs' (Alam 2001). In the spirit of this proposition, an ascent in input-conserving efficiency of PSBs during the post-deregulation years would reflect a positive response by the banks to the reform measures and thus, signals the success of the reforms process in accomplishing its goal of attaining high operating efficiency in the public sector banking industry.

In the recent years, there has been a proliferation of academic studies focusing on the impact of institutional changes, such as deregulation and liberalization, on the efficiency and productivity of the Indian banking sector (see Sect. 3 for a brief survey of these studies). Nonetheless, these studies concentrated primarily on the efficiency differences across ownership groups and the trends in efficiency during the post-reforms years in different ownership groups. A common feature which appears in these studies is that a pooled data set of banks belonging to different ownership groups has been used to estimate a single common efficient frontier to assess the relative efficiency of banks. However, the results based on a single common frontier may be distorted because the banks across different ownership groups are not likely to face identical frontiers due to the differences in economic and regulatory environments, and the production and cost structures faced by the banks that are separated on the basis of ownership. Nevertheless, the result of the present study are more likely to be free from any such distortions because 27 PSBs that have been included in the present empirical setting constitute a homogeneous sample since these institutions are operating under similar economic environment and are subject to the same regulatory regime.

[4] This committee is popularly known as Narasimham Committee II, named after its chairman M. Narasimham.

[5] As on March 31, 2006, PSBs accounted for 72.3% of the total assets, 74.9% of the deposits, and 72.9% of the advances of all the scheduled commercial banks.

The contribution of the present study to the literature on Indian banks is twofold. First, it provides a bank-wise analysis pertaining to the impact of deregulatory policies on the technical efficiency (TE) of PSBs. This is contrary to the results of existing studies that reported the results at highly aggregated levels such as public versus private banks, private versus foreign banks, and public versus foreign banks. The bank-wise results would be more useful in designing micro-level policies in the banking industry. Secondly, no attempt has been made in the existing literature to test the presence of the phenomenon of convergence or divergence in the efficiency levels across Indian banks using the concepts of σ-convergence and β-convergence. The present study also aims to fill this void. More specifically, the principal objective of this study is not only to analyze the trends in TE of individual PSBs, but also examine whether the efficiency levels of these banks have converged under the deregulatory regime or not.

Our analysis evolves in two steps. First, we calculate TE scores for individual PSBs using the technique of data envelopment analysis (DEA), a deterministic non-parametric approach of efficiency measurement. DEA as introduced by Charnes et al. (1978) based on Farrell's work (Farrell 1957), identifies a group of optimally performing banks that are defined as efficient and assigns them a TE score of one. These efficient banks are then used to create an efficient or best-practice frontier. The TE scores for inefficient banks are then calculated relative to this frontier. More away the inefficient bank is from this frontier, lower is its TE score. In DEA, the inefficient banks are given TE scores of strictly less than 1, but greater than zero. DEA was firstly applied by Sherman and Gold (1985) for assessing the efficiency of bank branches and, thereafter, it proved a very promising tool for monitoring the efficiency in banking industry. Of the 122 studies reviewed in the extensive survey carried out by Berger and Humphrey (1997) on efficiency of depository financial institutions in 21 countries, 62 studies (i.e., just over 50%) employed DEA to examine the efficiency of the banking sector.[6] The connotation of this reference is that over the years, DEA has emerged as a well accepted and popular technique for evaluating the efficiency of the banking system. Second, we use traditional cross-sectional regression approach for investigating the presence of σ-convergence and β-convergence in TE levels of PSBs. In the contemporary literature, similar approach has been used by Tomova (2005), Mamatzakis et al. (2007), and Weill (2008) to examine the convergence in bank efficiency levels across European countries.

Our empirical investigation suggests that the majority of PSBs have experienced an increase in technical efficiency during the post-reforms years. Further, the improvement in TE was more pronounced in the years belonging to second phase of reforms in relation to those in the first phase. The empirical findings pertaining to σ-convergence and β-convergence provide strong evidence in favor of convergence in TE levels among PSBs during the post-reforms years. One implication of these results is that the originally inefficient banks in the Indian public sector banking industry are not only catching up with the originally efficient ones (i.e., the banks

[6] The 60 remaining studies applied other four-frontier approaches namely, stochastic frontier analysis (SFA), thick frontier approach (TFA), distribution free approach (DFA), and free disposal hull (FDH).

with low level of efficiency at the beginning of the period are growing more rapidly than highly efficient banks), but their performance is improving at such a rate which enabled them to overtake banks that were performing well. In sum, Indian public sector banking industry not only experienced significant efficiency gains during the post-reforms period but also witnessed strong convergence in TE levels among PSBs.

The rest of this paper is organized as follows. In Sect. 2, we provide a brief review of the relevant literature on the subject matter. Section 3 provides an overview of the process of banking reforms in India. Section 4 presents the conceptual framework for measuring technical efficiency using DEA approach. Section 5 explains the methodological framework for testing σ-convergence and β-convergence using regression analysis. Specification of bank inputs and outputs, and data are presented in Sect. 6. Section 7 discusses the empirical findings and, finally, Sect. 8 concludes the paper.

2 Review of literature

In recent times, a significant body of literature has evolved which explores the performance of banks in the wake of financial deregulation and liberalization. The basic hypothesis underlying deregulation is that it promotes competition and, thus, can induce efficiency improvements (Ali and Gstach 2000). It is expected a priori that deregulation would unleash competitive forces in the operating environment. Such competition would, in turn, enable banks to alter their input and output mix, which when combined with technological developments facilitates increase in output that raises overall bank productivity and efficiency (Mohan 2006). In sum, the main intent of the deregulation process is to enhance efficiency and productivity gains by reinforcing competitiveness in the banking system. Since the 1990s, there is a flurry of studies on the effect of deregulation on efficiency and productivity of banks. Nonetheless, the empirical results have been mixed (Berger and Humphrey 1997). Results appear to vary depending on the country, bank ownership, and size (Avkiran 2000).

Notable studies which reported a positive impact of deregulation on the efficiency and productivity of banks are Berg et al. (1992) for Norway; Zaim (1995), Isik and Hassan (2002a), Isik et al. (2002) for Turkey; Maghyereh (2004) for Jordan; Leightner and Lovell (1998) for Thailand; Chen et al. (2005) for China; Qayyum (2008), Patti and Hardy (2005) for Pakistan; Mukherjee et al. (2000), Alam (2001) for US; Kumbhakar et al. (2001), Kumbhakar and Lozano-Vivas (2005), Lozano-Vivas (1998) for Spain; Avkiran (2000), Sturm and Williams (2004) for Australia; Rebelo and Mendes (2000), Canhoto and Dermine (2003) for Portugal; Ali and Gstach (2000) for Austria; Lopez-Cortes (1997) for Mexico; Ariss (2008) for Lebanon; Kondeas et al. (2008) for European Union countries.

In contrast to aforementioned studies, there are studies which reported a negative effect of deregulatory measures on the efficiency and productivity of banks. Some prominent studies in this context are Humphrey (1991), Humphrey (1993), Humphrey and Pulley (1997), Grabowski et al. (1994), Elyasiani and Mehdian

(1995), Wheelock and Wilson (1999) for US; Grifell-Tatjé and Lovell (1996) for Spain; Kumbhakar and Wang (2007) for China; Christopoulos and Tsionas (2001) for Greece; Denizer et al. (2000, 2007) for Turkey; Rizvi (2001) for Pakistan; Hao et al. (2001), Mahadevan and Kim (2001) for Korea; Cook et al. (2001) for Tunisia.

In the Indian context too, though the majority of studies portrayed a positive impact of deregulation and liberalization policies on the efficiency and productivity of Indian banks yet a few studies also reported an adverse or insignificant effect of these policies on the performance of banks. The studies of Bhattacharyya et al. (1997a), Bhattacharyya et al. (1997b), Ram Mohan and Ray (2004), Shanmugam and Das (2004), Ataullah et al. (2004), Reddy (2004), Das et al. (2005), Chatterjee (2006), Mahesh and Rajeev (2006), Sensarma (2006), Howcroft and Ataullah (2006), Zhao et al. (2007), Jaffry et al.(2007), Rezvanian et al. (2008) broadly concluded that the deregulatory policy regime has had a positive and favorable impact in terms of efficiency improvement and productivity surge of Indian banking industry. The studies that reported either an adverse or insignificant effect of deregulation on the performance of Indian banks include Kumbhakar and Sarkar (2003), Sensarma (2005), Galagedera and Edirisuriya (2005), Das and Ghosh (2006) (see Table 1 for the main findings of Indian studies).

An inspection of literature highlights that the empirical studies relied on both parametric (especially stochastic frontier approach) and non-parametric (particularly DEA) techniques to compute the efficiency scores for individual banks using different specifications of input and output variables. Further, the empirical evidences about impact of deregulation on efficiency of banks has been mixed in the literature but the majority of studies, especially confined to banking sectors of developing countries, has shown a positive impact of liberalization and deregulation on the relative efficiency of banks. In the Indian case too, the most of the studies focusing on the trends of efficiency concluded that banking reforms process since 1992 has had a positive impact on the efficiency of Indian banking industry as a whole and its distinct segments defined on the basis of ownership. Further, many studies have not found any significant difference between the efficiency indicators of PSBs vis-à-vis private sector banks in the post-reforms period and reported the presence of a weak ownership effect on the performance of banks (see, for example, Ram Mohan and Ray 2004; Mahesh and Rajeev 2006). Even the most recent study by Reserve Bank of India (2008) also concluded that in the Indian banking sector, ownership has no definite relationship with efficiency.

3 Banking reforms in India: an overview

During the period 1947–1969, the commercial banks in India largely confined their activities to urban affluent customers and industry, trade and commerce in the urban areas of the country. The evolution of the Indian banking sector as an instrument of economic change started when the planning era was ushered during the early 1950s. The first step in this direction was the nationalization of the Imperial Bank of India in 1955 to create the State Bank of India. In the 1960s, more regulatory and control measures were introduced to shape the banking system as an instrument for

Table 1 Impact of deregulation on the efficiency of Indian banks: a literature review

S. no.	Author	Period of study	Methodology	Approach for selecting inputs and outputs	Major finding (s)
Panel A: studies showing a positive effect of deregulation					
1	Bhattacharyya et al. (1997a)	1970–1992	SFA	VA	A positive impact of deregulation on the total factor productivity (TFP) growth of Indian public sector banks
2	Bhattacharyya et al. (1997b)	1986–1991	DEA	VA	Deregulation has led to an improvement in the efficiency of Indian commercial banks
3	Ram Mohan and Ray (2004)	1992–2000	DEA	IA	There is an improvement in the revenue efficiency of Indian banks. A convergence in performance between public and private sector banks has been noticed in the post-reforms era
4	Shanmugam and Das (2004)	1992–1999	SFA	IA	During the deregulation period Indian banking industry showed a progress in terms of efficiency of raising non-interest income investments and credits
5	Ataullah et al. (2004)	1988–1998	DEA	Leightner and Lovell's approach	Overall technical efficiency of the banking industry of India and Pakistan has improved following the financial liberalization
6	Reddy (2004)	1996–2002	DEA	IA	An upturn in the overall technical efficiency of Indian banks during the deregulatory period
7	Das et al. (2005)	1997–2003	DEA	IA	The efficiency of Indian banks in general and of the bigger banks in particular has improved during the post-reforms period
8	Chatterjee (2006)	1995–2002	SFA	VA	The average cost inefficiency of Indian domestic banks has declined during the study period
9	Mahesh and Rajeev (2006)	1985–2004	SFA	PA	Deposit and investment efficiencies have improved during the reforms period while efficiency in making advances has declined marginally. On the whole the post-liberalization reforms measures have exerted a positive impact on the banking sector

Table 1 continued

S. no.	Author	Period of study	Methodology	Approach for selecting inputs and outputs	Major finding (s)
10	Sensarma (2006)	1986–2000	SFA	PA	Deregulation in Indian banking industry especially in its public sector banking segment has achieved the objectives of reduction in intermediation costs and improving TFP
11	Howcroft and Ataullah (2006)	1988–1998	DEA-based Malmquist index	Leightner and Lovell's approach	The TFP growth in the banking sector of both India and Pakistan has improved slowly during the study period. Also loan-based model revealed more improvement in TFP growth than income-based model
12	Zhao et al. (2007)	1992–2004	DEA-based Malmquist index	IA	After an initial adjustment phase Indian banking industry has experienced a sustained TFP growth driven mainly by technological progress
13	Jaffry et al. (2007)	1993–2001	DEA-based Malmquist index	IA	Technical efficiency both increases and converges across the Indian sub-continent (including India, Pakistan and Bangladesh) in response to financial reforms
14	Rezvanian et al. (2008)	1998–2003	DEA	IA	An ascent in cost efficiency in all ownership groups and industry as a whole has taken place due to its allocative efficiency component rather than technical efficiency component
15	Reserve Bank of India (2008)	1991–2007	DEA	IA	Efficiency has improved across all bank groups during the study period and most of the observed efficiency gains have emanated after few years of reforms i.e. from 1997–1998 onwards
Panel B: studies showing a negative or insignificant effect of deregulation					
16	Kumbhakar and Sarkar (2003)	1985–1996	Shadow cost function	PA	A significant TFP growth has not been observed in Indian banking sector during the deregulatory regime. Further public sector banks have not responded well to deregulatory measures

Table 1 continued

S. no.	Author	Period of study	Methodology	Approach for selecting inputs and outputs	Major finding (s)
17	Sensarma (2005)	1986–2003	SFA	PA	Profit efficiency of Indian banks has shown a declining trend during the period of deregulation
18	Galagedera and Edirisuriya (2005)	1995–2002	DEA-based Malmquist index	IA	Deregulation has brought no significant growth in the productivity of Indian banks
19	Das and Ghosh (2006)	1992–2002	DEA	Both IA and VA	The period after liberalization did not witness any significant increase in number of efficient banks and some banks have high degree of inefficiency during the period of liberalization

DEA and SFA are the acronyms for data envelopment analysis and stochastic frontier analysis, respectively. IA, PA and VA stand for intermediation approach, production approach and value-added approach, respectively. Leightner and Lovell's approach selects inputs and outputs on the basis of objectives from the perspectives of commercial banks and central bank

Authors' compilation

achieving rapid economic development. The scheme of 'social control' over banks was initiated by the government in December 1967 for more equitable and purposeful distribution of bank credit. After nationalizing 14 major commercial banks (banks with deposits of Rs. 500 million or more) in 1969 and another six banks (banks with deposits exceeding Rs. 20 billion) in 1980, the Reserve Bank of India (Central Bank) directed these banks to bring wider diffusion of banking facilities in hitherto unbanked areas by undertaking the program of branch expansion, and re-deploy bank credit in favor of the priority sector so as to achieve an even distributive pattern of bank lending. On the whole, the nationalization of banks brought a complete transformation in the character of the Indian banking sector from class banking to mass banking.

In 1977, Reserve Bank of India imposed the 1:4 license rule, which stated that for every branch opened in an already banked location a commercial bank must open four in unbanked locations. This rule was disbanded in 1990. Between the period of bank nationalization in 1969 and the onset of the reforms program in the early 1990s, bank branches were opened in over 3,000 rural locations which had no prior presence of commercial banks. Alongside the share of bank credit and savings which accounted for by rural branches rose from 1.5 and 3%, respectively, to 15% each. Further, increased financial intermediation in rural areas aided output and employment diversification out of agriculture. Burgess and Pande (2003) estimated that a 1% increase in the number of rural banked locations reduced poverty by roughly 0.4% and increased non-agriculture output by 0.3%. On the whole, the post-nationalization scenario was dominated by a uniform conglomerate of banks in the public sector with an increased branch network and little differentiation in terms of products and services offered. After nationalization, the focus on directed lending helped largely in availability of credit to the borrowers at lower-end. Ketkar and Ketkar (1992), and Ketkar (1993) observed that bank nationalization has been a mixed blessing. Aggressive bank branch expansion program, especially in rural areas, has increased financial savings and investment but credit controls had a negative effect on the deposit mobilization, efficiency and profitability of PSBs. Notwithstanding, Indian banks, especially PSBs, have made remarkable progress in achieving social goals and bringing financial deepening along with catering to the needs of planned development in a mixed economy framework.

From the mid-1960s to the early 1990s, the Government of India (GOI) increasingly used the banking system as an instrument of public finance (Hanson and Kathuria 1999). Substantial and increasing volumes of credit were channeled to the government at below-market rates through high and increasing cash reserve requirements (CRR) and statutory liquidity requirements (SLR) in order to fund a large and increasing government deficit at relatively low cost (Sen and Vaidya 1997). In fact, the heavy hand of government has been omnipresent in the banking sector, especially in the working of PSBs; and there was very limited market-based decision making. Also, the competition in the banking sector was virtually absent. Bank deposit and lending rates were mostly controlled and high statutory pre-emptions and directed lending requirements left banks with little funds for commercial lending (Bhattacharyya and Patel 2003). Reddy (1998) observed that in

the pre-reforms years, for every rupee of deposit in banks, only about one-third to one-half was available for lending to the commercial sector.

Further, rates of return were low by international standards, the capital base had eroded, NPAs were on the rise, and customer service was below expectation (Sarkar 2004). More important, the lack of proper disclosure norms led to many problems being kept under cover. Poor internal controls raised serious doubts about the integrity of the system itself (Reddy 1998). Nevertheless, many banks became unprofitable, inefficient, and unsound owing to their poor lending strategies and lack of internal risk management under government ownership (Joshi and Little 1996; Shirai 2002). Jagirdar (1996) observed that the average return on assets (ROA) in the second half of the 1980s was only about 0.15% which was abysmally low by all standards. Further, in 1992/1993, NPAs of 27 PSBs amounted to 24% of total credit, only 15 PSBs achieved a net profit, and half of the PSBs faced negative net worth (Shirai 2002). This not only reduced the incentives of the banks to operate properly and hence their performance, but also undermined the incentives of the regulators to properly supervise the performance of the banks (Shirai and Rajasekaran 2002). On the whole, all the signs of 'financial repression' were found in the system.

Recognizing the growing deficiencies in the banking system, and the need to catch up with international standards in an increasing globalized environment, the GOI decided in 1992 to overhaul the regulatory environment of Indian banking industry. The roadmap for the first phase of comprehensive reforms in the banking sector was prepared in 1992 on the basis of path-breaking recommendations of the Committee on the Financial System (Chairman: M. Narasimham 1991). The focus of this phase was on the creation of a sound and efficient banking sector in a competitive environment. Following the report of the Committee on the Banking Sector Reforms (Chairman: M. Narasimham 1998), the second phase of reforms began in 1998 and is continuing till now. The major emphasis of this phase is on increase in minimum capital adequacy ratio; recognition of market risks; tightened assets classification, income recognition, and provisioning norms; introduction of the Asset Liability Management System; and for further enhancing the transparency and disclosure practices, etc. On the basis of twin criteria of solvency and profitability, the committee identified three weak banks in the public sector, namely, Indian Bank, UCO Bank, and United Bank of India. However, the task of formulating a policy to deal with these weak banks was, instead, left for the Working Group on Restructuring of Weak Public Sector Banks (Chairman: M. S. Verma 1999).[7] The working group suggested a four-dimensional comprehensive restructuring program covering operational, organizational, financial and systemic restructuring.

During the last 16 years, an extensive program of banking reforms has been followed to strengthen market institutions and allow greater autonomy to the banks. The details on various reform measures and their impact on the structure of the Indian banking industry have been documented. In this context, reference may be made to the works of Sen and Vaidya (1997), Hanson and Kathuria (1999), Arun and Turner (2002), Shirai (2002), Bhide et al. (2002), Yoo (2005), Hanson (2005),

[7] This committee is popularly known as Verma Committee, named after its chairman M. S. Verma.

Reddy (2005), and Roland (2008). However, a brief discussion on the areas in which reforms have been introduced is presented here. First, the structure of administered interest rates has been almost totally dismantled in a phased manner.[8] The purpose of deregulating interest rates was to stimulate healthy competition among the banks and to encourage their operational efficiency. Second, for making available a greater quantum of resources for commercial purposes, the statutory pre-emptions have gradually been lowered.[9] Third, towards strengthening PSBs, GOI recapitalized PSBs to avert any financial crisis and to build up their capital base for meeting minimum capital adequacy norms.[10] Further, the policy makers permitted PSBs to expand their capital base with equity participation by private investors up to the limit of 49%.[11] Fourth, the policy makers introduced improved prudential norms related to capital adequacy,[12] asset classification[13] and income recognition in line with international norms, as well as increased disclosure level.[14] Fifth, the burden of directed sector lending has been gradually reduced by (a) expanding the definition of priority sector lending, and (b) liberalizing lending rates on advances in excess of Rs. 0.2 million. Sixth, entry regulations for domestic and foreign banks have been relaxed to infuse competition in the banking sector.[15] Seventh, impressive institutional reforms have been introduced to strengthen the supervisory authorities.[16] Eighth, PSBs have been allowed to rationalize some branches while branch licensing has been removed.

[8] Except saving deposit account, non-resident Indian (NRI) deposits, small loans up to Rs. 0.2 million and export credit, the interest rates are fully deregulated.

[9] The combined pre-emptions under CRR and SLR, amounting to 63.5% of net demand and time liabilities in 1991 (of which CRR was 25%) have since been reduced and presently, the combined ratio stands below 35% (of which, the SLR is at its statutory minimum at 25%).

[10] The GOI has injected about 0.1% of GDP annually into weak public sector banks (Hanson 2005; Rangarajan 2007). During the period 1992/1993 to 2001/2002, GOI contributed some Rs. 177 billion, about 1.9% of the 1995/1996 GDP, to nationalized banks (Mohan and Prasad 2005).

[11] In 1993, the State Bank of India (SBI) Act, 1955 was amended to promote partial private shareholding. The SBI became the first PSB to raise equity in the capital markets. The amendment of the Banking Regulation Act in 1994 allowed the PSBs to raise private equity up to 49% of paid up capital. Since then 20 PSBs have diversified their ownership, although the government has remained as the largest shareholder.

[12] India adopted the Basel Accord Capital Standards in April 1992. An 8% capital adequacy ratio was introduced in phases between 1993–1996, according to banks ownership and scope of their operations. Following the recommendations of Narasimham Committee II, the regulatory minimum capital adequacy ratio was later raised to 10% in the phased manner.

[13] The time for classification of assets as non-performing has been tightened over the years, with a view to move towards the international best practice norm of 90 days by end 2004.

[14] From 2000–2001, the PSBs are required to attach the balance sheet of their subsidiaries to their balance sheets.

[15] In 1993, the RBI issued guidelines concerning the establishment of new private sector banks. Nine new private banks have entered the market since then. In addition, over 20 foreign banks have started their operations since 1994.

[16] A high powered Board of Financial Supervision (BFS) has been constituted in 1994. BFS exercised the power of supervision in relation to the banking companies, financial institutions, and non-banking companies, creating an arms–length relationship between regulation and supervision. On-site supervision was introduced in 1995, and annual supervision of capital adequacy, asset quality, management quality, earnings, liquidity, and systems (CAMELS) was introduced in 1997.

While India's approach to banking reforms has been in line with global trends, one unique feature of this approach is that instead of launching the banking reforms in a 'big bang' fashion, Indian policy makers pursued a 'cautious' or 'gradualist' approach to strengthen accounting, legal, supervisory, and regulatory frameworks pertaining to banking sector. In sum, the process of reforms was initiated in a gradual and properly sequenced manner so as to have a reinforcing effect (Reddy 2007). The policy makers sought to consistently upgrade the banking sector by adopting the international best practices through a consultative process.

During the post-deregulation years since 1992, Indian banking system has undergone significant changes. A remarkable trend is the shift from traditional banking activities such as lending and deposits taking to a more universal banking character with financial market activities such as brokerage and portfolio management growing in importance. Thus, the traditional role of banks as mere financial intermediaries has since altered and risk management has emerged as the defining attribute. While deregulation has opened up new vistas for banks to augment incomes, it has also entailed greater competition and consequently greater risks. Banks have been provided significant operational freedom in their resource allocation using their commercial judgments in a market-oriented environment. The banking system has also witnessed greater levels of transparency and standard of disclosure.

A positive externality of the banking reforms process has been the building up of the institutional architecture in terms of markets, and creation of enabling environment through technological and legal infrastructure and improving the managerial competence, etc. (Bhide et al. 2002). The most notable achievement of the banking industry is the significant improvement in capital adequacy and asset quality. This has been achieved despite convergence of the prudential norms with the international best practices. The capital adequacy ratio has increased to 12.4% for scheduled commercial banks as at end March 2006, which is much above the international norm. The net profits of the commercial banks were at 0.9% of total assets during 2004/2005 and 2005/2006, up from 0.16% in 1995/1996. The net NPAs declined to 1.2% of net advances during 2005/2006 from 8.91% in 1995/1996. Further, the intermediation process has improved during the post-reforms years. In the post-1992 period, a wave of mergers and acquisitions swept through the industry as banks tried to cut cost and improved efficiency.

Another notable development in the Indian banking industry during the post-reforms years is that the PSBs got fierce competition from private banks, especially from de nova domestic private banks that were better equipped with banking technology and practices. Consequently, the market share of PSBs in terms of deposits, investments, advances, and total assets has declined constantly (see Table 2). It is evident from the table that the PSBs still enjoy a pre-eminent position in the Indian banking sector, albeit their market share has declined in the deregulatory regime. Nonetheless, the growth of PSBs is still high on the agenda of the policy makers because of their gargantuan role as an effective catalytic agent of socio-economic change in the country. In fact, the main focus of the reform measures introduced since 1992, is to pick up the performance of PSBs in their operations and to inculcate competitive spirit in them. Against this backdrop, we confine our analysis to PSBs which constitute the most significant segment of the Indian banking sector.

Table 2 Market share of public sector banks: 1992/1993 to 2005/2006

Year	Market share (%)			
	Deposits	Investments	Advances	Total assets
1992/1993	87.9	85.9	89.3	87.2
1993/1994	86.8	86.3	87.3	87.1
1994/1995	85.9	87.0	85.1	85.2
1995/1996	85.4	87.6	82.2	84.4
1996/1997	83.6	85.3	79.9	82.7
1997/1998	82.6	83.5	80.1	81.6
1998/1999	82.6	81.5	80.5	81.0
1999/2000	81.9	80.6	79.4	80.2
2000/2001	81.4	80.1	78.9	79.5
2001/2002	80.5	77.2	74.4	75.3
2002/2003	79.6	78.7	74.3	75.7
2003/2004	77.9	78.0	73.2	74.5
2004/2005	78.2	79.1	74.3	75.4
2005/2006	74.9	73.1	72.9	72.3

Authors' calculations from 'Statistical Tables Relating to Banks in India (various issues)'

4 Data envelopment analysis

As already pointed out, DEA has been utilized to compute technical efficiency (TE) scores for individual PSBs. DEA is a non-stochastic, non-parametric linear programming technique to measure the relative efficiency of similar decision making units (DMUs)[17] with common inputs and outputs. DEA generalizes the Farrell's technical efficiency measure to the multiple-inputs and multiple-outputs setting. Farrell (1957) defined technical efficiency as the producer's ability to avoid the waste of resources by producing as much output as input usage allows (output-augmenting orientation), or by using as little input as output production allows (input-conserving orientation). In the spirit of Farrell's definition, TE is the degree to which a particular DMU is able to convert its inputs into outputs. The main goals of DEA are to identify best-practice and worst-practice DMUs and to find the ways for an improved efficiency performance. DEA floats a piecewise linear surface to rest on the top of observations (Seiford and Thrall 1990) which is known as efficient or best-practice frontier. The DMUs that lie on the efficient frontier are efficient and those which lie below this frontier are relatively inefficient. The inefficiency of a DMU can be measured by the radial 'distance' of a DMU to the efficient frontier. One main feature of DEA is that the efficiency or inefficiency of a DMU is determined relative to other units in the data set utilizing a benchmark score of unity which no DMU can exceed. The DMUs that lie on the frontier are the best-practice institutions and retain a value of one; those enveloped by the external surface are

[17] DMUs are usually defined as entities responsible for turning input(s) into output(s), such as firms and production units. In the present study, DMUs refer to banks. A DMU must, as the name indicates, have at least some degree of freedom in setting behavioral goals and choosing how to achieve them.

scaled against a convex combination of the DMUs on the frontier facet closest to it and have values somewhere between 0 and 1.

Some notable advantages of DEA which motivated the researchers including us to use it over other efficiency measurement techniques, especially its closest rival stochastic frontier analysis (SFA), are as follows. First, DEA is able to manage complex production environments with multiple inputs and output technologies (Jacobs 2000). Second, in DEA, efficiency is measured relative to the highest observed performance rather than some average (Majumdar and Chang 1996; Odeck and Alkadi 2004). Third, DEA produces a scalar measure of efficiency for each unit, which makes the comparison easy (Sowlati and Paradi 2004). Fourth, in DEA, the computations are value-free and do not require specification or knowledge of a priori weights of prices for inputs or outputs (Charnes et al. 1994). Fifth, DEA does not require any pre-specified functional form between inputs and outputs i.e., production function (Mirmirani et al. 2008). Therefore, the probability of a misspecification of the production technology is zero (Jemric and Kujcic 2002). However, a key drawback of DEA is that it assumes that there is no random error owing to luck, data problems, or other measurement errors.

Using actual data for the DMUs under consideration, DEA employs mathematical programming methods to construct efficient frontiers. In fact, several different mathematical programming DEA models have been proposed in the literature (see, for example, Charnes et al. 1994; Cooper et al. 2007). Essentially, each DEA model seeks to establish which of n DMUs determine the envelopment surface or efficient frontier. The geometry of this surface is prescribed by the specific DEA model employed. In the present study, we use the input-oriented version of CCR model,[18] named after Charnes et al. (1978), to reduce the multiple-inputs and multiple-outputs situation for each bank to a scalar measure of TE.

To illustrate CCR model, we assume there are data on N inputs and M outputs for each of I DMUs. For the ith DMU, these are represented by the column vectors x_i and q_i, respectively. The $N \times I$ input matrix, X, and the $M \times I$ output matrix, Q, represent the data for all I DMUs. For each DMU, we would like to obtain a measure of the ratio of all outputs over all inputs, such as $u'q_i/v'x_i$, where u is an $M \times 1$ vector of output weights and v is a $K \times 1$ vector of input weights. To select the optimal weights, we specify the following mathematical programming problem:

$$\begin{aligned} &\max_{u,v}(u'q_i/v'x_i) \\ &\text{subject to} \\ u'q_j/v'x_j \leq 1, \quad &j = 1, 2, \ldots I \\ &u, v \geq 0 \end{aligned} \tag{1}$$

This involves finding values for u and v, such that the efficiency measure of the ith DMU is maximized, subject to the constraint that all efficiency measures must be

[18] Given the small sample size (27 PSBs in each year) in the present study, CCR model provides better discrimination than any other DEA model, especially BCC model, named after Banker et al. (1984). In the CCR model, it is assumed that constant returns-to-scale prevail in the industry while BCC model is based on the assumption of variable returns-to-scale.

less than or equal to 1. It is significant to note that optimal values of u and v are DMU-specific. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this one can impose the constraint $v'x_i = 1$, which provides:

$$\begin{aligned} &\max_{\mu,\upsilon}(\mu' q_i), \\ &\text{subject to} \\ &\upsilon' x_i = 1, \\ &\mu' q_j - \upsilon' x_j \le 0, \quad j = 1, 2, \ldots, I \\ &\mu, \upsilon \ge 0. \end{aligned} \tag{2}$$

where the notation change from u and v to μ and υ is used to stress that this is a different linear programming problem. The form of the DEA model in linear programming problem (2) is known as the multiplier form (Coelli et al. 1998).

Using the duality in linear programming, one can derive an equivalent envelopment form of this problem:

$$\begin{aligned} &\min_{\theta,\lambda} \theta \\ &\text{subject to} \\ &-q_i + Q\lambda \ge 0, \\ &\theta x_i - X\lambda \ge 0, \\ &\lambda \ge 0 \end{aligned} \tag{3}$$

where θ is a scalar and λ is a $I \times 1$ vector of constants. This envelopment form involves fewer constraints than the multiplier form (i.e., $N + M < I + 1$), and hence is generally the preferred form to solve. The value of θ obtained will be the technical efficiency score for the ith DMU. It will satisfy $\theta \le 1$, with a value of 1 indicating a point on the efficient frontier and hence a technically efficient DMU, according to the Farrell's definition. Note that the linear programming problem must be solved I times, once for each DMU in the sample. A value of θ is then obtained for each DMU.

5 Tests for σ-convergence and β-convergence

The main objective of this paper is to find the answer to the following questions: (1) Are less efficient PSBs catching up to their more efficient counterparts? (2) Are less efficient banks growing faster than more efficient ones? (3) To what extent there exists a common trend towards the convergence or divergence of efficiency levels among PSBs? To explore the answer to the aforementioned questions, we utilized the concept of convergence as used in the field of economic growth. The term convergence as used in the literature on international comparison of economic growth refers to the catching-up phenomenon i.e., poor economies tend to grow faster than richer economies. In a cross-section context, the term has also been used to refer to the tendency of differences in per-capita income between economies to

decline over time. We adapted the similar concept of convergence to answer the abovementioned questions that are pertinent to understand the efficiency dynamics of banks. The concept of convergence as used in the present study refers to the tendency of two or more banks to become similar in terms of efficiency levels. Therefore, if the banks with low levels of efficiency at the beginning of the period grow more rapidly than those with high initial level of efficiency, convergence occurs, implying that the less efficient banks are catching up.

The literature spells out two different concepts of convergence: (1) σ-convergence and (2) β-convergence (see Barro and Sala-i-Martin 1991, 1992, 1995; Sala-i-Martin 1996a, b). Convergence of the σ-type considers whether gaps between inefficient and efficient banks decline over time. The concept of σ-convergence is said to exist if the distribution of efficiency levels across banks gets tighter over time, thus reducing some measure of dispersion over time. It focuses on the evolution of cross-sectional distribution of efficiency over time. The existence of σ-convergence implies a tendency of efficiency levels to be equal across banks over time. The σ-convergence can be tested empirically by regressing the standard deviations (or coefficient of variations) of the cross-sections over time on a trend variable. Symbolically, it implies that

$$\ln(\mathrm{SD}_t \text{ or } \mathrm{CV}_t) = a + \sigma t + \varepsilon_t \tag{4}$$

where SD_t and CV_t denote the standard deviation and coefficient of variation of mean TE score across all banks, 'a' is a constant and 't' is a trend variable. A negative and significant slope coefficient sigma (σ) is taken as evidence for σ-convergence, i.e., a decline in SD (or CV) of TE scores over time implies a narrowing of the dispersion of efficiency levels.

The concept of β-convergence relates to the catch-up phenomenon. Convergence of the β-type considers whether the improvement in efficiency exhibit a negative correlation with the initial level of efficiency. There exists β-convergence in a cross-section of banks, if the inefficient banks tend to improve in efficiency faster than efficient ones. The existence of β-convergence can be examined empirically by estimating a cross-sectional regression of annual average growth rates of efficiency on the initial levels of efficiency. Thus, the testing for β-convergence involves estimation of the following regression equation:

$$g_{i,t,t-\tau} = [\ln(\theta_{i,t}) - \ln(\theta_{i,t-\tau})]/\tau = \alpha + \beta \ln(\theta_{i,t-\tau}) + \varepsilon_{i,t} \tag{5}$$

where $g_{i,t,t-\tau} = [\ln(\theta_{i,t}) - \ln(\theta_{i,t-\tau})]/\tau$ is the ith bank's average growth rate of TE between the periods t and $t - \tau$, respectively. τ is the length of the time period. If the regression coefficient on the initial level of TE bears a statistically significant negative sign, i.e., if $\beta < 0$, then we can say that there exists absolute β-convergence. The negative coefficient of the variable 'initial level of TE' signifies that relatively inefficient banks have higher growth rates that enable them to catch up with efficient banks. It should be observed that Eq. (5) gives absolute, also denoted unconditional, β-convergence under the assumption that all PSBs face homogenous economic and regulatory environments.

Alongside the absolute β-convergence, we also tested the presence of conditional β-convergence using the following equation:

$$g_{i,t,t-\tau} = [\ln(\theta_{i,t}) - \ln(\theta_{i,t-\tau})]/\tau = \alpha + \beta \ln(\theta_{i,t-\tau}) + \sum_{j=1}^{k} \delta_j \ln(X^j_{i,t-\tau}) + \varepsilon_{i,t} \quad (6)$$

Equation (6) allows us to control for the variables, which might influence the steady-state level of technical efficiency. The choice of the control variables (or conditioning variables) X^j depends upon economic theory, a priori beliefs about growth process, and availability of data (Ghosh 2006). Conditional β-convergence implies a negative correlation between growth and initial level of technical efficiency, after controlling for factors impacting the steady-state position. Thus, conditional β-convergence holds if $\beta < 0$. The difference between these two concepts of β-convergence is that absolute convergence means that each bank moves toward the same steady-state TE, whereas conditional convergence suggests that each bank possesses its own steady-state TE to which it is converging. The conditional convergence and absolute convergence hypotheses coincide only if all banks have the same steady-state (Fung 2006).

While the concepts of σ-convergence and β-convergence are related, they are not the same. A necessary condition for σ-convergence is the existence of β-convergence although β-convergence itself does not guarantee a reduction in the distribution dispersion (Thirtle et al. 2003). In particular, β-convergence is a necessary, but not sufficient, condition for σ-convergence (Sala-i-Martin 1996a). One possible explanation illustrating this relationship is the 'cross-over' scenario. For instance, initially less efficient banks may not only manage to catch up with efficient ones, indicating β-convergence, but they may also cross-over and continue to surge ahead. The cross-over scenario, thus, could cause an increase in the dispersion of TE levels.

Koski and Majumdar (2000) suggested that both σ-convergence and β-convergence should be used simultaneously for drawing inference about the presence of the catching-up phenomenon and leapfrogging phenomenon. They listed four distinct possibilities that are enumerated in Table 3.

The first possibility is that both σ-convergence and β-convergence occur. The connotation of this possibility is that the originally inefficient banks are catching up the originally efficient (well-performing) banks; and moreover, their performance is improving at such a rate that banks which were previously lagging, overtake the well-performing banks in terms of the chosen performance measure. The second possibility is the presence of σ-convergence without β-convergence. This implies that the dispersion of the distribution of performance measure decreases overtime which means that catching-up occurs but no leapfrogging is taking place. However, this possibility is unlikely to happen because as noted above, β-convergence is a

Table 3 The implications of σ-convergence and β-convergence for catching-up and leapfrogging

	σ-convergence: yes	σ-convergence: no
β-convergence: yes	Catching-up and leapfrogging	Catching-up and leapfrogging
β-convergence: no	Catching-up but no leapfrogging	No catching-up and no leapfrogging

Koski and Majumdar (2000)

necessary condition for σ-convergence and we cannot observe σ-convergence without β-convergence.

The third option, β-convergence without σ-convergence, highlights that catching-up may occur even if the σ-convergence measure indicates that the dispersion of the distribution of the performance measure has not decreased. This happens when formerly poor performing banks improve so much faster than the previous leaders and they overtake them. Then, it is possible that the dispersion of the distribution does not decrease but nevertheless, the initially poor-performing banks have been catching up with the leading banks, if evaluated in terms of the performance measure used. The fourth possibility, the presence of neither σ-convergence nor β-convergence illustrates intra-distributional stability (i.e., no leapfrogging) and inter-distributional stability (i.e., no catching-up) across time.

6 Data and measurement of input and output variables

In computing the efficiency scores, the most challenging task that an analyst always encounters is to select the relevant inputs and outputs for modeling banks' behavior. It is worth noting here that there is no consensus on what constitute the inputs and outputs of a bank (Casu and Girardone 2002; Sathye 2003). In the literature on banking efficiency, there are mainly two approaches for selecting the inputs and outputs for a bank: (1) the production approach, also called the service provision or value added approach; and (2) the intermediation approach, also called the asset approach (Humphrey 1985; Hjalmarsson et al. 2000). Both these approaches apply the traditional microeconomic theory of the firm to banking and differ only in the specification of banking activities. The production approach as pioneered by Benston (1965) treats banks as the providers of services to customers. The output under this approach represents the services provided to the customers and is best measured by the number and type of transactions, documents processed or specialized services provided over a given time period. However, in case of non-availability of detailed transaction flow data, they are substituted by the data on the number of deposits and loan accounts, as a surrogate for the level of services provided. In this approach, input includes physical variables (like labor, material, space or information systems) or their associated cost. This approach focuses only on operating cost and completely ignores interest expenses.

The intermediation approach as proposed by Sealey and Lindley (1977) treats banks as financial intermediaries channeling funds between depositors and creditors. In this approach, banks produce intermediation services through the collection of deposits and other liabilities and their application in interest-earning assets, such as loans, securities, and other investments. This approach is distinguished from the production approach by adding deposits to inputs, with consideration of both operating cost and interest cost. Berger and Humphrey (1997) pointed out that neither of these two approaches is perfect because they cannot fully capture the dual role of banks as providers of transactions/document processing services and being financial intermediaries. Nevertheless, they suggested that the intermediation approach is best suited for analyzing bank level efficiency, whereas the production

approach is well suited for measuring branch level efficiency. This is because, at the bank level, management will aim to reduce total costs and not just non-interest expenses, while at the branch level a large number of customer service processing takes place and bank funding and investment decisions are mostly not under the control of branches. Also, in practice, the availability of flow data required by the production approach is usually exceptional rather than in common.

Elyasiani and Mehdian (1990) gave three advantages of the intermediation approach over other approaches. They argue that (a) it is more inclusive of the total banking cost as it does not exclude interest expense on deposits and other liabilities; (b) it appropriately categorizes deposits as inputs; and (c) it has an edge over other definitions for data quality considerations. Therefore, as in the majority of the empirical literature, we adopted a modified version of the intermediation approach as opposed to the production approach for selecting input and output variables for computing technical efficiency scores for individual PSBs. The selected output variables are (1) net-interest income (measured as the difference between interest earned and interest expanded), and (2) non-interest income (proxied by 'other income'). The inputs used for computing TE scores are (1) physical capital (measured as the value of fixed assets), (2) labor (measured as the number of employees), and (3) loanable funds (measured as the sum of deposits and borrowings). Thus, the efficiency scores capture the ability of the banks to generate net-interest and non-interest incomes using the inputs of physical capital, labor, and loanable funds. Further, all the input and output variables except labor are measured in Rupee lacs (note that 10 lacs = 1 million).

The output variable 'net-interest income' connotes net-income received by the banks from their traditional activities like advancing of loans and investments in government and other approved securities. The output variable 'non-interest income' accounts for income from off-balance sheet items such as commission, exchange and brokerage, etc. The inclusion of 'non-interest income' enables us to capture the recent changes in the production of services as Indian banks are increasingly engaging in non-traditional banking activities. As pointed out by Siems and Clark (1997), the failure to incorporate these types of activities may seriously understate the bank output and this is likely to have statistical and economic effects on estimated efficiency. Some notable banking efficiency analyses that include 'non-interest income' as an output variable are Isik and Hassan (2002a, b), Drake and Hall (2003), Sufian (2006), Sufian and Majid (2007), Hahn (2007) among others. Further, a majority of the studies on efficiency of Indian banks have also included 'non-interest income' in the chosen output vector. It is worth noting here that our choice of output variables is consistent with the managerial objectives that are being pursued by Indian banks. In the post-reforms years, intense competition in the Indian banking sector has forced banks to reduce all input costs to the minimum and to earn maximum revenue with less and less inputs. In this context, Ram Mohan and Ray (2004) rightly remarked that in the post-liberalization period, Indian banks are putting all their efforts in the business of maximizing incomes from all possible sources.

The required data on the input and output variables have been culled out from the various issues of 'Statistical Tables Relating to Banks in India', an annual

publication of the Reserve Bank of India and 'Performance Highlights of Public Sector Banks', an annual publication of the Indian Banks' Association. In the terminal year of the study, 28 PSBs were operating in India and data on the IDBI Ltd. (a new PSB) were available only after 2004/2005. Therefore, we excluded this bank from the sample and confined the study to 27 PSBs that were operating in the Indian banking sector during the period spanning from 1992/1993 to 2005/2006. Following Barman (2007) and Roland (2008), we bifurcated the entire study period into distinct sub-periods: (1) first phase of banking reforms (1992/1993–1998/1999), and (2) second phase of banking reforms (1999/2000–2005/2006). To compute TE scores, the analysis has been carried out with real values of the variables (except labor) which have been obtained by deflating the nominal values by the implicit price deflator of gross domestic product at factor cost (base 1993–1994 = 100). Following Denizer et al. (2007), we normalized all the input and output variables by dividing them by number of branches of individual banks for the given year. The main purpose of using this normalization procedure is that it reduces the effects of random noise due to measurement error in the inputs and outputs.

7 Empirical results

7.1 Trends of technical efficiency

This section delineates the trends of technical efficiency (TE) in the Indian public sector banking industry during the post-reforms period. Instead of constructing a 'grand or inter-temporal frontier'[19] as suggested by Tulkens and van den Eeckaut (1995) and implemented by Bhattacharyya et al. (1997b) for estimating the efficiency scores of individual banks, we followed Isik and Hassan (2002b), and Pasiouras et al. (2007) and estimated separate annual efficient frontiers for obtaining year-by-year technical efficiency estimates. Isik and Hassan (2002b) pointed out the following two advantages of this approach. First, it is more flexible and thus, more appropriate than estimating a single multi-year frontier for the banks in the sample. Second, it alleviates, at least to some extent, the problems related to the lack of random error in DEA by allowing an efficient bank in 1 year to be inefficient in another under the assumption that the errors owing to luck or data problems are not consistent over time.

Since DEA results are influenced by the size of the sample, some discussion on the adequacy of sample size is provided here. The size of the sample utilized in the present study for estimating separate annual efficient frontiers is consistent with the various rules of thumb available in the DEA literature. Cooper et al. (2007) provides two such rules that can be expressed as: $I \geq \max\{N \times M; 3(N + M)\}$ where I = number of DMUs, N = number of inputs, and M = number of outputs. The first rule of thumb states that sample size should be greater than equal to product of inputs and outputs. While the second rule states that the number of observations in the data set should be at least three times the sum of the number of input and output

[19] The 'grand frontier' envelops the pooled input–output data of all banks in all years.

variables. Given $N = 3$ and $M = 2$, the sample size ($I = 27$) used for estimating separate annual efficient frontiers exceeds the desirable size as suggested by the abovementioned rules of thumb to obtain sufficient discriminatory power. The sample size in this study is feasible and larger than that used in some of the studies in the DEA literature (see, for example, Avkiran 1999).

Table 4 provides year-wise mean TE scores for the public sector banking industry and its sub-groups. At the bottom of the table and extreme right-hand side, the figures in italics provide grand mean of the TE scores for the entire study period and distinct sub-periods (i.e., the first and second phases of reforms). Recall that the TE score belongs to the range (0, 1], and is 1 if the bank is fully efficient. The mean TE measure among PSBs varies from a minimum of 0.773 in 1992/1993 to a maximum of 0.895 in 2005/2006. Thus, the results reveal that in general, PSBs have not been successful in employing best-practice production methods and achieving the maximum possible outputs from new and existing technologies. In each year of the study period, the majority of PSBs was found to be operating away from the observed yearly efficient frontiers and experienced some degree of technical inefficiency. This is evident from the fact that leaving one or two exceptions, the number of banks on the efficient frontier was between 5 and 9 in a specific year. The grand mean of the TE measure over PSBs and time is 0.834 which implies that in the Indian public sector banking industry, on an average, 16.6% decrease in inputs (physical capital, labor, and loanable funds) is feasible with current technology and unchanged output quantities, in each year of the study period under consideration. Alternatively, the level of mean technical inefficiency[20] (TIE) in Indian public sector banking industry during the entire period of study is 16.6%.

In order to analyze the group-specific behavior of the mean TE over the entire study period and distinct sub-periods, we followed the prevalent grouping criterion in the Indian public sector banking industry and bifurcated the PSBs into two groups namely, State Bank of India group (SBI group) and group of nationalized banks (NB group). In the Indian banking system, this grouping of PSBs is vital and matters to the policy makers and analysts because of the following differences in institutional characteristics of these groups in terms of ownership, functions and organizational structure. First, the SBI, India's largest commercial bank in terms of branches and assets, was established under the State Bank of India Act, 1955 and its seven subsidiary banks which were established under the State Bank of India Act, 1959. While the 19 nationalized banks were established under the two acts, i.e., Banking Companies (Acquisition and Transfer of Undertakings) Act, 1970 and the Banking Companies (Acquisition and Transfer of Undertakings) Act, 1980. Thus, the banks in SBI and NB groups are governed by the different statutes. Second, the Reserve Bank of India (RBI) owns the majority share of SBI, while the shares of subsidiary banks are owned by the SBI. On the other hand, nationalized banks are wholly owned by the Government of India. Third, SBI besides carrying out its normal banking functions also acts as an agent of the Reserve Bank of India. SBI undertakes most of the government business transactions (including major borrowing programs), thereby earning more non-interest income than nationalized

[20] Mean technical inefficiency (TIE) = (1-mean TE) × 100.

Table 4 Technical efficiency scores of public sector banks (1992/1993–2005/2006)

Bank	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	Entire study period	First phase of reforms	Second phase of reforms
State Bank of Bikaner and Jaipur	0.958	0.955	1	1	1	1	0.978	1	1	1	0.967	1	1	1	0.990	0.984	0.995↑
State Bank of Hyderabad	1	1	1	1	1	0.988	1	1	1	0.926	0.88	0.953	0.856	1	0.972	0.998	0.945↓
State Bank of India	1	0.999	1	1	1	0.975	0.96	0.833	0.826	0.763	0.786	0.797	0.85	1	0.914	0.991	0.836↓
State Bank of Indore	0.852	1	1	1	1	1	1	1	1	1	1	1	0.914	0.948	0.980	0.979	0.980↑
State Bank of Mysore	0.877	1	1	1	1	1	1	1	1	1	1	0.94	1	1	0.987	0.982	0.991↑
State Bank of Patiala	1	1	1	1	0.938	1	1	1	1	1	1	0.978	1	0.971	0.992	0.991	0.993↑
State Bank of Saurashtra	1	0.989	1	1	1	1	1	1	0.911	1	0.835	0.911	0.956	0.774	0.955	0.998	0.912↓
State Bank of Travancore	0.879	1	1	0.882	0.942	0.97	1	0.962	0.827	0.799	0.807	0.824	1	0.955	0.918	0.953	0.882↓
Allahabad Bank	0.706	0.556	0.557	0.667	0.74	0.797	0.714	0.745	0.701	0.736	0.849	0.814	0.805	0.85	0.731	0.677	0.786↑
Andhra Bank	0.497	0.544	0.842	0.732	0.745	0.905	0.883	0.965	0.807	0.784	0.979	0.938	1	1	0.830	0.735	0.925↑
Bank of Baroda	1	1	1	0.996	0.849	0.837	0.945	0.887	0.804	0.804	0.783	0.84	0.861	0.851	0.890	0.947	0.833↓
Bank of India	0.723	0.644	0.704	0.725	0.795	0.817	0.779	0.734	0.824	0.765	0.811	0.749	0.626	0.696	0.742	0.741	0.744↑
Bank of Maharashtra	0.491	0.514	0.693	0.875	0.837	0.874	0.817	0.786	0.78	0.741	0.726	0.692	0.752	0.755	0.738	0.729	0.747↑
Canara Bank	1	0.769	0.897	0.846	0.766	0.856	0.867	0.776	0.811	0.765	0.773	0.78	0.793	0.867	0.826	0.857	0.795↓
Central Bank of India	0.507	0.443	0.603	0.722	0.713	0.776	0.734	0.735	0.685	0.697	0.858	0.88	0.882	0.822	0.718	0.643	0.794↑
Corporation Bank	0.773	1	1	1	1	1	1	1	1	0.942	1	0.982	1	1	0.978	0.968	0.989↑
Dena Bank	0.61	0.739	0.827	0.88	0.949	0.958	0.878	0.776	0.78	0.816	0.893	1	0.774	1	0.849	0.834	0.863↑
Indian Bank	0.86	0.604	0.743	0.593	0.702	0.607	0.549	0.556	0.618	0.606	0.721	0.842	0.833	0.836	0.691	0.665	0.716↑
Indian Overseas Bank	1	1	0.595	0.541	0.587	0.58	0.627	0.646	0.678	0.734	0.765	0.903	0.965	0.976	0.757	0.704	0.810↑
Oriental Bank of Commerce	0.833	1	1	1	1	0.925	1	1	1	1	1	1	0.945	0.94	0.975	0.965	0.984↑
Punjab & Sind Bank	0.481	0.557	0.616	0.547	0.665	0.762	0.661	0.686	0.722	0.648	0.744	0.896	1	0.859	0.703	0.613	0.794↑
Punjab National Bank	0.737	0.762	0.674	0.765	0.783	0.816	0.865	0.773	0.769	0.773	0.948	0.951	0.879	0.904	0.814	0.772	0.857↑

Table 4 continued

Bank	1992/1993	1993/1994	1994/1995	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	Entire study period	First phase of reforms	Second phase of reforms
Syndicate Bank	0.576	0.674	0.685	0.747	0.707	0.7	0.694	0.758	0.828	0.832	0.913	0.788	0.851	0.855	0.758	0.683	0.832↑
UCO Bank	0.714	0.389	0.606	0.557	0.487	0.538	0.565	0.665	0.653	0.698	0.682	0.71	0.671	0.697	0.617	0.551	0.682↑
Union Bank of India	0.662	0.944	1	0.831	0.81	0.815	0.763	0.779	0.818	0.843	0.824	0.819	0.801	0.844	0.825	0.832	0.818↓
United Bank of India	0.317	0.334	0.478	0.44	0.419	0.713	0.523	0.53	0.546	0.745	0.808	0.78	0.816	0.881	0.595	0.461	0.729↑
Vijaya Bank	0.822	0.751	0.73	0.588	0.673	0.685	0.728	0.738	0.732	0.727	0.884	0.944	0.916	0.89	0.772	0.711	0.833↑
All PSBs	0.773	0.784	0.824	0.812	0.819	0.848	0.834	0.827	0.819	0.820	0.861	0.878	0.879	0.895	*0.834*	*0.814*	*0.854*
SBI Group	0.946	0.993	1.000	0.985	0.985	0.992	0.992	0.974	0.946	0.936	0.909	0.925	0.947	0.956	*0.963*	*0.985*	*0.942*
NB Group	0.700	0.696	0.750	0.740	0.749	0.787	0.768	0.765	0.766	0.771	0.840	0.858	0.851	0.870	*0.779*	*0.741*	*0.817*
Standard deviation	0.201	0.227	0.181	0.182	0.168	0.142	0.160	0.148	0.132	0.120	0.099	0.094	0.105	0.094	*0.122*	*0.160*	*0.095*
No. of efficient banks	7	9	12	9	8	6	8	8	7	6	5	4	7	7			

The arrows ↑ and ↓ indicate that mean TE of the bank has increased and decreased, respectively in the second phase of reforms relative to what has been observed during the first phase of reforms

Authors' calculations

banks (Shanmugam and Das 2004). However, this privilege has not been bestowed on the nationalized banks. Fourth, the SBI has a well-defined system of decentralization of authority, while in the case of nationalized banks the organizational structure differs from bank to bank (see Arun and Turner 2004; Maheshwari 2006, for more details).

The inter-group analysis reveals that in the SBI group, the mean TE scores ranged between 0.909 and 1. We also note that the grand mean of the TE measure for the entire study period is 0.963, a very high value by all standards. Thus, on an average, there is very little scope (about 3.7%) of efficiency improvement in the banks belonging to this group. For the NB group, the mean TE scores ranged between 0.696 and 0.870. The grand mean of the TE measure is 0.779 for the NB group during the entire period of the study. This suggests that on average, the banks affiliated to this group have the opportunity for efficiency gain up to about 22.1% from potential reduction in the inputs through their better utilization. Thus, the results clearly point out that the banks in the SBI group are more efficient than those in the NB group.

As far as the comparative analysis of the mean TE between the sub-periods is concerned, we notice from Table 4 that the average waste of inputs (as reflected by the mean TIE) has decreased during the years belonging to the second phase of reforms in comparison to the first phase of reforms (14.6 vs. 18.6%). Thus, the mean TE of the public sector banking industry has increased by about 4% with the deepening of reforms since 1998. This should not be surprising because on the eve of the second phase of banking reforms, the PSBs had almost fully adjusted to liberalization, enhanced competition, and new prudential regulations of the banking sector. We further find that the observed increase in the mean TE during the years of the second phase was entirely contributed by nationalized banks. Note that for the NB group, the value of grand mean TE score of 0.817, during the second wave of reforms, was higher than that during the first wave of reforms, at 0.741. This indicates an increase in input-saving potentials of nationalized banks by 7.6%. On the other hand, the mean TE of the SBI group declined by 4.3% during the second phase of reforms relative to the first phase of reforms. This is evident from the fact that the grand mean of TE scores for the SBI group in the second phase of reforms was 0.942 against 0.985 in the first phase of reforms. The analysis further reveals that despite the large efficiency gains by nationalized banks during the post-reforms period, the banks in the SBI group retained the status of market leader in so far as technical efficiency levels were concerned.

To test whether the differences in the mean TE between the sub-periods are statistically significant or not, we applied the non-parametric Kruskal–Wallis test. The observed values of *H*-statistics for SBI group, NB group, and public sector banking industry as a whole have been noted to be 7.24, 6.21, and 4.19, respectively. These values are greater than the critical value of $\chi^2 = 3.84$ and thus, suggest the rejection of null hypotheses of no differences in the mean TE scores between the sub-periods. On the whole, the results of Kruskal–Wallis test show that the differences in the estimated mean TE between the first and second phases of reforms are statistically significant at 5% level of significance. This not only holds for Indian public sector banking as a whole but also for SBI and NB groups. In sum,

Table 5 Average annual growth rates of mean TE scores

Period	All PSBs	SBI group	NB group
First phase of reforms	1.352	0.447	1.866
Second phase of reforms	1.595	−0.234	2.511
Entire study period	0.887	−0.453	1.581

Authors' calculations

the technical efficiency of the Indian public sector banking industry has improved significantly during the post-reforms period and most of the observed efficiency gains have emanated after the completion of the first phase of reforms.

To ascertain a more concrete picture about the trends of the mean TE scores, we also estimated trend growth rates for the entire study period and sub-periods (see Table 5). The statistics presented in the table reveal that the mean TE has grown during the entire study period at a rate of 0.887% per annum. It is significant to note that the mean TE of the SBI group has declined at the rate of (−) 0.453% per annum. However, the mean TE recorded a growth rate of 1.581% per annum in the NB group. The analysis of growth rates for the distinct sub-periods reveals that the mean TE in the SBI group has declined at a rate of (−) 0.234% per annum during the second phase of reforms while the same has observed a positive growth at the rate of 0.447% per annum in the first phase of reforms. Also, in the NB group, the mean TE grew at the rate of 2.511% in the second phase of reforms relative to 1.866% during the first phase reforms. Thus, there is clear evidence that the mean TE of the NB group has observed an increase with the deepening of the reforms process. Further, this increase in the mean TE of the NB group was responsible for an upturn in the mean TE of the Indian public sector banking industry during the second phase of reforms.

7.2 Inter-bank analysis

Table 4 also provides the information on the behavior of mean TE scores of individual PSBs over the entire study period and distinct sub-periods (see bold figures on the right side of the table). The results reveal that there are large inter-bank variations in mean TE scores over the entire study period. The highest mean TE score was for State Bank of Patiala (0.992), followed by State Bank of Bikaner and Jaipur (0.990), and State Bank of Mysore (0.987). Further, United Bank of India had the lowest mean TE score (0.595), followed by UCO Bank (0.682), and Indian Bank (0.716). The comparative analysis of mean TE scores between the sub-periods yields the following observations: (1) The mean TE has improved in 20 PSBs during the second phase of reforms relative to the first phase of reforms; (2) In seven PSBs, of which four banks belong to the SBI group, the mean TE recorded a downturn in the second phase of reforms compared to the first phase of reforms. The largest decline in the mean TE has been observed in the State Bank of India (about 16%), followed by Bank of Baroda (about 11%), and State Bank of Saurashtra (about 9%); and (3) the three weak banks (Indian Bank, UCO Bank, and United Bank of India) that were identified as weak banks by the Committee on the Banking Sector Reforms, and Working Group on Restructuring of Weak Public Sector Banks, have

observed an upturn in the mean TE over the second phase of reforms compared to the first phase of reforms.

The inter-bank analysis of the trend growth rates of TE is provided in Table 6. The results show that 19 PSBs have a positive trend in TE during the entire study period. The highest growth in TE has been observed in United Bank of India, followed by Punjab and Sind Bank, and Andhra Bank. In the remaining eight PSBs,

Table 6 Growth rates of technical efficiency scores: an inter-bank analysis

Bank	Growth rates		
	First phase of reforms	Second phase of reforms	Entire study period
Category 1: negative to positive growth rates			
State Bank of India	−0.611	2.318	−1.647
Bank of Baroda	−2.462	0.202	−1.638
Canara Bank	−1.327	1.097	−0.810
Indian Bank	−4.976	7.677	1.097
Indian Overseas Bank	−8.941	7.683	1.557
UCO Bank	−0.972	0.758	2.433
Union Bank of India	−0.281	0.605	−0.603
Vijaya Bank	−2.248	4.541	1.974
Category 2: positive to negative growth rates			
State Bank of Indore	1.716	−1.214	0.088
State Bank of Mysore	1.406	−0.221	0.252
State Bank of Saurashtra	0.079	−2.733	−1.337
Bank of India	2.933	−2.608	0.068
Bank of Maharashtra	9.921	−0.936	1.642
Oriental Bank of Commerce	1.401	−1.067	0.259
Category 3: negative to negative growth rates			
State Bank of Hyderabad	−0.086	−1.008	−0.744
State Bank of Patiala	−0.228	−0.394	−0.057
Category 4: positive to positive growth rates			
State Bank of Bikaner and Jaipur	0.550	0.001	0.187
State Bank of Travancore	0.951	1.388	−0.577
Allahabad Bank	3.707	2.761	2.465
Andhra Bank	9.356	2.554	4.130
Central Bank of India	8.566	3.836	3.952
Corporation Bank	2.758	0.148	0.634
Dena Bank	6.247	3.388	1.593
Punjab & Sind Bank	5.917	5.893	4.230
Punjab National Bank	2.740	3.372	1.862
Syndicate Bank	2.380	1.291	2.587
United Bank of India	10.310	8.478	7.443

Authors' calculations

of which five banks belong to the SBI group, we notice a declining trend in TE during the entire study period. However, the analysis of TE growth rates between the first and second phase of reforms provides four different categories of banks. Overall, the results of growth rates of TE are in consonance with the change in mean TE scores between the first and second phases of banking reforms. The results indicate that to a large extent, the India's experience with banking reforms offers a success story to be emulated by other developing economies, since the majority of the PSBs have experienced the efficiency gains over the years.

The aforementioned empirical findings vividly indicate an improvement in the TE of the Indian public sector banking industry during the post-reforms years, but some discussion on what caused this improvement is warranted here. In this context, the most significant factor is the heightened competition in the Indian banking sector during the post-reforms period due to relaxed entry norms for de nova private domestic and foreign banks. To keep their survival intact in the highly competitive environment, the PSBs, especially the weak ones, started allocating resources efficiently, and changed their behavioral attitude and business strategies. Further, in their drive to achieve higher levels of operating efficiency, Indian PSBs during the post-reforms years, primarily concentrated on the rationalization of the labor force and reduction in the cost of financial transactions. For making optimal use of labor force, these banks evolved policies aimed at 'rightsizing' and 'redeployment' of the surplus staff either by way of retraining them and giving them appropriate alternate employment or by introducing a 'voluntary retirement scheme (VRS)' with appropriate incentives. Consequently, the labor cost per unit of earning assets fell from 2.44% in 1992/1993 to 1.57% in 2005/2006. With the objectives of cutting the cost of day-to-day banking operations in the long run and retaining their existing customers and attracting new ones by providing new technology-based delivery channels (like internet banking, mobile banking and card based funds transactions), PSBs made heavy investment in technology during the post-reforms years. Between September 1999 and March 2006, PSBs incurred an expenditure of Rs. 10,676 crores (1 crore = 10 millions) on computerization and development of communication networks (Reserve Bank of India 2006). The computerization of branches and installation of ATMs are two major areas in which the use of technology is clearly visible. By end-March 2007, about 86% branches of PSBs were fully computerized, of which a little more than half the branches were under core banking solutions. The number of both on-site and off-site ATMs by PSBs increased from 3,473 at the end of March 2003 to 16,329 at the end of March 2007. On the whole, the post-reforms period witnessed an enhanced level of IT usage by PSBs which might have contributed to efficiency improvement.

Another major influential factor that contributed to efficiency gains is that due to profound changes in the regulatory and legal frameworks, there has been a better recovery of non-performing loans which led to an improvement in the assets quality of the PSBs. This is evident from the fact that in the public sector banking segment, the quantum of net NPAs as percentage of net advances declined from 10.7% in 1994/1995 to 1.3% in 2005/2006. Consequently, the share of net-interest income in total income of PSBs has increased significantly. Further, in the Indian banking industry, the off-balance sheet activities business has soared during the post-reforms

years. This has led to increase in 'other income' of the PSBs. The improvement in efficiency could also be attributable to the fact that there has been a change in the orientation of PSBs from social objectives towards an ascent on profitability, particularly, given that with the dilution of the government equity in most of these banks, a stake of private investors is involved. The capital market discipline imposed on PSBs since 1992/93 when these banks were allowed to raise capital from stock market has led to significant efficiency gains.

8 Convergence phenomenon

The simple correlation coefficient between a bank's technical efficiency level in 1992/1993 (the initial year) and the change in TE over the entire study period turned out to be (−) 0.907 and is statistically significant at 1% level. This high correlation indicates that there has been a catching-up process, with those banks having lower TE in 1992/1993 experiencing a greater increase over the entire study period. Nonetheless, this is really a very rudimentary test of convergence in TE levels. For getting a more solid idea about the presence of σ and β types of convergence in TE levels across PSBs, we estimated models (4), (5) and (6) using the OLS technique for the distinct sub-periods and entire study period. Tables 7, 8 and 9 give the results of regression analysis for ascertaining the presence of σ-convergence and β-convergence in the Indian public sector banking industry. In each table, we presented three regression equations. The first two regression equations are for examining the presence of convergence in the sub-periods; while the third regression equation is confined to the entire study period.

Table 7 presents the regression results pertaining to σ-convergence. In all the three regression equations given in Panel A, the dependent variable is taken as the natural logarithm of standard deviations of mean TE scores which is also regressed on trend variable t. While the three regression equations given in Panel B involve natural logarithm of coefficient of variations of mean TE scores as dependent variable which is also regressed on trend variable t. The results reveal that in all the regression equations given in Panels A and B, the estimated parameter σ (which is the coefficient of trend variable t) bears a negative sign and is statistically significant at 1% level. Further, all the regression equations show a reasonable goodness of fit with the values of R^2 greater than 70%. Thus, the empirical findings highlight that dispersion in the distribution of mean TE scores has decreased over time. This implies that the gap between inefficient and efficient PSBs has declined during the post-reforms years. In nutshell, the results confirm the presence of strong σ-convergence in the Indian public sector banking industry.

For testing the hypothesis of absolute β-convergence, we estimated regression model (5) and hypothesized that the average annual growth rate of TE has a negative relationship with the initial level of TE. Table 8 shows the regression results for absolute β-convergence. We notice that all the regression equations indicate a reasonable goodness of fit of the model. Further, the results reveal that the estimated β coefficients in all regression equations are both negative and statistically significant at 1% level and thus, indicate a negative relationship between the initial

Table 7 Testing for σ-convergence

Period	Variable	Coefficient	*t*-statistics	R^2 (%)
Panel A: dependent variable: ln (SD_t)				
1992/1998	Constant	−1.481	−20.23	73.3
	t	−0.061*	−3.70	
1999/2006	Constant	−1.898	−25.75	80.0
	t	−0.073*	−4.47	
1992/2006	Constant	−1.456	−31.99	92.9
	t	−0.067*	−12.54	
Panel B: dependent variable: ln (CV_t)				
1992/1998	Constant	3.383	40.74	76.2
	t	−0.074*	−4.00	
1999/2006	Constant	2.93	38.68	84.9
	t	−0.089*	−5.30	
1992/2006	Constant	3.396	67.66	93.2
	t	−0.756*	−12.84	

Authors' calculations

* Coefficients are significantly different from zero at 1% level of significance

Table 8 Testing for absolute β-convergence

Dependent variable: average growth rate of TE				
Period	Variable	Coefficient	*t*-statistics	R^2 (%)
1992/1998	Constant	−0.0153	−1.879	53.8
ln $\theta_{1992–1993}$	−0.1054*	−5.4		
1999/2006	Constant	−0.0101	−2.119	66.5
	ln $\theta_{1999–2000}$	−0.1217*	−7.044	
1992/2006	Constant	−0.0068**	−2.997	86.8
	ln $\theta_{1992–1993}$	−0.0697*	−12.79	

Authors' calculations

* Coefficients are significantly different from zero at 1% level of significance

** Coefficients are significantly different from zero at 5% level of significance

level of TE and the change in TE. Regarding the speed of absolute β-convergence in TE levels, we note that (1) it was about 6.9% per annum during the entire study period; and (2) it was greater in the second phase relative to the first phase (12.17 vs. 10.54%). The empirical findings, thus, confirm the presence of absolute β-convergence in the Indian public sector banking industry during the deregulatory regime.

In order to test the hypothesis of conditional β-convergence, we estimated the regression model (6) with three conditioning variables and hypothesized that the steady-state TE growth rate of a bank is positively related to the bank's *profitability* (PROF),[21] *size* (SIZE)[22] and negatively related to *intermediation cost* (IC)[23] The results for testing conditional β-convergence appear in Table 9. The regression results reveal that the variable natural logarithm of the initial level of TE bears a negative and statistically significant coefficient at 1% level in all the regression

[21] The 'profitability' is measured in terms of return on assets (ROA).

[22] The variable 'size' is measured in terms of value of total assets.

[23] The 'intermediation cost' is measures as the ratio of operating expenses as a percentage of total assets.

Table 9 Testing for conditional β-convergence

Dependent variable: average growth rate of TE				
Period	Variable	Coefficient	*t*-statistics	R^2 (%)
1992/1998	Constant	−21.734*	−3.26	74.0
	ln $\theta_{1992–1993}$	−0.0942*	−5.76	
	ln $PROF_{1992–1993}$	9.4550*	3.27	
	ln $SIZE_{1992–1993}$	−0.0074	−1.19	
	ln $IC_{1992–1993}$	0.0148	0.42	
1999/2006	Constant	0.0048	0.08	66.9
	ln $\theta_{1999–2000}$	−0.1193*	−4.89	
	ln $PROF_{1999–2000}$	−0.00245	−0.38	
	ln $SIZE_{1999–2000}$	−0.0004	−0.08	
	ln $IC_{1999–2000}$	−0.0088	−0.35	
1992/2006	Constant	−6.978*	−3.77	92.6
	ln $\theta_{1992–1993}$	−0.0674*	−14.83	
	ln $PROF_{1992–1993}$	3.0361*	3.78	
	ln $SIZE_{1992–1993}$	−0.0018	−1.04	
	ln $IC_{1992–1993}$	−0.0029	−0.30	

Authors' calculations

* Coefficients are significantly different from zero at 1% level of significance

equations and thus indicates the presence of strong conditional β-convergence in the Indian public sector banking industry. Further, the estimated coefficients of conditioning variable ln SIZE are negative and statistically insignificant in all the regression equations. Thus, we find no definite relationship between size and growth of TE in the Indian public sector banking industry. Similarly, we also failed to get a crystal-clear relationship between the variable ln IC and growth of TE. The coefficients of control variable ln PROF are positive and statistically significant in the regression equations for the first sub-period and entire study period; whereas it is negative and insignificant in the regression equations for the second sub-period. Thus, we can infer that in the Indian public sector banking industry, the relationship between the profitability and growth of TE is moderate in nature. Regarding the speed of conditional β-convergence, we note that it was 6.74% per annum during the study period under consideration. Also, the speed of convergence in TE levels is relatively more in the second sub-period (11.93 vs. 9.42%). The implication of this finding is that there was a smooth process of diffusion of new banking technology in the Indian public sector banking industry during the post-reforms years, especially during the second phase of reforms; and this process led to decrease in inter-bank disparities in the TE levels over time.

On the whole, the empirical findings provide evidence in favor of both σ-convergence and β-convergence in TE levels across PSBs. Following Koski and Majumdar's (2000) terminology, we can, thus, infer that the Indian public sector banking industry witnessed the presence of both catching-up as well as leapfrogging phenomena during the post-reforms period. This implies that the originally inefficient banks in the Indian public sector banking industry are not only catching up with the originally efficient ones (i.e., the banks with low level of efficiency at

the beginning of the period are growing more rapidly than highly efficient banks), but their performance is improving at such a rate which enabled them to overtake the well-performing banks. The most plausible reason for catching-up and leapfrogging phenomena in the Indian public sector banking industry is not only the improved performance of initially lagging banks due to rationalization of the labor force, better recovery of non-performing loans, increased application of technology, more optimal allocation of resources, etc., but also to the deterioration in the performance of initially well-performing banks, especially the banks belonging to the SBI group.

9 Conclusions

After years of financial repression due to heavy government regulatory control, the policy makers introduced a comprehensive banking reforms program in the year 1992 based on the recommendations of the Committee on the Financial System. The banking reforms process was further intensified after the acceptance of most of the recommendations of the Committee on the Banking Sector Reforms by the Reserve Bank of India in the year 1998. The thrust of banking reforms was not only on the improvement of operating efficiency through inculcating the spirit of competition among Indian banks but also on strengthening the shock absorptive capacity of the banking system through the adoption of internationally accepted prudential regulations.

In this paper, we have measured the technical efficiency (TE) of 27 PSBs during the post-reforms period spanning from 1992/1993 to 2005/2006. In particular, we intended to investigate whether the phenomenon of convergence in efficiency levels has taken place in the Indian public sector banking industry during the post-reforms years or not. To accomplish the task of measuring TE scores for individual PSBs, we have used the increasing popular methodology of DEA. Further, we have utilized the traditional cross-sectional regression approach for investigating the presence of σ-convergence and β-convergence in efficiency levels of PSBs.

From a scrupulous inspection of the empirical results pertaining to trends of TE, the following conclusions have emerged. First, there has been a considerable improvement in TE of the Indian public sector banking industry during the post-reforms years with mean TE scores rising from 0.773 in 1992/1993 to 0.895 in 2005/2006. This suggests that Indian PSBs have started learning how to use the right input-mix in the production process. However, the majority of PSBs were found to be operating away from the observed yearly efficient or best-practice frontiers. This is evident from the fact that, barring a few exceptions, the number of efficient banks defining the efficient frontier was between 5 and 9 in a particular year. Second, despite the large efficiency gains by nationalized banks during the post-reforms period, the banks in SBI group continued to be the market leader in so far as mean TE levels were concerned. Third, the average level of technical inefficiency was to the tune of 16.6% in each year of the study period. Fourth, the improvement in TE was more pronounced during the second phase of reforms in comparison to the first phase of reforms. This is evident from the fact that the mean TE has increased by

4% during the second phase relative to what has been observed during the first phase. Further, the whole increase in mean TE of the industry was contributed by an ascent in mean TE of nationalized banks. Fifth, out of 27 PSBs in the sample, only in 7 PSBs, of which 4 banks belong to the SBI group, the mean TE has declined in the second phase of reforms compared to the first phase of reforms. This suggests that the majority of PSBs have started to use the best-practice production technology with the deepening of reforms process. Sixth, the 3 weak PSBs (Indian Bank, UCO Bank, and United Bank of India) those were identified by the government appointed committees for restructuring, improved their performance with an increase in the intensity of reforms.

The aforementioned conclusions portray that to a large extent, the banking reforms process seems to be successful in achieving the efficiency gains in the Indian public sector banking industry. This is evident from the fact that the reforms process has strengthened the technical efficiency of the majority of PSBs. It is significant to note that the observed efficiency gains stemmed due to factors like heightened price and non-price competition among banks, rationalization of the labor force, more exposure to off-balance sheet activities, increased application of information and communication technology, and better recovery of non-performing loans. The empirical findings also indicate a grim aspect relating to the efficiency performance of the Indian public sector banking industry. This aspect is that the TE levels of leading PSBs like State Bank of India, Bank of Baroda, and State Bank of Saurashtra have deteriorated during the post-reforms years. This is really a matter of serious concern for policy makers and needs the evolving of appropriate strategies to arrest further decline of efficiency in these banks.

Our empirical analysis pertaining to σ-convergence and β-convergence provides strong evidence in favor of convergence in TE levels across PSBs during the post-reforms years. The testing of absolute and conditional β-convergence reveal that the speed of convergence in TE levels across PSBs is more than 6.5% per annum during the entire study period. The implication of the observed empirical findings of the study is that the originally inefficient PSBs are catching up with the originally efficient ones i.e., banks with low level of efficiency at the beginning of the period are improving their efficiency in resource utilization more rapidly than highly efficient banks. Not only this, their performance is improving at such a rate that banks which were previously lagging, have overtaken the well-performing banks, indicating the presence of both catching-up as well as leapfrogging phenomena. The presence of strong convergence among PSBs reflects that the process of technology diffusion was working properly in the Indian public sector banking industry and, thus, implies that the lagging banks were able to imitate the use of the best-practice technology of highly efficient banks.

On the whole, the results of this study signify that the level of competitive practices and technology in the Indian banking industry during the post-reforms years served as a catalyst to improve technical efficiency and to bring convergence across PSBs in terms of their efficiency levels. This suggests that banking reforms initiated in 1992 provided a strong economic incentive to the bankers for organizing inputs in a manner that minimized their waste. In sum, the banking reforms process in India has achieved the desired results to a large extent and, thus, offers a success

story that may be emulated by other developing economies that are undergoing banking reforms not only because an ascent in the efficiency of PSBs has been observed in the majority of PSBs, but also because their efficiency levels have converged over time. In the light of our empirical findings, the future reforms in the banking sector should be directed towards strengthening competitive and market-oriented policies.

Acknowledgments We would like thank anonymous reviewers and the editor of this journal for providing useful comments and suggestions which have resulted in significant improvements in the quality of the paper. Errors remain unerringly our own.

References

Agarwal P (2000) Regulation and reform of the financial sector in India: an analysis of the underlying incentives. In: Kahkonen S, Lanyi A (eds) Institutions, incentives and economic reforms in India. Sage Publications India Pvt, New Delhi

Alam ISM (2001) A non-parametric approach for assessing productivity dynamics of large US banks. J Money Credit Bank 33:121–139

Ali AI, Gstach D (2000) The impact of deregulation during 1990–1997 on banking in Austria. Empirica 27:265–281

Ariss RT (2008) Financial liberalization and bank efficiency: evidence from post-war Lebanon. Appl Finan Econ 18:931–946

Arun TG, Turner JD (2002) Financial sector reforms in developing countries: the Indian experience. World Econ 25:429–445

Arun TG, Turner JD (2004) Financial sector reforms and corporate governance of banks in developing economies: the Indian experience. South Asia Econ J 4:188–204

Ataullah A, Cockerill T, Le H (2004) Financial liberalization and bank efficiency: a comparative analysis of India and Pakistan. Appl Econ 36:1915–1924

Avkiran NC (2000) Rising productivity of Australian trading banks under deregulation 1986–1995. J Econ Fin 24:122–140

Avkiran NK (1999) The evidence on efficiency gains: the role of mergers and the benefits to the public. J Bank Fin 23:991–1013

Banker RD, Charnes A, Cooper WW (1984) Some models for estimating technical and scale inefficiencies in DEA. Manage Sci 30:1078–1092

Barman RR (2007) Determinants of profitability of banks in India. Presidential address delivered at the 43rd annual conference of The Indian Econometric Society (TIES) at Indian Institute of Technology, January 5–7, Mumbai

Barro R, Sala-i-Martin X (1991) Convergence across states and regions. Brook Pap Econ Act 1:107–182

Barro R, Sala-i-Martin X (1992) Convergence. J Polit Econ 100:223–251

Barro R, Sala-i-Martin X (1995) Economic growth. McGraw Hill, Boston

Benston GJ (1965) Branch banking and economies of scale. J Fin 20:312–331

Berg SA, Forsund FR, Jansen ES (1992) Malmquist indices of productivity growth during the deregulation of Norwegian banking 1980–89. Scand J Econ 94:S211–S228

Berger AN, Humphrey DB (1997) Efficiency of financial institutions: international survey and directions for future research. Eur J Oper Res 98:175–212

Bhattacharyya A, Bhattacharyya A, Kumbhakar SC (1997a) Changes in economic regime and productivity growth: a study of Indian public sector banks. J Comp Econ 25:196–219

Bhattacharyya A, Lovell CAK, Sahay P (1997b) The impact of liberalization on the productive efficiency of Indian commercial banks. Eur J Oper Res 98:332–345

Bhattacharyya S, Patel UR (2003) Reforms strategies in the Indian financial sector. Paper presented at conference on 'India's and China's experience with reform and growth' held at National Council of Applied Economic Research, November 15–16, New Delhi

Bhaumik SK, Mukherjee P (2001) The Indian banking industry: a commentary. Discussion paper no. 17, Centre for New and Emerging Markets, London Business School, UK

Bhide MG, Prasad A, Ghosh S (2002) Banking sector reforms: a critical overview. Econ Polit Weekly 37:399–407
Burgess R, Pande R (2003) Do rural banks matter? Evidence from the Indian social banking experiment. LSE STICERD research paper no. DEDPS 40. Available via DIALOG http://ssrn.com/abstract_id=1127009. Accessed on 10 September 2008
Canhoto A, Dermine J (2003) A note on banking efficiency in Portugal: new vs. old banks. J Bank Fin 27:2087–2098
Casu B, Girardone C (2002) A comparative study of the cost efficiency of Italian bank conglomerates. Manage Fin 28:3–23
Charnes A, Cooper WW, Lewin AY, Seiford LM (ed) (1994) Data envelopment analysis: theory, methodology and applications. Kluwer Academic, Boston
Charnes A, Cooper WW, Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2:429–444
Chatterjee G (2006) Is inefficiency of banks in India a cause for concern? Evidence from the post-reforms era. J Emerg Markets Fin 5:151–182
Chen X, Skully M, Brown K (2005) Banking efficiency in China: application of DEA to pre- and post-deregulation eras: 1993–2000. China Econ Rev 16:229–245
Christopoulos DK, Tsionas EG (2001) Banking economic efficiency in the deregulation period: results from heteroscedastic stochastic frontier models. Manchester Sch 69:656–676
Coelli T, Rao DSP, Battese GF (1998) An introduction to efficiency and productivity analysis. Kluwer Academic, Boston
Cook WD, Hababou M, Roberts GS (2001) The effect of financial liberalization on the Tunisian banking industry: a non-parametric approach. Topics in Middle Eastern and North African Economies, Electronic J 3, Middle East Economic Association and Loyola University, Chicago. Available via. DIALOG http://www.luc.edu/orgs/meea/volume3/meea3.html. Accessed on 12 July 2008
Cooper WW, Seiford LM, Tone K (2007) Data envelopment analysis: a comprehensive text with models, applications, references and DEA-solver software, 2nd edn. Springer Science—Business Media, New York
Das A, Ghosh S (2006) Financial deregulation and efficiency: an empirical analysis of Indian banks during post-reforms period. Rev Fin Econ 15:193–221
Das A, Nag A, Ray SC (2005) Liberalization, ownership and efficiency in Indian banking: a nonparametric analysis. Econ Polit Weekly 40:1190–1197
Denizer CA, Dinc M, Tarimcilar M (2000) Measuring banking efficiency in the pre- and post-liberalization environment: evidence from the Turkish banking system. World Bank policy research working paper no. 2476
Denizer CA, Dinc M, Tarimcliar M (2007) Financial liberalization and banking efficiency: evidence from Turkey. J Prod Anal 27:177–195
Drake L, Hall MJB (2003) Efficiency in Japanese banking: an empirical analysis. J Bank Fin 27:891–917
Elyasiani E, Mehdian S (1990) Efficiency in the commercial banking industry: a production frontier approach. Appl Econ 22:539–551
Elyasiani E, Mehdian S (1995) The comparative efficiency performance of small and large US commercial banks in the pre- and post-deregulation eras. Appl Econ 27:1069–1079
Farrell MJ (1957) The measurement of productive efficiency. J R Stat Soc 120:253–290
Fung MK (2006) Scale economies, X-efficiency, and convergence of productivity among bank holding companies. J Bank Fin 30:2857–2874
Galagedera DUA, Edirisuriya P (2005) Performance of Indian commercial banks (1995–2002). South Asian J Manage 12:52–74
Ghosh M (2006) Regional convergence in Indian agriculture. Indian J Agric Econ 61:610–629
Grabowski R, Rangan N, Rezvanian R (1994) The effect of deregulation on the efficiency of US banking firms. J Econ Bus 39:39–54
Grifell-Tatjé E, Lovell CAK (1996) Deregulation and productivity decline: the case of Spanish saving banks. Eur Econ Rev 40:1281–1303
Hahn FJ (2007) Environmental determinants of banking efficiency in Austria. Empirica 34:231–245
Hanson JA (2005) Improving performance of the Indian banks. In: Basu P (ed) India's financial sector: recent reforms, future challenges. Macmillan India, New Delhi
Hanson JA, Kathuria S (1999) India: a financial sector for the twenty-first century. Oxford University Press, New Delhi

Hao J, Hunter WC, Yang WK (2001) Deregulation and efficiency: the case of private Korean banks. J Econ Bus 53:237–254
Hjalmarsson L, Andersson I, Mlima A (2000) Swedish banking efficiency and productivity in an international perspective. Estocolmo: Supplement no. 28 to the Government Inquiry on the International Competitiveness of the Swedish Financial Sector
Howcroft B, Ataullah A (2006) Total factor productivity change: an examination of the commercial banking industry in India and Pakistan. Serv Ind J 26:189–202
Humphrey DB (1985) Costs and scale economies in bank intermediation. In: Aspinwall RC, Eisenbeis RA (eds) Handbook for banking strategy. Wiley, New York, pp 745–783
Humphrey DB (1991) Productivity in banking and effects from deregulation. Fed Reserve Bank Richmond Econ Rev 77:16–28
Humphrey DB (1993) Cost and technological change: effects from bank deregulation. J Prod Anal 4:9–34
Humphrey DB, Pulley LB (1997) Banks' responses to deregulation: profits, technology, and efficiency. J Money Credit Bank 29:73–93
Isik I, Hassan MK (2002a) Financial deregulation and total factor productivity change: an empirical study of Turkish commercial banks. J Bank Fin 27:1455–1485
Isik I, Hassan MK (2002b) Technical, scale and allocative efficiencies of Turkish banking industry. J Bank Fin 26:719–766
Isik I, Meleke U, Isik E (2002) Liberalization, ownership and productivity in Turkish banking. Paper submitted to the 9th annual conference of the Economic Research Forum, October 2002. Available via. DIALOG http://www.erf.org.eg/cms/getFile.php?id=724. Accessed on 21 July 2008
Jacobs R (2000) Alternative methods to examine hospital efficiency: data envelopment analysis and stochastic frontier analysis. Discussion paper no. 177, University of York Centre for Health Economics. Available via DIALOG http://www.york.ac.uk/inst/che/pdf/DP177.pdf. Accessed on 14 September 2008
Jaffry S, Ghulam Y, Pascoe S, Cox J (2007) Regulatory changes and productivity of the banking sector in the Indian sub-continent. J Asian Econ 18:415–438
Jagirdar B (1996) Capital adequacy: some issues. Econ Polit Weekly 31:731–739
Jemric I, Kujcic B (2002) Efficiency of banks in Croatia: a DEA approach. Working paper no. 7, Croatian National Bank, Zagreb
Joshi V, Little IMD (1996) India's economic reforms 1991–2001. Clarendon, Oxford
Ketkar KH, Ketkar SL (1992) Bank nationalization, financial savings and economic development—a case study. J Dev Areas 27:69–84
Ketkar KW (1993) Public sector banking, efficiency and economic growth in India. World Dev 21:1685–1697
Kondeas AG, Caudill SB, Gropper DM, Raymond JE (2008) Deregulation and productivity changes in banking: evidence from European unification. Appl Fin Econ Lett 4:193–197
Koski HJ, Majumdar SK (2000) Convergence in telecommunications infrastructure development in OECD countries. Inf Econ Pol 12:111–131
Kumbhakar SC, Lozano-Vivas A (2005) Deregulation and productivity: the case of Spanish banks. J Regul Econ 27:331–351
Kumbhakar SC, Sarkar S (2003) Deregulation, ownership and productivity growth in the banking industry: evidence from India. J Money Credit Bank 35:403–424
Kumbhakar SC, Vivas AL, Lovell CAK, Hasan I (2001) The effects of deregulation on the performance of financial institutions: the case of Spanish savings banks. J Money Credit Bank 33:101–120
Kumbhakar SC, Wang D (2007) Economic reforms, efficiency and productivity in Chinese banking. J Regul Econ 32:105–129
Leightner JE, Lovell CAK (1998) The impact of financial liberalization on the performance of Thai banks. J Econ Bus 50:115–131
Lopez-Cortes GC (1997) An efficiency analysis of Mexico's commercial banks before, during and after financial liberalization. Discussion paper no. EC5/97, Manage Sch, Lancaster University, UK
Lozano-Vivas A (1998) Efficiency and technical change for Spanish banks. Appl Fin Econ 8:289–300
Maghyereh A (2004) The effect of financial liberalization on the efficiency of financial institutions: the case of Jordanian commercial banks. J Trans Manage Dev 9:71–106
Mahadevan R, Kim S (2001) Did financial deregulation since 1980s prior to 1997 affect the efficiency performance of Korean banks? Indian J Quant Econ 16:81–100

Mahesh HP, Rajeev M (2006) Liberalization and productive efficiency of Indian commercial banks: a stochastic frontier analysis. MPRA paper no. 827 Available via. DIALOG http://mpra.ub.uni-muenchen.de/827/1/MPRA_paper_827.pdf. Accessed on 24 July 2008
Maheshwari SN (2006) Banking law and practice. Kalyani, New Delhi
Majumdar SK, Chang H (1996) Scale efficiencies in US telecommunications: an empirical investigation. Manage Dec Econ 17:303–318
Mamatzakis E, Staikouras C, Koutsomanoli-Filippaki A (2007) Bank efficiency in the new European Union member states: is there convergence? Int Rev Fin Anal. doi:10.1016/j.irfa.2007.11.001
Mirmirani S, Li HC, Ilacqua JA (2008) Health care efficiency in transition economies: an application data envelopment analysis. Int Bus Econ Res J 7:47–56
Mohan R (2006) Reforms, productivity and efficiency in banking: the Indian experience. Reserve Bank India Bull, pp 279–293
Mohan R (2007) India's financial sector reforms: fostering growth while containing risk. Address at Yale University, December 3, 2007. Available via DIALOG http://www.rbidocs. rbi.org.in/rdocs/Speeches/PDFs/81616.pdf. Accessed on 10 June 2008
Mohan R, Prasad A (2005) India's experience with financial sector development. In: Basu P (ed) India's financial sector: recent reforms, future challenges. Macmillan India, New Delhi
Mukherjee K, Ray SC, Miller SM (2000) Productivity growth in large US commercial banks: the initial post-deregulation experience. J Bank Fin 25:913–939
Narasimham M (1991) Report of the committee on financial system, Reserve Bank of India, Mumbai
Narasimham M (1998) Report of the committee on banking sector reforms, Ministry of Finance, New Delhi
Odeck J, Alkadi A (2004) The performance of sub sized urban and rural public bus operators: empirical evidence from Norway. Ann Reg Sci 38:413–431
Pasiouras F, Sifodaskalakis E, Zopounidis C (2007) Estimating and analyzing the cost efficiency of Greek co-operative banks: an application of two-stage data envelopment analysis. Working paper no. 12, School of Management, University of Bath, UK
Patti EB, Hardy DC (2005) Financial sector liberalization, bank privatization, and efficiency: evidence from Pakistan. J Bank Fin 29:2381–2406
Qayyum A (2008) Financial sector reforms and the efficiency of banking in Pakistan. Unpublished study completed under the SANEI-VIII Round Projects. Available via DIALOG http://www.saneinetwork.net/pdf/SANEI_VIII/11.pdf. Accessed on 7 July 2008
Ram Mohan TT, Ray SC (2004) Comparing performance of public and private sector banks: a revenue maximization efficiency approach. Econ Polit Weekly 39:1271–1275
Rangarajan C (2007) Financial and banking sector reforms in India. First R.K. Talwar Memorial Lecture-2007, Indian Institute of Banking and Finance, July 31. Available via DIALOG http://iibf.org.in/portal/documents/crangarajan_Lecture.doc. Accessed on 14 July 2008
Rebelo J, Mendes V (2000) Malmquist indices of productivity change in Portuguese banking: the deregulation period. Int Adv Econ Res 6:531–543
Reddy AA (2004) Banking sector liberalization and efficiency of Indian banks. ICFAI J Bank Manage 3:37–53
Reddy YV (1998) RBI and banking sector reforms. Reserve Bank India Bull, pp 99–1008
Reddy YV (2005) Banking sector reforms in India: an overview. Reserve Bank India Bull, pp 577–583
Reddy YV (2007) India-perspective for growth with stability. Econ J Orient Bank Commer 3:1–13
Reserve Bank of India (2006) Report of trend and progress in banking: 2005–06, Mumbai
Reserve Bank of India (2008) Efficiency, productivity and soundness of the banking sector. Rep Currency Fin 2:393–446
Rezvanian R, Rao N, Mehdian SM (2008) Efficiency change, technological progress and productivity growth of private, public and foreign banks in India: evidence from the post-liberalization era. Appl Fin Econ 18:701–713
Rizvi SYA (2001) Post-liberalisation efficiency and productivity of the banking sector in Pakistan. Pakistan Dev Rev 40:605–632
Roland C (2008) Banking sector liberalization in India: evaluation of reforms and comparative perspectives on China. Physica, Heidelberg
Sala-i-Martin X (1996a) Regional cohesion: evidence and theories of regional growth and convergence. Eur Econ Rev 40:1325–1352
Sala-i-Martin X (1996b) The classical approach to convergence analysis. Econ J 106:1019–1036

Sarkar J (2004) The banking industry. In: Gorkan S, Sen A, Vaidya RR (eds) The structure of Indian industry. Oxford University Press, New Delhi
Sarma RH (1995) Customer the crown prince of today and monarch of tomorrow. J Indian Inst Bankers 66:50–52
Sathye M (2003) Efficiency of banks in a developing economy: the case of India. Eur J Oper Res 148:662–671
Sealey CW, Lindley JT (1977) Inputs, outputs, and a theory of production and cost at depository financial institutions. J Fin 32:1251–1266
Seiford LM, Thrall RM (1990) Recent developments in DEA: the mathematical programming approach to frontier analysis. J Econ 46:7–38
Sen K, Vaidya RR (1997) The process of financial liberalization in India. Oxford University Press, New Delhi
Sensarma R (2005) Cost and profit efficiency of Indian banks during 1986–2003: a stochastic frontier analysis. Econ Polit Weekly 40:1198–1208
Sensarma R (2006) Are foreign banks always the best? Comparison of state-owned, private and foreign banks in India. Econ Model 23:717–735
Shanmugam KR, Das A (2004) Efficiency of Indian commercial banks during the reform period. Appl Fin Econ 14:681–686
Sherman HD, Gold F (1985) Bank branch operating efficiency: evaluation with data envelopment analysis. J Bank Fin 9:297–315
Shirai S (2002) Road from state to market-assessing the gradual approach to banking sector reforms in India. ADB Institute research paper series no. 32, Asian Development Bank Institute, Tokyo
Shirai S, Rajasekaran P (2002) Is India's banking sector reform successful? KEIO SFC J 1:150–163
Siems TF, Clark JA (1997) Rethinking bank efficiency and regulation: how off-balance sheet activities make a difference. Finan Industry Stud 3: 1–11. Available via DIALOG http://www.dallasfed.org/banking/fis/fis9702.pdf. Accessed on 12 July 2008
Sowlati T, Paradi JC (2004) Establishing the practical frontier in data envelopment analysis. Omega 32:261–272
Sturm JE, Williams B (2004) Deregulation, entry of foreign banks and bank efficiency in Australia. J Bank Fin 28:1775–1799
Sufian F (2006) The efficiency of non-bank financial institutions: empirical evidence from Malaysia. Int J Fin Econ 1:49–65
Sufian F, Majid MA (2007) Singapore banking efficiency and its relation to stock returns: a DEA window analysis approach. Int J Bus Stud 15:83–106
Thirtle C, Piesse J, Lusigi A, Suhariyanto K (2003) Multi-factor agricultural productivity, efficiency and convergence in Botswana: 1981–96. J Dev Econ 71:605–624
Tomova M (2005) X-efficiency of European banking- inequality and convergence. Free University of Brussels. Available via DIALOG http://www.ecomod.net/conferences/ecomod2005/ecomod2005_papers/865.pdf. Accessed on 15 June 2008
Tulkens H, van den Eeckaut P (1995) Non-parametric efficiency, progress, and regress measures for panel data: methodological aspects. Eur J Oper Res 80:474–499
Verma MS (1999) Report of the working group on restructuring of weak public sector banks, Reserve Bank of India, Mumbai
Weill L (2008) Convergence in banking efficiency across European countries. Working paper no. 2008–07, LaRGE (Laboratoire de Recherche en Gestion et Economie) from Laboratoire de Recherche en Gestion et Economie, Université Louis Pasteur, Strasbourg (France). Available via DIALOG http://cournot2.u-strasbg.fr/users/large/publications/2008/2008-07.pdf. Accessed on 9 July 2008
Wheelock DC, Wilson PW (1999) Technical progress, inefficiency, and productivity change in US banking: 1984–1993. J Money Credit Bank 31:212–234
Yoo TH (2005) Indian banking sector reforms: review and prospects. Int Area Rev 8:167–190
Zaim O (1995) The effect of financial liberalization on the efficiency of Turkish commercial banks. Appl Fin Econ 5:257–264
Zhao T, Casu B, Ferrari A (2007) Deregulation and productivity growth: a study of Indian commercial banking. Economic analysis research group working papers no. 2006–07, School of Business, Reading University