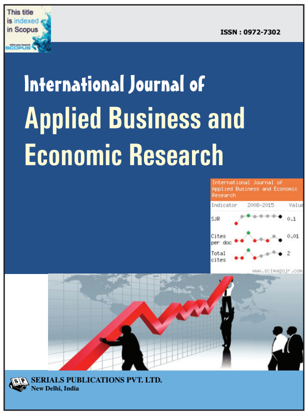

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Malmquist Total Factor Productivity Index with an Illustrative Application to Indian Public Sector Banks

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ABSTRACT

Over the last few decades literature has been struggling over finding suitable method to measure productivity. Out of varied methods like Index numbers, Regression analysis, Data envelopment analysis, Stochastic frontier approach, it is found that the Malmquist Total Factor productivity index has many advantages over others. It can measure efficiency or productivity of DMUs, with multiple inputs and outputs, over a single time period, multi-period and even cross period changes. Moreover, Malmquist total factor productivity index can be decomposed in factors like overall efficiency, technical efficiency etc to have a clear information about the factors responsible for changes in total factor productivity. The present study endeavours to examine Malmquist total factor productivity index as a tool and uses the same to measure productivity changes in 25 public sector banks operating in India, from the year 1998 to 2013. Further, the efficiency changes and technical changes have also been analysed. The findings suggest that out of 25 public sector banks under study, 20% banks showed a decrease in overall TFP, whereas, 80% banks showed positive growth in TFP. It is found that technological changes have played a major role, in growth of total factor productivity of the public sector banks operating in India. Out of 20 public sector banks, with increased total factor productivity, 5 have shown increase in both components, efficiency and technical efficiency, 3 have shown improvement only in technical efficiency with no improvement in efficiency, 12 banks have shown improvement in technical efficiency but a decline in efficiency.

Keywords: Data Envelopment Analysis (DEA), Malmquist Total Factor Productivity Index (MTFPI), Decision Making Units (DMUs), Public Sector Banks (PSBs), Efficiency Change (EC), Technical Efficiency Change (TEC).

1. INTRODUCTION

Productivity primarily establishes a relationship between inputs and outputs. The level of productivity of a decision making unit can be measured by observing the extent of Outputs corresponding to each unit of input. Productivity is also used to measure relative performance of DMUs. Coelli et. al., (2005) opined that it is relatively easy to measure productivity of decision making units (DMUs) when there is only one output produced by using one input, but the same becomes complicated when multiple inputs are used to produce multiple outputs. In such cases, productivity is measured by weighted sums of inputs as well as outputs.

Over last few decades, literature has been struggling for identification of suitable techniques to measure productivity. Literature has been advocating advantages of one method over another. Much talked about techniques of measuring productivity includes Laspeyres Index (Allen, 1975), Paasche's Index (Diewert et. al., 2003), Fisher Index (Diewert,1992, Triplett, 1992), Tornqvist Index (Kohli, 2004, Rao et. al., 1995), Stochastic Frontier Approach (Kumbhakar and Lovell,2000, Kokkinou and Geo, 2009), Regression Analysis (Zaddach et. al., 2012, Armstrong, 2012), Data Envelopment Analysis (Charnes et. al., 1978, Ramanathan, 2003), Malmquist Productivity Index (Fare et. al., 1992, Garg and Deepti, 2009) etc. It has also been identified that choice of productivity measurement method depends on the purpose of measurement, availability of data and desired accuracy level.

Malmquist TFP Index has many advantages over the use of Index numbers. Laspeyres Index, Paasche Index, Fisher Index and Tornqvist Index need quantities of outputs and inputs, as well as the relevant prices, for analysing productivity change whereas, the Malmquist TFP Index can be calculated only with the data providing quantities of inputs and outputs, without any information on prices of inputs and outputs. Thus, Malmquist TFP Index can be used to evaluate the change in productivity, even in the situations where the prices of Inputs and Outputs are either not available or they are not relevant as per purpose of study. Also, the Malmquist TFP Index does not demand any assumption of behaviour or functional kind such as 'Minimization of Cost' or 'Maximization of Profit' as required by the parametric techniques like Fisher Index, Tornqvist Index and Stochastic Frontier Approach. Also, these parametric techniques require specified error term, which is not required in the Malmquist TFP Index. Finally, for the Panel data, the Malmquist TFP Index estimates the TFP change and decomposes it into some useful factors such as 'Change in Technical Efficiency', 'Change in Efficiency', 'Scale Efficiency' and 'Pure Technical Efficiency', and thus providing an insight into the factors responsible for change in TFP as well as comparative assessment of DMUs. Both Regression analysis and Correlation Analysis involve complex calculations when multiple inputs and outputs are involved. On the other hand, Malmquist TFP Index enjoys the ease of computation. Data Envelopment Analysis (DEA) is a technique to measure efficiency of DMUs for a single time period whereas, Malmquist TFP Index can measure efficiency for a single period, multi-periods and even cross-period changes. Hence, it is concluded here that for effective Productivity measurement of DMUs with multiple inputs and outputs, over a period of time, Malmquist TFP Index has many advantages over other techniques of productivity measurement.

2. INTRODUCTION TO MALMQUIST TFP INDEX

The Malmquist TFP Index is the technique, which is found most commonly in the literature as a measure of productivity change. It evaluates the changes between two different data points by calculating the ratio of the distances of each data point relative to a common technology (Casu et. al., 2004). The Malmquist Total Factor Productivity TFP index was introduced by Caves, Christensen and Diewert, in the year 1982. Caves et. al., (1982) named their proposed productivity index after Swedish Economist Sten Malmquist. As, in the year 1953, Sten Malmquist had used distance functions for the first time, to define a quantity index, as ratios of distance functions, when multiple inputs and outputs are involved. Caves et. al., (1982) had used distance function approach of Sten Malmquist, to define their TFP index in a theoretical framework. They also referred to the original paper authored by Sten Malmquist. Although the research work of Caves et. al., (1982) became very popular, but computational use of Malmquist TFP Index increased only after research work of Färe, Grosskopf, Lindgren and Roos (1992). Fare et. al., (1992) calculated the Malmquist TFP Index, using the fact that the distance functions, which are used to evaluate Malmquist TFP index, can be related to the technical- efficiency measures proposed by Michael J. Farrell (1957). In other words, Fare et. al., (1992, 1994) made use of the connection between Farell's measures of technical efficiency (1957), Charnes et. al., (1978)'s DEA and Caves et. al., (1982)'s Malmquist Productivity Index, to introduce the DEA estimation method for the Malmquist TFP index (FGLR model) (Cooper et. al., 2011). The main contribution of Fare et. al., (1992) was the consideration of inefficiency of DMUs, and using DEA to calculate distance functions.

Fare et. al., (1992) had defined Malmquist TFP index as geometric mean of two Malmquist indices suggested by Caves et. al., (1982) in reference to the technology at time periods t and $t + 1$. Another achievement of Fare et. al., (1992) was to demonstrate that Malmquist TFP indices could be decomposed into two factors, Efficiency Change (EC) and Technological Change (TC), over time, assuming constant returns to scale (i.e. MPI = EC × TC).

Further Färe, Grosskopf, Norris and Zhang (FGNZ model) (1994) considered variable returns to scale to extend the decomposition of MPI into three factors Pure Technical Efficiency Change (PTEC), Scale Efficiency Change (SEC) and Technical Efficiency Change (TEC) (i.e. MPI = PTEC × SEC × TEC. This development made the Malmquist TFP index, quite a famous empirical method, to evaluate the change in productivity (Arjomandi et. al., 2011).

In literature, there are many decompositions of Malmquist TFP Index, proposed by various researchers. To mention a few are as follows, **Ray and Desli (1997)** gave a three-factor decomposition of Malmquist TFP index, to measure technical efficiency change based on VRS-based framework. **Simar and Wilson (1998)** & **Zofio and Lovell (1998)** gave a four-factor decomposition of Malmquist TFP Index. **Zofio (2007)** proposed a decomposition of Malmquist Index including all components popular in literature. **Alirezaee and Afsharian (2010)** offered a four-factor decomposition of Malmquist TFP Index, with a new component giving the contribution of changes in regulation efficiency.

Other researchers have also attempted productivity measurement by extending Malmquist TFP index. For example, **Berg et. al., (1992)**proposed an approach to determine the Malmquist TFP index, by comparing adjacent periods, using a benchmark technology related to the base period. **Chung et. al., (1997)** gave a Malmquist Luenberger indicator to measure productivity growth in presence of some undesirable outputs. **Grifell-Tatje et. al., (1998)** proposed a quasi- MI applying quasi-distance functions. **Zofio and Lovell (2001)** suggested Hyperbolic MI using Hyperbolic distance functions. **Chen (2003)** developed a MI using slack based distance functions**. Shestalova (2003)** suggested to measure the Malmquist index using sequential technology, which computes Malmquist index as a single measure of productivity change. **Pastor and Lovell (2005)** proposed Global Malmquist index based on all observations from all contemporaneous technologies. **Portela and Thanassoulis (2010)** presented Meta-Malmquist index for measuring productivity change over time where some of inputs and/or outputs take negative values. **Afsharian and Ahn (2015)** proposed Overall Malmquist index, generating a single measure of productivity change. **Alirezaee M. and Tanha M (2015**) extended Malmquist index by considering 'Balance Factor' with an objective to compute that to what extent DMUs are aligned with strategies defined by policy-makers. It is observed that Malmquist index has been decomposed into factors, depending on the need of researcher. For the purpose of present research, basic decomposition of Malmquist productivity index (Fare et. al., 1992) has been used.

Malmquist indices of TFP calculate the change in total output relative to inputs (Sakar B., 2006). Mohammadreza A. and Mohsen A., (2011) stated that The Malmquist productivity index is an important and widely used index for measuring relative productivity change DMUs in multiple time periods. Fare et. al., (1994) termed Malmquist productivity index as 'more general', as it considers the possible inefficiency in the DMU, along with measuring productivity and does not presume an underlying functional form for technology. Malmquist TFP Index enjoys a vast area of applications due to the ease of calculations. MI is based on distance functions which can be calculated by either a parametric technology (e.g. Fisher Index, Tornqvist Index) or a non-parametric technology (e.g. Data Envelopment Analysis). This compatibility of Malmquist Index, with other methods, adds to its benefits and increases its application area. The Malmquist TFP indices differ according to the orientation used (Coelli et. al., 2005). The distance functions in Malmquist Index can be calculated with an output orientation, which focuses on producing the maximum level of outputs using a fixed level of inputs, in reference of a fixed production technology or with an input orientation, which focuses on the minimum level of inputs required to produce fixed output levels, under a reference technology. The input and output oriented Malmquist TFP index results in the same value, if the technology in reference, in two time periods follows the constant returns to scale. Malmquist TFP Index determines the change in the level of productivity, between time periods by calculating the efficiency measure for one year relative to that of previous year. Its noteworthy that this measure is non-transitive and thus cannot be used to estimate cumulative impacts over time.

3. JUSTIFICATION OF STUDY

In the present study, MPI with constant returns to scale was considered as Grifell-Tatje' and Lovell (1995) proved that Malmquist TFP index may not correctly measure TFP changes when variable returns to scale is assumed. The model has been applied to measure productivity of Indian Public Sector Banks (PSBs) where the returns are constant. Indian PSBs are a critical segment of Indian Financial System which were formed with the basic objective of generating surplus from the masses and lending the same for productive uses. Since 1991, with the liberalisation and privatisation of Indian economy, these banks are facing intense competition from the Private Sector Banks which are technologically more advanced since their inceptions. So, it becomes altogether important for PSBs to operate with total productivity so as to sustain in the environment of competition. Moreover, continuous increase in the level of non-performing assets, ever increasing customer demand, adoption of computerisation has necessitated the measurement of its overall efficiency.

4. REVIEW OF LITERATURE

This Section provides review of existing literature related to application of Malmquist TFP Index on Banks in India and abroad.

Neal (2004) examined the differences in efficiency between various types of banks in Australia between 1995 and 1999 using Malmquist Productivity Index (MPI). It was found that TFP grew by an average 7.6% annually. **Ausina, Tatje, Armero and Conesa (2004)** analysed the efficiency of 50 Spanish Savings Banks for the period 1992-1998, considering two sub-periods 1992-1995 and 1995-1998, using DEA based Malmquist productivity index, assuming constant returns to scale following Intermediation approach. They found that about 90% of firms grew in terms of productivity over the period 1992-1998, only 10% of firms suffered productivity decline. **Sakar (2006)** investigated Turkish commercial banking performance listed in Istanbul Stock Exchange using Malmquist DEA analysis on 11 Turkish banks during ten quarters between 31 Dec 2002 to 31 March 2005, with an output orientation, using variable returns to scale. Out of total 11 banks, six banks were found to be highly efficient and able to generate maximum output with the given set of inputs. **Lin, Hsu and Hsiao (2007)** investigated the relative efficiency of management and variation of managerial efficiency among 37 domestic banks in Taiwan, using Malmquist Index. They recommended the usage of Malmquist Index for the formulation of a marketing strategy. **Arjomandi, Valadkhani and Harvie (2011),** employed bootstrapped Malmquist indices and efficiency scores developed by Simar and Wilson (1998 b, 1999) to investigate the effects of government regulation on the performance of the 14 Iranian Banks, over the period 2003-2008 following an intermediation approach. They found that the industry efficiency level improved over the period 2003-2006 and deteriorated soon after the regulatory changes were introduced. **Bi, Ding, Luo and Liang (2011)** formulated a mixed linear integer programming model using a DEA based Malmquist productivity index. They illustrated the approach by an application to 17 branches of Bank of China in Anhui Province, which resulted to show a slight decrease in productivity during the year 2007-08 and the productivity change positively during 2008-09 due largely to efficiency increase. **Gitau, Gor (2011)** examined the productivity of commercial banks in Kenya in the context of liberalization from a time series dataset using Malmquist index of total factor productivity for a sample of 34 banks for the period 1999-2008, assuming constant returns to scale. Productivity measured by Malmquist index was found to be equal to 0.973, which means that total productivity decreased by 2.7%. Technological change index was found to be equal to 0.967 and technical efficiency change index was found to be 1.006. **Liu, Chuang and Huang (2011)** measured the operating efficiency and productivity of banking subsidiaries under 11 financial holding companies, between 2003 and 2007 in Taiwan using Malmquist Productivity index (MPI). They combined the GRA, DEA and MPI to create a performance evaluation model. They found that some of banks had inefficiencies due to lack of scale and few others due to lack of technical efficiency. **Raphael (2013)** used DEA based MPI to examine Tanzanian commercial banks and found that most of the commercial banks had shown improvement in efficiency by 67%. **Asmild, Paradi, Aggarwal and Schaffnit (2004)** evaluated the performance of Canadian banking industry, over the twenty years' period, 1981-2000 using Malmquist Indices from DEA scores. It was observed that the standard decomposition of either the adjacent or the base period Malmquist index into frontier shift and catching up effects was not appropriate when based on DEA window analysis scores.

Howcroft and Ataullah (2006) applied a DEA-type Malmquist Total Factor Productivity Index to examine productivity growth in the commercial banking industries of India and Pakistan during 1992-98. It was found that in India, the loan-based model revealed an improvement in TFPCH of around 4.6 percent for the entire study period and income-based model showed a comparable improvement of 4.2 percent. **Mahesh and Rajiv (2007)** examined the changes in the Total Factor Productivity (TFP) of 62 Indian Commercial Banks for the period 1985-2004, by using Malmquist Productivity Index, assuming constant returns to scale, following an output oriented Production approach, considering four different bank groups: (1) State Bank of India and Associates (SBI & A) (2) Nationalized Banks (NB) (3) Private Banks (PB) (4) Foreign Banks. Three outputs were taken as deposits, loan and Investments. Three inputs used were labour, fixed capital and material. They found that on an average there is productivity growth of the total banking sector over the period of study. **Pal, Bishnoi (2009)** applied Malmquist TFP index on panel data of 63 commercial banks operating in India from 1996-2005 with a focus on three major approaches (a) asset approach (b) value added approach and (c) income approach. It was found that national public sector banks had attained the highest growth in overall productivity and its components under the asset and income approaches. The foreign sector banks had performed better than other categories of banks for value addition approach. **Sekhri (2011)** compared 62 banks operating in India, over 2004-09, including 20 public sector banks, 17 private banks and 25 foreign banks, using Malmquist TFP growth measure. It was found that the foreign sector banks scored a high TFP mainly because of their high technical efficiency change and the public sector banks performed better than foreign & private banks in pure efficiency change index. **Casu, Ferrari and Zhao (2013)** examined the impact of regulatory reforms on Productivity growth and its components for all commercial Indian Banks, including Foreign, domestic private and state owned Banks, from 1992 to 2009, using Malmquist TFP index and a parametric meta frontier Divisia index. Both DEA and SFA results indicate relatively high levels of efficiency, which worsen after 1998. Results were found to be consistent for state owned and Foreign Banks. **Pandey and Singh (2015)** examined 40 banks in India including 26 public sector banks, 10 private banks and 4 foreign banks during the period 2008-2013, using Malmquist Productivity Index using panel data. They found that the whole banking system in India had a positive growth during the period of study.

Although, a number of studies analysing the efficiency of Indian banks in a cross-sectional manner as well as based on panel data, already exist in the literature. But even then, it has been found by a detailed review of literature that there is a huge gap in terms of the time periods taken and the banks under study. Thus it is difficult to comment on the overall change in efficiency of Indian Public Sector Banks in post-liberalisation period that is 1998 onwards. The present paper is an attempt to analyse the productivity of Indian Public Sector banks in the period starting from the year 1998 to the year 2013.

5. OBJECTIVES

The primary objective of the present study is to measure efficiency of Indian Public Sector banks using a non-parametric technique of measuring efficiency i.e. Data Envelopment Analysis (DEA) based Malmquist Productivity Index (MPI). However, the specific objectives are as follows:

1. To analyse the TFP change of each public sector bank operating in India, during the time period 1998 to 2013.
2. To analyse the efficiency changes of public sector banks operating in India.
3. To analyse the technical change of public sector banks operating in India.

6. HYPOTHESIS

On the basis of above stated objectives, following hypotheses have been created.

$H_{1,0}$: The TFP of majority of the Public Sector Banks operating in India changed positively.

$H_{1,1}$: The TFP of majority of the Public Sector Banks operating in India changed negatively.

$\mathbf{H_{2,0}}$: TFP changed positively due to positive change in EC.

$\mathbf{H_{2,1}}$: TFP changed positively due to positive change in TC.

7. DATA BASE AND RESEARCH METHODOLOGY

This study is based on the efficiency analysis of 25 public sector banks, operating in India, for the period of 15 years i.e. from 1998-99 to 2012-13. The data were obtained from the Statistical Tables Relating to Banks in India published by the Reserve Bank of India. For the purpose of uniformity in Data, the IDBI Bank and the Bhartiya Mahila Bank were eliminated as these banks were formulated in the year 2011 & 2015 respectively.

For the analysis, a non-parametric, input oriented DEA based Malmquist Productivity Index (FGLR & FGNZ) model has been used, with constant returns to scale, taking four inputs and two outputs. Inputs are considered to be Owned funds, Deposits, Borrowings and Wage bills. Whereas, outputs have been taken as, Spread and Other income.

Table 1 presents the list of Banks under Study.

Table 1
List of Banks under study

SBI & Associates	*Other Nationalized Banks*
1. State Bank of India	1. Allahabad Bank
2. State Bank of Bikaner and Jaipur	2. Andhra Bank
3. State Bank of Hyderabad	3. Bank of Baroda
4. State Bank of Mysore	4. Bank of India
5. State Bank of Patiala	5. Bank of Maharashtra
6. State Bank of Travancore	6. Canara Bank
	7. Central Bank of India
	8. Corporation Bank
	9. Dena Bank
	10. Indian Bank
	11. Indian Overseas Bank
	12. Oriental Bank of Commerce
	13. Punjab National Bank
	14. Punjab and Sind Bank
	15. Syndicate Bank
	16. UCO Bank
	17. Union Bank of India
	18. United Bank of India
	19. Vijaya Bank

8. MATHEMATICAL FORMULATION OF MALMQUIST TFP INDEX

The Malmquist TFP index measures the change in productivity of a DMU, between two data periods (coelli et. al., 2005) t_1 and t_2, by calculating the ratio of the distances of each data point relative to a common technology.

Let us assume that in period t_1, a firm uses input x^{t_1} to produce output y^{t_1} and in period t_2 the same firm uses input x^{t_2} to produce the output y^{t_2} .

Let S_t be the production set at time t, defined as

$$S_t = \{(x^t, y^t): x^t \text{ can produce } y^t \text{ at time } t\}$$

where, x^t is an input vector and y^t is an output vector such that $x^t \in R_+^N$ and $y^t \in R_+^M$ at time t. Assuming that (i) is convex (ii) all production requires the use of some inputs i.e. $(x^t, y^t) \notin S_t$ if $y^t \geq 0$, $x^t = 0$ (iii) Both inputs and outputs are strongly disposal i.e. if $(x^t, y^t) \in S_t$, then $\bar{x} \geq x^t(\bar{x}, y^t) \in S_t$ and $\bar{y} < y^t$ ϕι $(x^t, \bar{y}) \in S_t$. An input distance function defines the production technology according to the most contracted input vector when the output vector is given. Similarly, an output distance function defines the production technology according to the most expanded output vector when the input vector is given. Following Fare et. al., (1994), an output distance function, for a firm, at time t_1, is defined as

$$D^{t_1}(x^{t_1}, y^{t_1}) = \inf\left\{\theta \in R \,\middle|\, \left(x^{t_1}, \frac{y^{t_1}}{\theta}\right) \in S_{t_1}\right\} \tag{1}$$

The distance function (1) can also be defined as the inverse of Farrell's (1957) technical efficiency measure i.e.

$$D^{t_1}(x^{t_1}, y^{t_1}) = (\text{Sup}\{\theta \in R \mid (x^{t_1}, \theta y^{t_1}) \in S_{t_1}\})^{-1} \tag{2}$$

(1) gives the maximum proportional change in the outputs y^{t_1} with the same inputs x^{t_1}, at time t_1 and θ is the ratio of current output quantity to the maximum achievable multiple of that output quantity, with present quantity of inputs. Also, $D^{t_1}(x^{t_1}, y^{t_1}) \leq 1$, with $D^{t_1}(x^{t_1}, y^{t_1}) = 1$ iff DMU is efficient and further increase in output y^t with same input x^t is not possible i.e., (x^{t_1}, y^{t_1}) is on boundary (or frontier) of technology and $D^{t_1}(x^{t_1}, y^{t_1}) < 1$ iff $(x^{t_1}, y^{t_1}) \in S_t$.

Also,

$$D^{t_2}(x^{t_2}, y^{t_2}) = \inf\left\{\theta \in R \,\middle|\, \left(x^{t_2}, \frac{y^{t_2}}{\theta}\right) \in S_{t_2}\right\} \tag{3}$$

To compute Malmquist productivity index, we define

$$D^{t_1}(x^{t_1}, y^{t_1}) = \inf\left\{\theta \in R \,\middle|\, \left(x^{t_2}, \frac{y^{t_2}}{\theta}\right) \in S_{t_1}\right\} \tag{4}$$

where, $D^{t_1}(x^{t_2}, y^{t_2})$ gives the maximum proportional change in outputs y^{t_2} with same inputs x^{t_2}, at time t_1.

and

$$D^{t_2}(x^{t_1}, y^{t_1}) = \inf\left\{\theta \in R \,\middle|\, \left(x^{t_1}, \frac{y^{t_1}}{\theta}\right) \in S_{t_2}\right\} \tag{5}$$

where $D^{t_2}(x^{t_1}, y^{t_1})$ gives the maximum proportional change in outputs y^{t_2} with same inputs x^{t_2}, at time t_2.

Caves, Christensen and Diewert (1982) had defined Malmquist productivity index with reference to the technology of initial period, t_1 as:

$$M^{t_1} = \frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \tag{6}$$

Or alternatively, with reference to the technology of final period, t_2 as

$$M^{t_2} = \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_1}, y^{t_1})} \tag{7}$$

To avoid an arbitrary choice of reference technology, Fare et. al., (1992, 1994) defined the Malmquist productivity index of TFP, between periods t_1 and t_2; $t_1 < t_2$, as the geometric mean of M^{t_1} and M^{t_2},

$$M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = \left(\frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_1}, y^{t_1})} \right)^{\frac{1}{2}} \tag{8}$$

Equation (8) can also be written as:

$$M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = \frac{D^{t_2}(x^{t_2}, y^{t_2})}{D^{t_1}(x^{t_1}, y^{t_1})} \left(\frac{D^{t_1}(x^{t_2}, y^{t_2})}{D^{t_2}(x^{t_2}, y^{t_2})} \frac{D^{t_1}(x^{t_1}, y^{t_1})}{D^{t_2}(x^{t_1}, y^{t_1})} \right)^{\frac{1}{2}} \tag{9}$$

Equation (9) is the decomposition of the Malmquist productivity index into two factors. The first factor outside the bracket represents the efficiency change (or catching-up effect) component and the second factor, with the bracket, represents the technological change (or Innovation).

Thus for constant returns to scale,

$$\text{TFP change} = \text{Change in Efficiency} \times \text{Change in Technology} \tag{10}$$

If the level of inputs and outputs remains same from time period t_1 to t_2 i.e. $x^{t_1} = x^{t_2}$ and $y^{t_1} = y^{t_2}$ then Malmquist index given by eq. (8) indicates no change in productivity and $M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1}) = 1$. In this case value of efficiency change and technological change are reciprocal of each other, but not necessarily equal to one, individually.

There is an improvement or deterioration in productivity, over the time period, if the value of $M(x^{t_2}, y^{t_2}, x^{t_1}, y^{t_1})$ is greater than or less than unity, respectively. Also, any component of Malmquist index indicate improvement if it has value greater than one and show deterioration if its value is less than one.

Although, the value of Malmquist index is equal to the product of efficiency change and technical change, but these components EC and TC can have values moving in opposite directions i.e. the value of one component may increase and that of the other can decrease, at the same time resulting in corresponding increase or decrease in the value of Malmquist index.

There are various methods for measuring distance functions, and the most famous is linear programming method. But since the research work of Fare et. al., (1992), Empirical calculation of MPI using DEA i.e. a non-parametric linear programming technique has become popular.

Following Fare et. al., 1992, distance functions are calculated by using non-parametric linear programming technique, DEA.

To calculate the change in productivity of DMU '*k*' from the time period t_1 to t_2, four linear programming problems are solved to find the values of distance functions $D^{t_1}(x^{t_1}, y^{t_1})$, $D^{t_1}(x^{t_2}, y^{t_2})$, $D^{t_2}(x^{t_2}, y^{t_2})$ and $D^{t_2}(x^{t_1}, y^{t_1})$.

For each $k = 1, 2, \ldots, K$

$$[D^{t_1}(x^{k,t_1}, y^{k,t_1})]^{-1} = \max \theta^k$$

$$\text{Such that} \quad \theta^k y_m^{k,t_1} \leq \sum_{k=1}^{K} z^{k,t_1} y_m^{k,t_1} \;;\; m = 1, \ldots, M.$$

$$\sum_{k=1}^{K} z^{k,t_1} x_n^{k,t_1} \leq x_n^{k,t_1} \;;\; n = 1, \ldots, N.$$

$$z^{k,t_1} \geq 0 \;;\; k = 1, \ldots, K \qquad (11)$$

$$[D^{t_2}(x^{k,t_2}, y^{k,t_2})]^{-1} = \max \theta^k$$

$$\text{Such that} \quad \theta^k y_m^{k,t_2} \leq \sum_{k=1}^{K} z^{k,t_2} y_m^{k,t_2} \;;\; m = 1, \ldots, M.$$

$$\sum_{k=1}^{K} z^{k,t_2} x_n^{k,t_2} \leq x_n^{k,t_2} \;;\; n = 1, \ldots, N.$$

$$z^{k,t_2} \geq 0 \;;\; k = 1, \ldots, K. \qquad (12)$$

$$[D^{t_1}(x^{k,t_2}, y^{k,t_2})]^{-1} = \max \theta^k$$

$$\text{Such that} \quad \theta^k y_m^{k,t_2} \leq \sum_{k=1}^{K} z^{k,t_1} y_m^{k,t_1} \;;\; m = 1, \ldots, M.$$

$$\sum_{k=1}^{K} z^{k,t_1} x_n^{k,t_1} \leq x_n^{k,t_2} \;;\; n = 1, \ldots, N.$$

$$z^{k,t_1} \geq 0 \;;\; k = 1, \ldots, K. \qquad (13)$$

$$[D^{t_2}(x^{k,t_1}, y^{k,t_1})]^{-1} = \max \theta^k$$

$$\text{Such that} \quad \theta^k y_m^{k,t_1} \leq \sum_{k=1}^{K} z^{k,t_2} y_m^{k,t_2} \;;\; m = 1, \ldots, M.$$

$$\sum_{k=1}^{K} z^{k,t_2} x_n^{k,t_2} \leq x_n^{k,t_1} \;;\; n = 1, \ldots, N.$$

$$z^{k,t_2} \geq 0 \;;\; k = 1, \ldots, K. \qquad (14)$$

where, k^{th} DMU, (for $k = 1, \ldots, K$) uses inputs $x_n^{k,t}$ ($n = 1, \ldots, N$) to produce outputs $y_m^{k,t}$ ($m = 1, \ldots, M$), at time t. $z^{k,t}$ is the variable indicating that to what extent, k^{th} DMU is employed in production process.

9. FINDINGS AND ANALYSIS

The year wise as well as annual average changes in Malmquist Productivity Index of each PSB under study, is given in Table 2. It is observed that in the total time period of fifteen years, from the year 1998-1999 to the year 2012-2013, **State Bank of India (SBI)** had an increased TFP during the years 1998-99, 1999-2000, 2000-2001, 2006-2007, 2011-2012 and 2012-2013 but the TFP for the same decreased during the periods 2001-2002, 2002-2003, 2003-2004, 2004-2005, 2005-2006, 2007-2008, 2008-2009, 2009-2010 and 2010-2011. Overall from 1998 to 2013, annual average TFP of SBI increased by 2.35% with a notable increase of 22.7% in TFP during 2006-2007. **State Bank of Bikaner and Jaipur** had an increase in TFP for the years 1998-1999, 2002-2003, 2004-2005, 2005-2006, 2006-2007, 2007-2008, 2009-2010, 2011-2012 and 2012-2013, whereas the TFP decreased during rest of the years under study. On an average, TFP increased by 2.5% annually, from 1998 to 2013, with a maximum increase of 26.5% in 2009-2010. For **State Bank of Hyderabad,** TFP increased for the years except 1999-2000, 2001-2002, 2003-2004, 2006-2007, 2007-2008 with an average increase of 1.25% annually. Maximum increase of 36.9% in TFP took place in the year 2004-2005. **State Bank of Mysore** has shown an increase in TFP for only seven years namely 1998-1999, 2003-2004, 2004-2005, 2005-2006, 2006-2007, 2008-2009, 2011-2012 and a regress in TFP for rest of the years under study, with an annual average increase of 1.94% and a maximum increase of 25.4% in TFP during the year 2005-2006.TFP of **State Bank of Patiala** shows an increasing trend for most of the years unless showing regress in the years 1999-2000, 2000-2001, 2003-2004, 2007-2008, 2008-2009 and it remains unchanged for the year 2006-2007. The TFP increased maximum by 30.5% during the year 2004-2005 and average annual increase in TFP is 2.52% for this bank. **State Bank of Travancore** shows an increase in TFP only in seven years i.e.

Table 2
Yearwise and Overall Malmquist TFP change of DMUs

DMUs	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*G.M.*
State Bank of India	1.068	1.026	1.088	0.946	0.998	0.96	0.976	0.979	1.227	0.98	0.964	0.995	0.999	1.118	1.066	1.023545638
State Bank of Bikaner and Jaipur	1.109	0.885	0.908	0.776	1.1	0.95	1.048	1.11	1.106	1.1	0.969	1.265	0.965	1.157	1.035	1.025020155
State Bank of Hyderabad	1.067	0.936	1.01	0.864	1.009	0.866	1.369	1.093	0.894	0.942	1.018	1.044	1.071	1.063	1.037	1.012456601
State Bank of Mysore	1.024	0.948	0.949	0.898	0.958	1.021	1.111	1.254	1.194	0.976	1.111	0.907	0.961	1.132	0.927	1.0194484
State Bank of Patiala	1.218	0.862	0.711	1.056	1.049	0.889	1.305	1.235	1	0.856	0.981	1.175	1.048	1.089	1.088	1.02515476
State Bank of Travancore	1.117	0.789	0.981	0.98	0.907	0.962	0.988	1.182	0.997	1.134	0.934	1.259	1.018	1.027	1.006	1.012632676
Allahabad Bank	1.081	0.647	1.054	0.885	0.904	1.053	1.013	1.007	2.527	1.015	0.926	1.286	1.245	1.037	1.127	1.071444441
Andhra Bank	1.123	0.801	1.187	0.863	0.806	0.95	1.128	1.302	0.96	0.976	1.029	1.086	1.04	0.957	1.115	1.012455462
Bank of Baroda	0.972	0.953	1.051	0.982	0.883	0.884	1.173	1.15	0.952	1.032	0.943	1.162	1.072	0.918	1.062	1.00833593
Bank of India	1.087	0.946	1.039	0.816	0.844	0.986	1.352	0.968	0.917	0.975	0.895	1.208	1.091	0.945	1.003	0.996524424
Bank of Maharashtra	0.986	1.013	0.929	0.99	1.065	1.091	1.137	0.863	0.963	0.908	0.969	1.612	1.015	0.958	1.057	1.026028344
Canara Bank	1.044	1.005	1.078	0.759	0.849	1.061	0.998	0.783	6.383	0.87	1.124	0.994	1.245	1.012	1.062	1.113510312
Central Bank of India	1.174	1.058	0.919	0.85	0.929	0.986	0.992	1.139	1.158	0.875	1.041	1.062	1.091	1.128	1.072	1.026665846
Corporation Bank	1.109	0.862	1.092	0.889	0.838	0.954	1.016	1.299	0.984	0.972	0.823	1.292	1.044	0.904	1	0.995871737
Dena Bank	1.153	1.068	1.09	0.694	0.88	0.816	1.434	0.381	17.471	0.929	0.52	2.777	1.078	1.157	1.067	1.176135923
Indian Bank	1.125	0.814	0.938	0.669	1.006	0.772	1.152	1.067	0.942	1.018	0.913	1.199	1.305	1.514	0.797	0.99350051
Indian Overseas Bank	0.936	0.867	0.885	0.98	0.994	1.007	0.974	1.062	1.015	1.119	0.969	1.168	0.936	1.012	1.012	0.992851317
Oriental Bank of Commerce	1.025	0.997	1.038	0.852	0.979	0.89	1.153	1.172	0.978	1.17	0.877	1.382	0.968	1.128	1.014	1.033275242
Punjab National Bank	0.987	1.274	0.931	0.992	0.882	1.018	1.142	1.026	0.96	1.182	0.958	1.074	1.003	1.029	1.037	1.028605294
Punjab and Sind Bank	1.076	0.999	0.867	0.842	0.697	0.817	0.537	0.36	21.288	1.305	0.993	1.084	1.03	1.165	0.875	1.068781789
Syndicate Bank	0.921	1.162	0.893	0.976	1.144	1.059	1.024	1.105	1.163	1.068	0.936	1.182	0.846	1.049	1.086	1.035741588
UCO Bank	0.991	0.891	0.983	0.732	0.944	0.966	1.031	1.104	1.018	1.008	1.029	1.247	0.855	1.072	0.909	0.978649509
Union Bank of India	1.032	1.575	0.691	0.808	1.125	1.052	0.99	1.008	0.905	1	0.965	1.159	1.234	0.958	1.08	1.021955128
United Bank of India	1.347	0.964	0.895	0.721	0.925	0.909	0.969	1.165	1.283	1.405	0.874	0.981	1.174	0.964	0.844	1.010761326
Vijaya Bank	0.95	0.807	0.916	0.996	0.962	0.903	1.096	1.144	0.955	1.086	0.908	1.334	1.194	1.196	1.106	1.027924279
G.M.	1.06494	0.95148	0.95798	0.8661	0.9414	0.9492	1.06858	0.99886	1.4418	1.02855	0.93869	1.20521	1.05487	1.06117	1.01563	1.028729644

1998-1999, 2005-2006, 2007-2008, 2009-2010, 2010-2011, 2011-2012, 2012-2013 and a decrease in the same for rest of the time period under study. The maximum increase in TFP is 25.9% during the year 2009-2010 and annual average increase in TFP is 1.26%. **Allahabad Bank** has an increase in TFP for eleven years and a decrease in TFP only in years 1999-2000, 2001-2002, 2002-2003, 2008-2009. Annual average increase is observed to be 7.2% and the yearly maximum increase of 152.7% took place in the year 2006-2007. For **Andhra Bank**, TFP increases for the years 1998-1999, 2000-2001, 2004-2005, 2005-2006, 2008-2009, 2009-2010, 2010-2011, 2012-2013 and the same decreases for rest of the years, TFP increases maximum by 30.2% in the year 2005-2006 and the annual average increase is 1.25%. **Bank of Baroda** had an increase in TFP during only seven years, namely 2000-2001, 2004-2005, 2005-2006, 2007-2008, 2009-2010, 2010-2011, 2012-2013 and a decrease in others. An average annual increase of only 0.8% is found and the TFP increased by maximum by 17.3% in the year 2004-2005. **Bank of India** has a decline in TFP for most of the years. Only for six years, 1998-1999, 2000-2001, 2004-2005, 2009-2010, 2010-2011, 2012-2013, the TFP had an increase, with maximum increase of 35.2% in 2004-2005 but on annual average there was a decline in TFP by 0.35%. TFP of **Bank of Maharashtra** increased for only seven years, namely 1999-2000, 2002-2003, 2003-2004, 2004-2005, 2009-2010, 2010-2011, 2012-2013 and decreased for other years. Even then, due to a steep increase of 61.2% in TFP during 2009-2010 has helped the bank to maintain an average annual increase of 2.6%. **Canara Bank** has shown an increasing trend in TFP for most of the years except 2001-2002, 2002-2003, 2004-2005, 2005-2006, 2007-2008, 2009-2010. An increase in TFP by 538.3% in 2006-2007 and 24.5% in 2010-2011 have contributed greatly for the annual average increase of 11.35% in TFP of the bank. **Central Bank of India** shows an increase in TFP for the years other than 2000-2001, 2001-2002, 2002-2003, 2003-2004, 2004-2005, 2007-2008. TFP increased maximum by 17.4% in 1998-1999 and average annual increase is 2.67%. TFP of **Corporation Bank** increased for the years 1998-1999, 2000-2001, 2004-2005, 2005-2006, 2009-2010, 2010-2011, remained unchanged for the year 2012-2013 and declined for rest of the years. In spite of a huge increase in TFP by 29.9% in 2005-2006 and by 29.2% in 2009-2010, there is a decline of 0.41% in TFP on an average, annually. Although, **Dena Bank** has shown an increase in TFP for nine years and a decline in the years 2001-2002, 2002-2003, 2003-2004, 2005-2006, 2007-2008, 2008-2009, like many other PSBs under study, but a huge increase of 15.3%, 43.4%, 1647.1%, 177.7% and 15.7% in TFP during the years 1998-1999, 2004-2005, 2006-2007, 2009-2010 and 2011-2012 respectively, has given this bank the maximum average annual increase of 17.61 % in TFP. **Indian Bank** has an increase in TFP in years 1998-1999, 2002-2003, 2004-2005, 2005-2006, 2007-2008 along with a huge increase during 2009-2010 (19.9%), 2010-2011 (30.5%) and 2011-2012 (51.4%). But annual average TFP faces a regress of 0.65% due to a low productivity in rest of the years. **Indian Overseas Bank** has an increase in TFP for the years 2003-2004, 2005-2006, 2006-2007, 2007-2008, 2009-2010, 2011-2012, 2012-2013 and a decline in rest of the years. TFP increased maximum by 16.8%, during the year 2009-2010, but the annual average TFP decreased by 0.71% for the bank. For **Oriental Bank of Commerce**, TFP increased for the years 1998-1999, 2000-2001, 2004-2005, 2005-2006, 2007-2008, 2009-2010, 2011-2012 and 2012-2013, whereas the same decreased for rest of the years. Maximum increase in TFP is observed to be by 38.2%, took place in the year 2009-2010. Also, there is an increase of 3.33% in annual average TFP. **Punjab National Bank** shows an increased TFP in nine years and a decrease in TFP during 1998-1999, 2000-2001, 2001-2002, 2002-2003, 2006-2007, 2008-2009. On an average, TFP increased by 2.9% annually with a maximum increase of 27.4% in the year 1999-2000. **Punjab and Sind**

Bank records an increase in TFP only in six years namely 1998-1999, 2006-2007, 2007-2008, 2009-2010, 2010-2011, 2011-2012 and a decrease otherwise, but a huge increase of TFP, by 2028.8% in 2006-2007, 30.5% in 2007-2008 and 16.5% in 2011-2012, results in an average increase of 6.88% in TFP annually. **Syndicate Bank** has an increased TFP in ten years and decreased TFP in the years 1998-1999, 2000-2001, 2001-2002, 2008-2009, 2010-2011. Highest increased in TFP is observed to be 18.2% during the year 2009-2010 with an annual average increase of 3.5% in TFP. **UCO Bank** shows an increased TFP only in seven years namely, 2004-2005, 2005-2006, 2006-2007, 2007-2008, 2008-2009, 2009-2010 and 2011-2012 whereas a decrease in rest of the years. Anincrease of 24.7% is recorded as highest increase in TFP during the year 2009-2010, but the average annual TFP declines by 2.14%. TFP of Union **Bank of India** increased for most of the years except a decline during the years 2000-2001, 2001-2002, 2004-2005, 2006-2007, 2008-2009, 2011-2012 and remaining unchanged for the year 2007-2008. Maximum increase in TFP is observed to be 57.5% during the year and the average annual increase in TFP is 2.2%. **United Bank of India** has an increased TFP only in five years and decreased TFP in others, but a high increase during 1998-1999 (34.7%), 2005-2006 (16.5%), 2006-2007 (28.3%), 2007-2008 (40.5%) and 2010-2011 (17.4%) results into an average increase of 1.08% in TFP. **Vijaya Bank** has a TFP increase only inthe years 2004-2005, 2005-2006, 2007-2008, 2009-2010, 2010-2011, 2011-2012 and 2012-2013, whereas a decrease otherwise, with highest increase of 33.4% during the year 2009-2010, resulting in an average increase of 2.79% in TFP annually.

Table 3 gives the detailed view of year wise and annual average change in efficiency of all PSBs under study. Most of the PSBs in sample have either shown a decline in efficiency or a slight improvement in efficiency level, on an average annually. To be specific, out of total 25 banks in sample, 16 banks have suffered a regress in efficiency, 2 banks have shown no improvement, 6 banks have shown nominal increase (less than one percent) in efficiency and only one bank (central Bank of India) with an annual average improvement of 1.3% in efficiency level. For a year wise review of the efficiency level of all PSBs under study, it is observed that efficiency improved only for the years 1999-2000 (4.44%), 2004-2005 (4.2%), 2007-2008 (0.8%), 2008-2009 (1.75%), 2010-2011 (3.28%), 2011-2012 (0.73%) and decreased for rest of the years. Overall, the efficiency has declined by 0.57% during the sample period.

As the technology in banking sector has undergone major developments in last two decades, the study of technical efficiency of banks becomes even more important. Table 4 gives the changes which took place for the PSBs year after year. Last row of the table gives average change of all PSBs for corresponding year and last column gives a cumulative change for each PSB, on an annual average, during entire period of study. It is found that Technical efficiency increased for the year 1998-1999 (9.34%), but thereafter it kept on decreasing for next five years till 2003-2004. From 2004-2005 till 2012-2013 it followed an increasing trend except a regress of 7.72% in 2008-2009. Some notable improvements in technical efficiency are during 2006-2007 (45.8%) and 2009-2010 (23.4%). Over the entire period, only Corporation Bank has shown a regress in technical efficiency (0.36%), rest all the PSBs have improved their technical efficiency. Canara Bank has maximum annual average increase of 11.15% in technical efficiency. Overall, for all PSBs in entire time period 1998-2013, technical efficiency increased by 3.47%.

Table 3
Yearwise and Overall Efficiency Change (EC) of DMUs

DMUs	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*G.M.*
State Bank of India	0.954	1.193	1.04	0.923	1.067	0.98	0.949	0.88	1.057	0.946	1	1	1	1	1	0.996862573
State Bank of Bikaner and Jaipur	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
State Bank of Hyderabad	1	1	1	1	1	1	1.166	0.954	0.899	1	1.042	0.959	1	1	1	0.999952866
State Bank of Mysore	1	1	1	1	1	1	1	1	1	1	1.105	0.905	1	1.117	0.895	0.999982664
State Bank of Patiala	1	1	1	1	1	1	1	1.056	1.058	0.895	1.089	0.923	0.995	1.032	1.042	1.004858352
State Bank of Travancore	1	1	1	1.053	0.95	1	1	1	1	1.016	0.985	1	1.112	0.962	0.989	1.003838553
Allahabad Bank	1	1	1.043	0.959	1	1	1	1	1	1.018	0.982	1	1.062	0.983	1.08	1.008024137
Andhra Bank	1.017	0.921	1.125	0.893	0.908	1	1	1.087	0.931	0.988	1.071	0.934	1	1	1.013	0.990429327
Bank of Baroda	0.863	1.072	1.025	1.078	0.866	0.951	1.058	1.054	0.934	1.001	0.951	1.03	0.968	0.949	1	0.984390795
Bank of India	0.952	1.091	0.947	0.902	0.948	1.061	1.22	0.845	0.901	0.971	0.983	1.125	1.074	0.91	0.951	0.987436057
Bank of Maharashtra	0.966	0.934	0.952	1	1.073	1.145	1.075	0.785	0.965	1	1.007	1.039	1.069	0.914	1.027	0.993163455
Canara Bank	0.929	1.157	0.974	0.842	1	1	1	1	1.095	0.913	1.147	0.872	1.033	0.969	1.166	1.001891068
Central Bank of India	1.068	1.133	0.994	0.797	0.943	1	1	1	1	1	1.27	0.831	1.117	1.096	1.045	1.013373372
Corporation Bank	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dena Bank	1.07	1.168	1.076	0.727	0.956	1	1.19	0.841	1	1	1	1	1	1.034	1.032	0.999873272
Indian Bank	0.988	0.976	0.922	0.814	1.047	0.821	1.086	0.988	0.896	1	1	1	1	1	1	0.96630994
Indian Overseas Bank	0.876	0.822	1	1	1	1	1	1	1	1	1.011	1.132	1.015	1.013	0.963	0.986533155
Oriental Bank of Commerce	0.955	1	1	1	1	1	1	1	1	1.004	0.996	1	1	1	1	0.996934047
Punjab National Bank	1	1.182	0.959	0.926	0.952	1	1.14	0.943	0.931	1	1	1	1	1.01	0.99	1.000001046
Punjab and Sind Bank	0.926	1.082	0.853	0.985	0.895	1	1	1	1	1.063	1.032	1.007	1.149	1.181	0.835	0.996100195
Syndicate Bank	0.965	1	1	1	1	1.018	1.071	0.919	1.033	1.057	0.982	0.96	0.972	1	1.04	1.000404985
UCO Bank	0.883	0.929	1	0.811	0.963	0.954	1.152	0.871	0.957	0.983	1.046	1.021	0.9	1.115	0.893	0.961366567
Union Bank of India	0.888	1.708	0.697	0.84	1.053	1.081	1.007	0.872	1	1	1	1	1.114	0.897	1.037	0.994438555
United Bank of India	1.21	1.128	0.934	0.735	0.792	0.963	1	1.027	1.099	1.285	0.903	0.764	1.121	0.969	0.92	0.977844918
Vijaya Bank	0.9	0.878	0.984	0.928	1.006	0.949	1	1	1	1.119	0.899	0.995	1.166	1.085	1.057	0.994605131
G.M.	0.9738	1.0444	0.9777	0.9234	0.9747	0.9954	1.0422	0.9619	0.9888	1.0081	1.0175	0.9767	1.0328	1.0073	0.9968	0.994275108

Table 4
Yearwise and Overall Technical Change (TC) of DMUs

DMUs	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*G.M.*
State Bank of India	1.12	0.86	1.046	1.025	0.935	0.98	1.028	1.112	1.161	1.036	0.964	0.995	0.999	1.118	1.066	1.02674898
State Bank of Bikaner and Jaipur	1.109	0.885	0.908	0.776	1.1	0.95	1.048	1.11	1.106	1.1	0.969	1.265	0.965	1.157	1.035	1.025020155
State Bank of Hyderabad	1.067	0.936	1.01	0.864	1.009	0.866	1.174	1.146	0.994	0.942	0.976	1.088	1.071	1.063	1.037	1.012380201
State Bank of Mysore	1.024	0.948	0.949	0.898	0.958	1.021	1.111	1.254	1.194	0.976	1.006	1.002	0.961	1.013	1.036	1.019477726
State Bank of Patiala	1.218	0.862	0.711	1.056	1.049	0.889	1.305	1.169	0.945	0.956	0.901	1.273	1.053	1.056	1.044	1.02016026
State Bank of Travancore	1.117	0.789	0.981	0.93	0.955	0.962	0.988	1.182	0.997	1.116	0.949	1.259	0.915	1.068	1.017	1.008757181
Allahabad Bank	1.081	0.647	1.01	0.923	0.904	1.053	1.013	1.007	2.527	0.997	0.943	1.286	1.173	1.055	1.044	1.062966359
Andhra Bank	1.104	0.87	1.054	0.966	0.887	0.95	1.128	1.197	1.031	0.988	0.961	1.163	1.04	0.957	1.1	1.022039186
Bank of Baroda	1.127	0.889	1.026	0.911	1.02	0.93	1.109	1.092	1.02	1.03	0.992	1.128	1.108	0.968	1.062	1.024633226
Bank of India	1.141	0.867	1.097	0.904	0.891	0.93	1.107	1.146	1.018	1.005	0.91	1.074	1.016	1.038	1.055	1.009202649
Bank of Maharashtra	1.021	1.085	0.975	0.99	0.993	0.953	1.058	1.099	0.997	0.908	0.962	1.551	0.949	1.048	1.029	1.032956667
Canara Bank	1.124	0.869	1.107	0.901	0.849	1.061	0.998	0.783	5.829	0.952	0.98	1.141	1.205	1.045	0.911	1.111482308
Central Bank of India	1.098	0.934	0.924	1.067	0.986	0.986	0.992	1.139	1.158	0.875	0.819	1.279	0.977	1.029	1.025	1.013052563
Corporation Bank	1.109	0.862	1.092	0.889	0.838	0.954	1.016	1.299	0.984	0.972	0.83	1.292	1.044	0.904	1	0.996434198
Dena Bank	1.078	0.914	1.013	0.954	0.921	0.816	1.205	0.453	17.471	0.929	0.52	2.777	1.078	1.119	1.033	1.176200372
Indian Bank	1.138	0.834	1.017	0.822	0.961	0.94	1.061	1.079	1.051	1.018	0.913	1.199	1.305	1.514	0.797	1.028004355
Indian Overseas Bank	1.069	1.055	0.885	0.98	0.994	1.007	0.974	1.062	1.015	1.119	0.959	1.032	0.923	0.999	1.051	1.006570532
Oriental Bank of Commerce	1.073	0.997	1.038	0.852	0.979	0.89	1.153	1.172	0.978	1.165	0.881	1.382	0.968	1.128	1.014	1.036451154
Punjab National Bank	0.987	1.078	0.971	1.07	0.926	1.018	1.002	1.089	1.032	1.182	0.958	1.074	1.003	1.019	1.047	1.028629093
Punjab and Sind Bank	1.162	0.924	1.016	0.854	0.778	0.817	0.537	0.36	21.288	1.228	0.962	1.076	0.896	0.986	1.048	1.072765981
Syndicate Bank	0.954	1.162	0.893	0.976	1.144	1.041	0.957	1.202	1.126	1.011	0.953	1.232	0.87	1.049	1.045	1.035484355
UCO Bank	1.121	0.96	0.98	0.903	0.98	1.013	0.895	1.267	1.064	1.026	0.983	1.222	0.95	0.962	1.019	1.018124358
Union Bank of India	1.162	0.922	0.992	0.962	1.068	0.973	0.983	1.155	0.905	1	0.965	1.159	1.107	1.068	1.042	1.027588623
United Bank of India	1.113	0.854	0.959	0.981	1.168	0.944	0.969	1.134	1.167	1.094	0.968	1.285	1.047	0.994	0.918	1.033686827
Vijaya Bank	1.055	0.92	0.931	1.073	0.957	0.951	1.096	1.144	0.955	0.971	1.01	1.341	1.024	1.102	1.046	1.033539266
G.M.	1.0934	0.9111	0.9797	0.9378	0.9659	0.9536	1.0253	1.0383	1.4581	1.0203	0.9228	1.2341	1.0214	1.0535	1.0189	1.034673675

Table 5
Average Annual Changes in TFP, Efficiency and Technical Efficiency of DMUs

DMUs	*TFPCH*	*ECH*	*TCH*
State Bank of India	1.023546	0.996863	1.026749
State Bank of Bikaner and Jaipur	1.02502	1	1.02502
State Bank of Hyderabad	1.012457	0.999953	1.01238
State Bank of Mysore	1.019448	0.999983	1.019478
State Bank of Patiala	1.025155	1.004858	1.02016
State Bank of Travancore	1.012633	1.003839	1.008757
Allahabad Bank	1.071444	1.008024	1.062966
Andhra Bank	1.012455	0.990429	1.022039
Bank of Baroda	1.008336	0.984391	1.024633
Bank of India	0.996524	0.987436	1.009203
Bank of Maharashtra	1.026028	0.993163	1.032957
Canara Bank	1.11351	1.001891	1.111482
Central Bank of India	1.026666	1.013373	1.013053
Corporation Bank	0.995872	1	0.996434
Dena Bank	1.176136	0.999873	1.1762
Indian Bank	0.993501	0.96631	1.028004
Indian Overseas Bank	0.992851	0.986533	1.006571
Oriental Bank of Commerce	1.033275	0.996934	1.036451
Punjab National Bank	1.028605	1.000001	1.028629
Punjab and Sind Bank	1.068782	0.9961	1.072766
Syndicate Bank	1.035742	1.000405	1.035484
UCO Bank	0.97865	0.961367	1.018124
Union Bank of India	1.021955	0.994439	1.027589
United Bank of India	1.010761	0.977845	1.033687
Vijaya Bank	1.027924	0.994605	1.033539
G.M.	1.02873	0.995204	1.034674

Table 5 gives the annual average changes of Total Factor Productivity and its decomposition into efficiency change and technical efficiency change. It is observed that over the entire period of study, out of total 25 PSBs, 20 have shown an increased TFP on average annually. Among these 20 banks, five banks i.e. The State Bank of Patiala, The State Bank of Travancore, The Allahabad Bank, The Canara Bank, The Central Bank of India, have shown improvement in Efficiency as well as Technical efficiency, although rate of improvement in efficiency is far less than improvement in technical efficiency, with an exception of The Central Bank of India, which has same rate of improvement in both factors i.e. 1.3 percent. Three banks i.e. The State Bank of Bikaner and Jaipur, The Punjab National Bank and The Syndicate Bank, have shown no improvement in efficiency level but have considerable rate of improvement i.e. 2.5%, 2.9% and 3.5% respectively in technical efficiency. Twelve banks namely, The State Bank of India, The State Bank of Hyderabad, The State Bank of Mysore, The Andhra Bank, The Bank of Baroda, The Bank of Maharashtra, The Dena Bank, The Oriental Bank of Commerce, The Punjab and Sind Bank, The Union Bank of India, The United Bank of India, The Vijaya Bank, have faced a decline in efficiency level, but even then, high rate of growth of technical efficiency (2.7%, 1.2%, 1.9%, 2.2%, 2.5%, 3.3%, 17.6%, 3.6%, 7.28%, 2.76%, 3.37% and 3.35% respectively) of these banks has resulted into, growth of Total Factor productivity.

10. CONCLUSION

As found from Table 5, annual average Total factor productivity increased for 20 public sector banks and decreased for 5 public sector banks. Therefore, majority of public sector banks have increased annual productivity. So, $H_{1,0}$ is true and accepted. Thus, it is concluded that Total factor productivity of majority of PSBs has changed positively. Also, it is found that, majority of public sector banks have shown growth in total factor productivity due to increase in technical efficiency. Therefore, $H_{2,0}$ is false and rejected. Thus, alternative hypothesis, $H_{2,1}$ is true and accepted. Thus, it can be said that total factor productivity changed positively due to positive change in technical efficiency. Further, it can be concluded that Malmquist index is a powerful technique to find the changes in productivity of a DMU, over a period of time. It has a wide application area and has a varied extension, used for various purposes. Despite many advantages, this method has many drawbacks also. A further research is suggested for getting an improved model.

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