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Mukesh Kumar  
Vincent Charles

**CENTRUM Católica – Pontificia Universidad Católica del Perú**

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# Evaluating the performance of Indian banking sector using data envelopment analysis during post-reform and global financial crisis

Mukesh Kumar and Vincent Charles

*CENTRUM Católica, Pontificia Universidad Católica del Perú, Santiago de Surco, Perú*

E-mail: [mkumar@pucp.edu.pe](mailto:mkumar@pucp.edu.pe), [vcharles@pucp.pe](mailto:vcharles@pucp.pe)

Enticed by the reform of Indian banking sector in the early 1990s and further slowdown in the economy as a result of global financial crisis in late 2000s, the current study analyzes the performance of Indian banks using data envelopment analysis. The performance is measured in terms of technical efficiency, returns-to-scale, and Malmquist productivity index for a sample of 33 banks, consisting of 19 public sector and 14 private sector banks during the period spanning 1995-96 to 2009-10. The jackknifing analysis, followed by the dummy variable regression model is used to identify the outlier and its possible impact on overall efficiency trends. Findings reveal that efficiency scores are robust in the sense that the inclusion of outlier does not affect the overall efficiency trends. The public sector bank is faintly doing better than the private sector banks in terms of (i) technical efficiency since 2003-04 and (ii) scale efficiency from 2000-01 onwards. There is growing tendency of public banks operating under increasing returns to scale, implying that substantial gains could be obtained from altering scale via either internal growth or consolidation in the sector. The difference in the Total Factor Productivity (TFP) change between these two types of banks is found to be statistically significant in favour of public sector banks. The technological change has been the dominating source of productivity growth, whereas, the contribution of pure efficiency change and scale change are found to be negligible in Indian banking sector during the period of study. The reform in Indian banking sector has clearly re-energized the Indian banking sector as a whole, resulting in a positive change in TFP through technological change possibly as a result of adoption of latest technology and new business practices in post reform period. However, there is evidence of shrink in the market resulting in movement of the banks towards increasing returns-to-scale as well as negative growth in TFP in both the sectors during the period of global financial crisis.

**Keywords:** Data envelopment analysis; Indian banking sector reform; global financial crisis; technical efficiency; returns-to-scale; Malmquist productivity index; Jackknifing analysis

## Introduction

A sound financial system is crucial for an indispensable and vibrant economy. Thus, the performance of any economy to a large extent is dependent on the performance of the banking sector as it being the predominant component of the financial service industry. The Indian banking sector went through structural changes since its independence keeping in view its financial linkages with the rest of the economy and to meet the social and economic objectives of development (Kumbhakar and Sarkar, 2005). Consequently, the sector was initially following strict controls on interest rates, as well as stringent regulations relating to branch licensing, directed credit programs, and mergers. However, the closed and strict regulated environment started showing adverse affect on the sector, resulting in under-performance of the banks over the years. As a result, Indian banking sector underwent a sea of changes through its liberalization policy in early 1990s with implementation of a series of reforms with an objective to make the banking sector more productive and efficient by limiting the state intervention and enhancing the role of market forces.

Like most developing countries, the banking sector in India is characterized by the co-existence of different ownership groups, public and private, and within private, domestic and foreign. The Indian public sector banks (PSBs) came into existence in several phases. In 1955, the Government of India took

over the ownership of the Imperial Bank of India and reconstituted it as State Bank of India (SBI) under the State Bank of India Act of 1955. Later, the State Bank of India (subsidiary banks) Act was passed in 1959 allowing SBI to take over seven banks of large states as its associate banks. However, in spite of the progress made of SBI and its subsidiaries in terms of geographic coverage and credit expansion, it was felt that bank credits were flowing mainly to the large and well established business firms and primary sector such as agriculture and small scale industries were almost neglected. This resulted in an announcement of policy of social control over banks in 1969 and consequently fourteen largest private banks were nationalized under the Nationalization Act 1969. In the second phase of nationalization, another six private banks were nationalized in 1980. The private and foreign banks were operating side-by-side, but on a relatively small scale and their activities were restricted through entry regulation and strict branch licensing policies. During the period of 1969-1991, the number of banks increased slightly, but savings were successfully mobilized in part because the number of branches held by public sector banks was encouraged to expand rapidly. Further, relatively low inflation kept negative real deposit interest rates at a mild level, which in turn helped the banks to increase deposits. However, many banks remained unprofitable, inefficient, and unsound owing to their poor lending strategy and lack of internal risk management under government ownership. The prolonged presence of excessively large PSBs resulted in inefficient resource allocation and concentration of power in a few banks.

Facing major economic crisis, the Reserve bank of India (RBI) launched major banking sector reforms in 1991 aimed at creating a more profitable, efficient and sound banking system, based on the recommendations of the first Narasimham committee on financial sector reforms. The reforms sought to improve the bank efficiency through entry regulation<sup>1</sup>, branch delicensing, deregulation of interest rate<sup>2</sup>, and diversifying ownership of PSBs by enabling the state-owned banks to rise up to 49 per cent of their capital from the market. The reforms also targeted at improving bank profitability through the gradual reduction of the Cash Reserve Ratio (CRR)<sup>3</sup> and the Statutory Liquidity Ratio (SLR)<sup>4</sup>, and to strengthen the banking system by introducing the micro prudential measures<sup>5</sup> (see Bhide *et al.*, 2001; Reddy, 2006; Prasad and Ghosh, 2007; and Kumar and Charles, 2011 for extensive review of the recent banking sector reform). These reforms are expected to have an impact on the operations of banks. With reduced statutory requirements banks will have more funds at their disposal for commercial lending and the interest rate liberalization is expected to bring flexibility and competition into the banking system. The competition is further infused by opening up banking sector for the private and foreign banks. Along with these flexibilities, certain regulatory reforms are also introduced, which are meant to equip the banks to face fluctuations in the economy.

However, the turmoil in the international financial markets of advanced economies that started around mid-2007 has exacerbated substantially since August 2008. The first hint of the trouble came from the collapse of two Bear Stearns hedge funds in early 2007 (Prasad and Reddy, 2009). Subsequently a number of other banks and financial institutions also began to show signs of distress. Matters really came to the force with the bankruptcy of Lehman Brothers, a big investment bank, in September 2008. In spite of the fact that Indian banking system is not directly exposed to the sub-prime mortgage assets, the shock has been felt in Indian financial market as well, since India is far more exposed to international markets after macro-economic reforms of 1991. The financial sector, especially banks, is subject to prudential regulations, both in regard to capital and liquidity. As the current global financial crisis has shown, liquidity risks can increase manifold during a crisis and can pose serious downside risks to macroeconomic and financial stability (Mohan, 2008). The RBI's policy response aimed at containing the contagion from the outside in order to keep the domestic money and credit markets functioning normally and see that the liquidity stress does not trigger solvency cascades (Subbarao, 2009). In particular, three objectives<sup>6</sup> were targeted: first, to maintain a comfortable rupee liquidity position; second, to augment foreign exchange liquidity; and third, to maintain a policy framework that would keep credit delivery on track so as to arrest the moderation in growth.

Given this background the current study examines (i) how far such reform measures have been successful in their objective of improving the performance of the Indian banks during the post liberalization period and (ii) whether the global financial crisis had any impact on the performance of

Indian banking sector. We use the technique of Data Envelopment Analysis (DEA) to examine the performance of Indian banking sector and two major ownership structure within it in terms of technical efficiency, returns-to-scale, and total factor productivity (TFP) change for the entire 15 years of post-liberalization period as well as two sub-periods: (i) pre global financial crisis period (1996-2007) and (ii) global financial crisis period (2008-2010). Within the framework of the current study, the results seem to be conclusive. The DEA efficiency scores are found to be robust in the sense that the inclusion of outlier bank does not affect the overall trends of efficiency in the present context. PSBs perform as par with its counterpart private sector banks in terms of efficiency. Further, there is growing tendency of PSBs operating under increasing-returns-to-scale (IRS), implying that substantial gains could be obtained from altering scale via either internal growth or consolidation in the sector. Coming to the TFP change, PSBs outperform private sector banks as a result of significant differences in technological change in sub-period I. However, there is evidence of shrink in the market and negative growth in TFP in both the sectors in sub-period II providing a gesture of adverse affect of global financial crisis on Indian banking sector.

The rest of the paper proceeds as follows. The next section provides the literature review and highlights the contributions of the current study in Indian banking literature. It is followed by a section on methodology, wherein we briefly present the DEA models for measuring efficiency, returns-to-scale and Malmquist productivity index. Next, the paper provides the detailed description of data, followed by results of the empirical analysis. Finally, the paper concludes with some future scope of the study.

## Literature Review

A number of attempts have been made to study the efficiency and productivity of banking sector in developed countries (Berger and Humphrey, 1997; Berger *et al.*, 1999; Isik and Hassan, 2002 a, b; Yildirim and Philippatos, 2007). However, studies analyzing the efficiency of banks in developing countries, including India, are relatively modest. In their extensive international literature survey, Berger and Humphrey (1997) noted that the vast majority of the efficiency literature focuses on the banking markets of well-developed countries with particular emphasis on the U.S. markets. Fethi and Pasiouras (2010) provided an extensive survey on efficiency and productivity studies in banking sector published in various research journals covering the period 1998-2008. They identified 151 studies that use DEA to estimate various measures of bank efficiency and productivity growth, and 30 studies that provide similar estimates at the branch level. More than 75% of the studies focus on efficiency and productivity issues of banks in developed countries.

The literature on bank efficiency reveals mixed experiences of liberalization policies undertaken in various countries. A number of studies report the existence of efficiency gains due to liberalization programmes undertaken in various emerging and transition countries including Turkey (Zaim, 1995; Isik and Hassan, 2003), Thailand (Leightner and Lovell, 1998), Hungary (Hasan and Marton, 2003), the Central and Eastern European (CEE) transition countries (Brissimis *et al.*, 2008), Pakistan (Ataullah and Le, 2006), and Egypt (Fethi *et al.*, 2011). However, there are few studies which show no improvement in bank efficiency over the transition period such as, Havrylchuk (2006) for Polish, Kasman and Yildirim (2006) for the CEE transition countries, Fu and Heffernan (2009) for China. Moreover, a number of studies (Burki and Niazi, 2009; Hsiao *et al.*, 2010) illustrate that the efficiency impact of the reform process may not be immediately visible or uniform over time. The efficiency may go down at first due to the initial costs of adjustment prior to improving later. Burki and Niazi (2010), for example, show that efficiency fell during the initial reform period in Pakistan due to the adjustment process before increasing in the later stages of the reform process. Similarly, Hsiao *et al.* (2010) find that the efficiency of Taiwanese banks was lower during the restructuring reform period than pre-reform period while being higher in the post-reform period.

In the Indian context, there are few studies which especially focused on the efficiency measurement of PSBs using DEA. For example, Das (1997) studied technical, allocative and scale efficiency of different PSBs for the period 1990-1996 using DEA approach. The study found decline in overall efficiency over time, decline in technical efficiency with slight improvement in allocative efficiency. The State bank of India was found to be more efficient than other PSBs. Saha and Ravisankar (2000) analyzed

the performance of Indian banks using DEA approach for a sample of 25 PSBs banks over a period 1992-1995. Their findings reveal that barring few exceptions, the public sector banks have in general improved their efficiency over the years.

Other group of studies which focused on the comparison of various categories of banks based on ownership includes Bhattacharya *et al.* (1997), Sathye (2003), Sahoo *et al.* (2007), Sinha (2008), Mahesh and Rajeev (2009) and Kumar and Charles (2011).

Bhattacharya *et al.* (1997) used DEA to measure the productive efficiency of Indian commercial banks in the late 1980's to early 1990's and to study the impact of policy of liberalizing measures taken in 1980's on the performance of various categories of banks. They found that the Indian PSBs were the best performing banks, as the banking sector was overwhelmingly dominated by the PSBs, while the new private sector banks were yet to emerge fully in the Indian banking scenario. Sathye (2003) measured the productive efficiency of 94 banks in India for the year 1996-1997 by using DEA wherein, they found that the PSBs were on average more efficient than foreign banks, which in turn were more efficient than private banks. Similarly, Gupta *et al.* (2008) found that the SBI and its group have the highest efficiency, followed by private banks, and the other nationalized banks for the period 1999-2003. The results are consistent over the period, but efficiency differences diminish over period of time. Mahesh and Rajeev (2009) examined the changes in productive efficiency of Indian commercial banks for the post reform period 1985-2004. They found that deregulation has significant impacts on all three types of efficiency measures. PSBs as a group ranks first in all the three efficiency measures showing that, as opposed to the general perception, these banks are doing better than their private counterparts. Private banks, however have shown marked improvement during the post-liberalization period in terms of all three types of efficiency measures.

Contrary to the above stated studies, Sahoo *et al.* (2007) who examined the efficiency trends of the Indian commercial banks during the period 1997-1998 to 2004-2005 observed that foreign banks are seen outperforming over both the nationalized banks and private banks, and private and foreign banks as a group outperforming over the nationalized banks. Similarly, Sinha (2008) observed that the private sector commercial banks have higher mean technical efficiency score when compared to the public sector commercial banks and most of the commercial banks experienced decreasing-returns-to-scale (DRS) during the study period spanning from 2002-2003 to 2004-2005.

To sum-up, most of the studies show the evidence of affirmative gesture of reform process on the efficiency of Indian banking sector. While most of the studies provided the evidence of PSBs performing better than its counterpart, private and foreign banks, few other studies have found the PSBs as underperforming compared to other group of banks. The differences in the findings of various studies in Indian context are attributed to many factors including the selection of time period, sample size, selection of inputs and outputs variables and the orientation of efficiency measurement.

However, one of the major limitations of all the above studies is that they focused on only one aspect of performance measurement, i.e., efficiency. Controversy is not only concerned with whether deregulation stimulates efficiency but also on different sources of productivity growth. While some studies attribute the growth of productivity to technological progress (Avkiran, 2000; Alam, 2001; Mukherjee *et al.*, 2001; Canhoto and Dermine, 2003; Kumbhakar, Lozano-Vivas, Lovell, & Hasan, 2001; Sturm and Williams, 2004) others are in favour of efficiency improvement (Berg *et al.*, 1992; Gilbert and Wilson, 1998; Isik and Hassan, 2003). Compare to efficiency analysis, the literature on the issue of TFP growth in Indian banking sector is very limited. Galagedera and Edirisuriya (2005) investigated the efficiency and productivity for a sample of Indian commercial banks over the period 1995-2002 by using the technique of DEA. The results reveal that there has been no significant growth in productivity during the study period. When analyzed separately, the PSBs reveal a modest growth in productivity that appears to have been brought about by technological change. The private sector banks indicate no growth. Zhao *et al.* (2008) used balanced panel data set covering the period 1992-2004 to measure DEA-based Malmquist index of TFP change in Indian banking sector. The results revealed that after an initial adjustment phase of deregulation period, the Indian banking sector experienced sustained productivity growth, driven mainly by technological progress. Bank's ownership structure seems to have an impact on

bank efficiency but doesn't appear to have an influence of TFP change. Kumar *et al.* (2010) observed that TFP growth for Indian banking sector for the period of 1995-2006 was driven mainly by technological progress as compared to efficiency change.

The current study contributes to the literature significantly in many ways. Most of the literature in Indian banking sector focused on measurement of efficiency (e.g., Das, 1997; Saha and Ravishankar, 2000; Sathye, 2003; Ram Mohan & Ray, 2003; Sahoo *et al.*, 2007) and a few studies on benchmarking (e.g., Gupta *et al.*, 2008; Kumar and Charles, 2011). A detailed systematic study on the measurement of productivity change in Indian banking sector is comparatively limited. Along with the issue of efficiency and returns-to-scale, we also use a broad dynamic indicator, TFP change index, as the measure of performance. It is an important tool for reviewing past growth patterns and for assessing the potential for future growth. Ahluwalia and Shanker (1985) pointed out that one needs to look at the concept of TFP to evaluate the performance of the service sector in India, which not merely reflects productive efficiency of inputs but also the capacity of the management to combine these and other factors to enhance the outputs of the firm.

Secondly, in comparison to previous studies (e.g., Galagedera and Edirisuriya, 2005; Sinha, 2008; Zhao *et al.*, 2008), this study considers more recent data for a relatively longer period of latest 15 years of post-liberalization which includes 3 years of global financial crisis period. There has been debate among the policy makers, bankers and researchers since the mid of 2007 whether the global financial crisis had any impact on the performance of India banking sector. It is believed that Indian banking sector is unlikely to get affected with global financial crisis as (i) the banking system in India has had no direct exposure to the sub-prime mortgage assets or to the failed institutions. It has very limited off-balance sheet activities or securitized assets (ii) India's recent growth has been driven predominantly by domestic consumption and domestic investment with very limited reliance of external demand. Other contrary view is that with the increasing integration of the Indian economy and its financial markets with rest of the world, there is possibility that the country does face some downside risks from these international developments. However, no attempt has been made till date to empirically resolve this debate. The current paper compares the performance of Indian banks before and after the global financial crisis.

Thirdly, most of the previous studies in the Indian context decompose the Malmquist productivity index into its different components by using the extended decomposition model proposed by Färe *et al.* (1994). The extended model of Färe *et al.* (1994) assumes constant-returns-to-scale (CRS) at the stage of measuring technological change but subsequently switches to variable-returns-to-scale (VRS) to separate the scale effect component, which is not internally consistent. Hence, the current study uses the decomposition model developed by Ray and Desli (1997) that assumes VRS to measure each and every component of Malmquist productivity index.

Finally, DEA is a computationally convenient way to measure efficiency that does not require an explicit functional relationship between inputs and outputs. However, because the frontier is constructed using extreme observations, DEA can be sensitive to extreme points, especially when data may be contaminated by measurement error. In such settings, the technical efficiency scores calculated from datasets that include outliers can be misleading. In spite of this limitation, most of previous studies did not give much attention to verify the robustness of the DEA efficiency scores. The current paper diagnoses the robustness of efficiency scores obtained through DEA by using Jackknifing analysis. Further, the sensitivity of outlier on overall efficiency trends is tested through dummy variable regression models.

## **Methodology**

The stochastic frontier (parametric) model and DEA (non-parametric) model emerged as two alternative developments of ideas that originated with Farrell (1957). Grosskopf (1986) noted that the parametric approach has been developed mainly by economists, whereas, nonparametric has been left to those in operations research. The choice of a non-parametric approach in the current study is based on several considerations. Firstly, when using panel data parametric approaches often use a time trend, which smoothes the variation of productivity changes over time. By contrast, non-parametric approaches allow for substantial variations embedded in data to be revealed (Alam, 2001). Secondly, in the parametric

approach, the decomposition of error term into two parts, one representing stochastic error and the other inefficiency is not useful for the data sets of fewer than one hundred observations (Aigner *et al.*, 1977). In contrast, DEA works well with a small sample size. Thirdly, the incomplete knowledge of the statistical properties of the estimates and restrictiveness of reference technology affects the bias of the estimates in parametric model. Grosskopf (1986) pointed out that both the degree of restrictiveness of the reference technology as well as choice of error structure greatly affects the values of efficiency. In contrast, DEA does not require any underlying assumption of a functional form relating to inputs and outputs. Given the set of inputs and outputs of different firms, it constructs its own functional form, thus avoiding the danger of miss-specification of the frontier. Also, it does not make the assumption that all decision making units (DMUs) are using the same technology, but instead evaluates the efficiency of DMU relative to its peer or combination of peers. Further, DEA readily incorporates the existence of multiple outputs. However, a major drawback of DEA is its inability to detect measurement error. Thus, an exceptionally well performing unit (outlier) may seriously compromise the analysis.

### **The Reference Technology**

Let us consider a sample of  $J$  DMUs from an industry producing a vector of  $M$  outputs ( $y$ ) from a vector of  $N$  inputs ( $x$ ). Let  $B$  denotes  $J \times M$  matrix of observed outputs and  $A$  denotes the  $J \times N$  matrix of observed inputs. Individual elements of  $B$ , denoted by  $y_m^j$  measure the quantity of  $m^{th}$  output produced by the  $j^{th}$  DMU, while the individual elements of  $A$ , denoted by  $x_n^j$ , measure the employment level of  $n^{th}$  input by the  $j^{th}$  DMU. A production technology at time  $t$  transforming input vector  $x^t$  to output vector  $y^t$  can be represented by the graph of technology  $GR^t$

$$GR^t(x^t, y^t) = \left\{ (x^t, y^t) \mid x^t \geq \sum_{j=1}^J \lambda_j x^{j,t}; y^t \leq \sum_{j=1}^J \lambda_j y^{j,t}; \lambda_j \geq 0 \right\} \quad (1)$$

which exhibits CRS and strong disposability of inputs and outputs (Färe *et al.*, 1994). Following Afrait (1972), the assumption of CRS can be relaxed to allow for VRS by putting the restriction in (1):

$\sum_{j=1}^J \lambda_j = 1$  (Banker *et al.*, 1984), where  $\lambda_j$  is an intensity variable indicating the level of intensity at which a particular activity (DMU) may be employed in production.

### **The Distance Function**

Following Shephard (1970) and Färe (1988), the output distance function in time period  $t$  is defined as:

$$D^t(x^t, y^t) = \inf \left\{ \theta \mid (x^t, y^t / \theta) \in GR^t \right\} \quad \text{or} \quad \sup \left\{ \theta \mid (x^t, \theta y^t) \in GR^t \right\} \quad (2)$$

It is to be noted that  $D^t(x^t, y^t) \leq 1$  if and only if  $(x^t, y^t) \in GR^t$ . In addition,  $D^t = 1$ , if and only if  $(x^t, y^t)$  is on the boundary or frontier of the technology. This function is reciprocal to Farrell's (1957) output oriented measures of technical efficiency, i.e., the reciprocal of the maximum proportional expansion of the output vector,  $y^t$  given the input vector  $x^t$ .

### **Measurement of Output Technical Efficiency**

The output-oriented distance function under CRS technology can be obtained by using the following the CCR Model (Charnes *et al.*, 1978).

Model I: *Output-oriented single-period distance function under CRS (CCR Model)*

$$\begin{aligned} \mathbb{P}_c^t(x^{j,t}, y^{j,t}) &= \text{Max} \theta_c^{j,t} \\ \text{s.t. } \sum_{j=1}^J \lambda_j x_n^{j,t} &\leq x_n^{j,t}; \sum_{j=1}^J \lambda_j y_m^{j,t} \geq \theta_c^{j,t} y_m^{j,t}; \lambda_j \geq 0, \forall j. \end{aligned} \quad (3)$$

The output-oriented *single period* distance function measures the maximum proportional change in outputs required to make  $(x^t, y^t)$  feasible in relation to the technology at time period  $t$ . In other words, the efficiency of DMU in time period  $t$  is evaluated with reference to the technology in the same time period  $t$ . The output distance function under VRS technology can be obtained by adding additional convexity constraint  $\sum_{j=1}^J \lambda_j = 1$  in CCR model, popularly known as BCC model (Banker *et al.*, 1984).

Model II: *Output-oriented single period distance function under VRS (BCC Model)*

$$\begin{aligned} \mathbb{P}_v^t(x^{j,t}, y^{j,t}) &= \text{Max} \theta_v^{j,t} \\ \text{s.t. } \sum_{j=1}^J \lambda_j x_n^{j,t} &\leq x_n^{j,t}; \sum_{j=1}^J \lambda_j y_m^{j,t} \geq \theta_v^{j,t} y_m^{j,t}; \sum_{j=1}^J \lambda_j = 1; \lambda_j \geq 0, \forall j. \end{aligned} \quad (4)$$

### **Measurement of Returns to Scale**

Decomposing technical efficiency (TE) into pure efficiency (PE) and scale efficiency (SE) allows an insight into the sources of inefficiencies. It also helps to determine whether banks operate under optimal or non-optimal returns-to-scale. The CRS efficiency score obtained from the Model I represents technical efficiency, which measures inefficiencies due to the input/output configuration and as well as the size of operations. On the other hand, the VRS efficiency score obtained from the Model II represents pure efficiency, that is, a measure of efficiency without scale efficiency. The scale efficiency can be obtained as the ratio of technical efficiency to pure efficiency.

Once the scale efficiency scores are computed, the analysis can be taken a step further. This involves determining whether a particular DMU is experiencing the optimal scale, operating under CRS or non-optimal returns-to-scale, either operating under IRS or DRS. To make this assessment, DEA is repeated with non-increasing returns-to-scale (NIRS) by incorporating the restriction  $\sum_{j=1}^J \lambda_j \leq 1$  in the Model I. If the score for a DMU under VRS equals the NIRS score, it implies that DMU operates under DRS. If not; it implies that DMU operates under IRS (Coelli *et al.*, 1998). If the VRS score equals the CRS score, then the DMU is said to be operating at the optimal scale or the most productive scale size.

### **Measurement of Malmquist Productivity Index**

To define a Malmquist productivity index, let us define the distance functions with respect to two different time periods as follows:

$$D_o^t(x^{t+1}, y^{t+1}) = \inf \left\{ \theta / (x^{t+1}, y^{t+1} / \theta) \in S^t \right\} \text{ and } D_o^{t+1}(x^t, y^t) = \inf \left\{ \theta / (x^t, y^t / \theta) \in S^{t+1} \right\} \quad (5)$$



where ‘o’ indicates that the distance function is output-orientated. The first mixed-period distance function in (5) measures the maximum proportional change in outputs required to make  $(x^{t+1}, y^{t+1})$  feasible in relation to the technology at time period  $t$ . Similarly, the second mixed-period distance function in (5) measures the maximum proportional change in outputs required to make  $(x^t, y^t)$  feasible in relation to the technology at time period  $t+1$ . In both these mixed-period cases, the value of the distance function may exceed unity if the observation being evaluated is not feasible in the other period.

Following Ray and Desli (1997), the Malmquist productivity index can be defined as:

$$M_0 = \left[ \frac{D_v^t(x^{t+1}, y^{t+1})}{D_v^t(x^t, y^t)} \times \frac{D_v^{t+1}(x^{t+1}, y^{t+1})}{D_v^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \left[ \frac{SE^t(x^{t+1}, y^{t+1})}{SE^t(x^t, y^t)} \times \frac{SE^{t+1}(x^{t+1}, y^{t+1})}{SE^t(x^t, y^t)} \right]^{\frac{1}{2}} \quad (6)$$

The first component of (6) can further decomposed as:

$$\left[ \frac{D_v^t(x^t, y^t)}{D_v^{t+1}(x^t, y^t)} \frac{D_v^t(x^{t+1}, y^{t+1})}{D_v^{t+1}(x^{t+1}, y^{t+1})} \right]^{\frac{1}{2}} \times \left[ \frac{D_v^{t+1}(x^{t+1}, y^{t+1})}{D_v^t(x^t, y^t)} \right] \quad (7)$$

where the first component of (7) is the geometric mean of two ratios, which measures the shift in the technology calculated at  $x^t$  and  $x^{t+1}$ . The second component measures the change in relative efficiency between the years  $t$  and  $t+1$ . The second component of (6) which involves both CRS and VRS distance functions at both the time periods, measures the change in scale efficiency. Thus, Malmquist productivity index is the product of technological change, pure efficiency change and scale efficiency change.

The single-period distance functions under the CRS and VRS are solved using Model I and II respectively; whereas the mixed-period distance functions under CRS are solved using Model III and IV (see Appendix A). The mixed-period distance functions under the VRS are solved using Model III and IV

with the restriction on sum of intensity variables, i.e.,  $\sum_{j=1}^J \lambda_j = 1$ .

## The Database

### *Selection of Inputs and Outputs and Purification of Data*

There is on-going discussion in the banking literature regarding the proper definition of inputs and outputs (Fethi and Pasiouras, 2010). Till today, there is no all-encompassing theory of the banking firm and no agreement on the explicit definition and measurement of banks' inputs and outputs (Casu, 2002; Sathye, 2003). Two different approaches appear in the literature regarding the measurement of inputs and outputs of a bank, popularly known as *production approach* and *intermediation approach* (Humphrey, 1985). The production approach views banks as using purchased inputs to produce deposits and various categories of bank assets. Both loans and deposits are, therefore, treated as outputs and measured in terms of the number of accounts. This approach considers only operating costs and excludes the interest expenses paid on deposits since deposits are viewed as outputs. The intermediation approach on the other hand considers banks as financial intermediaries and uses volume of deposits, loans and other variables as inputs and outputs. It views the banks as using deposits together with purchased inputs to produce various categories of bank assets. Outputs are measured in monetary values and total costs include all operating and interest expenses<sup>7</sup>.

Following Berger and Humphrey (1997), we have used intermediation approach<sup>8</sup> with restricted choice of variables<sup>9</sup>. As the number of variables increases in DEA analysis, the ability of the model to discriminate among the DMUs decreases. The more variables are added the greater becomes the chance that some inefficient unit dominates in the added dimension and becomes efficient (Smith, 1997). In order to preserve the discriminatory power of DEA, the number of inputs and outputs should be kept at a reasonable level. The choice of the inputs and outputs are guided by the choices made in previous studies

and also on the data availability. In the current study, we have used two inputs – total cost<sup>10</sup> and total deposits. The input *total cost* is measured as the sum of total interest expenses and non-interest expenses including personal expenses. Non-interest expenses include service charges and commissions, expenses of general management affairs, salaries, and other expenses (including health insurance and securities portfolios). Some researchers (Yeh, 1996; Sathye, 2003; Ram Mohan and Ray, 2004; Kao and Liu, 2004) have treated interest expenses and non-interest expenses as two different inputs along with other inputs. However, following Casu and Molyneux (2003) and Sealey and Lindley (1977), we have treated both together as a single input as *total cost*. This kind of treatment is mainly due to the well-known dimensionality problem associated with DEA particularly with limited sample size: a high number of variables relative to the number of observations cause more units to be wrongly identified as efficient (Zhao *et al.*, 2008). The input, *total deposit* is taken as the sum of demand and savings deposits held by bank and non-bank depositors.

The above two inputs are used to produce two outputs namely, *total loans* and *other earning assets*. The output, *total loan* is measured as the sum of all loan accounts intermediated by banks and the output, *other earning assets* is measured as the sum of total securities (treasury bills, government bonds and other securities), deposits with banks and equity investments.

To ensure the validity of the DEA model specification, an isotonicity test (Avkiran, 1999) was conducted, which involves the calculation of all inter-correlations between inputs and outputs for identifying whether increasing amounts of inputs lead to greater outputs. The inter-correlation between inputs and outputs were observed positive (Pearson correlations  $> 0.80$ ;  $\alpha = 0.01$ ), the isotonicity test was passed and the inclusion of inputs/outputs was justified. The summary statistics of inputs and outputs is available from the author on request.

#### *4.2 Sources of Data, Selection of time-period and Sample Size*

The basic data on inputs and outputs has been taken from the electronic database, PROWESS provided by Centre for Monitoring Indian Economy (CMIE), Pvt. Ltd. Mumbai for the period spanning 1995-1996 to 2009-2010. The CMIE, established in 1976 is the most accomplished corporate database in India and contains a highly normalized data on time-series built on a sound understanding of disclosures in India on over 17000 companies from different sectors. The CMIE has been proven the most conveniently and widely used source of database for the researchers for conducting the empirical studies at firm-level in the manufacturing sector (Kumar and Charles, 2009; Ram Mohan, 2005; Kumar and Basu, 2004) as well as service sector (Kumar and Charles, 2011; Udayakumar *et al.*, 2011; Ghosh, 2009; Debasish, 2006; Ram Mohan, 2005; Saha and Ravisankar, 2000). The sample consists of commercial banks including both public and private banks for which the data were available for the entire period 1995-1996 to 2009-2010. The commercial banking is the most important part of modern banking set up in India. Today, the commercial banks are having their branches all over India including the rural areas and their functions are confined not only to advancing loans to the public and accepting their deposits, but they also play significant role in accelerating the rate of economic development and fulfilment of various socio economic objectives of the Government. The total number of branches of all schedules commercial banks is 79735 with approximately 40% of their branches located in rural areas, followed by 24%, 19% and 17% respectively located in semi-urban, urban and metropolitan cities (Government of India, 2010). There were 35 commercial banks in total for which the data were available during the study period. However, one of the private banks, Kotak Mahindra Bank Ltd. was dropped from the sample because of excessive missing data. Another private bank, i.e., ICICI Bank Ltd. was dropped from the sample as it did not fit into any of the broad cluster during the screening of the data. Nunamaker (1985) and Raab and Lichty (2002) suggested a rule of thumb on deciding the minimum size of the sample in any DEA study. The sample size should be at least three times larger than the sum of the number of inputs and outputs. In our study, with a total of two inputs and two outputs, we ended up with a reasonably good sample size of 33 banks (see Appendix B) consisting of 19 public banks and 14 private banks. All the public sector banks in the sample are nationalized banks. In May 2008, Centurion Bank of Punjab Ltd. (CBPL) merged

with HDFC Bank Ltd. (HDFCBL). As a result, our sample for period 2007-2008 to 2009-2010 is confined to 32 banks with 19 public banks and 13 private banks.

## **Empirical Results**

Though, the commercial banks are homogeneous with respect to their organizational structure, goals and objectives, they differ significantly in size and production level. So, scale of banks plays a vital role in their relative efficiency. The CCR measures of technical efficiency captures not only the productive inefficiency of a bank at its actual scale size, but also some inefficiency resulting from its actual scale size being different from the most productive scale size (Banker *et al.*, 1984). If a DMU is scale efficient, it implies that it operates under the most productive scale size and thus, maximizes its average productivity. As the productivity growth could be achievable solely through reduction in wastefulness or through the change in scale of operation, without resort to new technology, we begin our discussion with the issue of efficiency and scale of production in Indian banking sector.

### ***Productive Efficiency of Indian banking sector***

Table I provides the summary statistics of technical efficiency and its components in Indian banking sector during the period 1995-1996 to 2009-2010 along with their average trends shown in Figure 1-a to 1-c respectively.

Out of total 33 banks in the sample the number of efficient banks varies from 3 to 8 with average technical efficiency score varying from 0.859 to 0.946 during the period of study. The percentage of banks found to be technically efficient in the private sector is more than that in public sector throughout the period, except during the year 2007-2008. The average technical efficiency of PSBs varies from 0.828 to 0.955 and that of private sector banks varies from 0.877 to 0.940. However, the difference in the average technical efficiency scores between the private and public sector banks is found to be insignificant except during the year 1998-1999. The findings of this study reinforce those of Kumar and Charles (2011) for the period 1996-2007 and Ram Mohan and Ray (2003, 2004) for the period 1992-2000. They failed to uncover any significant differences between public and private sector banks using financial measures of performance. As it can be observed from Figure 1-a, the private sector banks are performing faintly better than the PSBs during 1995-1996 to 2003-2004 except in the years 1997-1998 and 2002-2003. However, the PSBs are continuously performing better than private sector banks since 2004-2005 onwards. The coefficient of variations (CV) measures the consistency in technical efficiency across the banks in each year. It can be observed that the variations in efficiency across the private sector banks are relatively high throughout the study period as it is evident from relatively high value of CV in private sector banks than that of its counter sector banks.

(Insert Table I about here)

In 9 out of 15 years of study period, PSBs perform relatively better than private sector banks. The finding are quite consistent with some of the past studies such as Sathye (2003) for the period 1996-1997; Sinha (2008) for the period 2002-2003 to 2004-2005; Mahesh and Rajeev (2009) for the period 1985 to 2004. The radial changes in accounting, deregulation of interest rates, close follow-up of non-performing assets, introduction of prudential norms, voluntary retirement of old generation staff, concern for customer care, professionalism as a part of reform process have made the management of PSBs to turn to generate surpluses and make these banks self-sufficient even by approaching capital market (Ram Mohan and Ray, 2004). With these developments and by taking advantage of information technology in the banking system, the PSBs have geared up to achieve the performance as par with its counterpart in the post-reform period.

The nature of technical inefficiency may be due to ineffective implementation of the production plan of the banks in converting inputs to outputs and due to the divergence of the bank from the most productive scale size. Thus, decomposition of technical efficiency into pure efficiency and scale efficiency allows an insight into the sources of inefficiency. Larger the difference between pure efficiency

and technical efficiency, more scale inefficient a bank is, which in turn, indicates the larger deviation of the bank from the most productive scale size. On the other hand, as pure efficiency approaches technical efficiency, the bank approaches to the most productive scale size and a bank becomes scale efficient as pure efficiency equals technical efficiency.

On an average, the number of pure efficient banks under VRS varies from 7 to 16 with average pure efficiency score varying from 0.917 to 0.961. The average pure efficiency score of public and private sector banks varies from 0.905 to 0.970 and 0.920 to 0.976 respectively. The PSBs has surpassed the private sector banks in terms of pure efficiency till 1998-99. However, the reverse is true since 2000-2001 onwards except for the years 2002-2003 and 2005-2006. However, the average pure efficiency score does not differ significantly between two types of banks except for the year 1997-1998.

The number of banks that are scale efficient varies from 3 to 8 out of total 33 banks in the sample with average scale efficiency score varying from 0.915 to 0.984. The average scale efficiency score of PSBs varies from 0.914 to 0.994 and that of private sector banks varies from 0.942 to 0.988. The difference in the average scale efficiency is found to be statistically significant between public and private sector banks during 1998-1999, 1999-2000, 2004-2005 and 2006-2007. On an average, the private sector banks are performing better than the PSBs in terms of scale efficiency till 2000-2001. However, the scenario is just the reverse since 2001-2002 onwards.

(Insert Table II here)

Table II reports the average technical efficiency and its sources for each individual bank for the entire post-reform period (1996-2010) as well as two sub-periods: (i) Pre-Global Financial Crisis Period (1996-2007) and (ii) Global Financial Crisis Period (2008-2010). The HDFC Bank Ltd. is the only bank which is technically efficient in sub-period I. The next most efficient bank is found to be Bank of India, followed by State Bank of India during the entire period of study. Though, they failed to become efficient throughout the sup-period I, they are the only banks which are technical as well scale efficient in sup-period II. It is worth noting that in spite of global financial crisis, both public as well as private sector banks are performing better in terms of technical efficiency in sub-period II and it continues to show increasing trends. However, it will be misleading to conclude at this stage that Indian banking sector has been operating completely under the clear sky during the global financial crisis period. It could be vital to address the issue through other performance measures such as returns-to-scale and mixed period Malmquist productivity index before we arrive at any definite conclusion.

### ***Robustness of efficiency scores: sensitivity analysis***

To test the robustness of the DEA results with regards to outliers, we have applied the jackknifing procedure wherein we ran DEA that drops out each efficient bank one at a time from analysis. Unlike Bonesronning and Rattso (1994) who dropped each unit once at a time, we have dropped only the efficient units that construct the frontier (Mostafa, 2010; Charles *et al.*, 2011). The similarity of mean efficiency between the model with all the banks included and those based on dropping out each efficient bank one at a time has been tested by One-way ANOVA. The null hypothesis that “the removal of an efficient bank from the sample of banks under study does not affect its mean efficiency” has been tested for each year under study.

(Insert Table III and Table IV about here)

The results of hypotheses tests are reported in Table III. It can be observed that the null hypothesis is accepted in all the years except during 1997, 1999, 2004 and 2005 under CRS and during 2004 and 2005 under VRS. Post-hoc analysis revealed that the mean efficiency score is sensitive only to DMU 15 in the above stated years. Next, we examine how far the inclusion of DMU15 during the above years affects the overall efficiency trends of Indian banking sector. In order to test whether there is any significant

difference in the slope and intercept of the trends before and after the removal of DMU 15, we have used the following dummy variable regression model:

$$y_i = \alpha_1 + \alpha'_1 D_i + \alpha_2 t + \alpha'_2 D_i t + e_i \quad (8)$$

where,  $y_i$  is the average efficiency score as the dependent variable,  $t$  is time as an independent variable and  $e_i$  is the stochastic disturbance term which is assumed to satisfy all the usual assumptions of least square estimates.  $D_i = 1$  for trend I (with inclusion of DMU 15 in the sample during the sensitive years) and  $D_i = 0$  for trend II (without the inclusion of DMU 15 in the sample during the sensitive years). In the above model,  $\alpha_1$  and  $\alpha_2$  are the coefficients of trend II and  $(\alpha_1 + \alpha'_1)$  and  $(\alpha_2 + \alpha'_2)$  are the coefficients of trend I.  $\alpha'_1$  and  $\alpha'_2$  are the differential coefficients, showing the effect of DMU 15 on the trend line. In order to test the significance of coefficients of variables in trend I, we fit the following model:

$$y_i = \beta_1 + \beta'_1(1 - D_i) + \beta_2 t + \beta'_2(1 - D_i)t + e_i \quad (9)$$

where,  $\beta_k = (\alpha_k + \alpha'_k)$  and  $\alpha'_k = (\beta_k - \beta_k')$ ;  $k = 1, 2$ . The trend lines before and after the removal of DMU 15 are shown in Appendix C for technical efficiency as well as its two components, namely pure efficiency and scale efficiency. As it can be observed from Table IV that the differential coefficients, intercept and slope of the trends are insignificant in all the three cases. This indicates that the inclusion of DMU 15 does not affect the overall trends in spite of it being an outlier in the present context.

#### ***The Returns to Scale in Indian Banking Sector***

The presence of scale inefficiency in a bank indicates that it does not operate under the optimal scale and thus, efficiency gains could be achieved by either expanding the production level for a bank operating under IRS or contracting the production level for a bank operating under DRS. Table V reports the summary statistics of returns to scale in Indian banking sector during the period 1995-1996 to 2009-2010. As it appears from the Table V, most of the banks operate at non-optimal scale (IRS or DRS). Only 9% to 33% of banks in the sample operate under optimal scale. It is worth noting that the number of banks that operate under DRS declines over a period of time and banks that operate under IRS increases over a period of time.

(Insert Table V about here)

The percentage of banks that operate at optimal scale is higher in the private sector than its counterpart throughout except during the year 2005-2006, 2007-2008 and 2008-2009. Most of the banks in the public sector operate at DRS. On the other hand, majority of the banks in the private sector operate at IRS. The finding is well supported with the study of Zhao *et al.* (2008) who found that a substantial proportion of PSBs remain characterized by DRS, whereas, two-third of foreign and private banks operate under IRS and optimal returns-to-scale during the period 1992-2004. Figure 1-d to 1-f shows the percentage of banks operating under optimal, decreasing and increasing returns-to-scale respectively during the period 1995-1996 to 2009-2010. One can observe from Figure 1-e that (i) the percentage of PSBs operating under DRS is substantially higher than that of private sector banks at any point of time (ii) on an average, percentage of banks operating under DRS declines over a period of time for both the sectors. Similarly, it can be observed from Figure 1-f that (i) the percentage of PSBs operating under IRS is substantially higher than that of private sector banks and (ii) on an average, percentage of banks operating under IRS increases over a period of time for both the sectors. There is sharp decline (increase) in number of banks operating under DRS (IRS) in 2007-08 possibly because of shrink in the market as a result of global financial crisis.

### **Sources of TFP Change in Indian banking sector**

The Malmquist productivity index can be decomposed into (i) *technological change* indicating how much benchmark production frontier shifts at each bank's observed input mix (innovation or shocks), (ii) *pure efficiency change* indicating how much closer a bank gets to the efficient frontier and (iii) *scale efficiency change* indicating how much closer the banks are moving towards the most productive scale size. Table VI reports the summary of Malmquist productivity index and its components for the entire period as well as two sub-periods and their trends over the years are shown in Figure 1-g to 1-j.

(Insert Table VI about here)

The average annual change of TFP in Indian banking sector is observed as 1.27% during the post-reform period, with an average annual change of 1.68% and 0.72% in public and private sector banks respectively. The difference in the TFP change between these two types of banks is found to be statistically significant. When we look at the contributions of different components towards TFP change, we observe that the technological change has been the dominating source of productivity growth in Indian banking sector during the post reform period with average annual technological change for all banks, public banks and private banks as 1.16%, 1.49% and 0.70% respectively. On an average, the contribution of both pure efficiency change as well as scale efficiency change is found to be negligible for the entire period in both the sectors. During the entire 15 years of post liberalization period, the bank that achieves the highest change in TFP is Union Bank of India with average annual change of 4.20%. This is followed by Corporation Bank (3.91%), Uco Bank (2.87%), Canara Bank (2.84%), ING Vysya Bank Ltd. (2.82%) and Syndicate Bank (2.63%) just to name few. In all the above banks, technological change is found to be the dominating source of productivity change. The banks that suffer loss during the entire period of study are Karnataka Bank Ltd. (-0.64%), Indian Bank (-0.48%), Bank of Maharashtra (-0.46%), State Bank of India (-0.33%), City Union Bank Ltd. (-0.10%) and Dena Bank (-0.08%). The technological regress is found to be the cause of loss in TFP in Karnataka Bank Ltd, Indian Bank and State Bank of India. On the other hand, the pure efficiency change in the case of Bank of Maharashtra and Dena Bank and the scale efficiency change in the case of City Union Bank Ltd. are the main cause of negative growth in their TFP.

On an average, Indian banking sector has achieved a positive growth of 1.76% in pre-global financial crisis period with an average annual growth of 2.14% and 1.24% respectively in public and private sector banks. Most of the banks experience positive average annual change in TFP except for few exceptions such as Bank of Rajasthan Ltd. (-1.43%), State Bank of India (-0.67%), Karnataka Bank Ltd. (-0.57%), Development Credit Bank Ltd. (-0.45%), Indian Bank (-0.39%) and Bank of Maharashtra (-0.31%). The technological regress was observed to be the major cause of decline in TFP for Bank of Rajasthan Ltd., State Bank of India and Karnataka Bank Ltd. On the other hand, loss in pure efficiency in Bank of Maharashtra and negative change in scale efficiency in Development Credit Bank Ltd. was the cause of negative average annual change in their TFP.

However, the scenario in the global financial crisis period, as expected is somewhat discouraging. On an average, banks suffer loss in TFP by 0.55% with an average annual loss of 0.01% and 1.33% respectively in public and private sector banks. The banks which manage to sustain the positive change in TFP are Indusind Bank Ltd., Allahabad Bank, Canara Bank, Dhanalakshmi Bank Ltd., Federal Bank Ltd., State Bank of Bikaner & Jaipur, Syndicate Bank, Uco Bank, and Union Bank of India. The source of positive change in TFP for these banks during global financial crisis period is basically due to pure efficiency change, except for Development Credit Bank Ltd. and Dhanalakshmi Bank Ltd., which achieves the gain in TFP through the scale efficiency change.

In contrast with the findings of Ram Mohan and Ray (2004) for the period 1992-2000 who could not ascertain the proposition that productivity is lower in PSBs relative to their peers in the private sector, our study shows significant difference in favour of PSBs mainly as a result of technological change. This is quite consistent with the findings of Galagedera and Edirisuriya (2005) for the period 1995-2002, Kumar *et al.* (2010) for the period 1995-2006; Zhao *et al.* (2008) for the period 1992-2004 and Heffernan

and Fu (2010) for the period 2000-2007, Mahesh and Rajeev (2009) for the period 1985-2004. They observed that TFP change in Indian banking sector is largely driven by technological progress/innovation.

## **Discussion**

Two decades have elapsed since the initiation of banking sector reforms in India. Over this period, the banking sector has experienced a paradigm shift. One of the more significant measures instituted since the reform in 1991 has been the permission for new private banks to be set up and the more liberal approach towards private sector banks and the diversification of ownership in public sector banks. The change in the competitive conditions in the banking industry has resulted in positive change in TFP, more in favour of PSBs due to technological change. The unions of PSBs which voiced strong opposition to the adoption of technology in bank branches after independence were put under tremendous pressure to permit the adoption of technology within banks. In October 1993, the bank unions signed a Computerization Settlement Agreement with the Indian Bank Associations (IBA) that paved the way for the introduction of modern technology within PSBs. In March 1997, bank unions signed a new settlement with the IBA that allowed for an extension of new technology in operations and equipment.

The number of banks under IRS shows an increasing trend over the years during the post reform period. One implication is that for most Indian banks, increases in outputs would result in less than proportional increases in inputs (and costs). Hence, those banks with the IRS could achieve significant cost savings and efficiency gains by increasing the scale of their operations. In other words, substantial gains could be obtained from altering scale via internal growth or consolidation in the sector. Thus, those banks that experience IRS should either eliminate their scale inefficiency or be ready to become a prime target for acquiring banks, which can add value from underperforming banks by streamlining their operations and eliminating their redundancies and inefficiencies (Evanoff and Israilevich, 1991; Cummins *et al.*, 1999). As realized by the Government, it is important to look for merger and acquisition to achieve optimal economies of scale. The smaller banks with firm financials as well as the large ones with weak income statements would be the obvious targets for the larger and better run banks (Government of India, 2004). The need for size, in a market like India which is marked by an abundance of small and mid-sized banks, implies that consolidation must take place to transform a large number of small banks into a small number of large banks (Leeladhar, 2006) as it will lead to gain larger business volumes, and therefore an increased market share, which can make the banks to operate at most of economies of scale.

There is sharp increase in number of banks operating under IRS in 2007-08 because of shrink in the market. Further, on average, Indian banks suffer loss in TFP change during the global financial crisis period. This provides the tentative evidence of slowdown in Indian banking sector possibly as a result of increasing integration of the Indian economy and its financial markets with rest of the world. Thus, the belief that the Indian banking sector is unlikely to get affected with global financial crisis seems to be wrong. Jha (2008) reported three major impacts of global financial crisis on the Indian economy: (i) the quantum of liquidity available during the first half of the financial year 2008-09 is about a third lower than during the first half of the financial year 2007-08; (ii) with slackening external demand, export growth is expected to slow; and (iii) Foreign Institutional Investors have withdrawn from Indian stock markets leading to sharp falls in key indices. Indian banking sector does face some downside risks during the crisis period possibly from the potential reversal of capital flows on a sustained medium-term basis from the projected slow down of the global economy. Further, Lehman Brothers and Merrill Lynch had invested substantially in the stocks of Indian banks. Finally, there are clear signs of fragility and inadequacy within the banking sector: the recent rapid growth of often dodgy retail credit, associated attempts to securitize such debt, the emergence of a credit crunch in the face of macroeconomic uncertainty, and the inability or unwillingness of the banking system to provide loans to medium and small borrowers other than in the form of personal credit.

## **Conclusion**

In this study we examine the performance of Indian banking sector and different ownership structure within it during the post liberalization period. The time period spans from 1996 to 2010, which also

covers 3 years of global financial crisis. The technique of DEA is applied to measure efficiency, returns-to-scale and Malmquist indices of TFP change. The TFP change is further decomposed into its different components – technological change, pure efficiency change and scale efficiency change. The results reveal that DEA efficiency scores are robust with an exception. However, inclusion of the outlier does not affect the overall efficiency trends of Indian banking sector in the present context. The performance of PSBs is as par with private sector banks in terms of efficiency. The public sector bank is faintly doing better than the private sector banks in terms of (i) technical efficiency since 2003-04 and (ii) scale efficiency from 2000-01 onwards. Contrary to our general believe, PSBs have performed better than its counterpart in terms of TFP change as a result of significant differences in technological change. The performance of PSBs in post reform period could be attributed to the number of factors such as, import of better risk management skills from private domestic banks, intensified competition, the diversification effect, adoption of information technology, concentration towards customer care in terms of service quality and professionalism as a part of reform process. However, there is growing tendency of public banks operating under increasing returns-to-scale, implying that substantial gains could be obtained from altering scale via either internal growth or consolidation in the sector. The banks that experience IRS should either eliminate their scale inefficiency or be ready to become a prime target for acquiring banks, which can add value from underperforming banks by streamlining their operations and eliminating their redundancies and inefficiencies, which in turn, will further boost the efficiency and productivity of Indian banking sector. The analysis for two different sub-periods reveals that in spite of global financial crisis, Indian banks continue to show increasing trends in efficiency. However, there is evidence of shrink in the market resulting in movement of the banks towards increasing returns-to-scale as well as negative growth in TFP in both the sectors during the period of global financial crisis.

One of the future directions of the study could be to evaluate the performance of Indian banks by also taking into account of off balance-sheet (OBS) business such as, lines of credit, loan commitments, securitization and derivatives with larger set of sample including the foreign banks. Further, production or value-added approach could be considered side-by-side to give further insight on banks' performance. Finally, it could be useful from the policy perspective to examine the determinants of efficiency and productivity change in Indian banking sector.

(Insert Figures 1-a to 1-j about here)

(Insert Appendix A, B & C)

#### Notes:

1. In 1993, the RBI permitted private entry into the banking sector, provided that new banks were well capitalized and technologically advanced, and at the same time prohibited cross-holding practices with industrial groups. The RBI also imposed some restrictions on new banks with respect to opening branches, with a view to maintaining the franchise value of existing banks.
2. RBI allowed banks the freedom to choose their deposit and lending rates. The RBI now directly controls only the interest rates charged on credit to exports, and also there is a ceiling on lending rate on small loans (i.e., up to Rs 2 lakhs). On the deposit side, except the interest rate paid on savings deposits, all other interest rates have been deregulated.
3. The CRR requires banks to hold a certain portion of deposits in the form of cash balances with the RBI. In the 1960s and 1970s, the CRR was 5 per cent, but then rose steadily to its legal upper limit of 15 per cent in early 1991.
4. The SLR requires banks to hold a certain amount of deposits in the form of government and other approved securities. It was 25 per cent in 1970 and then increased to 38.5 per cent in 1991 – nearly to the level of its legal upper limit of 40 per cent. With respect to direct lending, the priority sector target of 33 per cent of



total advances was introduced in 1974, and the ratio was gradually raised to 40 per cent in 1985. There were sub-targets for agriculture, small farmers, and disadvantaged sections.

5. In 1992, the RBI issued guidelines for income recognition, asset classification and provisioning, and also adopted the Basle Accord capital adequacy standards. The government also established the Board of Financial Supervision in the RBI and recapitalized public-sector banks in order to give banks sufficient financial strength and to enable them to gain access to capital markets.
6. The RBI measures to meet the above objectives came in several policy packages including both conventional as well as unconventional measures starting mid-September 2008. On the conventional side, RBI reduced the policy interest rates aggressively and rapidly, reduced the quantum of bank reserves impounded by the central bank and expanded and liberalized the refinance facilities for export credit. Measures aimed at managing FOREX liquidity included an upward adjustment of the interest rate ceiling on the foreign currency deposits by non-resident Indians, substantially relaxing the external commercial borrowings (ECB) regime for corporates, and allowing non-banking financial companies and housing finance companies access to foreign borrowing. The important among the many unconventional measures taken by the RBI are a rupee-dollar swap facility for Indian banks to give them comfort in managing their short-term foreign funding requirements, an exclusive refinance window as also a special purpose vehicle for supporting non-banking financial companies, and expanding the lendable resources available to apex finance institutions for refinancing credit extended to small industries, housing and exports.
7. See Sealey and Lindley, 1977 for a detailed discussion.
8. The justification on choice of intermediary approach in the present case can be viewed in Kumar and Charles (2011).
9. An increase in the number of outputs or inputs leads to an increase in efficiency scores. In small samples with many variables almost all units may be on the frontier.
10. The production approach focuses on the bank's operating costs, that is, the cost of labour (employees) and physical capital (plant and equipment). The intermediary approach considers a financial firm's production process to be one of the financial intermediaries (the borrowing of funds and subsequent lending to these funds). Thus, the focus in the intermediary approach is on the total costs, including both interest and operating expenses.

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**Appendix A:** Output-oriented mixed-period distance function

Model III: *Output-oriented mixed period distance function with respect to technology at time period t*

$$\begin{aligned} \mathbf{p}_c^t \left( x^{j,t+1}, y^{j,t+1} \right)_{\mathcal{L}}^{\mathcal{S}_1} &= \text{Max} \theta_c^{j,t} \\ \text{s.t.} \quad \sum_{j=1}^J \lambda_j x_n^{j,t} &\leq x_n^{j,t+1}; \sum_{j=1}^J \lambda_j y_m^{j,t} \geq \theta_c^{j,t} y_m^{j,t+1}; \lambda_j \geq 0, \forall j. \end{aligned}$$

Model IV: *Output-oriented mixed period distance function with respect to technology at time period t+1*

$$\begin{aligned} \mathbf{p}_c^{t+1} \left( x^{j,t}, y^{j,t} \right)_{\mathcal{L}}^{\mathcal{S}_1} &= \text{Max} \theta_c^{j,t+1} \\ \text{s.t.} \quad \sum_{j=1}^J \lambda_j x_n^{j,t+1} &\leq x_n^{j,t}; \sum_{j=1}^J \lambda_j y_m^{j,t+1} \geq \theta_c^{j,t+1} y_m^{j,t}; \lambda_j \geq 0, \forall j. \end{aligned}$$

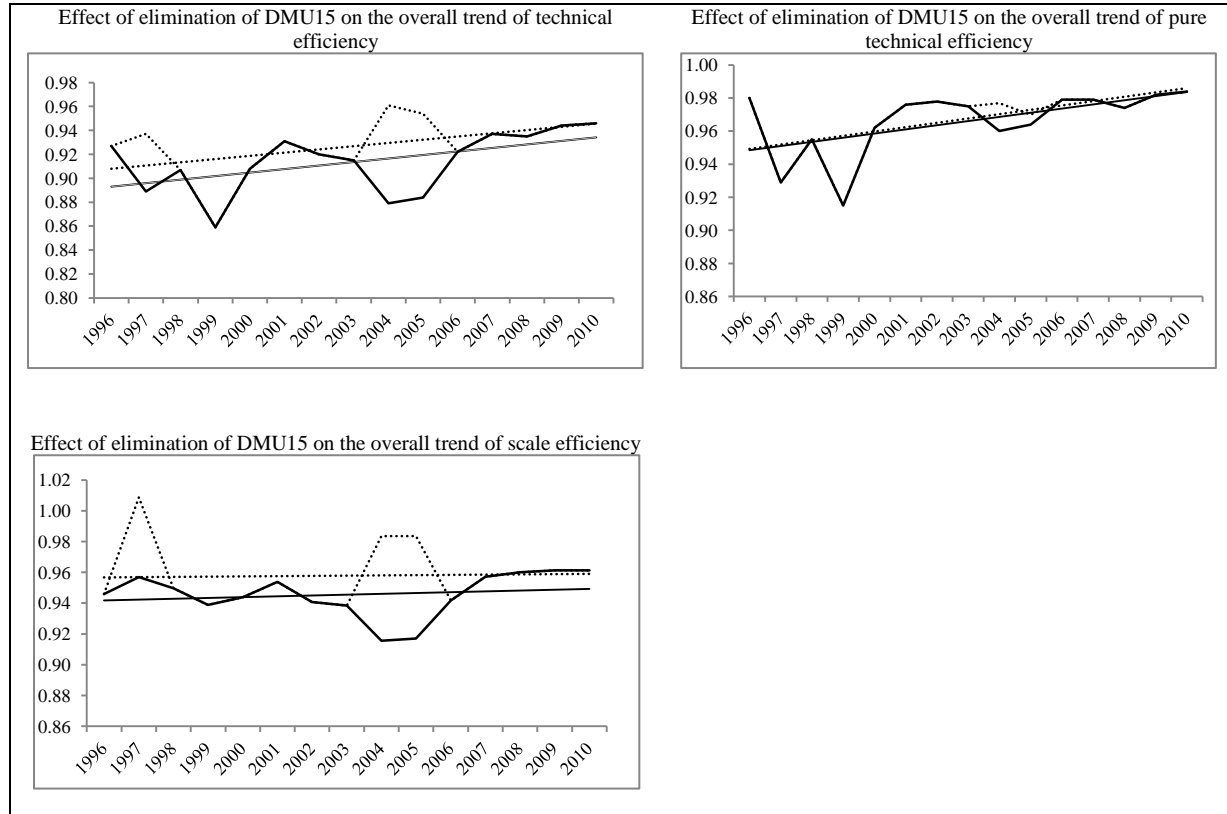
In models I and II,  $(x^{j,t}, y^{j,t}) \in GR^t$  and therefore  $D_c^t(x^{j,t}, y^{j,t}) \leq 1$ . However, in models III and IV,  $(x^{j,t+1}, y^{j,t+1})$  need not to belong to  $GR^t$  and so it may take value greater than 1.

**Appendix B:** List of banks

SN	Abbreviation	Name of the Bank	SN	Abbreviation	Name of the Bank
1	AB	Allahabad Bank <sup>1</sup>	18	IOB	Indian Overseas Bank <sup>1</sup>
2	AnB	Andhra Bank <sup>1</sup>	19	IBL	Indusind Bank Ltd. <sup>2</sup>
3	BOB	Bank Of Baroda <sup>1</sup>	20	JKBL	Jammu & Kashmir Bank Ltd. <sup>2</sup>
4	BOI	Bank Of India <sup>1</sup>	21	KBL	Karnataka Bank Ltd. <sup>2</sup>
5	BOM	Bank Of Maharashtra <sup>1</sup>	22	KVBL	Karur Vysya Bank Ltd. <sup>2</sup>
6	BORL	Bank Of Rajasthan Ltd. <sup>2</sup>	23	LVBL	Lakshmi Vilas Bank Ltd. <sup>2</sup>
7	CB	Canara Bank <sup>1</sup>	24	OBOC	Oriental Bank Of Commerce <sup>1</sup>
8	CBOPL	Centurion Bank Of Punjab Ltd. <sup>2</sup>	25	PNB	Punjab National Bank <sup>1</sup>
9	CUBL	City Union Bank Ltd. <sup>2</sup>	26	SIBL	South Indian Bank Ltd. <sup>2</sup>
10	CoB	Corporation Bank <sup>1</sup>	27	SBBJ	State Bank of Bikaner & Jaipur <sup>1</sup>
11	DB	Dena Bank <sup>1</sup>	28	SBI	State Bank Of India <sup>1</sup>
12	DCBL	Development Credit Bank Ltd. <sup>2</sup>	29	SBM	State Bank Of Mysore <sup>1</sup>
13	DBL	Dhanalakshmi Bank Ltd. <sup>2</sup>	30	SB	Syndicate Bank <sup>1</sup>
14	FBL	Federal Bank Ltd. <sup>2</sup>	31	UB	Uco Bank <sup>1</sup>
15	HDFCBL	H D F C Bank Ltd. <sup>2</sup>	32	UBI	Union Bank Of India <sup>1</sup>
16	INGVBL	I N G Vysya Bank Ltd. <sup>2</sup>	33	VB	Vijaya Bank <sup>1</sup>
17	IB	Indian Bank <sup>1</sup>			

Note: superscript 1 and 2 respectively indicate that the corresponding bank is public and private bank.

### Appendix C: Effects of elimination of outlier on efficiency trends



**Note:** Liner trends of average efficiencies with (without) outlier are shown with solid bold lines (dotted lines).

**Table 1:** Summary statistics of technical efficiency and its components in Indian banking sector

<b>Technical Efficiency</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999<sup>+</sup></b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Average (All banks)</i>	0.927	0.889	0.907	0.859	0.908	0.931	0.920	0.915	0.879	0.884	0.922	0.937	0.935	0.944	0.946
<i>Coefficient of Variation (%)</i>	6.01	8.51	8.93	10.37	6.87	5.19	5.20	6.22	7.05	8.16	6.92	5.23	5.56	4.69	4.96
<i>Efficient banks (in %)</i>	24.2	9.09	12.1	12.1	9.09	15.2	12.1	15.2	9.09	9.09	9.09	18.2	18.8	21.9	
<i>Average (Public banks)</i>	0.924	0.882	0.920	0.828	0.892	0.924	0.920	0.922	0.873	0.889	0.933	0.941	0.945	0.950	0.955
<i>CV (%)</i>	5.64	5.75	6.34	9.07	6.08	4.56	4.63	4.45	5.40	7.30	4.68	3.73	4.81	4.16	3.55
<i>Efficient public banks (in %)</i>	21.1	0.00	5.3	5.3	5.3	10.5	10.5	10.5	0.00	5.26	5.26	10.5	26.3	21.1	15.8
<i>Average (Private banks)</i>	0.931	0.897	0.889	0.901	0.929	0.940	0.921	0.907	0.887	0.877	0.907	0.931	0.919	0.936	0.933
<i>CV (%)</i>	6.66	11.35	11.70	10.18	7.34	5.93	6.08	8.19	8.91	9.46	9.21	6.92	6.38	5.45	6.47
<i>Efficient private banks (in %)</i>	28.6	21.4	21.4	21.4	14.3	21.4	14.3	21.4	21.4	14.3	14.3	28.6	7.69	23.1	23.1
<b>Pure Technical Efficiency</b>	<b>1996</b>	<b>1997</b>	<b>1998<sup>+</sup></b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Average (All banks)</i>	0.946	0.958	0.949	0.940	0.944	0.953	0.941	0.939	0.918	0.917	0.942	0.957	0.960	0.961	0.961
<i>CV (%)</i>	5.58	5.39	7.18	7.88	6.21	4.65	5.06	5.83	7.56	7.97	6.88	4.28	4.30	4.17	4.06
<i>Pure efficient banks (in %)</i>	36.4	48.5	42.4	42.4	27.3	30.3	21.2	27.3	24.2	24.2	30.3	36.4	43.8	34.4	25.0
<i>Average (Public banks)</i>	0.949	0.965	0.970	0.949	0.944	0.949	0.935	0.939	0.905	0.909	0.948	0.948	0.950	0.956	0.961
<i>CV (%)</i>	5.53	4.55	4.46	5.74	5.45	3.69	4.50	4.61	6.91	6.47	4.81	3.58	4.67	4.04	3.48
<i>Pure efficient public banks (in %)</i>	36.8	47.4	47.4	42.1	21.1	21.1	15.8	15.8	15.8	10.5	26.3	15.8	36.8	21.1	15.8
<i>Average (Private banks)</i>	0.943	0.948	0.920	0.928	0.944	0.959	0.949	0.939	0.935	0.928	0.934	0.968	0.976	0.969	0.962
<i>CV (%)</i>	5.84	6.43	9.29	10.29	7.34	5.79	5.79	7.36	8.22	9.72	9.18	4.95	3.27	4.37	4.95
<i>Pure efficient private banks (in %)</i>	35.7	50.0	35.7	42.9	35.7	42.9	28.6	42.9	35.7	42.9	35.7	64.3	53.8	53.8	38.5
<b>Scale Efficiency</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999*</b>	<b>2000*</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005<sup>+</sup></b>	<b>2006</b>	<b>2007<sup>+</sup></b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Average</i>	0.980	0.929	0.955	0.915	0.962	0.976	0.978	0.975	0.960	0.964	0.979	0.979	0.974	0.982	0.984
<i>CV (%)</i>	2.84	8.09	4.48	8.32	3.65	2.30	2.46	3.29	4.88	4.29	3.25	3.82	4.70	2.91	2.91
<i>Scale efficient banks (in %)</i>	24.2	9.09	12.1	12.1	9.09	15.2	12.1	15.2	9.09	9.09	9.09	18.2	18.8	25.0	18.8
<i>Average (Public banks)</i>	0.974	0.914	0.948	0.874	0.945	0.973	0.984	0.981	0.966	0.977	0.985	0.992	0.996	0.994	0.994
<i>CV (%)</i>	3.39	4.38	3.87	7.96	3.85	2.26	1.76	2.69	4.27	2.50	1.94	0.90	0.45	0.74	0.67
<i>Scale efficient public banks (in %)</i>	21.1	0.00	5.26	5.26	5.26	10.5	10.5	10.5	0.00	5.26	5.26	10.5	26.3	26.3	15.8
<i>Average (Private banks)</i>	0.988	0.948	0.965	0.972	0.984	0.980	0.971	0.966	0.950	0.947	0.972	0.962	0.942	0.966	0.970
<i>CV (%)</i>	1.71	11.04	5.16	4.11	1.69	2.37	3.08	3.89	5.65	5.60	4.47	5.49	6.31	4.05	4.25
<i>Scale efficient private banks (in %)</i>	28.6	21.4	21.4	21.4	14.3	21.4	14.3	21.4	21.4	14.3	14.3	28.6	7.69	23.1	23.1

**Note:** (i) CV = coefficient of variations (ii) \* and + indicate that there is significant difference in the scale efficiency scores between public and private sector banks in the corresponding year respectively at 99% and 95% level of confidence.

Table 2: Technical efficiency and its sources in Indian banking sector

SN	Bank	Pre-Global Financial Crisis (1995-96 to 2006-07)			Global Financial Crisis (2007-08 to 2009-10)			Post-liberalization (1995-96 to 2009-10)		
		TE	PE	SE	TE	PE	SE	TE	PE	SE
1	AB <sup>1</sup>	0.877	0.913	0.963	0.939	0.944	0.995	0.890	0.919	0.969
2	AnB <sup>1</sup>	0.900	0.931	0.967	0.942	0.948	0.994	0.908	0.934	0.972
3	BOB <sup>1</sup>	0.868	0.930	0.934	1.000	1.000	1.000	0.895	0.944	0.947
4	BOI <sup>1</sup>	0.977	1.000	0.977	0.990	0.990	0.999	0.980	0.998	0.982
5	BOM <sup>1</sup>	0.903	0.938	0.964	0.916	0.922	0.993	0.905	0.935	0.970
6	BORL <sup>2</sup>	0.848	0.878	0.967	0.960	0.982	0.977	0.870	0.899	0.969
7	CB <sup>1</sup>	0.874	0.966	0.905	0.938	0.947	0.992	0.887	0.962	0.922
8	CBOPL <sup>2</sup>	0.860	0.929	0.924	-	-	-	-	-	-
9	CUBL <sup>2</sup>	0.918	0.991	0.927	0.889	0.954	0.933	0.912	0.983	0.928
10	CoB <sup>1</sup>	0.953	0.973	0.980	0.977	0.980	0.997	0.958	0.975	0.983
11	DB <sup>1</sup>	0.924	0.940	0.984	0.909	0.920	0.988	0.921	0.936	0.985
12	DCBL <sup>2</sup>	0.955	0.992	0.963	0.951	1.000	0.951	0.955	0.993	0.961
13	DBL <sup>2</sup>	0.873	0.979	0.894	0.834	1.000	0.834	0.865	0.983	0.882
14	FBL <sup>2</sup>	0.909	0.916	0.992	0.976	0.984	0.992	0.922	0.930	0.992
15	HDFCBL <sup>2</sup>	1.000	1.000	1.000	0.980	0.986	0.994	0.996	0.997	0.999
16	INGVBL <sup>2</sup>	0.905	0.919	0.984	0.974	0.982	0.992	0.919	0.932	0.986
17	IB <sup>1</sup>	0.894	0.921	0.970	0.973	0.975	0.998	0.909	0.932	0.975
18	IOB <sup>1</sup>	0.861	0.897	0.959	0.955	0.964	0.991	0.880	0.911	0.965
19	IBL <sup>2</sup>	0.968	0.973	0.995	0.934	0.947	0.986	0.961	0.968	0.993
20	JKBL <sup>2</sup>	0.902	0.916	0.985	0.891	0.908	0.981	0.900	0.915	0.984
21	KBL <sup>2</sup>	0.883	0.897	0.985	0.958	0.977	0.980	0.898	0.913	0.984
22	KVBL <sup>2</sup>	0.962	0.980	0.981	0.933	0.957	0.974	0.956	0.976	0.980
23	LVBL <sup>2</sup>	0.878	0.923	0.951	0.906	0.992	0.914	0.883	0.936	0.944
24	OBOC <sup>1</sup>	0.897	0.946	0.949	0.898	0.907	0.991	0.897	0.938	0.958
25	PNB <sup>1</sup>	0.897	0.971	0.925	0.973	0.977	0.996	0.912	0.972	0.939
26	SIBL <sup>2</sup>	0.877	0.887	0.989	0.895	0.927	0.965	0.881	0.895	0.985
27	SBBJ <sup>1</sup>	0.938	0.952	0.985	0.968	0.977	0.991	0.944	0.957	0.986
28	SBI <sup>1</sup>	0.954	1.000	0.954	1.000	1.000	1.000	0.963	1.000	0.963
29	SBM <sup>1</sup>	0.936	0.944	0.992	0.985	0.996	0.989	0.946	0.954	0.991
30	SB <sup>1</sup>	0.889	0.926	0.961	0.927	0.931	0.996	0.897	0.927	0.968
31	UB <sup>1</sup>	0.894	0.937	0.955	0.914	0.924	0.990	0.898	0.934	0.962
32	UBI <sup>1</sup>	0.875	0.929	0.942	0.952	0.953	0.999	0.890	0.934	0.953
33	VB <sup>1</sup>	0.866	0.894	0.969	0.898	0.902	0.995	0.872	0.895	0.974
	All Banks	0.906	0.942	0.963	0.942	0.961	0.980	0.913	0.946	0.966
	Public Banks	0.904	0.943	0.960	0.950	0.956	0.994	0.913	0.945	0.967
	Private Banks	0.910	0.941	0.967	0.929	0.969	0.960	0.913	0.946	0.965

**Note:** (i) TE = Technical Efficiency, PE = Pure Efficiency, SE = Scale Efficiency (ii) the superscript 1 and 2 indicates that the corresponding bank is respectively from public sector and private sector.



Table 3: Jackknifing analysis for robustness of efficiency scores: one-way ANOVA

	CRS			VRS		
	<i>df</i>	<i>F</i>	<i>Sig.</i>	<i>df</i>	<i>F</i>	<i>Sig.</i>
1996	(8, 280)	0.128	0.998	(12, 404)	0.274	0.993
1997	(3, 125)	3.369	0.021*	(16, 528)	0.200	1.000
1998	(4, 156)	0.142	0.966	(14, 466)	0.063	1.000
1999	(4, 156)	3.706	0.007*	(14, 466)	0.111	1.000
2000	(3, 125)	0.811	0.490	(9, 311)	0.470	0.895
2001	(5, 187)	0.918	0.470	(10, 342)	0.339	0.970
2002	(4, 156)	1.610	0.174	(6, 218)	1.052	0.392
2003	(5, 187)	1.700	0.136	(8, 280)	1.142	0.335
2004	(3, 125)	17.297	0.000*	(8, 280)	3.910	0.000*
2005	(3, 125)	8.835	0.000*	(7, 249)	3.568	0.001*
2006	(3, 125)	1.288	0.281	(9, 311)	0.548	0.839
2007	(6, 218)	0.442	0.850	(9, 311)	0.597	0.800
2008	(6, 211)	0.246	0.960	(14, 451)	0.194	0.999
2009	(7, 241)	0.355	0.927	(11, 361)	0.293	0.987
2010	(6, 211)	0.703	0.647	(8, 271)	0.590	0.786

Note: \* and \*\* indicates that the mean difference across the groups in the corresponding year is significant at 99% and 95% level of confidence respectively.

Table 4: Effect of elimination of DMU 15 on efficiency trends: dummy-variable regression model

Dependent Variable		Trend I $\beta_k = (\alpha_k + \alpha'_k)$	Trend II $\alpha_k = (\beta_k + \beta'_k)$	Differential Effect $\alpha'_k = \beta'_k$	R <sup>2</sup>	n
<i>TE</i>	<i>Constant</i>	0.9053 (0.001)	0.8900 (0.001)	-0.0152 (0.389)	0.304	30
	<i>t</i>	0.0027 (0.0561)	0.0029 (0.039)	0.0002 (0.903)		
<i>PE</i>	<i>Constant</i>	0.9460 (0.001)	0.9467 (0.001)	-0.0007 (0.958)	0.328	30
	<i>t</i>	0.0025 (0.021)	0.0026 (0.017)	-0.0001 (0.944)		
<i>SE</i>	<i>Constant</i>	0.9411 (0.001)	0.9546 (0.001)	-0.0135 (0.315)	0.133	30
	<i>t</i>	0.0005 (0.596)	0.0003 (0.740)	0.0002 (0.889)		

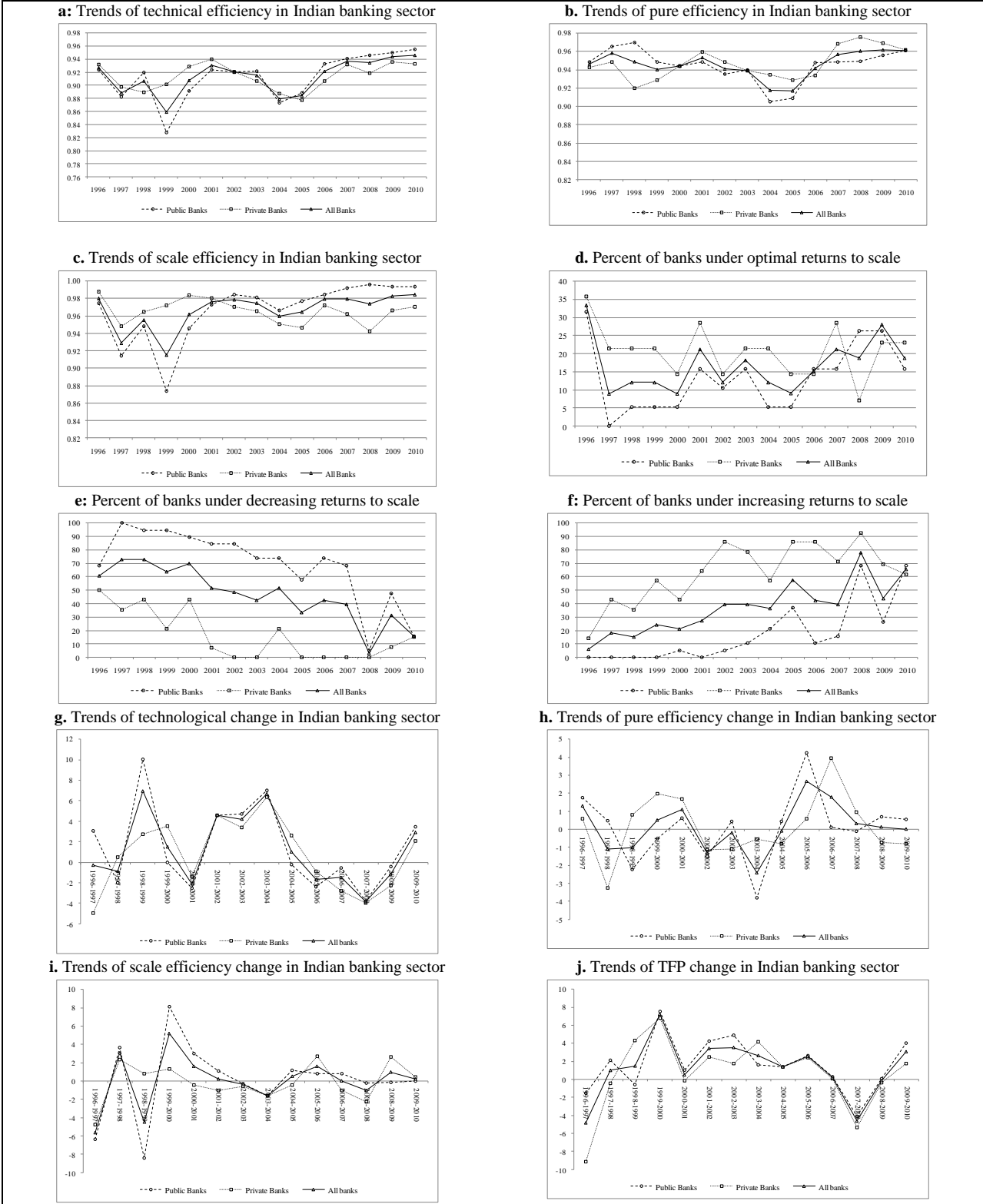
Table 5: Summary statistics of returns to scale in Indian banking sector

	Pre-Global Financial Crisis												Global Financial Crisis		
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<b>No of Banks</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>33</b>	<b>32</b>	<b>32</b>	<b>32</b>
<i>Optimal Scale</i>	11	3	4	4	3	7	4	6	4	3	5	7	6	8	6
<i>DRS</i>	20	24	24	21	23	17	16	14	17	11	14	13	1	10	5
<i>IRS</i>	2	6	5	8	7	9	13	13	12	19	14	13	25	14	21
<b>No of Public Banks</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>	<b>19</b>
<i>Optimal Scale</i>	6	0	1	1	1	3	2	3	1	1	3	3	5	5	3
<i>DRS</i>	13	19	18	18	17	16	16	14	14	11	14	13	1	9	3
<i>IRS</i>	0	0	0	0	1	0	1	2	4	7	2	3	13	5	13
<b>No of Private Banks</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>14</b>	<b>13</b>	<b>13</b>	<b>13</b>
<i>Optimal Scale</i>	5	3	3	3	2	4	2	3	3	2	2	4	1	3	3
<i>DRS</i>	7	5	6	3	6	1	0	0	3	0	0	0	0	1	2
<i>IRS</i>	2	6	5	8	6	9	12	11	8	12	12	10	12	9	8

Table 6: Sources of TFP change in Indian banking sector

SN	Bank	Pre-Global Financial Crisis (1995-96 to 2006-07)				Global Financial Crisis (2007-08 to 2009-10)				Post-liberalization (1995-96 to 2009-10)			
		TC	PEC	SEC	TFPC	TC	PEC	SEC	TFPC	TC	PEC	SEC	TFPC
1	AB <sup>1</sup>	1.69	-0.14	0.02	1.61	0.46	1.68	-0.23	1.93	1.43	0.25	-0.03	1.68
2	AnB <sup>1</sup>	2.61	0.24	-0.05	2.82	-1.99	0.22	-0.34	-2.08	1.63	0.24	-0.11	1.77
3	BOB <sup>1</sup>	0.89	-0.36	0.60	1.11	1.32	2.04	0.17	3.54	0.98	0.15	0.51	1.63
4	BOI <sup>1</sup>	2.48	0.00	0.53	3.01	-0.47	-0.98	-0.03	-1.49	1.85	-0.21	0.41	2.04
5	BOM <sup>1</sup>	0.52	-0.82	0.01	-0.31	-0.34	-0.65	-0.04	-1.02	0.33	-0.79	0.00	-0.46
6	BORL <sup>2</sup>	-1.11	0.34	-0.67	-1.43	-7.32	2.83	2.58	-1.91	-2.44	0.88	0.02	-1.53
7	CB <sup>1</sup>	3.72	-0.64	0.35	3.43	-0.02	0.48	0.18	0.68	2.92	-0.40	0.31	2.84
8	CBOPL <sup>2</sup>	2.44	0.01	0.00	2.44	-	-	-	-	2.44	0.01	0.00	2.44
9	CUBL <sup>2</sup>	0.72	0.91	-0.29	1.34	-0.66	-3.64	-1.07	-5.41	0.43	-0.06	-0.45	-0.10
10	CoB <sup>1</sup>	4.25	0.87	0.00	5.14	-0.58	0.00	0.00	-0.60	3.21	0.68	0.00	3.91
11	DB <sup>1</sup>	0.59	-0.51	0.04	0.12	-0.32	0.03	-0.47	-0.81	0.39	-0.39	-0.07	-0.08
12	DCBL <sup>2</sup>	0.15	0.00	-0.63	-0.45	-0.30	0.00	2.27	1.97	0.05	0.00	0.00	0.07
13	DBL <sup>2</sup>	0.81	1.23	-1.84	0.19	-0.60	0.00	1.33	0.77	0.51	0.97	-1.16	0.32
14	FBL <sup>2</sup>	-0.49	0.14	0.38	0.01	-0.69	1.05	-0.13	0.20	-0.54	0.34	0.27	0.05
15	HDFCBL <sup>2</sup>	3.51	0.00	0.00	3.51	-2.86	-1.43	-0.07	-4.31	2.15	-0.31	-0.02	1.84
16	INGVBL <sup>2</sup>	2.11	1.18	0.45	3.71	-0.44	0.00	0.01	-0.45	1.56	0.93	0.36	2.82
17	IB <sup>1</sup>	-1.38	0.59	0.41	-0.39	-0.31	-0.41	-0.07	-0.82	-1.15	0.38	0.31	-0.48
18	IOB <sup>1</sup>	1.63	0.54	0.06	2.20	-1.66	-0.41	0.12	-2.01	0.92	0.34	0.08	1.30
19	IBL <sup>2</sup>	2.41	-1.23	-0.19	0.98	0.20	4.26	0.26	4.71	1.94	-0.05	-0.10	1.78
20	JKBL <sup>2</sup>	2.78	-0.01	0.00	2.80	-1.84	-5.42	-0.58	-7.80	1.79	-1.17	-0.12	0.53
21	KBL <sup>2</sup>	-0.62	0.16	-0.13	-0.57	-2.70	1.68	0.17	-0.91	-1.07	0.48	-0.06	-0.64
22	KVBL <sup>2</sup>	1.87	0.07	0.12	2.06	-0.15	-1.96	-0.60	-2.73	1.44	-0.36	-0.03	1.04
23	LVBL <sup>2</sup>	1.60	0.46	-0.63	1.42	0.26	-0.84	0.23	-0.36	1.31	0.18	-0.45	1.04
24	OBOC <sup>1</sup>	2.87	-0.84	-0.05	2.00	0.11	-0.86	-0.17	-0.92	2.28	-0.85	-0.07	1.38
25	PNB <sup>1</sup>	2.22	-0.60	0.71	2.34	-0.09	0.33	0.23	0.41	1.73	-0.40	0.60	1.93
26	SIBL <sup>2</sup>	1.13	0.19	-0.08	1.28	-0.88	0.93	-1.06	-1.00	0.70	0.35	-0.29	0.79
27	SBBJ <sup>1</sup>	1.18	0.44	-0.01	1.63	0.22	1.58	-0.47	1.28	0.97	0.68	-0.11	1.55
28	SBI <sup>1</sup>	-0.68	0.00	0.01	-0.67	0.92	0.00	0.00	0.92	-0.34	0.00	0.01	-0.33
29	SBM <sup>1</sup>	1.58	1.72	-0.01	3.28	-0.18	-0.37	-0.71	-1.29	1.20	1.27	-0.16	2.30
30	SB <sup>1</sup>	3.97	-0.77	-0.20	3.02	-1.30	2.31	0.20	1.22	2.84	-0.11	-0.12	2.63
31	UB <sup>1</sup>	3.18	-0.19	0.48	3.45	0.27	0.99	-0.57	0.73	2.56	0.07	0.26	2.87
32	UBI <sup>1</sup>	3.86	0.87	0.35	5.09	0.69	0.24	-0.03	0.95	3.18	0.73	0.27	4.20
33	VB <sup>1</sup>	2.22	-0.35	-0.02	1.82	-1.64	0.90	-0.17	-0.91	1.39	-0.09	-0.05	1.23
All Banks		1.66	0.11	-0.01	1.76	-0.72	0.14	0.03	-0.55	1.16	0.11	0.00	1.27
Public Banks		1.97	0.00	0.17	2.14	-0.26	0.37	-0.13	-0.01	1.49	0.08	0.11	1.68
Private Bank		1.24	0.25	-0.25	1.24	-1.38	-0.20	0.26	-1.33	0.70	0.15	-0.14	0.72

**Note:** (i) TC, PEC, SEC and TFPC respectively indicates technological change, pure efficiency change, scale efficiency change and total factor productivity change (ii) Centurion Bank of Punjab Ltd. (CBOPL) merged with HDFC Bank Ltd. (HDFCBL) in May 2008 (ii) the superscript 1 and 2 indicates that the corresponding bank is respectively from public sector and private sector.



**Figure 1: Trends of performance indicators in Indian banking sector**