Dynamics of Cost Efficiency in Indian Public Sector Banks: A Post-deregulation Experience

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Abstract:

This paper analyses the trends of cost efficiency and its components across Indian public sector banks (PSBs) during the post-deregulation period spanning from 1992/93 to 2007/08. The study also examines the issue of convergence in cost, technical and allocative efficiencies levels of Indian PSBs. The empirical results indicate that deregulation has had a positive impact on the cost efficiency levels of Indian public sector banking industry over the period of study. Further, technical efficiency of Indian public sector banking industry followed an upward trend, while allocative efficiency followed a path of deceleration. We note that, in Indian public sector banking industry, the cost inefficiency is mainly driven by technical inefficiency rather than allocative inefficiency. The convergence analysis reveals that the inefficient PSBs are not only catching-up but also moving ahead than the efficient ones, i.e., the banks with low level of cost efficiency at the beginning of the period are growing more rapidly than the highly cost efficient banks. In sum, the study confirms a strong presence of σ - and β - convergence in cost efficiency levels of Indian public sector banking industry.

Keywords: Data envelopment analysis, Public sector banks, Cost efficiency, Technical efficiency, Allocative efficiency, Convergence.

JEL Codes: G21, G15

1. Introduction

From the early 1970s through the late 1980s, the role of market forces in Indian banking system was almost missing, and excess regulation in terms of high liquidity requirements and state interventions in allocating credit and determining the prices of financial products has resulted in serious financial repression. The main consequence of this financial repression was an ascent in the volume of bad loans due to ineffective credit evaluation system and poorer risk assessment policies. Further, poor disclosure standards abetted corruption by window-dressing the true picture of banks. The overstaffing and over-branching and undue interference by labour unions resulted in huge operating losses. This led to a gradual decline in the profitability and efficiency of Indian banks, especially of public sector banks (PSBs). Infact, in late 1990s, Indian banking system was on the verge of a crisis and lacking viability even in its basic function of financial intermediation.

Realizing the presence of the signs of financial repression and to get an escape from any potential crisis in the banking sector, Government of India (GOI) embarked on a comprehensive banking reforms plan in 1992 with the objective to create a more diversified, profitable, efficient and resilient banking system. The broad contour of this plan was sketched by the Committee on the Financial System (Chairperson: M. Narasimham, 1991), while the definite shape to the plan was provided by the Committee on the Banking Sector Reforms (Chairperson: M. Narasimham, 1998. The main agenda of reforms process was to focus on key areas: i) restructuring of PSBs by imparting more autonomy in decision making, and by infusing fresh capital through recapitalization and partial privatization; ii) creating contestable markets by removing entry barriers for *de novo* domestic private and foreign banks; iii) improving the regulatory and supervisory framework; and iv) strengthening the banking system through consolidation. To meet this agenda, the policy makers heralded an episode of interest-rates deregulation, standardized minimum capital requirements as per Basle norms, prudential norms relating to income recognition, assets classification and provisioning for bad loans, and changes in regulatory and supervisory environment.

Given the broad sketch of banking reforms portrayed above, one may ask whether the efficiency performance of PSBs since the launching of reforms in 1992 has improved or not. In this paper, we made an attempt in this direction. In particular, our endeavour here is to evaluate the performance of PSBs in the post-reforms period by looking at the trends of cost efficiency (CE) and convergence in its levels across banks. The paper has extended the existing literature related to the efficiency of Indian banks in two directions. First, this study reports the bank-wise analysis of trends of cost efficiency and its components, namely technical and allocative efficiencies. Barring a few exceptions, most of existing studies on the efficiency of Indian banks have reported the results for specific groups of banks (particularly defined by ownership and size) rather than those of individual banks. However, we may get a misleading picture from a group-specific analysis if one or a set of some out-performing bank(s) supersede the dismal efficiency levels of the remaining banks of the group. The bank-wise results reported in the present study avoid the problem of dominance of one bank over others within the same group, and would be more useful in designing micro-level policies in the banking industry. Second, to best of our knowledge, this is perhaps the first empirical study that has analyzed the convergence or divergence in the levels of cost efficiency and its distinct components.

Our analysis evolves in two steps. First, using the data of 27 PSBs over a period 16 years (from 1992/93 to 2007/08), we calculate cost efficiency (CE), technical efficiency (TE) and allocative efficiency (AE) scores for individual PSBs using the technique of data envelopment

analysis (DEA), a deterministic non-parametric frontier approach of efficiency measurement. In recent years, many studies have appeared in academic journals that applied DEA to assess the relative cost efficiency of banks (see, for example, Aly et al. 1990; Ferrier and Lovell, 1990; Maudos and Pastor, 2001; Isik and Hassan, 2002; Darrat et al., 2003; Elyasaini et al., 2003; Burki and Dashti, 2003; Maudos and Pastor, 2003; Chen, 2004; Neal 2004; Chen *et al.* 2005; Hassan 2005; Havrylchyk, 2005; Fiorentino et al., 2006; Matthews et al., 2006; Ariss et al., 2007; Rezvanian et al., 2007; Hassan and Sanchez, 2007; Barry et al., 2007; Rezvanian et al. 2007 ; Asimakopoulos et al.,2008; Isik and Darrat, 2008; Ariff and Can, 2008; Burki and Naizi, 2009; Shamsi et al., 2009; Brack and Jimborean, 2009; Awdeh and Moussawi, 2009; Roberta et al., 2009). Second, we use traditional cross-sectional regression approach for investigating the presence of σ -convergence and β -convergence in CE, TE and AE levels. In the contemporary literature, similar approach has been used by Tomova (2005), Mamatzakis et al. (2007), and Weill (2008), Brack and Jimborean (2009) to examine the convergence in bank efficiency levels across European countries and by Daley and Matthews (2009) for testing the convergence in efficiency levels of Jamaican banks.

Our empirical investigation suggests that deregulation has had a positive impact on the performance of Indian public sector banking industry in terms of cost efficiency over the entire period of 1992/93-2007/08. However, improvement in cost efficiency has been noticed to be more pronounced in the years belong to second phase (1998/99-2007/08) relative to first phase (1992/93-1997/98). Further, an average level of cost efficiency among Indian PSBs is to the tune of 79.6%, indicating an average potential total production cost saving of 25.6% over 16 years, if all banks had been full cost efficient. The disaggregate analysis reveals that cost inefficiency in Indian public sector banking industry originates primarily due to technical inefficiency (managerial problems in using the financial resources) rather than allocative inefficiency (regulatory environment in which PSBs are operating). Finally, the study reports the presence of strong σ -convergence and β -convergence in cost efficiency levels of Indian PSBs during the deregulatory regime. Overall, Indian public sector banking industry not only experienced significant efficiency gains during the post-reforms period but also witnessed strong σ - and β -convergence in cost efficiency levels among PSBs.

The paper is structured as follow. In the next section, we present the relevant literature review of the studies aiming at studying the impact of liberalization and deregulation on the efficiency and productivity of the banking system. Section 3 provides an overview of the process of banking reforms in India. Section 4 presents the conceptual framework for measuring cost efficiency and its components 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 Section 6. Section 7 discusses the empirical findings and, finally, Section 8 concludes the paper.

2. Impact of Deregulation on Banking Efficiency and Productivity: Literature Review

2.1 International experience

One of the most studied issues in banking efficiency literature during the last years has been the impact of liberalization and deregulation on the efficiency and productivity of the banking system. In theory, financial liberalization is expected to improve bank efficiency (Berger and Humphrey, 1997). The elimination of government control and intervention aims at restoring and strengthening the price mechanism, as well as improving the conditions for market competition (Hermes and Lensink, 2008). This stimulates the efficiency of banks in resource utilization process. Competitive pressure stimulates banks to become more efficient by reducing

overhead costs, improving on overall bank management, improving risk management and offering new financial instruments and services (Denizer et al., 2000). Since 1990s, there is a flurry of studies on the effect of deregulation on efficiency and productivity of banks. Nevertheless empirical studies investigating the relationship between financial deregulation and efficiency of banks provide mixed results.

In context of Norwegian banking industry, Berg *et al*. (1992) reported a productivity regress at the average bank prior to the deregulation, but rapid growth when deregulation took place. Zaim (1995) concluded that the post-1980 financial liberalization policies succeeded in enhancing both technical and allocative efficiency of Turkish banks. Leightner and Lovell (1998) observed that from the perspective of commercial bank objective, financial liberalization had a significant and positive impact on total factor productivity growth of Thai banks. Lozano-Vivas (1998) painted a more positive picture regarding the effects of deregulation on the Spanish banking industry in terms of cost efficiency. Rebelo and Mendes (2000) noted an improvement in the efficiency and productivity of Portugese banks during the deregulation period. The findings of the study of Ali and Gstach (2000) revealed that deregulation in Austrian banking industry spurred the competition which in turn brought an improvement in efficiency. Kumbhakar et al. (2001), and Kumbhakar and Lozano-Vivas (2005) concluded that deregulation contributed positively to TFP growth for Spanish banks. Maghyereh (2004) noted that financial liberalization program of early 1990s was successful in bringing an observable increase in the efficiency of Jordian banks. Chen *et al.* (2005) found that financial deregulation of 1995 was successful to improve cost efficiency levels of Chinese banks including both technical and allocative efficiency. Hua and Randhawa (2006) observed that deregulation in banking sectors of Hong Kong and Singapore has yielded the desired results in terms of efficiency improvement. Retizis(2006) found that productivity growth in Greek Banking industry is clearly higher after deregulation. Fethi et al. (2009) noted that liberalization and privatization policies adopted by the Egyptian government in 1991 and late 1995 respectively have managed to improve the efficiency of the banking sector overall. Hermes and Nhung (2008) observed a positive impact of financial liberalization programme on efficiency of banking sectors of ten Latin American and Asian countries. Jiang et al. (2009) reported improved efficiency levels for Chinese banks during post-reforms period. Burki and Ahmad (2009) found that X-inefficiency of Pakistan banks decreased over the reform period.

In contrast to aforementioned studies that painted a rosy picture about the impact of deregulation on the efficiency and productivity of banking system, the following studies present the instances where a negative or insignificant effect has been observed. Humphrey (1993) observed that deregulation was found to have negative effect on US bank productivity. Grabowski et al. (1994) concluded that the empirical results relating with US banks do not appear to support the hypothesis that deregulation had a favorable effect on the economic efficiency of banking firms. Grifell-Tatjé and Lovell (1996) observed a negative productivity change in Spanish saving banking industry. Humphrey and Pulley (1997) also found that the productivity of US banks has fallen because deregulation of interest rates in the early 1980s raised bank funding costs and lowered profits. . Denizer et al. (2000, 2007) painted a very gloomy picture and concluded that liberalization programs were followed by a decline in efficiency among Turkish banks. Christopoulos and Tsionas (2001) reported that deregulation has brought no significant improvement in the technical and allocative inefficiencies of Greek banks. Hao et al. (2001) noticed that in Korea, the financial deregulation of 1991 was found to have had little or no significant effect on the level of bank efficiency. Cook (2001) concluded

that in Tunisia, deregulation has been less successful in closing the efficiency gap between public, private, and foreign banks. Dogan and Fausten (2003) revealed deterioration in the Malaysian commercial banks productivity in the post-liberalisation era. Kamberoglou et al. (2004) noted that scale economies have declined throughout the post-deregulation period. In context of Chinese banking industry, Kumbhakar and Wang (2007) found no evidence to support the view that deregulation improved the efficiency of banks significantly. Moffat et al. (2008) noted a loss or little productivity gain in Botswana's banks during the post-reform years. Naceur et al. (2009) observed that the effect of deregulatory and liberalization initiatives on bank efficiency and performance in Egypt, Jordan, Morocco, and Tunisia has been limited.

2.2 Indian experience

The literature concerning to bank efficiency in India shows that good number of studies has assessed the impact of transition from regulation to competition on the efficiency and productivity of banks. The most of literature on the effect of deregulation and liberalization on Indian banking industry portraits a positive impact of deregulatory policies on the efficiency and productivity of Indian banks. Followings are the key findings of the prominent studies in Indian context. The study of Bhattacharya *et al.* (1997a) divulged that deregulation has led to the improvement in the overall performance of Indian commercial banks. Bhattacharyya et al. (1997b) also reported a positive impact of deregulation on the TFP growth of Indian public sector banks. Ram Mohan and Ray (2004) found an improvement in the revenue efficiency of Indian banks. Also, they noticed convergence in performance between public and private sector banks in the post-reform era. Shanmugam and Das (2004) observed that during the deregulation period, the Indian banking industry showed a progress in terms of efficiency of raising non-interest income, investments and credits. Ataullah *et al. (*2004) reported that overall technical efficiency of the banking industry of India and Pakistan improved following the financial liberalization. Das et al. (2005) the efficiency of Indian banks, in general, and of bigger banks, in particular, has improved during the post-reform period. The findings of the study of Mahesh and Rajeev (2006) are completely similar to that of Shanmugam and Das (2004). Sensarma (2006) noted that deregulation in Indian banking industry (especially public sector banks) achieved the aim of reduction in intermediation costs and improving TFP. On comparing the effect of deregulation on the productivity growth of banks in Indian sub-continent(including India, Pakistan and Bangladesh), Jaffry *et al.*(2007) concluded that technical efficiency both increases and converges across the Indian sub-continent in response to reform. Zhao et al. (2007) noted that, after an initial adjustment phase, the Indian banking industry experienced sustained productivity growth, driven mainly by technological progress. Sahoo et al. (2007), and Sahoo and Tone (2009) observed that the government reform process instituted in the banking industry has had a favourable effect on the performance of the Indian banking industry. Mahesh and Bhide (2008) found that deregulation has a significant positive impact on the cost and profit efficiencies of commercial banks. Das and Ghosh (2009) concluded that the liberalization of the banking sector in India has generally produced positive results in terms of improving the cost and profit efficiencies of banks.

In Indian context too, the mixed results have also been noticed. For example, Kumbhakar and Sarkar (2003) concluded that 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 the deregulatory measures. Galagedera and Edirisuriya (2005) observed that deregulation has brought no significant growth in the productivity of Indian banks. Sensarma (2005) pointed out that profit efficiency of Indian banks has shown a declining trend during the period of

deregulation. Das and Ghosh (2006) found that 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.

3. Banking Sector Reforms in India

From the late 1960s through the early 1990s, Indian banks, especially the PSBs essentially served as agents of the government in channelizing the investment resources to selected sectors under the country's economic development policy. The development strategy was designed to accelerate India's transition from an agrarian economy to a self-reliant industrialized state. The direct involvement of the state in economic development process resulted in the heavily regulated markets with distorted price mechanism. The financial market was not an exception. Indian banking industry was heavily controlled by the government, and characterized by extensive financial repression. The dominance of state-owned banks was visible and perceptible since their share in industry's total assets was over 85 percent. The prime goal of the banking system was 'to serve better the needs of the development of the economy in conformity with the national policy and objectives' (Mohan and Prasad, 2005). In this period, PSBs expanded through a network of more than 65,000 branches and their operations were guided primarily by the social and political considerations rather than by the considerations of profitability.

Up until the launching of banking reforms in 1992, Government of India 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)[1]. The commercial banks, especially, PSBs were obliged to allocate a substantial part of their total loan portfolio to "priority" sectors (such as agriculture and small-scale industries) at a rate that was below the market rate of interest. Furthermore, interest rates on both deposits and advances were completely administered by the RBI. There was virtually no autonomy to the banks even in taking decision to open new bank branches. The government also tightly regulated the licensing of market entry of new domestic and foreign banks. As a result PSBs dominated the market. Indian PSBs stumbled downhill throughout the period 1980-1992 since non-performing assets had continued to pile up whilst standard assets were doing little to return any significant profits for the banks.Besides this, there were many weaknesses in the organizational structure of banks - lack of delegation, weak internal controls, and nontransparent accounting standards (Mohan and Prasad, 2005). In sum, all the signs of financial repression such as excessively high-reserve requirements, credit controls, interest rate controls, strict entry barriers, operational restrictions, pre-dominance of state-owned banks, etc, were present in the Indian banking system.

The extensively repressed financial environment led to inefficiency in credit allocation and eroded the profitability of banks. The inefficiency in the deployment of credit and deteriorating bank profitability also went hand in hand with inadequate capitalization and insufficient provisions for bad debts by the banks. Jagirdar (1996) observed that the average return on assets (ROA) in the second half of the 1980s was only about 0.15 percent which was abysmally low by all standards. Further, in 1992/93, non-performing assets (NPAs) of 27 PSBs amounted to 24 percent of total credit, only 15 PSBs achieved a net profit, and half of the PSBs faced negative net worth (Shirai, 2002). On commenting the state of Indian banking industry in

[1] By 1991, the pre-emptions under the cash reserve ratio and the statutory liquidity ratio, on an incremental basis, had reached 63.5 percent of net demand and time liabilities

the pre-reform period, Sarkar (2004) remarked that the rates of return were low by international standards, the capital base had eroded, non-performing assets were on the rise, and customer service was below expectation. Further, 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). In such an environment, PSBs had little motivation to improve their performance by reducing operating costs and improving the efficient allocation of loans.

To get rid of distressed banking situation, the Government of India embarked on a strategy of reform measures in the financial sector, in general and banking sector, in particular. Note that the banking reforms in India had two distinct phases. The first phase of reforms introduced consequent to the release of the Report of the Committee on the Financial System (Chairperson: M. Narasimham), 1992.The focus of this phase of the reforms was economic deregulation targeting at relaxing credit and interest rates controls, and removing restrictions on the market entry and diversification. The second phase of reforms, introduced subsequent to the recommendations of the Committee on Banking Sector Reforms (Chairperson: M. Narasimham), 1998. This phase targeted on enhancing prudential regulations, and improving the standards of disclosure and levels of transparency so as to minimize the risks banks assume and to ensure the safety and soundness of both individual banks and the Indian banking system as a whole. On the whole, the key objective of the banking reforms was to transform the operating environment of the banking industry from a highly regulated system to a more market-oriented one, with a view to increase competitiveness and efficiency (Sarkar, 2004).

Although the broad contours of reform measures in the banking sector have been provided by the aforementioned committees but a large number of committees/working groups have been constituted for addressing the specific issues in the banking sector. For example, Janakiraman Committee (1992) investigated irregularities in fund management in commercial banks and financial institutions. Padmanabhan Committee (1996) focused on the on-site supervision of banks, and recommended the implementation of CAMELS rating methodology for on-site supervision of the banks. Khan Committee (1997) suggested measures for bringing about harmonization in the lending and working capital finance by banks and Development Financial Institutions (DFIs). Verma Committee (1999) concentrated on restructuring of weak PSBs. The committee identified three weak banks, viz. Indian Bank, United Commercial Bank and United Bank of India, and suggested introducing Voluntary Retirement Fund enabling bank to reduce excess manpower. Vasudevan Committee (1999) recommended the strategy of up gradation of the existing technology in the banking sector. Mittal Committee (2000) made vital recommendations on the regulatory and supervisory frameworks for internet banking in India. Mohan Committee (2009) which is popularly known as Committee on Financial Sector Assessment has suggested significant measures to improve the stability and resilience of Indian financial system.

In post-1992 period, the reform measures have been taken in six directions for improving the efficiency and profitability of Indian banks, (see Reddy, 2002; Rangarajan, 2007; Ahluwalia, 2002; Shirai, 2002, for details). First, for making available a greater quantum of resources for commercial purposes, the statutory pre-emptions have gradually been lowered[2]. Second, the

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

structure of administered interest rates has been almost totally dismantled in a phased manner[3]. Third, 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. Fourth, entry regulations for domestic and foreign banks have been relaxed to infuse competition in the banking sector[4]. Fifth, the policy makers introduced improved prudential norms related to capital adequacy[5], asset classification[6]and income recognition in line with international norms, as well as increased disclosure level[7]. Sixth, towards strengthening PSBs, GOI recapitalized public sector banks to avert any financial crisis and to build up their capital base for meeting minimum capital adequacy norms[8].

4. Methodological framework

An analytical framework to measure cost efficiency[9] of a firm dates back to the seminal work of Farrell (1957). Measuring cost efficiency requires the specification of an objective function and information on market prices of inputs. If the objective of the production unit is that of cost minimization, then a measure of cost efficiency is provided by the ratio of minimum cost to observed cost (Lovell, 1993). In Farrell's framework, the cost efficiency (*CE*) is composed of two distinct and separable components: *technical efficiency* (*TE*) - the ability of a firm to produce existing level of output with the minimum inputs (input-oriented), or to produce maximal output from a given set of inputs (output-oriented); and *allocative efficiency* (*AE*) - the ability of a firm to use the inputs in optimal proportions, given their respective prices. Allocative efficiency relates to prices, while technical efficiency relates to quantities (Barros and Mascarennas, 2005). Thus, cost inefficiency incorporates both allocative inefficiency from failing to react optimally to relative prices of inputs and technical inefficiency from employing too much of the inputs to produce a certain output bundle (Gjirja, 2004). It is noteworthy here that technical inefficiency is caused and correctable by management, and allocative inefficiency is caused by regulation and may not be controlled by the management (Hassan, 2005) An illustration of these efficiency measures as well as the way they are computed is given in Figure 1.

[3]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.

[4] 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 twenty foreign banks have started their operations since 1994.

[5] India adopted the Basel Accord Capital Standards in April 1992. An eight percent 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 ten percent in the phased manner.

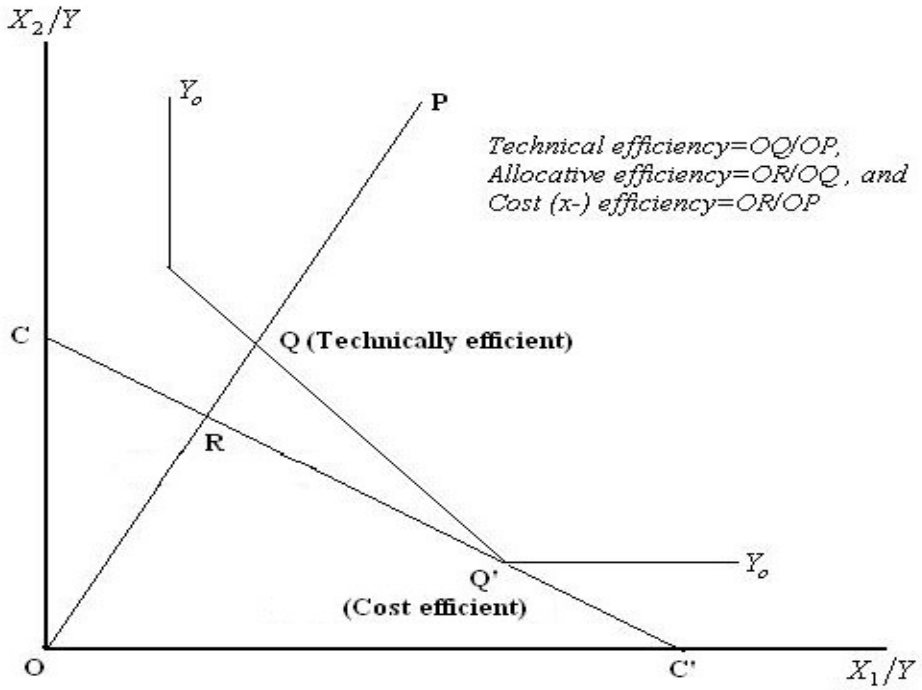
[6] The time for classification of assets as non-performing has been tightened over the years, with a view to move towards the international best practice norm of 90 days by end 2004.

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

[8]The GOI has injected about 0.1 percent of GDP annually into weak public sector banks (Hanson 2005, Rangarajan 2007). During the period 1992/93 to 2001/02, GOI contributed some Rs. 177 billion, about 1.9 percent of the 1995/96 GDP, to nationalized banks (Mohan and Prasad 2005).

[9] In banking efficiency literature, the term *cost efficiency* is being used interchangeably with *economic efficiency, X-efficiency and overall efficiency.*

Figure 1: Technical, allocative and cost efficiencies



Source: Authors' elaboration

In Figure 1, it is assumed that the firm uses two inputs, X_1 and X_2, to produce output Y. The firm's production frontier $Y = f(X_1, X_2)$ is characterized by constant returns-to-scale, so that $1 = f(X_1/Y, X_2/Y)$; and the frontier is depicted by the efficient unit isoquant Y_oY_o. A firm is technically efficient if it is operating on Y_oY_o. However, technical inefficiency relates to an individual firm's failure to produce on Y_oY_o. Hence, firm *P* in the figure is technically inefficient. Thus, for firm *P*, the technical inefficiency can be represented by the distance *QP*. A Farrell's measure of *TE* is the ratio of the minimum possible inputs of the firm (i.e., inputs usage on the frontier, given its observed output level) to the firm's observed inputs. Accordingly, the level of *TE* for firm *P* is defined by the ratio OQ/OP. It measures the proportion of inputs actually necessary to produce output. Allocative inefficiencies result from choosing the wrong input combinations given input prices. Now suppose that CC' represents the ratio of input prices so that cost minimization point is Q'. Since the cost at point *R* is same as the cost at Q', we measure the *AE* of the firm as OR/OQ, where the distance *RQ* is the reduction in production costs which could occur if production occurs at Q'. Finally, the cost efficiency of the firm is defined as OR/OP, which can be considered a composite measure efficiency that includes both technical and allocative efficiencies. In fact, the relationship between *CE*, *TE*, and *AE* is expressed as:

$$CE = TE \times AE$$
$$(OR/OP) = (OQ/OP) \times (OR/OQ)$$

Most empirical analyses pertaining to the measurement of cost efficiency in banking industry applied either parametric or non-parametric methods. These approaches use different techniques to envelop the observed data and make different accommodations for random noise and for the flexibility in the structure of the production technology (Lovell, 1993). In parametric approaches, a specific functional form of the production function like Cobb-Douglas and transcendental logarithmic (translog), etc. is required to specify *a priori*. The efficiency is then assessed in relation to this function with constant parameters and will be different depending on the chosen functional form. The most commonly used parametric methods are the Stochastic Frontier Approach (SFA), the Thick Frontier Approach (TFA), and the Distribution Free Approach (DFA). In contrast, non-parametric approaches do not specify a functional form, and involve solving linear program, in which an objective function envelops the observed data; then efficiency scores are derived by measuring how far an observation is positioned from the envelope or frontier (Delis *et al.*, 2009). The most widely used non-parametric approaches are Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). However, no consensus has been reached in the literature about the appropriate and preferred estimation methodology (Iqbal and Molyneux, 2005; Staikouras *et al*., 2008).

For getting a convenient decomposition of cost efficiency, this paper uses data envelopment analysis (DEA) to estimate empirically the cost, technical and allocative efficiency scores for individual public sector banks. The computational procedure used to implement the DEA approach to the measurement of cost efficiency and its components is of three steps. The first step is to obtain the measure of *TE* as introduced by Charnes *et al*. (1978). Consider *K* banks each of which uses *N* inputs to produce *M* outputs. For each bank $i = 1,.....,K$ denote input quantities by $x_{ni}, n = 1,.....,N$, and output quantities by y_{mi}, $m = 1,.....,M$, with $x_{ni} > 0$ and $y_{mi} > 0$, i.e., each DMU has at least one strictly positive input and one strictly positive output. Denote by Y a $M \times K$ matrix of outputs with bank *i*'s output in column *i.* Similarly, X is a $N \times K$ matrix of inputs. A measure $TE_i^{CRS} = \theta_i$ of technical efficiency can be calculated as a solution to

$$\begin{aligned} &\min_{\theta_i, \lambda_i} \; TE_i^{CRS} = \theta_i \\ &\text{subject to} \\ &\qquad Y\lambda_i \geq y_i, \\ &\qquad X\lambda_i \leq \theta_i x_i, \\ &\qquad \theta_i \text{ free}, \\ &\qquad \lambda_i \geq 0 \end{aligned} \tag{1}$$

By solving linear programming problem (1), we identify a linear combination, described by the $K \times 1$ vector of λ_i of weights, of all banks in the sample which produces at least the output quantities y_i of bank *i* and uses no more than a share $\theta_i \in (0,1]$ of its inputs x_i. Banks with a non-zero weight in λ_i are called reference banks for the bank *i*. For $\theta_i = 1$, a bank is called technically efficient; λ_i then has a value of 1 at element *i* as the only non-zero element. The way the problem was set up ensures that $\theta_i > 0$ and $\theta_i \leq 1$. By minimizing θ_i, we maximize the proportionate reduction of bank *i*'s inputs.

The second step is to calculate cost efficiency by solving the following linear program (see Fare and Grosskopf, 1985; Ferrier *et al*., 1993; for details).

$$\begin{aligned} &\min_{x_i,\lambda_i} \quad w_i' x_i \\ &\text{subject to} \\ &\quad Y\lambda_i \geq y_i, \\ &\quad X\lambda_i \leq x_i, \\ &\quad x_i \text{ free}, \\ &\quad \lambda_i \geq 0 \end{aligned} \qquad (2)$$

where w_i denotes the vector of input prices for bank *i*. This yields a cost-minimizing input vector x_i and a linear combination λ_i of all banks which produces at least bank *i*'s outputs y_i and uses no more than its ideal input vector x_i^{CRS} under a CRS technology. From the solution to model (2), we get minimum costs as $w_i' x_i^{CRS}$. Comparing minimum costs to observed costs $w_i' x_i$ of bank *i* gives cost efficiency as

$$CE_i^{CRS} = \frac{w_i' x_i^{CRS}}{w_i' x_i}$$

The third step involves the calculation of allocative efficiency component residually as the ratio of the measure of cost efficiency to the Farrell input-oriented input-oriented measure of technical efficiency. Thus, the measure of allocative efficiency is obtained as:

$$AE_i^{CRS} = \frac{CE_i^{CRS}}{TE_i^{CRS}}$$

This relationship facilitates the decomposition of cost efficiency as $CE_i^{CRS} = TE_i^{CRS} \times AE_i^{CRS}$. Note that the measures of cost, technical and allocative efficiencies range between 0 and 1. Corresponding to these efficiency measures, the measures of inefficiency can be obtained as $(CE_i^{-1} - 1), (TE_i^{-1} - 1),$ and $(AE_i^{-1} - 1)$, respectively (See Isik and Hassan, 2002; Welzel and Lang, 1997).

4. 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' behaviour. 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: i) the *production approach*, also called the *service provision* or *value added approach*; and ii) 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 labour, 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 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 services processing take 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 the deposits as inputs; and (c) it has an edge over other definitions for data quality considerations. Therefore, as in majority of the empirical literature, we adopted a modified version of intermediation approach as opposed to the production approach for selecting input and output variables for computing CE, TE and AE scores for individual PSBs. Table 1 provides the description of the variables used in measurement of cost efficiency and its components.

Table 1: Definition of variables used in efficiency measurement		
Variable	**Description in the balance sheet**	**Unit of measurement**
Total cost (TC)	Rent, taxes and lighting + Printing and stationary + Depreciation on bank's property + Repairs and maintenance + Insurance + Payment to and provisions for employees + Interest paid on deposits + Interest paid on borrowings from RBI and other agencies	Rupee lacs
Output variables		
1) Net-interest income (y_1)	Interest earned - Interest expended	Rupee lacs
2) Non-interest income (y_2)	Other income	Rupee lacs
Input variables		
1) Physical Capital (x_1)	Fixed assets	Rupee lacs
2) Labour (x_2)	Staff	Number
3) Loanable Funds (x_3)	Deposits + Borrowings	Rupee lacs
Input prices		
1) Price of physical capital (w_1)	(Rent, taxes and lighting + Printing and stationary + Depreciation on bank's property + Repairs and maintenance + Insurance) / Fixed assets	
2) Price of labour (w_2)	(Payment to and provisions for employees) / staff	
3) Price of loanable funds (w_3)	(Interest paid on deposits + Interest paid on borrowings from RBI and other agencies) / Loanable funds	
Note: 10 lacs=1 million		
Source: Authors' elaboration		

The output vector contains two output variables: i) net-interest income, and ii) non-interest income. The 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 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, 2002b), Drake and Hall (2003), Sufian (2006), Sufian and Majid (2007), Hahn (2007) among others. Further, 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 the Indian banks. In the post-reforms years, intense competition in the Indian banking sector has forced the banks to reduce all the input costs to the minimum and to earn maximum revenue with less of 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 input variables used for computing cost efficiency are i) *physical capital*, ii) *labour,* and iii) *loanable funds*, which are proxied by fixed assets, staff, and deposits plus borrowings, respectively. Correspondingly, the prices of these inputs are worked out as per unit price of physical capital, per employee wage bill, and cost of loanable funds. The details on the definitions of these variables are given in the above table. The required data on the variables used for computing various efficiency measures have been culled out from the various issues of 'Statistical Tables Relating to Banks in India', an annual publication of Reserve Bank of India and 'Performance Highlights of Public Sector Banks', an annual publication of Indian Banks' Association. In the terminal years of the study, 28 PSBs were operating in India and data on the IDBI Ltd. (a new public sector bank) were available only after 2004/05. 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 1992/93 to 2007/08. Following Barman (2007) and Roland (2008), we bifurcated the entire study period into distinct sub-periods: i) first phase of banking reforms (1992/93 to 1998/99), and ii) second phase of banking reforms (1999/2000 to 2007/08). To compute CE scores, the analysis has been carried out with real values of the variables (except labour) which have been obtained by deflating the nominal values by the implicit price deflator of gross domestic product at factor cost (base 1993-94=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.

5. Empirical results

This section delineates the trends of cost efficiency and its sources, namely, technical and allocative efficiencies, in Indian public sector banking industry at an aggregate and bank levels during the post-deregulation period. Also, the results concerning convergence in efficiency levels across PSBs are presented here.

5.1 Trends in cost (in)efficiency at aggregate level

Panel A of Table 1 provides year-wise mean estimates of cost, technical and allocative efficiencies for Indian public sector banking industry and its distinct sub-groups. The results show that there are noticeable variations across years in cost efficiency levels, and there appears to be an upward trend in the cost efficiency of Indian public sector banking industry. The cost efficiency increased consistently from 71% in 1992/93 to 80.6% in 1997/98, and then declined gently and reached to the level of 76.3% in 2001/02. Subsequently, a precipitous uplift in cost efficiency has been noticed which ceased at the level of 86.7% in 2006/07. However, cost efficiency turned down and attained a level of 81.6% in the terminal year. We further note that the average level of cost efficiency (inefficiency) in Indian public sector banking industry is 79.6% (25.6%). The 79.6% efficiency figure means that the average bank in the sample could have produced the same level of outputs using only 79.6% of the resources actually employed, if it were producing on the frontier rather than at its current location. On the other hand, the 25.6% inefficiency figure implies that in each year of the study period, the average bank needed 25.6 % more resources and, thus, incurred more cost to produce the same output as the average efficient bank. This divulges that Indian public sector banks, in general, have not been successful in employing best-practice production methods and achieving the maximum outputs from the minimum cost of inputs. Apparently, there exists substantial room for significant cost savings if Indian PSBs use and allocate their productive inputs more efficiently.

Table 1: Mean cost, technical, and allocative efficiencies in Indian public sector banking industry: an aggregate analysis									
Panel A: Year-wise mean efficiency scores									
Bank Groups→	**All PSBs**			**SBI Group**			**NB Group**		
Year↓	**CE**	**TE**	**AE**	**CE**	**TE**	**AE**	**CE**	**TE**	**AE**
1992/93	0.710	0.773	0.917	0.928	0.946	0.981	0.617	0.700	0.890
1993/94	0.756	0.784	0.962	0.981	0.993	0.988	0.661	0.696	0.952
1994/95	0.774	0.824	0.938	0.947	1.000	0.947	0.700	0.750	0.935
1995/96	0.782	0.812	0.961	0.954	0.985	0.969	0.710	0.740	0.957
1996/97	0.793	0.819	0.967	0.964	0.985	0.978	0.721	0.749	0.963
1997/98	0.806	0.848	0.949	0.961	0.992	0.969	0.741	0.787	0.941
1998/99	0.782	0.834	0.938	0.959	0.992	0.967	0.707	0.768	0.925
1999/2000	0.772	0.827	0.936	0.940	0.974	0.964	0.701	0.765	0.925
2000/01	0.774	0.819	0.947	0.928	0.945	0.981	0.709	0.766	0.932
2001/02	0.763	0.822	0.931	0.875	0.936	0.934	0.716	0.774	0.930
2002/03	0.825	0.861	0.959	0.890	0.909	0.979	0.797	0.840	0.951
2003/04	0.823	0.877	0.938	0.868	0.923	0.942	0.804	0.858	0.936
2004/05	0.839	0.880	0.956	0.891	0.947	0.941	0.818	0.851	0.962
2005/06	0.855	0.906	0.945	0.895	0.955	0.938	0.838	0.885	0.947
2006/07	0.867	0.916	0.946	0.890	0.936	0.951	0.858	0.908	0.944
2007/08	0.816	0.898	0.912	0.821	0.943	0.876	0.814	0.879	0.927
Panel B: Grand Mean of efficiency scores									
Entire study period	*0.796*	*0.844*	*0.944*	*0.918*	*0.960*	*0.956*	*0.745*	*0.795*	*0.939*
First phase of reforms	*0.772*	*0.814*	*0.948*	*0.957*	*0.985*	*0.971*	*0.694*	*0.741*	*0.938*
Second phase of reforms	*0.815*↑	*0.867*↑	*0.941*↓	*0.889*↓	*0.941*↓	*0.945*↓	*0.784*↑	*0.836*↑	*0.939*↑
Panel C: Hypothesis testing: Kruskal Wallis test									
Observed K-value	3.248	5.936	1.243	10.114	9.141	4.057	5.672	7.868	0.101
p-value	0.072	0.015	0.265	0.001	0.002	0.044	0.017	0.005	0.751
Inference	Reject H_o	Reject H_o	Accept H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Reject H_o	Accept H_o
Panel D: Growth Rates of mean efficiency scores									
Entire study period	0.868*	0.962*	-0.064	-0.845*	-0.275	-0.421*	1.761*	1.655*	0.083
First phase of reforms	0.829	0.749**	0.139	-0.178	0.228	0.023	1.462**	1.294*	0.190
Second phase of reforms	0.894**	1.108*	-0.203	-1.302*	-0.559	-0.725*	1.967*	1.902*	0.010
Note: (i) CE, TE and AE stands for cost, technical and allocative efficiencies, respectively, (ii) The arrows ↑ and ↓ indicate that mean CE, TE and AE of the bank has increased and decreased, respectively in the second phase of reforms relative to what has been observed during first phase of reforms.									
Source*:* Authors' calculations									

To analyze the group-specific behaviour of the cost efficiency over the entire study period and distinct sub-periods, we followed prevalent grouping criterion in 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). The banks belong to these groups operate under the same environment, and may exhibit variations in cost efficiency due to differences in their managerial skills and practices, natures of business, and government patronage. Some key differences in institutional characteristics of these groups in terms of ownership, functions and organizational structure are listed out in the Appendix A. The inter-group analysis reveals that, over the years understudy, the average cost efficiency levels ranged between 82.1 and 98.1% for SBI group, while the same ranged between 61.7 and 85.8% for NB group. Further, the average level of cost efficiency (inefficiency) for SBI and NB groups is about 91.8% (8.9%) and 74.5% (34.2%), respectively. Looking at these figures of average cost efficiency, we can safely infer that SBI and its associate banks score over nationalized banks.

The comparative analysis for distinct sub-periods highlights that the average cost efficiency of Indian public sector banking industry has increased by about 4.3% (81.5% vis-á-vis 77.2%). The straightforward implication of this finding is that the average cost inefficiency in Indian public sector banking industry has decreased during the second phase relative to the first phase (29.5% vis-á-vis 22.7%). This should not be surprising because at the time of introduction of second phase of banking reforms, the PSBs had almost fully adjusted to liberalization, enhanced competition, and new prudential regulations of the banking sector. Further, it has been identified that the observed increase in the average cost efficiency during the second phase was entirely contributed by the nationalized banks. The average cost efficiency of NB group has been found to be 78.4% for the second phase compared to 69.4% for the first phase, indicating a 9% increase in input cost-saving potentials. On the other hand, the average cost efficiency of SBI group declined by 6.8% between these two phases. This is evident from the fact that the average cost efficiency of SBI group for the second phase has been observed to be 95.7% against 88.9% for the first phase. The results clearly show the increase in average cost efficiency of the NB group was responsible for the observed upturn in the average cost efficiency CE of the Indian public sector banking industry during the second phase of reforms.

To test whether the differences in average cost efficiency between the sub-periods are statistically significant or not, we applied non-parametric Kruskal-Wallis test (see Panel B of Table 1). The observed values of *H*-statistics for public sector banking industry as a whole has been noted to be 3.248, which is lesser than the critical value of χ^2=2.706 at 10% level of significance. Hence, we reject the null hypothesis of no differences in average cost efficiency levels between the sub-periods. This suggests that cost efficiency in Indian public sector banking industry as a whole has improved significantly during the second phase of reforms relative to first one. In addition, the observed values of *H*-statistics for SBI and NB groups have been noted to be 10.11 and 5.67, respectively, which are greater than the critical value of χ^2=2.706. Thus, we reject the null hypothesis of no differences in average cost efficiency levels between the sub-periods. This indicates that (i) average cost efficiency of SBI group has declined significantly during the second phase relative to the first phase; (ii) average cost efficiency of NB group has increased significantly during the second phase of reforms in comparison of the first phase; and (iii) the impact of significant cost efficiency gains is completely vanished by the significant

losses in efficiency in SBI group, and this led to no significant change in cost efficiency of public sector banking industry with the progress of deregulation process.

5.2 Sources of cost (in)efficiency

Recall that technical and allocative efficiencies are two mutually exclusive components of cost efficiency. As a result, cost inefficiency stems from technical inefficiency (i.e., wastage of inputs in producing a certain output bundle) and/or allocative inefficiency (i.e., failing to react optimally to relative prices of inputs). Further, technical inefficiency emanates from the inefficient functioning of the management in utilizing inputs in production process, whilst allocative inefficiency occurs due to stringent regulatory environment inhibiting the correct mix of inputs. Regulation is typically given as a major source of allocative inefficiency, while technical inefficiency is attributed to lack of strong competitive pressures, which allow bank managers to continue with less than optimal performance. Because it relies solely on the amounts of inputs and outputs in its calculation and does not involve factor prices, which are mostly market or regulation driven, technical inefficiency is entirely under the control of bank management and thus results directly from management laxity and errors (Reda and Isik, 2006).

Table 1 also gives the year-wise estimates of technical and allocative efficiencies for Indian public sector banking industry and its distinct segments. From Panel A of the table, we note that over the years understudy, the average technical efficiency is 84.4%, indicating that an average PSB wasted about 18.5 % of factor inputs in the production process by operating off the efficient production frontier. The observed level of average allocative efficiency is 94.4%, pointing that average PSB incurred about 5.9% more production cost by choosing the incorrect input combination given input prices. For determining the dominant source of cost inefficiency, we make a comparison of the relative sizes of technical and allocative inefficiency levels. We note that, for all the sample years, allocative efficiency is consistently higher than technical efficiency, which signals that technical inefficiency (i.e., underutilization or wasting of inputs) has greater significance than allocative inefficiency (i.e., choosing the incorrect input combination given input prices) as a source of cost inefficiency within all inefficient PSBs. This result suggests that the observed cost inefficiency in Indian public sector banking industry originates primarily due to managerial problems in using the financial resources rather than regulatory environment in which PSBs are operating. Apparently, the managers of PSBs operate relatively efficient with respect to the optimal combination of inputs given their prices and technology, yet they are not efficient in transforming bank inputs into outputs. Turning to the segment-wise analysis, we note that average cost inefficiency in NB group is primarily driven by technical inefficiency rather than allocative inefficiency. However, in SBI group, both technical and allocative inefficiencies are roughly equally important source of cost inefficiency.

Turning to the impact of deepening of banking reforms, it has been observed that average technical efficiency of Indian public sector banking industry has increased by 5.3% in the second phase of reforms than what has been observed in first phase (86.7% vis-á-vis 81.4%). Further, this gain in the average technical efficiency has been observed to be statistically significant as indicated by the rejection of null hypothesis in Kruskal-Wallis test. Regarding average allocative efficiency, we note that an increase in the intensity of reforms did not bring any significant change in its level. The acceptance of null hypothesis in Kruskal-Wallis test confirms this. The segment-wise analysis reveals that in the second phase of reforms, a statistically significant gain in average technical efficiency in tune to 9.5% has noted for NB group, while a statistically

significant decline in average technical efficiency in order of (-)4.4% has been observed for SBI group. The analysis further reveals that a statistically significant decline in average allocative efficiency by (-)2.6% has taken place in SBI group. Nevertheless, mean allocative efficiency shown a negligible increase during the second phase of reforms, which is further observed to be statistically insignificant. Peeping deep into the results, we note that what so ever increase in cost and technical efficiencies in public sector banking industry has taken during the study period that was contributed by the significant improvement in technical efficiency of nationalized banks. In fact, the drag in allocative efficiency of the banks belong to SBI groups is not only responsible for a decline in allocative efficiency of the public sector banking industry as whole, but also offset, to a great extent, the impact of gains in technical efficiency of nationalized banks on the cost efficiency of the public sector banking industry as a whole.

5.3 Growth rates analysis

To ascertain a more concrete picture about the trends of efficiency measures, we relied on the trend growth rates of efficiency measures for the entire study period and distinct sub-periods. For computing the average annual growth rate of mean efficiency score for the entire study period, we estimated the log-linear trend equation: $\ln E_t = \alpha + \beta t + \varepsilon_t$, where E_t is mean efficiency score in year t and t=1,2,…,T denotes time and ε_t denotes stochastic error term. Following Boyce (1986), a kinked exponential model has been used for estimating the growth rates for the sub-periods. The regression equation in kinked exponential model for estimating the growth rates for sub-periods takes the form: $\ln E_t = \alpha + \beta_1(Dt + (1-D)k) + \beta_2(1-D)(t-k) + \varepsilon_t$, where D is a dummy variable (D=1 for first sub-period and 0 for second sub-period), k is the midpoint of the two discontinuous series (k=7.5 in the present study). The OLS estimates of β_1 and β_2 (i.e., $\hat{\beta}_1$ and $\hat{\beta}_2$) gives the growth rates for the first and second sub-periods, respectively.

Panel D of Table 1 provides the growth rate estimates of cost efficiency and its components. We note that cost efficiency of Indian public sector banking industry grew at a modest rate of 0.868% per annum over the entire study period. Further, it has declined at the rate of (-)0.845% per annum for SBI group and recorded a decent growth rate of 1.761% per annum for NB group. The analysis of growth rates for the distinct sub-periods reveals that (a) in SBI group, the declining trend of cost efficiency was more pronounced in the second phase, (b) in NB group, cost efficiency grew at the rate of 1.967% during the second phase which is about half percent more than what has been noticed during the first phase, and (c) the affect of decent growth in cost efficiency in NB group during the second phase of reforms was offset to a great extent by a pronounced decline in the same in SBI group. This led to a very slight improvement in growth of cost efficiency of Indian public sector banking industry during the second phase of reforms relative to the first one (0.894% vis-á-vis 0.829%).

Turning to the growth rates of disaggregate components of the cost efficiency, we note that, over the entire study period, technical efficiency of Indian public sector banking industry followed an upward trend, while allocative efficiency followed a path of deceleration. This is evident from the figures of growth rates at 0.96% per annum and (-)0.064% per annum for technical efficiency and allocative efficiency, respectively. In Indian public sector banking industry, the components of cost efficiency moved in opposite directions, and they are counterbalancing in nature. The segment-wise analysis reveals that in SBI group, both components followed a declining trend over the entire study period. However, in NB group, these components posted a positive trend. It is noteworthy here that growth in technical efficiency was relatively more impressive than that of allocative efficiency. Further, the analysis of growth rates for distinct sub-periods reports (i) a negative trend in both components of cost

efficiency in SBI group during the second phase relative to a positive trend during the first phase, (ii) a noticeable improvement in the growth of technical efficiency of Indian public sector banking industry as a whole and its segment of nationalized banks during the second phase relative to first one, and (iii) the allocative efficiency of Indian public sector banking industry has shown a decelerating trend during the latter phase relative to the former. Overall, the analysis manifests that in Indian public sector banking industry, the growth in technical efficiency contributed positively to the growth of cost efficiency and the deceleration in allocative efficiency actually drags it.

5.4 Inter-bank analysis

Table 2 provides the average cost, technical and allocative efficiencies scores for individual PSBs over the entire study period and distinct sub-periods. The perusal of table gives that there is heterogeneity of the level of average cost efficiency across PSBs. United Bank of India presents the lowest level of cost efficiency (58.6%) and State Bank of Hyderabad (95.3%) displays the highest ones (95.3%). Further, in 6 PSBs, the magnitude of average cost inefficiency is found to be less than 10%. These banks are State Bank of Hyderabad (95.3%), State Bank of India (93.9%), State Bank of Indore (94.6%), State Bank of Mysore (93.8%), State Bank of Patiala (93.2%), and Corporation Bank (91.3%). We can rightly designate these banks as 'marginally cost inefficient' banks. It is significant to note here that i) out of 6 marginally cost inefficient banks, 5 banks belong to SBI group, ii) all the observed marginally inefficient banks have both high level of technical and allocative efficiencies, and ii) average technical efficiency is more than average allocative efficiency in all these banks.

In the remaining 21 PSBs, the average cost efficiency ranged between 58.6% and 89.6%, indicating that the extent of cost inefficiency lies in the range between 11.6% and 70.6%. These banks can be categorized as 'distinctively cost inefficient banks'. Two points are noteworthy here that (a) in 20 distinctively cost inefficient banks, cost inefficiency emanates primarily due to technical inefficiency rather than allocative inefficiency, (b) the three banks viz., Indian Bank(67.4%), UCO Bank(58.9%) and United Bank of India(58.6%) which were identified as weak banks by the Committee on the Banking Sector Reforms (1998) and Working Group on Restructuring of Weak Public Sector Banks (1999) are the least cost efficient banks in the sample.

Table 2: Cost, technical and allocative efficiencies in Indian public sector banking industry: a bank-wise analysis									
Efficiency measures→	**Cost efficiency (CE)**			**Technical efficiency (TE)**			**Allocative efficiency (AE)**		
Period of study→ / **Bank↓**	**First phase of reforms**	**Second phase of reforms**	**Entire study period**	**First phase of reforms**	**Second phase of reforms**	**Entire study period**	**First phase of reforms**	**Second phase of reforms**	**Entire study period**
State Bank of Bikaner and Jaipur	0.960	0.845↓	0.896	0.991	0.867↓	0.921	0.969	0.974↑	0.972
State Bank of Hyderabad	0.945	0.960↑	0.953	0.984	0.994↑	0.990	0.960	0.965↑	0.963
State Bank of India	0.997	0.893↓	0.939	0.998	0.947↓	0.970	0.998	0.943↓	0.967
State Bank of Indore	0.978	0.922↓	0.946	0.979	0.974↓	0.976	0.999	0.946↓	0.969
State Bank of Mysore	0.931	0.944↑	0.938	0.982	0.993↑	0.989	0.948	0.950↑	0.949
State Bank of Patiala	0.969	0.903↓	0.932	0.991	0.992↑	0.992	0.978	0.910↓	0.940
State Bank of Saurashtra	0.984	0.806↓	0.884	0.998	0.859↓	0.920	0.985	0.942↓	0.961
State Bank of Travancore	0.889	0.836↓	0.859	0.953	0.902↓	0.924	0.933	0.929↓	0.931
Allahabad Bank	0.624	0.752↑	0.696	0.677	0.796↑	0.744	0.925	0.946↑	0.937
Andhra Bank	0.692	0.867↑	0.791	0.735	0.942↑	0.851	0.946	0.919↓	0.931
Bank of Baroda	0.868	0.794↓	0.827	0.947	0.858↓	0.897	0.918	0.928↑	0.924
Bank of India	0.683	0.751↑	0.721	0.741	0.792↑	0.770	0.924	0.949↑	0.938
Bank of Maharashtra	0.697	0.773↑	0.740	0.729	0.799↑	0.768	0.949	0.968↑	0.960
Canara Bank	0.798	0.765↓	0.780	0.857	0.816↓	0.834	0.933	0.940↑	0.937
Central Bank of India	0.619	0.733↑	0.683	0.643	0.771↑	0.715	0.961	0.952↓	0.956
Corporation Bank	0.920	0.907↓	0.913	0.968	0.997↑	0.984	0.952	0.910↓	0.928
Dena Bank	0.793	0.831↑	0.814	0.834	0.879↑	0.859	0.950	0.944↓	0.947
Indian Bank	0.570	0.754↑	0.674	0.665	0.781↑	0.730	0.869	0.963↑	0.922
Indian Overseas Bank	0.662	0.822↑	0.752	0.704	0.852↑	0.787	0.942	0.965↑	0.955
Oriental Bank of Commerce	0.897	0.833↓	0.861	0.965	0.986↑	0.977	0.927	0.845↓	0.881
Punjab & Sind Bank	0.579	0.783↑	0.694	0.613	0.830↑	0.735	0.946	0.947↑	0.947
Punjab National Bank	0.743	0.857↑	0.807	0.772	0.889↑	0.838	0.961	0.964↑	0.962
Syndicate Bank	0.639	0.771↑	0.713	0.683	0.823↑	0.762	0.932	0.937↑	0.935
UCO Bank	0.520	0.644↑	0.589	0.551	0.676↑	0.621	0.946	0.953↑	0.950
Union Bank of India	0.754	0.772↑	0.764	0.832	0.850↑	0.842	0.912	0.909↓	0.910
United Bank of India	0.444	0.696↑	0.586	0.461	0.722↑	0.608	0.959	0.966↑	0.963
Vijaya Bank	0.686	0.787↑	0.743	0.711	0.833↑	0.779	0.964	0.945↓	0.953
Note: The arrows ↑ and ↓ indicate that mean CE, TE and AE of the bank has increased and decreased, respectively in the second phase of reforms relative to what has been observed during first phase of reforms									
Source: Authors' calculations									

The comparative analysis of average cost efficiency between the sub-periods provides the following points: (i) the average cost efficiency has improved in 17 PSBs during the latter phase of reforms relative to first one; (ii) of 8 PSBs that belong to SBI group, the average cost efficiency in 6 banks recorded a downturn in the latter phase compared to the earlier phase; (iii) the three weak banks (Indian Bank, UCO Bank and United Bank of India) have observed an upturn in the average cost efficiency over the second phase of reforms compared to first phase; and (iv) out of 18 PSBs that belong to NB group, only in 4 banks namely, Bank of Baroda, Corporation Bank, Oriental Bank of Commerce, and Canara Bank, a decline in average cost efficiency has been observed during the second phase of reforms. The above result indicates that though at the aggregate level of banking industry, no significant change in average cost efficiency has been observed, but at the level of individual banks noticeable improvement in average cost efficiency has been observed with the deepening of the process of banking reforms since 1998/99. The main reason for insignificant improvement in the cost efficiency at the industry level is that the downturn in the average cost efficiency among most of banks in SBI group offsets the effect of an ascent in average cost efficiency in the majority of banks that belong to NB group.

As far as the components of cost efficiency are concerned, we observe that average technical efficiency has increased in the 20 PSBs during the second phase of reforms relative to first one. This indicates that operating efficiency of majority of PSBs improved with the increase in the intensity of reforms. The connotation of this finding is that PSBs have learnt to avoid the waste of inputs in transforming outputs with the deepening of reforms. Further, we note that in 15 PSBs, the average allocative efficiency has increased relatively in the latter phase of reforms compared to first one. Thus, the majority of PSBs have learnt to organize the inputs in the cost-minimizing way given their prices. On the whole, we observed that a majority of PSBs exhibited a decline in both technical and allocative inefficiencies with the ascent of deregulation in Indian banking industry.

The inter-bank analysis of trend growth rates of cost efficiency and its disaggregate components is provided in the Table 3. The results show that (i) the cost efficiency in majority of banks that belong to SBI group followed a declining trend. This is evident from the fact that, of 8 PSBs in SBI group, 6 banks posted a negative growth rate over the entire study period; (ii) barring 4 PSBs, the remaining 15 banks belonging to NB group experienced an increasing trend in cost efficiency. The highest growth in cost efficiency has been observed in United Bank of India (5.89%), followed by Bank of Maharashtra (4.65%) and Punjab & Sind Bank (4.10%); and iii) in 20 PSBs, cost efficiency and its disaggregate components evolve with the same tendency. That is, an increasing(decreasing) trend in cost efficiency is followed by the increasing(decreasing) trend in technical and allocative efficiencies. This undertones the presence of a phenomenon of co-movement in the growth of cost, technical and allocative in Indian public sector banking industry.

Turning to the analysis for the distinct sub-periods, it has been observed that the number of banks having a positive trend in cost efficiency (technical efficiency, allocative efficiency) during the second phase of reforms was 18(18,12), while this number stood at 17(18,19) during the first phase. This highlights that the number of banks showing downtrend in allocative efficiency has increased considerably during the latter phase of reforms. In a great majority of banks in SBI group, a declining trend in cost efficiency and its components has been noticed in the second phase. Further, only 9(8,6) PSBs experienced an improvement in the growth rate of cost efficiency (technical efficiency, allocative efficiency) in the second phase relative to the first one. This conveys that no considerable improvement in the growth of cost efficiency and its components has been noticed in Indian public sector banking industry with the ascent in the intensity of reforms since 1998/99. Considering both the sub-periods separately, we noticed the appearance of co-movement in trend growth rates of cost, technical and allocative efficiencies in majority of PSBs. By and large, the results of growth rates of cost efficiency are in consonance with the changes in average cost efficiency levels between the first and second phases of banking reforms. The inter-bank analysis indicates 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 experienced a positive trend in cost efficiency during the reforms period.

Table 3: Growth rates of cost, technical and allocative efficiencies: an inter-bank analysis									
Efficiency measures→	**Cost efficiency (CE)**			**Technical efficiency (TE)**			**Allocative efficiency (AE)**		
Period of study→ / **Bank↓**	**First phase of reforms**	**Second phase of reforms**	**Entire Study Period**	**First phase of reforms**	**Second phase of reforms**	**Entire Study Period**	**First phase of reforms**	**Second phase of reforms**	**Entire Study Period**
State Bank Of India	-3.578	1.437	-0.533	-2.689	1.326	-0.231	-0.569	0.372	-0.011
State Bank Of Bikaner & Jaipur	1.075	-0.392	0.205	0.487	-0.137	0.116	0.589	-0.259	0.086
State Bank Of Hyderabad	-0.459	-1.958	-1.348	-0.637	-0.452	-0.528	0.178	-1.512	-0.825
State Bank Of Indore	2.168	-3.259	-0.835	1.393	-1.043	-0.052	0.761	-2.722	-1.478
State Bank Of Mysore	1.506	-0.524	0.301	0.953	-0.272	0.226	0.554	-0.251	0.077
State Bank Of Patiala	1.011	-3.107	-1.645	0.021	-0.107	-0.055	0.991	-3.003	-1.613
State Bank Of Saurashtra	-0.139	-4.311	-2.819	0.690	-4.386	-2.476	-0.824	0.068	-0.294
State Bank Of Travancore	-2.554	1.284	-0.182	-1.062	0.436	-0.173	-1.494	0.845	-0.106
Allahabad Bank	3.986	1.197	2.331	3.090	1.611	2.213	0.882	-0.403	0.120
Andhra Bank	4.822	2.722	3.576	7.428	0.999	3.613	-2.598	1.720	0.052
Bank Of Baroda	-2.643	0.807	-0.596	-3.496	1.008	-0.506	0.853	-0.201	0.228
Bank Of India	1.773	1.155	1.406	1.417	0.950	1.140	0.357	0.207	0.268
Bank Of Maharashtra	8.796	1.370	4.657	6.885	1.480	3.863	1.232	-0.221	0.370
Canara Bank	-2.011	0.720	-0.390	-2.331	1.209	-0.230	0.327	-0.488	-0.157
Central Bank Of India	7.416	-0.940	2.034	7.282	-0.764	1.980	0.135	-0.175	-0.049
Corporation Bank	0.140	0.386	0.286	1.986	-0.440	0.546	-1.844	0.827	-0.259
Dena Bank	2.474	0.765	1.460	2.943	0.454	1.466	-0.474	0.306	-0.011
Indian Bank	-2.121	7.774	3.795	-5.242	7.540	1.976	3.092	0.240	1.400
Indian Overseas Bank	-5.421	8.078	1.596	-6.005	7.982	0.864	0.590	0.092	0.295
Oriental Bank Of Commerce	0.340	-1.097	-0.292	1.379	-0.561	0.228	-0.240	-0.866	-0.609
Punjab & Sind Bank	4.385	3.909	4.103	4.346	4.031	4.159	0.038	-0.125	-0.059
Punjab National Bank	1.711	2.666	2.277	1.381	2.625	2.119	0.327	0.050	0.163
Syndicate Bank	4.911	0.233	2.135	3.671	0.715	1.917	1.244	-0.485	0.218
UCO Bank	2.614	1.680	2.060	2.257	1.640	1.891	0.372	0.029	0.168
Union Bank Of India	-1.557	2.236	1.177	-1.058	1.754	0.611	-0.495	0.486	0.087
United Bank Of India	10.688	2.607	5.893	9.848	2.938	5.748	0.822	-0.326	0.238
Vijaya Bank	-0.891	-0.197	-0.498	-0.341	2.860	0.697	0.039	-1.056	-0.635
Note: The arrows ↑ and ↓ indicate that mean CE, TE and AE of the bank has increased and decreased, respectively in the second phase of reforms relative to what has been observed during first phase of reforms									
Source: Authors' calculations									

The aforementioned empirical findings vividly indicate a positive trend in the cost efficiency levels of Indian public sector banking industry during the post-reforms years, but some discussion on what derived this improvement is warranted here. In this context, the most significant factor is the heightened competition in Indian banking sector during the post-reforms period due to relaxed entry norms for *de novo* 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 behavioural 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 labour force and reduction in the cost of financial transactions. For making optimal use of labour 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 labour cost per unit of earning assets fell from 2.44 % in 1992/93 to 0.95% in 2007/08. 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 2008, PSBs incurred an expenditure of Rs.15015 crore (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 2008, about 93.7 % branches of PSBs were fully computerized, of which 67.7% branches of nationalized banks and 95% of SBI and its associates were under core banking solutions. The number of both on-site and off-site ATMs by PSBs increased from 3473 at the end of March 2003 to 34789 at the end of March 2008. On the whole, the post-reforms period witnessed enhanced level of IT usage by public sector banks which might have contributed to efficiency improvement.

Another major influential factor that contributed to cost 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 public sector banking segment, the quantum of net NPAs as percentage of net advances declined from 10.7% in 1994/95 to 0.99% in 2005/06. Among the various channels of recovery available to banks for dealing with bad loans, SARFAESI Act and the debt recovery tribunals(DRTs) have been the most effective in terms of amount recovered(RBI, 2008). Due to better recovery of NPAs, 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. From the above discussion, we may infer that cost efficiency gains in Indian public sector banking during the post-reforms years stemmed not only due to cost-curtailing measures adopted by PSBs, but also occurred due to measures aiming at augmenting income-generating capacity of banks.

5.5 Convergence in efficiency levels

5.5.1 Testing of σ -convergence

The concept of convergence as used in the present study refers to the tendency for 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: i) σ -convergence; and ii) β -convergence (see Barro and Sala-i-Martin 1991, 1992, 1995; Sala-i-Martin 1996a, 1996b). Convergence of 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

$$\ln(SD_t \text{ or } CV_t) = a + \sigma t + \varepsilon_t \quad (4)$$

where SD_t and CV_t denote the standard deviation and coefficient of variation of efficiency measure 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 efficiency measure over time implies a narrowing of the dispersion of efficiency levels.

Table 4 presents the regression results pertaining to σ -convergence. In all the nine regression equations given in Column 1 of Panel A, B and C, the natural logarithm of *standard deviations* of cost, technical and allocative efficiencies scores, respectively is taken as dependent variable which is regressed on trend variable *t*. Further, the regression equations given in Column 2 involves the natural logarithm of *coefficient of variations* of cost, technical and allocative efficiencies scores as dependent variable which is also regressed on trend variable *t*. The results reveal that in 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 for the first sub-period and entire study period; whereas it is negative and insignificant in the regression equations for the second sub-period. Further, all the regression equations show a reasonable goodness of fit with the values of R^2 greater than 70% for the first sub-period and entire study period. From the regression equations pertaining to mean allocative efficiency, as given in Panel C, we note that the estimated parameter σ is positive and insignificant for the entire study period. However, for the sub-periods, the sign of the parameter σ has been observed to be negative and insignificant.

The aforementioned empirical findings highlight that dispersion in the distribution of cost and technical efficiencies scores have decreased for the first sub-period and entire study period. This implies that the gap between both cost and technically inefficient and efficient PSBs has declined significantly during the entire study period and this phenomenon of narrowing the gap was more pronounced in the first phase of reforms relative to second one. Further, some insignificant signs of σ -convergence in allocative efficiency levels appeared in the sub-periods but on the whole no significant convergence in allocative efficiency levels has been noted in Indian public sector banking industry during the entire period under investigation. In a nutshell, the results confirm the presence of strong σ -convergence in the cost and technical efficiencies levels in Indian public sector banking industry throughout the entire study period.

Table 4: Testing for σ – convergence		
Panel A: Cost efficiency		
Period	**Regression equations**	
	Column 1	**Column 2**
Panel A: Cost efficiency (CE)		
Entire period (1992/93-2007/08)	$\ln(SD_t) = -1.54 - 0.0546^{*} t$ (-19.41) (-6.65) (R^2=76.0%)	$\ln(CV_t) = -1.24 - 0.0633^{*} t$ (-14.95) (-7.40) (R^2=79.6%)
First generation (1992/93-1998/99)	$\ln(SD_t) = -1.49 - 0.0589^{*} t$ (-24.73) (-4.38) (R^2=79.3%)	$\ln(CV_t) = -1.16 - 0.0747^{*} t$ (-18.64) (-5.36) (R^2=85.2%)
Second generation (1999/2000-2007/08)	$\ln(SD_t) = -2.13 - 0.0181\ t$ (-17.46) (-0.84) (R^2=9.1%)	$\ln(CV_t) = -1.86 - 0.0317\ t$ (-13.61) (-1.30) (R^2=19.5%)
Panel B: Technical efficiency (TE)		
Entire period (1992/93-2007/08)	$\ln(SD_t) = -1.54 - 0.0527^{*} t$ (-19.19) (-6.37) (R^2=74.3%)	$\ln(CV_t) = -1.28 - 0.0623^{*} t$ (-15.42) (-7.24) (R^2=78.9%)
First generation (1992/93-1998/99)	$\ln(SD_t) = -1.48 - 0.0608^{*} t$ (-20.15) (-3.70) (R^2=73.2%)	$\ln(CV_t) = -1.22 - 0.0744^{*} t$ (-14.72) (-4.01) (R^2=76.3%)
Second generation (1999/2000-2007/08)	$\ln(SD_t) = -2.04 - 0.0285\ t$ (-15.03) (-1.18) (R^2=16.6%)	$\ln(CV_t) = -1.83 - 0.0432\ t$ (-12.66) (-1.69) (R^2=28.9%)
Panel C: Allocative efficiency (AE)		
Entire period (1992/93-2007/08)	$\ln(SD_t) = -3.11 + 0.0030\ t$ (-17.62) (0.16) (R^2=0.2%)	$\ln(CV_t) = -3.06 + 0.0036\ t$ (-16.61) (0.19) (R^2=0.3%)
First generation (1992/93-1998/99)	$\ln(SD_t) = -2.91 - 0.0571\ t$ (-8.51) (-0.75) (R^2=10.0%)	$\ln(CV_t) = -2.84 - 0.0596\ t$ (-7.95) (-0.75) (R^2=10.0%)
Second generation (1999/2000-2007/08)	$\ln(SD_t) = -3.02 - 0.0048\ t$ (-13.68) (-0.12) (R^2=0.2%)	$\ln(CV_t) = -2.97 - 0.0034\ t$ (-12.95) (-0.08) (R^2=0.1%)
Note: Figures in parentheses are the *t* values of the respective coefficients. '*' indicates that coefficients are significantly different from zero at 5 % level of significance.		
Source: Authors' calculations.		

5.5.2 Testing of β -convergence

5.5.2.1 Absolute β -convergence

The concept of β -convergence relates to catch-up phenomenon. Convergence of 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 tends 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:

$$\dot{E}_{i,\,t,\,t-\tau} = [\ln(E_{i,t}) - \ln(E_{i,t-\tau})]/\tau = \alpha + \beta \ln(E_{i,t-\tau}) + \varepsilon_{i,t} \quad (5)$$

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

For testing the hypothesis of absolute β -convergence, we estimated regression model (5) and hypothesized that the average annual growth rates of cost, technical and allocative efficiencies has a negative relationship with their initial levels. Table 5 shows the regression results for absolute β -convergence. In all the nine regression equations reported in Panels A, B and C, we noticed a reasonable goodness of fit of the model. Further, the results reveal that barring one case, the estimated β coefficients in all regression equations are both negative and statistically significant at 5% level and, thus, indicating a negative relationship between the initial level of efficiency measures and growth in these measures. In particular, we note a significant β -convergence in cost and technical efficiencies levels over the entire study period and both the sub-periods. However, in case of allocative efficiency levels, the observed convergence was noted to be significant only for the entire study period and first sub-period, and insignificant in the second sub-period.

Regarding the speed of absolute β -convergence in cost efficiency (both aggregate and disaggregate) levels, we note that i) it was about 6.1% per annum during the entire study period; and ii) it was greater in second phase relative to first phase (10.7% vis-á-vis 9.5%). Further, the speed of absolute β -convergence in technical efficiency (allocative efficiency) levels, we note that it was 5.0% (7.4%) per annum during the study period under consideration. Also, the speed of convergence in technical efficiency (allocative efficiency) levels is relatively less in the second sub-period in comparison to first one. The empirical findings, thus, confirm the occurrence of absolute β -convergence in cost, technical and allocative efficiencies levels of Indian public sector banking industry during the deregulatory regime, but the rate at which the convergence occurred has declined for technical and allocative efficiencies levels in the latter sub-period relative to former.

Table 5: Testing for absolute β -convergence	
Period	**Regression equations**
Panel A: Cost efficiency (CE)	
Entire period (1992/93-2007/08)	$\dot{CE}_{1992/93-2007/08} = -0.0123 - 0.0613^{*} \ln CE_{1992/93}$ (-3.49) (-8.58) $R^2 = 74.7\%$
First generation (1992/93-1998/99)	$\dot{CE}_{1992/93-1998/99} = -0.0165 - 0.0948^{*} \ln CE_{1992/93}$ (-2.01) (-5.72) $R^2 = 56.6\%$
Second generation (1999/2000-2007/08)	$\dot{CE}_{1999/2000-2007/08} = -0.0237 - 0.107^{*} \ln CE_{1999/2000}$ (-3.42) (-5.02) $R^2 = 50.2\%$
Panel B: Technical efficiency (TE)	
Entire period (1992/93-2007/08)	$\dot{TE}_{1992/93-2007/08} = -0.00318 - 0.0501^{*} \ln TE_{1992/93}$ (-1.06) (-6.99) $R^2 = 66.2\%$
First generation (1992/93-1998/99)	$\dot{TE}_{1992/93-1998/99} = -0.0153 - 0.106^{*} \ln TE_{1992/93}$ (-1.88) (-5.41) $R^2 = 53.9\%$
Second generation (1999/2000-2007/08)	$\dot{TE}_{1999/2000-2007/08} = -0.00625 - 0.0729^{*} \ln TE_{1999/2000}$ (-1.25) (-4.04) $R^2 = 39.5\%$
Panel C: Allocative efficiency (AE)	
Entire period (1992/93-2007/08)	$\dot{AE}_{1992/93-2007/08} = -0.00699 - 0.0739^{*} \ln AE_{1992/93}$ (-5.02) (-7.11) $R^2 = 66.9\%$
First generation (1992/93-1998/99)	$\dot{AE}_{1992/93-1998/99} = -0.00965 - 0.152^{*} \ln AE_{1992/93}$ (-4.03) (-8.53) $R^2 = 74.4\%$
Second generation (1999/2000-2007/08)	$\dot{AE}_{1999/2000-2007/08} = -0.00702 - 0.0553 \ln AE_{1999/2000}$ (-2.69) (-2.07) $R^2 = 14.6\%$
Note: Figures in parentheses are the *t* values of the respective coefficients. '*' indicates that coefficients are significantly different from zero at 5 % level of significance.	
Source: Authors' calculations.	

5.5.2.2 Conditional β -convergence

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

$$\dot{E}_{i,\,t,\,t-\tau} = [\ln(E_{i,t}) - \ln(E_{i,t-\tau})]/\tau = \alpha + \beta \ln(E_{i,t-\tau}) + \sum_{j=1}^{k} \delta_j \ln(X^j_{i,t-\tau}) + \varepsilon_{i,t} \qquad (6)$$

The equation (6) allows us to control for the variables, which might influence the steady-state level of efficiency measure. 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 efficiency measure, after controlling for factors impacting 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 efficiency, whereas conditional convergence suggests that each bank possesses its own steady-state efficiency 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 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 efficiency levels.

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 efficiency growth rate of a bank is positively related to the bank's *profitability* (PROF)[10], *size* (SIZE)[11] and negatively related to *intermediation cost* (IC)[12]. The results for testing conditional β -convergence appear in Table 6. The regression results reveal that the variable natural logarithm of the initial level of cost, technical and allocative efficiencies bears a negative and statistically significant coefficient at 5% level in all the regression equations (except one) and, thus, indicates the presence of strong conditional β -convergence in Indian public sector banking industry. Further, the estimated coefficients of conditioning variable ln*SIZE* are statistically insignificant in all the regression equations. Thus, we find no definite relationship between size and growth of different efficiency measures in Indian public sector banking industry. Similarly, we also failed to get a crystal-clear relationship between the variable ln*IC* and growth of efficiency measures. The coefficients of control variable ln*PROF* are positive and statistically significant only in two regression equations; whereas it is insignificant in the remaining regression equations. Thus, we can infer that in Indian public sector banking industry, the relationship between the profitability and growth of cost and technical efficiencies is moderate in nature. Regarding the speed of conditional β -convergence, we note that it was 6.11% per annum during the study period under consideration. Also, the speed of convergence in CE levels is relatively more in the second sub-period (10.2 % vis-á-vis 9.9%). The implication of this finding is that there was a smooth process of diffusion of new banking technology in 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 technical efficiency levels over time. We further note that speed of convergence in AE levels is greater than the same in TE levels (7.6% vis-á-vis 5.19%).

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

[11] The variable 'size' if measured in terms of value of total assets.

[12] The 'intermediation cost' is measures as the ratio of operating expenses as a %age of total assets.

On the whole, the empirical findings provide evidence in favour of both σ -convergence and β -convergence in CE levels across PSBs. Following Koski and Majumdar's (2000) terminology, we can, thus, infer that 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 cost inefficient banks in 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 Indian public sector banking industry is not only the improved performance of initially lagging banks due to rationalization of the labour force, better recovery of non-performing loans, increased application of technology, more optimal allocation of resources, etc., but also the deterioration in the performance of initially well-performing banks, especially the banks belonging to SBI group.

8 Conclusions

After years of financial repression due to heavy government regulatory controls, the policy makers introduced a comprehensive banking reforms programme 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 Reserve Bank of India in the year 1998. The thrust of banking reforms was not only on the improvement of cost 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 cost efficiency (CE) of 27 PSBs during the post-deregulation period spanning from 1992/93 to 2007/08. In particular, we intend to investigate whether the phenomenon of σ - and β -convergence in CE levels has taken place in Indian public sector banking industry during the post-deregulation years or not. To accomplish the task of measuring CE scores for individual PSBs, we have used the increasing popular methodology of data envelopment analysis (DEA). Further, we have utilized traditional cross-sectional regression approach for investigating the presence of σ - and β -convergence in efficiency levels of PSBs.

From a scrupulous inspection of the empirical results pertaining to the dynamics of cost efficiency and its components the following conclusions have been evolved. First, the average CE among Indian PSBs has been estimated to be 79.6%, indicating an average potential total production cost saving of 25.6% over a period of 16 years, if all banks had been full cost efficient. Apparently, there is capacity for efficiency improvements in the Indian public sector banking industry. Second, the cost inefficiency (25.6%) across Indian PSBs, over the entire period of study, is mainly due to technical inefficiency (18.5%), while allocative inefficiency (5.9%) plays a little role in it. Further, in each year, allocative inefficiency is always smaller than technical inefficiency, which suggests that the dominant source of the cost inefficiency is technical (managerial) rather than allocative (regulatory). The higher technical inefficiency relative to allocative inefficiency also implies that the managers of Indian PSBs banks were relatively good at choosing the proper input mix given the prices, but they were not that good at utilizing all factor inputs. Third, despite the large cost 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 CE levels were concerned. Fourth, the cost efficiency of Indian public sector banking industry grew at a modest rate of 0.868% per annum over the entire study period. Also, the cost efficiency improved with the deepening of reforms. However, technical efficiency of Indian public sector banking industry followed an upward trend, while allocative efficiency followed a path of deceleration. We note that the growth in technical efficiency contributed positively to the growth of cost efficiency and the deceleration in allocative efficiency actually drags it. Fifth, the cost efficiency in majority of banks that belong to SBI group followed a declining trend, and the banks belong to NB group experienced an increasing trend in cost efficiency levels. At the level of individual banks, we note a significant improvement in average cost efficiency with the deepening of the process of banking reforms since 1998/99. The main reason for modest improvement in the cost efficiency at the industry level is that the downturn in the average cost efficiency among most of banks in SBI group offsets the effect of an ascent in average cost efficiency in the majority of banks that belong to NB group.

Sixth, the empirical analysis pertaining to convergence phenomenon provides a strong evidence of the presence of σ - and β -convergence in CE levels across PSBs during the post-deregulation years. The implication this finding is that the originally cost inefficient PSBs are catching-up with the originally efficient ones i.e., banks with low level of cost efficiency at the beginning of the period are improving their efficiency more rapidly than highly efficient banks. 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 best-practice cost reducing technology of highly efficient banks.

In sum, the aforementioned conclusions portray that to a large extent, the banking reforms process seems to be successful in achieving the efficiency gains in Indian public sector banking industry. This is evident from the fact that the deregulation process has strengthened the cost 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 labour 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 Indian public sector banking industry. This aspect is that the CE levels of banks belong with SBI group have deteriorated during the post-deregulation years. This is really a matter of serious concern for policy makers and needs evolving of appropriate strategies to arrest further decline of cost efficiency in these 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 cost 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 the manner that minimized their waste as well as the cost of production. 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 cost efficiency of PSBs has been observed in majority of PSBs but also their cost efficiency levels have

converged over time. In the light of empirical findings, the future reforms in the banking sector should be directed towards strengthening competitive and market-oriented policies.

Table 6: Testing for conditional β -convergence		
Period	**Regression equations**	
Panel A: Cost efficiency (CE)		
Entire period (1992/93-2007/08)	$\dot{CE}_{1992/93\text{-}2007/08} = -0.0103 - 0.0611^{*} \ln CE_{1992/93} + 0.00082 \ln SIZE_{1992/93} - 0.00097 \ln PROF_{1992/93} - 0.0113 \ln IC_{1992/93}$ (-0.18) (-8.11) (0.26) (-0.50) (-0.65)	$R^2 = 76.0\%$
First generation (1992/93-1998/99)	$\dot{CE}_{1992/93\text{-}1998/99} = -0.055 - 0.099^{*} \ln CE_{1992/93} - 0.00292 \ln SIZE_{1992/93} + 0.0113^{*} \ln PROF_{1992/93} + 0.0586 \ln IC_{1992/93}$ (-0.54) (-7.26) (-0.51) (3.24) (1.86)	$R^2 = 75.2\%$
Second generation (1999/2000-2007/08)	$\dot{CE}_{1999/2000\text{-}2007/08} = -0.128 - 0.102^{*} \ln CE_{1999/2000} + 0.00433 \ln SIZE_{1999/2000} + 0.0009 \ln PROF_{1999/2000} + 0.0415 \ln IC_{1999/2000}$ (-1.43) (-2.70) (0.82) (0.03) (1.69)	$R^2 = 57.2\%$
Panel B: Technical efficiency (TE)		
Entire period (1992/93-2007/08)	$\dot{TE}_{1992/93\text{-}2007/08} = 0.0288 - 0.0519^{*} \ln TE_{1992/93} - 0.00133 \ln SIZE_{1992/93} - 0.00016 \ln PROF_{1992/93} - 0.0138 \ln IC_{1992/93}$ (0.53) (-6.58) (-0.43) (-0.08) (-0.80)	$R^2 = 67.1\%$
First generation (1992/93-1998/99)	$\dot{TE}_{1992/93\text{-}1998/99} = -0.033 - 0.101^{*} \ln TE_{1992/93} - 0.00454 \ln SIZE_{1992/93} + 0.0118^{*} \ln PROF_{1992/93} + 0.0610 \ln IC_{1992/93}$ (-0.28) (-6.05) (-0.69) (3.00) (1.66)	$R^2 = 72.7\%$
Second generation (1999/2000-2007/08)	$\dot{TE}_{1999/2000\text{-}2007/08} = -0.0828 - 0.0538 \ln TE_{1999/2000} + 0.00353 \ln SIZE_{1999/2000} - 0.0102 \ln PROF_{1999/2000} + 0.0330 \ln IC_{1999/2000}$ (-1.05) (-1.55) (0.75) (-0.36) (1.59)	$R^2 = 47.2\%$
Panel C: Allocative efficiency (AE)		
Entire period (1992/93-2007/08)	$\dot{AE}_{1992/93\text{-}2007/08} = -0.0513 - 0.076^{*}1 \ln AE_{1992/93} - 0.00238 \ln SIZE_{1992/93} - 0.000732 \ln PROF_{1992/93} + 0.0124 \ln IC_{1992/93}$ (-2.12) (-6.45) (1.77) (-0.89) (1.52)	$R^2 = 73.9\%$
First generation (1992/93-1998/99)	$\dot{AE}_{1992/93\text{-}1998/99} = -0.0431 - 0.163^{*} \ln AE_{1992/93} + 0.00113 \ln SIZE_{1992/93} + 0.00043 \ln PROF_{1992/93} + 0.0159 \ln IC_{1992/93}$ (-0.95) (-7.31) (0.45) (0.28) (1.03)	$R^2 = 75.6\%$
Second generation (1999/2000-2007/08)	$\dot{AE}_{1999/2000\text{-}2007/08} = -0.0329 - 0.0689^{*} \ln AE_{1999/2000} + 0.00230 \ln SIZE_{1999/2000} - 0.0207 \ln PROF_{1999/2000} + 0.0009 \ln IC_{1999/2000}$ (-0.82) (-2.64) (0.08) (1.00) (-2.56)	$R^2 = 40.7\%$
Note: Figures in parentheses are the *t* values of the respective coefficient. '*' indicates that coefficients are significantly different from zero at 5 % level of significance.		
Source: Authors' calculations.		

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Appendix A

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 7 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 & Transfer of Undertakings) Act, 1970 and the Banking Companies (Acquisition & 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 programmes), thereby earning more non-interest income than nationalized banks (Shanmugham and Das, 2004). However, this privilege has not been bestowed upon the nationalized banks. Fourth, the SBI has a well defined system of decentralization of authority, while in case of nationalized banks the organizational structure differs from bank to bank.