Global Economic Crisis and Productivity Changes of Banks in India: A DEA-MPI Analysis

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Abstract   The present study explores the relationship between Global economic crisis (GEC) and productivity growth of Indian banking sector using data envelopment analysis based malmquist index (DEA-MI) for the study period 2005 to 2012, which are partition into three different period *viz.,* pre-crisis, crisis and post-crisis. The empirical result showed that total factor productivity (TFP) for pre and crisis regressed by 7 and 0.6% respectively and post by a slight progress of 0.3%. Comparing technical and technological efficiency changes over the study periods, during pre-crisis, improvements in productivity of Indian banking sector was influenced by technological innovation whereas it went down and technical efficiency influenced the productivity in crisis and post-crisis periods. This may be due to effect of economic crisis and banks would have struggled for survival and hard to concentrate on new technological innovations.

Keywords: productivity changes, Malmquist index, data envelopment analysis, Indian banking sector, Global economic crisis, technical and technological efficiency

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1. Introduction

Economic status of a country is fully depends on its financial system. Banking sector is predominate and plays a key role in the financial system of modern economy. Growth of banks accelerates financial system positively and contributes more in development of a nation. Many researches bear out countries with well equipped banking system develops very faster than weaken one. Indian financial system was very strong due to many reforms and policy changes undertaken by the rulers of the nation over the years. Liberalization, privatization and globalization policy integrated Indian economy with the global economy, which brought many structural changes in major sectors (primary, secondary and tertiary). Indian banking system also changed with technological innovations like internet banking, mobile banking, Automated teller machine (ATM), tele-banking and anywhere and anytime banking. These technical changes made Indian banks to cut their business boundaries and to penetrate into foreign market.

For the past few years' Indian economy showed fast growth but unexpected global meltdown occurred in 2008-09 turned it to downwards trend. It was strongly believed that Global economic crisis (GEC) did not affected Indian banking sector directly, due to limited operations outside India and not directly exposed to sub-prime mortgage assets, and also strong policies and regulations coined by both government and central bank of India. However, Indian banks would have affected indirectly, since, Indian economy was linked strongly with global economy and therefore it is impossible to think India to remain immune to the GEC. Crisis affected India in three different ways *viz.,* financial markets, trade flows and exchange rates. Banking sector, external commercial borrowings and equity markets falls under financial sector and Collapse of Lehman Brothers squeeze the liquidity of global market which made companies to shift their credit demands from external to domestic market and a sudden increase of internal credit demand raised inter-bank call money rate. Credit crisis and collapse of large banks in USA increased the risk aversion of Indian banks and eventually harm credit expansion in the domestic market [1]. With this background it was believed, that there would have been an impact of the crisis on productivity changes of Indian commercial banks. Therefore, the present study was focused to explore productivity growth of Indian banking sector during recent global financial crisis. For this purpose, Malmquist productivity index (MPI) based on DEA was used. MPI estimates the growth of Total factor productivity (TFP), which was a combination of product of technical efficiency change (EC) (Catch-up) and technology change (TEC) (Innovation). Further, EC was subdivided into product of Pure technical efficiency change (PTEC) and Scale efficiency change (SEC). These technical changes will provide a clear picture on the source of productive change and also enables to explore main source for efficiency change (either changes due to improvement in management practices or towards optimal size of commercial banks in India).

The rest of the paper is organized as follows: Section 2 provides the literature review related to productivity growth, Section 3 provides the objective of the current study. In section 4, theoretical construction of DEA based MPI are briefly explained, Section 5 includes selection data and variables for the present study, following that Section 6 presents the results and discussion, and section 7 concludes the study.

2. Literature Review

Numerous research works has been reported on the measurement of productivity growth; and most of them are from developed nations and in that majority, can be seen as studies on industry and agricultural sectors which are the backbone sectors for the economy of a country ([2-19]). In developed countries like U.S. too, research work on bank productivity came into existence in the late 1980's. Even though banking being an important sector for the economical reforms of a nation like India, only few studies were undertaken regarding productivity concern ([20-28]). Studying the banks productivity changes will be more useful for bank managers, policy makers, and share holders. From policy perspective, if productivity of banks increases, it can be used for many purposes *viz.,* to boost the overall performance of banks, reduce the service charges, giving more support and quality service to the customers. Besides these, it would be as a safety net against different type of risk associated to banking sectors.

3. Objective of the Study

The main objective of the present study was to explore productivity changes of commercial India banks.
The present study also focused to explore
- Whether Indian banking sector productivity was gained or lost during three different periods (pre-crisis, crisis and post-crisis).
- Productivity changes occurred due to technical or technological changes.

4. Theoretical Constriction of DEA Based MPI

4.1. DEA Based MPI

Even though Sten Malmquist introduced Malmquist index (MI) to measure the changes of consumption in different period in the year 1953, it was developed only after introducing theoretically in two influential papers ([29,30]). Since malmqusit distance function was used for calculation of TFP by these authors, it was referred as malmquist TFP index. The usage of this method increased in various fields after it was empirically applied by [31], and by combining the ideas of [29,30,31] on the measurement of efficiency and measurement of productivity. [31] Fare *et.al.,* introduced DEA- based MPI in a study of production improvements in Swedish hospital. [33] Mlima defined Malmquist total factor productivity Index (MTFPI) as the ratio of the malmquist output – quantity index to malmquist input-quantity index. The ratio of distance

functions forms the malmquist TFP index, which provides details on degree of production changes and its components [31]. The distance function makes to describe a multi-input and/or multi-output production technology without any specification of a behavioral objective such as cost minimization and profit maximization [34]. The distance function can be viewed in two ways *viz.,* input or output distance functions [35]. The differences between the two are, the input distance functions describes the production by looking at a minimal proportional decrease of the input vector, given as an output vector. Whereas, output uses the given input vector and describes a maximal proportion increase of the output vector. Banks have more control over inputs than outputs, and therefore, in the present study input oriented distance function was used for construction of MTFP – DEA.

4.2. Input Oriented Distance Function

Input oriented distance function is defined as follows. Let us consider a sample N DMUs using $X^t \in R_+^K$ (K X 1) inputs in the production of $Y^t \in R_+^M$ (M X 1) outputs in the time period $t(t = 1, 2, \ldots, T)$ and $P(Y)$ represents the set of all input vectors X, which can produce the output vector, Y. In an input-based approach, the production function was completely characterized by the input distance function, and is defined on input set, $P(Y)$, as follows:

$$D_i^t(Y_t, X_t) = \max\{\delta_t \in (0,1]:(X_t/\delta_t) \in P(Y)\} \quad (1)$$

Where, *i* indicates input oriented measure.

$D_i^t(Y_t, X_t)$ denotes the distance function from the period observation to the period technology. Similarly, for another set of time period say t+1, $D_i^{t+1}(Y_t, X_t)$ indicates the distance function from period t observation to period t+1 technology.
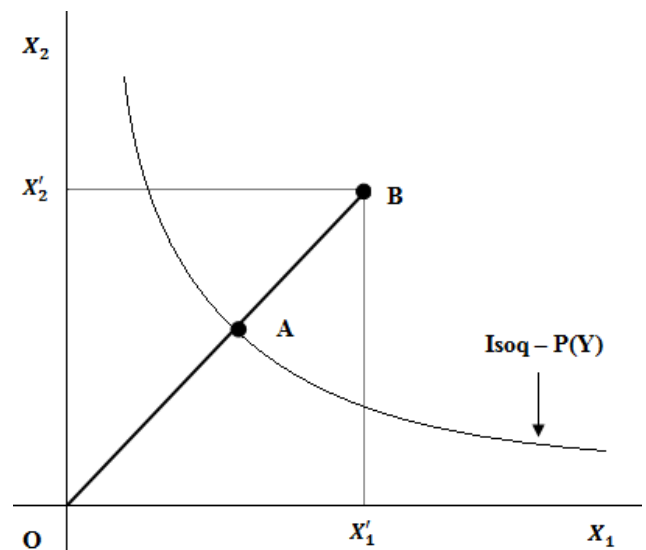

Figure 1. Input oriented distance function and production possible set (Source: Coelli *et. al* (2003) [36])

As an example, an input distance function is illustrated in Figure 1 with two inputs X_1 and X_2 and one output Y and for the given output vector, and production possibility

technology represented by the isoquant, $P(Y)$. The production possible was bounded below by the production possibility frontier. The value of input distance function for the DMU B is equal to the ratio $\delta = \dfrac{OB}{OA}$ and the DMU A is considered technically efficient, as the distance function is equal to one ($\delta = 1$).

Framework of input oriented MPI applied in the present study was illustrated with a diagram (Figure 2). On the assumption that frontier can shift over time, a productive frontier representing the efficient level of output (Y) that can be produced from a given level of input (X) was constructed. The diagram has clearly showed the shift of the frontiers as F(t) and F(t+1). Where, F(t) is the current time and F(t+1) was the future time frontiers. [37] inefficiency is assumed to be present; and the relative movement of any given DMU over time will therefore depend on both its position relative to the corresponding frontier (technical efficiency) and the position of the frontier itself (technology change). If inefficiency is not noticed, then productivity growth over time will be unable to distinguish between improvements that derive from DMU 'catching up' to its own frontier, or those that result from the frontier itself shifting up over time.
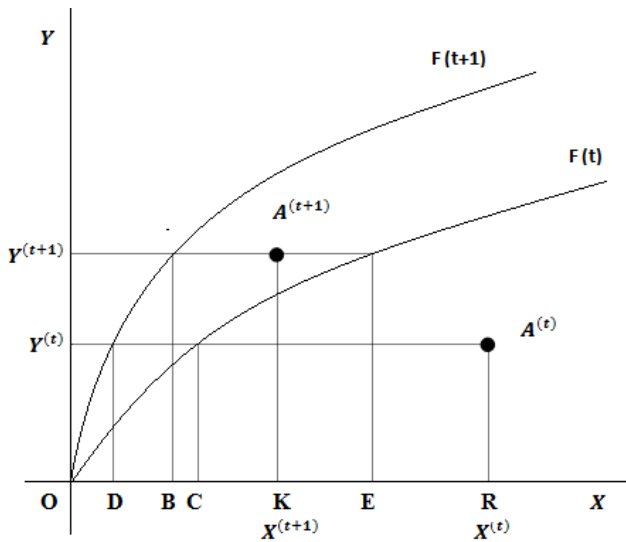

Figure 2. Malmquist index and productivity changes over time (t to t + 1) (Source: Worthington (1999) [37])

In time period t, any DMU can be represented by the input or output bundle $A^{(t)}$, an input-based measure of efficiency can be deduced by the horizontal distance ratio *OC/OR*. Inputs can be reduced in order to make production technically efficient in period *t* (i.e. movement onto the efficient frontier). By comparison, in period *t* + 1 inputs should be multiplied by the horizontal distance ratio *OE/OK* in order to achieve comparable technical efficiency to that found in period *t*. Since the frontier has shifted, *OE/OK* exceeds unity, even though it is technical inefficient when compared to the period *t* + 1 frontier. It was possible to decompose this total productivity change between the two periods into technical change and technical efficiency change by applying input-oriented MPI. Input-orientation refers to the emphasis on the equiproportionate reduction of inputs, within the context of a given level of output.

The input-based MPI between time period t and t+1 can be defined as:

$$M_{t+1}^{I}\left(Y_t, X_t, Y_{t+1}, X_{t+1}\right)$$

$$= \left[\left\{\frac{D_t^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_t^{I}\left(Y_t, X_t\right)}\right\}\left\{\frac{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_{t+1}^{I}\left(Y_t, X_t\right)}\right\}\right]^{0.5} \quad (2)$$

Where, superscript I indicate an input – orientation, $M_{t,t+1}^{I}\left(Y_t, X_t, Y_{t+1}, X_{t+1}\right)$ is the productivity of the most recent production point (Y_{t+1}, X_{t+1}) relative to the earlier production point (Y_t, X_t). And the ratio in the first curial bracket $D_t^{I}\left(Y_t, X_t\right)$ and $D_t^{I}\left(Y_{t+1}, X_{t+1}\right)$ denote the input distance function of DMUs in time t+1 separately with the time t technology as the reference technology. The ratio in the second curial bracket $D_{t+1}^{I}\left(Y_t, X_t\right)$ and $D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)$ denote the input distance function of DMUs in time t+1 separately with the time t+1 technology as the reference technology. Further the above equation 4.2 can be decomposed as below.

$$M_{t+1}^{I}\left(Y_t, X_t, Y_{t+1}, X_{t+1}\right)$$

$$= \frac{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_t^{I}\left(Y_t, X_t\right)}\left[\frac{D_t^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)} * \frac{D_t^{I}\left(Y_t, X_t\right)}{D_{t+1}^{I}\left(Y_t, X_t\right)}\right]^{0.5} \quad (3)$$

$$= EC * TEC$$

$$= EC * TEC^{t+1} * TEC^{t}$$

Where,

$M_{t+1}^{I}\left(Y_t, X_t, Y_{t+1}, X_{t+1}\right) =$ input oriented MPI,

$$EC = \frac{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_t^{I}\left(Y_t, X_t\right)}$$

$$TEC = \left[\frac{D_t^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)} * \frac{D_t^{I}\left(Y_t, X_t\right)}{D_{t+1}^{I}\left(Y_t, X_t\right)}\right]^{0.5}$$

$$TEC^{t+1} = \frac{D_t^{I}\left(Y_{t+1}, X_{t+1}\right)}{D_{t+1}^{I}\left(Y_{t+1}, X_{t+1}\right)}$$

$$TEC^{t} = \frac{D_t^{I}\left(Y_t, X_t\right)}{D_{t+1}^{I}\left(Y_t, X_t\right)}$$

From eq. (3) MPI is the multiplication of two component *viz.,* EC over the same period and measure of TEC as measured by shifts in the frontier measure at period t+1 to t (averaged geometrically). The results can be interpreted as, if MPI > 1 denotes the improvement of productivity change, MPI = 1 no change the productivity and MPI < 1 shows the decline of productivity change. Similarly, TEC and EC can be concluded as if TEC > 1 denotes improvements in technology progress, TC = 1 no change and TC < 1 denotes decline in technology. And EC > 1 improvement in efficiency change, EC = 1 No changes and EC < 1 decline in the efficiency change.

4.3. Computation of Input Orient Distance Function Using DEA

It is necessary to calculate the distance function to find the indices of MI. DEA is a Linear programming approach (LPP), in order to calculate indices and several sets of linear programs needed to be solved. Suppose 10 DMUs for 2 years of time period then calculate 40 LP's have to be calculated. If more time period are added, then a chain index has to be constructed to calculate a three more LP's for each DMUs. If we have T times periods and N DMUs then N x (3T-2) LP's had to calculate. Let us consider number of DMUs (N) = 10, and time period T = 8; 220 LPs have to be calculated. [37] assuming constant return - to - scale (CRS) and input based approach, LPP that is used to construct MTP change index is as follows.

$$\left[D_t^I \left(Y_t, X_t \right) \right]^{-1} = \min_{\theta,\lambda} \theta$$

Subject to constrain

$$-y_{t,i} + Y_t \lambda \geq 0 \quad\quad (4)$$

$$\theta x_{i,t} - X_t \lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_{t+1}^I \left(Y_{t+1}, X_{t+1} \right) \right]^{-1} = \min_{\theta,\lambda} \theta$$

Subject to constrain

$$-y_{t+1,i} + Y_{t+1} \lambda \geq 0 \quad\quad (5)$$

$$\theta x_{it+1} - X_t \lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_{t+1}^I \left(Y_t, X_t \right) \right]^{-1} = \min_{\theta,\lambda} \theta$$

Subject to constrain

$$-y_{t,i} + Y_{t+1} \lambda \geq 0 \quad\quad (6)$$

$$\theta x_{i,t} - X_{t+1} \lambda \geq 0$$

$$\lambda \geq 0$$

$$\left[D_t^I \left(Y_{t+1}, X_{t+1} \right) \right]^{-1} = \min_{\theta,\lambda} \theta$$

Subject to constrain

$$-y_{t+1,i} + Y_t \lambda \geq 0 \quad\quad (7)$$

$$\theta x_{i,t+1} - X_t \lambda \geq 0$$

$$\lambda \geq 0$$

LPP model 1 (eq.4) and model 2 (eq.5) are where the technology and the observation are to be evaluated are from the same period. Whereas, model 3 (eq.6) and model 4 (eq.7) reference technology is constructed from data in one period, and the observation to be evaluated is from other period.

The variable return - to - scale (VRS) DEA model can be obtained by adding constrain $N_1' \lambda = 1$, where I is an N x 1 vector of ones in model 1 to 4 (eq.4 to 7). Overall technical efficiency change (OTEC) and Pure technical efficiency change (PTEC) were obtained by running the above set of LP's with the same data under CRS and VRS. Scale efficiency change (SEC) was measured by dividing OTEC by PTEC. Whether technology or technical efficiency contributes more for gain or loss of productivity, it could be assessed by comparing the values of TEC and EC. If TEC were greater than EC, then technology growth was the main source for productivity gains, whereas if TEC are less than EC, productivity gains were due to efficiency improvements. Efficiency changes are products of PTEC and SEC (EC = PTEC X SEC). If PTEC are greater than SEC, then improvement in efficiency change (increase or decrease) was due to improvement in PTEC, whereas, if vice-versa, then efficiency change was contributed due to improvement in SEC.

5. Selection of Variables and Banks

The present study deals with the secondary data for the years 2005 - 2012 published in web pages of Reserved Bank of India (RBI) and Indian Banks' Association (IBA) are used for the analysis productivity changes of commercial banks in India.
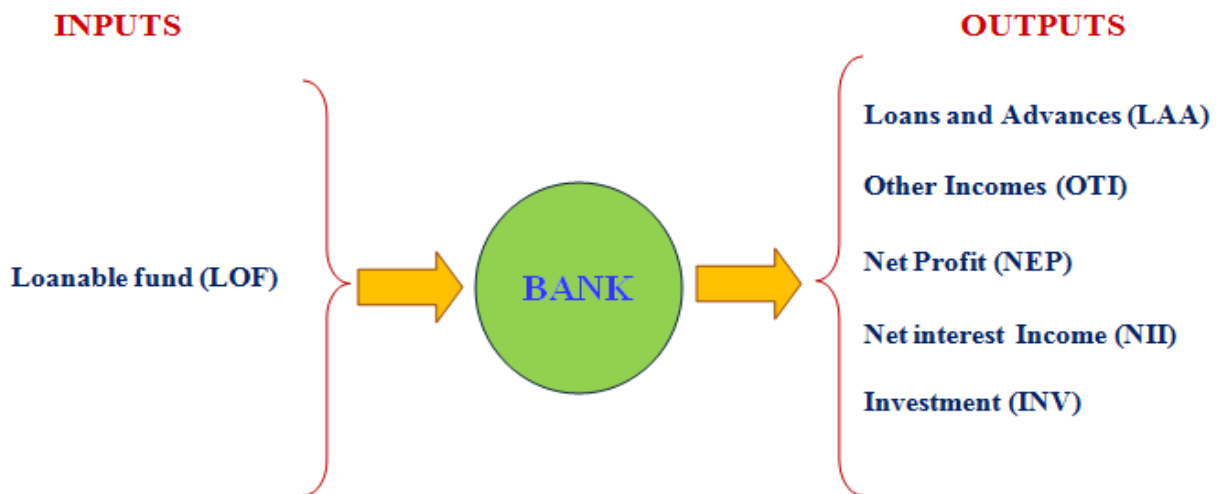

Figure 3. Best set of input and output variables selected through GA

5.1. Selection of Variables

DEA was more sensitive to input and output variables selected. There was a longstanding dispute over what banks produce and what resources banks consume [38].

According to Sealey and Lindley [39], in banking theory literature, there are two approaches for selection of input and output for DEA, *viz.,* production and intermediation approach. Intermediation approach was more suitable and was the most widely used in the banking literature reported by Berger and Humphrey [40]. Therefore, in the present study, intermediation approach was followed to estimate the efficiency of banks. Besides these, different variables to study the banks efficiency were mentioned by various researchers. Omission of relevant variables, inclusion of irrelevant variables and incorrect assumption on return-on-scale are the principal causes of model misspecifications [41]. After careful examination of literatures based on efficiency estimation on Indian commercial banks, maximum number of times repeated input and output variables where selected as initial variables (8 inputs and 7 outputs) and from that best set of variables for the present study was selected through Genetic algorithm (GA) search procedure. For detailed information about variables and selection procedure of best set of variables see [42]. The selected best set of variables for this study is given in following Figure 3.

5.2. Selection of Banks

Commercial banks in India (DMUs) for the present study are determined based on the following criteria i) Banks should be active in the Indian business market for a minimum period of five years (2008 – 2012), ii) Every selected bank should have more than three branches and 100 employees and iii) Banks should not be continuously in loss for two years. Based on the above conditions, 55 commercial banks were selected for the study of which 26 are public sector (six SBI and its association and twenty nationalized banks), 20 private sector (thirteen old and seven new private banks) and 9 foreign banks.

6. Results and Discussion

6.1. Productivity Changes of Commercial Banks in India

The present section summarizes the results of MTFP and corresponding changes in its components for commercial banks in India during pre and post crisis period (2005 to 2012). For computing the MTFP, DEAP - 2.1 version software package which was developed by Coelli was used [34].

Table 1. Means of malmquist index and it's components: summary of commercial banks in India

Bank Codes	EC	TEC	PTEC	SEC	TFPC	Bank Codes	EC	TC	PTEC	SEC	TFPC
B01	0.997	0.982	1.000	0.997	0.980	B30	1.015	0.987	1.019	0.996	1.002
B02	1.004	0.993	1.007	0.997	0.997	B31	1.021	0.984	1.009	1.011	1.004
B03	1.002	0.984	1.004	0.997	0.986	B32	1.001	0.989	1.007	0.993	0.990
B04	1.001	0.986	1.003	0.999	0.987	B33	1.001	0.986	1.007	0.994	0.987
B05	0.995	0.985	0.997	0.998	0.980	B34	1.004	0.996	1.009	0.994	1.000
B06	0.996	0.986	0.998	0.997	0.982	B35	1.016	0.990	1.016	1.000	1.006
B07	0.991	0.986	0.998	0.994	0.978	B36	0.988	0.913	1.000	0.988	0.902
B08	1.012	0.992	1.003	1.009	1.004	B37	1.005	0.875	1.007	0.998	0.879
B09	1.001	0.986	1.006	0.994	0.986	B38	1.019	0.984	1.017	1.001	1.003
B10	1.021	0.988	0.998	1.023	1.008	B39	1.000	1.001	1.000	1.000	1.001
B11	1.000	0.982	1.005	0.995	0.983	B40	1.008	0.991	1.021	0.988	0.999
B12	1.002	0.982	0.989	1.013	0.984	B41	1.004	1.007	1.006	0.998	1.011
B13	0.992	0.985	0.993	0.998	0.976	B42	0.994	1.006	1.000	0.994	0.999
B14	0.995	0.994	0.997	0.999	0.989	B43	1.003	0.983	1.000	1.003	0.986
B15	1.000	0.986	1.004	0.997	0.986	B44	1.021	0.996	1.010	1.011	1.017
B16	1.002	0.985	0.991	1.010	0.987	B45	0.993	1.007	1.001	0.992	1.000
B17	0.994	1.000	1.000	0.994	0.994	B46	0.979	0.953	0.992	0.987	0.933
B18	0.997	0.993	0.999	0.998	0.990	B47	1.000	1.012	1.000	1.000	1.012
B19	1.017	0.986	1.011	1.006	1.003	B48	1.025	0.980	1.027	0.998	1.004
B20	0.988	0.991	0.995	0.993	0.980	B49	1.000	0.986	1.000	1.000	0.986
B21	0.991	0.987	0.994	0.997	0.978	B50	0.965	1.015	1.000	0.965	0.980
B22	1.005	0.983	1.008	0.997	0.988	B51	0.966	0.993	0.981	0.985	0.959
B23	1.015	0.984	1.011	1.003	0.998	B52	1.000	1.084	1.000	1.000	1.084
B24	1.020	0.984	1.006	1.015	1.004	B53	0.975	1.026	1.000	0.975	1.000
B25	0.979	0.986	0.987	0.991	0.965	B54	1.000	0.973	1.000	1.000	0.973
B26	0.986	0.990	0.994	0.992	0.976	B55	1.003	1.008	1.000	1.003	1.011
B27	1.012	0.993	1.012	1.000	1.005	G.M	1.001	0.988	1.003	0.998	0.988
B28	1.011	0.982	1.012	1.000	0.994	% INC	52.73	16.36	49.09	21.82	29.09
B29	1.012	0.974	1.012	1.000	0.986	% NOC	12.73	01.82	23.64	16.36	05.45
						% DEC	34.55	81.82	27.27	61.82	65.45

Source: Authors' Calculation
EC –Technical efficiency change, TEC – Technological efficiency change, PTEC – Pure technical efficiency change, SEC – Scale efficiency change, TFPC – Total factor productivity change, G.M – Geometric mean, %INC – Percentage increased, %NOC – Percentage of no change, %DEC – Percentage decreased.

Table 1 demonstrates the MI summary of overall banks means. As reported earlier, TFP was the product of EC and TEC. Column 2 gives the mean of EC for each individual bank, followed by TEC in column 3. Similarly, EC was the product of Pure efficiency change (PEC) and Scale efficiency change (SEC) which are shown in column 4 and 5 respectively. The averages are calculated using geometric mean due to MTFP which are multiplicative. Column 6 of Table 6.1 represents TFP change. The annual average growth in TFP over the sample period is regressed at the rate of 1.2%. Mean efficient score ranges from 0.879 to 1.084. Overall it was observed that 29 and 66% of banks were in progress and regress respectively and 5% of banks found no changes. B52 stands first with growth of 8.4% and it's followed by B44 with 1.7%. B37 stands last with 12.1% and was preceded by B36 with 9.8% loss in TFP.

Colum 2 exhibits the results of EC, which ranges from 0.965 to 1.025 with mean value 1.001. Twenty nine (53%) banks increased their mean annual efficiency, Seven (13%) banks with no changes was observed and nineteen (35%) banks were found to be declined in mean annual efficiency over years. B48 stands on top with 2.5% increase in EC followed by three banks B10, B31 and B44 with 2.1% increase. EC value was equal to one for banks B11, B15, B39, B47, B49, B52 and B54 shows no changes during transition periods. With 3.5% decline, B50 stands last and it was preceded by B51 with 3.4% decline. Out of 29 banks which showed improvement, three banks belongs to SBI and its associates, nine public sector banks,

eleven old private sector banks, four new private sector banks and two foreign banks.

Similarly, Column 3 of Table 1 shows the mean annual TEC of the commercial banks, and it revealed the following results. The range of TEC lies between 0.875 to 1.084 and its mean value was 0.988. As per TEC approximately 45 (82%) banks showed decreasing trend, nine (16%) banks are in increasing trend and 2% (1) of bank with no change in mean annual efficiency over years (2006 – 2012). B52 stands first with 8.4% increase in TEC followed by B53 with 2.6% improvements. B17 neither improved nor declined in the transition period. Amongst the declined banks, B37 stands last with 12.5% and was preceded by B36 with 8.7% decrease in TEC. Nine banks showed improvement in TEC, of which five banks are from foreign sector banks. Three were new private sector banks and one bank was from old private sector banks. Forty five banks were inefficient in technology, in which, all the SBI and its association banks, nineteen public sectors, twelve were old private, four were new private and four belonged to foreign banks. Results which showed that SBI and its association banks were weak in technology.

As reported above, TFP was product of EC and TEC. Average value of EC was 1.001 and TEC was 0.988 which showed that technological innovation regress were the main sources for the productivity decline of commercial banks in India for entire periods. Technology regressed by 1.2% per annum and at the same time EC improved slightly over the study period. Thus, it could be proved that, annual TFP growth of Indian commercial banks declined because of decline in technology innovation.

Table 2. Average change of total productivity and it's components on overall commercial banks by year wise

Year	EC	TEC	PTC	SEC	TFPC
2006	0.897	1.037	0.980	0.916	0.930
2007	1.020	0.936	0.999	1.020	0.955
2008	1.090	0.939	1.019	1.070	1.023
2009	0.980	1.027	0.999	0.980	1.006
2010	1.006	0.994	1.015	0.992	1.000
2011	0.897	1.110	1.000	0.897	0.996
2012	1.139	0.889	1.009	1.129	1.012
G.M					
Entire Period (2005 – 2012)	1.001	0.988	1.003	0.998	0.988
Pre – Crisis (2005 – 2006)	0.897	1.037	0.980	0.916	0.930
Crisis (2007 – 2009)	1.029	0.966	1.006	1.023	0.994
Post – Crisis (2010 – 2012)	1.009	0.994	1.008	1.002	1.003

Source: Author's Calculation
G.M - Geometric means.

From Table 2 and Figure 4 it was observed that during beginning years of financial crisis EC increased and at the end it declined. In post financial crisis periods, EC declined and increased more steeply. Though lot of fluctuations were seen over years and in many banks, EC declined and some did not shown any changes and banks average annual improvement in EC index was 1.001. An increase in PTEC, improved the average annual EC level. Technology efficiency was just opposite to EC. The beginning two consecutive years showed a decline and improvement in last period of crisis year. Similarly, post financial crisis periods started with decline, improved but again fell down steeply. TFP hit the top in the year 2008 and stooped down in 2006. Due to decline in technology

efficiency, the banks average annual index of TFP was 0.988, and it declined by 1.2%.

From the average of the TFP and other components over three different periods (pre-crisis, crisis and post-crisis) (Figure 5) can be inferred that, during pre and crisis period TFP regress by 7 and 0.6% respectively. In post crisis period, TFP showed slight progress by 0.3%. Further, by observing the technical and technological changes, during the pre-crisis period EC (catch – up) was 0.897 and TEC (innovation) was 1.037 but occurred vice-versa in crisis and post-crisis period (i.e., EC was 1.029 and 1.009 and TEC was 0.966 and 0.994, respectively) which showed that before crisis period, Indian banking sector was influenced by technology innovation which

were the main sources for productivity improvement but after crisis, technology went down and productivity was influenced by technical efficiency changes. It might have happened due to competition between the banks for survival and could not concentrate on the technological improvements.

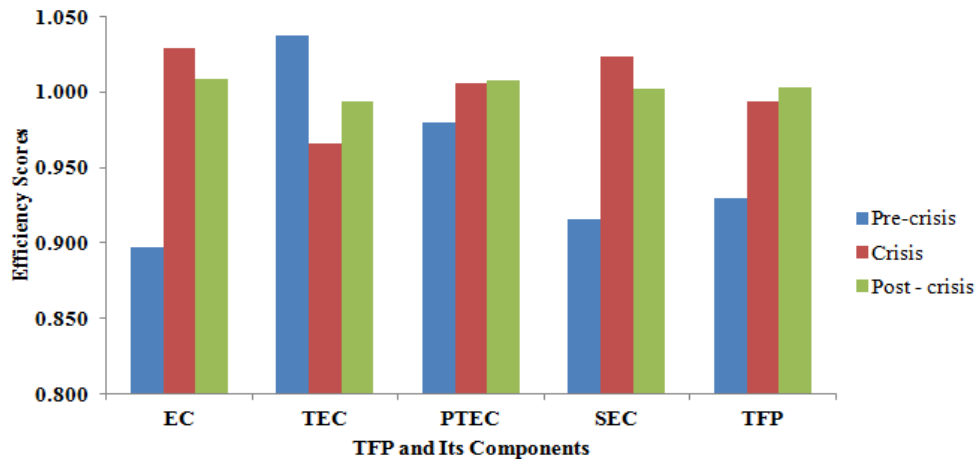**Figure 4.** Annual average shifts in TFP and it's components over the years

Figure 5. Average changes of TFP and it's components over three different Periods

Overall, the results revealed that technological progression in Indian banking sector declined due to financial crisis. Even though financial system of India was strong and the recent financial crisis was not much affected, it slowed down the technological improvements of the banking sector in India. Banks were more conscious on survival than improvement during the crisis period. The results of post-crisis again revealed that technology improvements slowly started to influence in productivity progress.

6.2. Number of Indian Banks Improvements with Respect to TFP Gain or Loss

Further analysis was elaborated by viewing the number of banks experiencing the gain or loss in TFP over the years.

Table 3. Gain and loss in TFP and its components of overall commercial banks in India

Year	N	Components									
		EC		TEC		PTC		SEC		TFPC	
		DEC	INC	DEC	INC	DEC	INC	DEC	INC	LOSS	GROWTH
2006	55	46	04	12	43	29	15	43	07	41	14
2007	55	18	36	42	13	18	28	17	37	31	24
2008	55	02	51	53	02	22	24	05	48	22	32
2009	55	38	12	4	50	21	22	38	12	36	19
2010	55	25	25	32	23	14	29	39	09	24	30
2011	55	51	02	04	51	21	24	50	03	23	30
2012	55	3	50	52	3	20	26	04	49	15	38

Source: Author's Calculation

N – Number of banks, DEC - Decrease (< 1), INC - Increase (> 1), Loss (< 1), Growth (> 1).

Table 3 provides information on the number of commercial banks in India that have a gain and loss TFP. It was found that the number of banks that obtained growth or loss in TFP varied across the study period and a steady growth over the years (except 2009). In the year 2006, out of 55 banks, 41 where in loss and the remaining 14 showed growth and this trend slowly changed over the period of study and number of banks gained in TFP increased. For instance, 38 banks showed improvements and 15 banks declined and one bank did not show any change in the year 2012. Further, it was noticed that during pre-crisis period (2005 – 2006) large number of banks were found in TFP loss. During the crisis period (2007 – 2009) less number of banks in loss was found but was vice-versa in 2009. In post-crisis period (2010 - 2012) it was observed that number of banks, improving were high.

7. Conclusion

The present study explores the relationship between Global economic crisis (GEC) and productivity growth of Indian banking sector using input-oriented data envelopment analysis based on malmquist index (DEA-MI) for the period 2005 to 2012, which are partition into three different period viz., per-crisis, crisis and post-crisis.

Total factor productivity estimated by DEA-MI is product of Technical (EC) and technological (innovations) (TEC). Therefore, it's possible to explore whether EC or TEC influences for changes. Major findings were outlined. Firstly, the research revealed that over the sample period, commercial banks in India as a whole showed productivity regress at the rate of 1.2% per annum. Average value of EC was 1.001 and TEC was 0.988 which showed that technological regress was the main source for the productivity decline of commercial banks in India for entire periods. Secondly, it was found that global crisis had impact on the productivity changes of Indian commercial banks. During per-crisis and crisis periods, TFP declined and in the post crisis period, it had showed slight progress. On observing the technical and technological changes it was found that during pre-crisis period, Indian banks were dominated by the technological changes, whereas during crisis and post crisis period technological progress declined.

Overall, results revealed that technological progression in Indian banking sector declined due to recent financial crisis. Even though financial system of India was strong and the financial crisis (2007 – 2009) not much affected, the technological improvements of the banking sector in India slowed down. Banks were more conscious on survival than new technological innovations during the crisis period. The results of post-crisis revealed, that technology improvements slowly started again to influence in productivity progress.

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