IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Performance and Efficiency: A Comparative Study of Public and Private Sector Banks in India by Stochastic Frontier Analysis

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Abstract

In the 21st-century banking sector has become an integral organ of economic growth and development. The banking sector helps financial stability and maintains the pace of smooth economic growth. In India, after independence, there was the nationalization of banks and the government kept full control of formal banking till 1990 by the implementation of economic reform the government has given space to private and foreign banks. For the last decade, there has been debate on the performance comparability of public and private sector banks as per the government of India public sector banks are not performing well compared to the private sector banks. The comparison criteria are mainly Non-Performing Assets (NPA). Public sector banks' NPA has indeed shown significant growth as compared to private sector bank NPA. For measuring banking performance NPA is a necessary but not sufficient indicator to judge the bank's performance. In this paper, we have examined the comparative performance of public and private sector banks in India through a stochastic frontier approach where we have estimated the total factor productivity, technical progress, scale efficiency, technical efficiency, and econometric analysis. In the production frontier, we have estimated both the used production function Translog production function(TLPF) and Cobb-Douglas production function(CDPF) in each estimation across public and private sector banks. We have used the total earnings of banks as an output variable and also taken two input variables interest extended and operating expenses where formal is a proxy for capital and the latter is a proxy for labour.

Keywords: *Stochastic frontier analysis, Translog production function, Cobb-Douglas production function, Total factor productivity, Scale efficiency, Technical efficiency, Technical change, Time-varying decay inefficiency model, Public sector banks, Private sector banks etc.*

Introduction

Banks are an important backbone of any country it just not only mobilizes the monetary fund but also generates employment and a stable economic system. In India, banking has passed through various phases and has a long history of evolution throughout. It has roots in the Vedic and ancient periods where it was partially regulated in formal genesis. During the Mughal empire it played an important role in credit circulation but the British, who had shown the root of modern banking in India, the first modern bank was established in Calcutta known as Bank of Hindustan in 1770. After that, in 1784 Bengal Bank had been set up and around 1786 General Bank of India was set up but due to its financial crises, these banks could not stimulate the banking services. After independence from colonial rule, in year 1969 Government of India has done major reform in banking sector through nationalisation of fourteen banks. In year 1980 government has again nationalised six more banks. Banking sector has seen the environment of competition and efficiency after 1990 economic reform where private and foreign banks have got entry in formal banking. In India, the banking sector is divided based on ownership namely public, private, and foreign banks, there is a difference in their business orientation. Public banks are operated by the government and their primary goal is to maximize the social and public welfare while private and foreign banks are operated by individual or foreign business entities and their prime goal is to maximize the profit. These all banks have to do business in India under the Reserve Bank of India (RBI) directions and guidelines. The objective of this paper is to examine the different efficiency and performance aspect of public and private sector banks in India by stochastic frontier approach. This paper has also estimated the impact of exogenous change like technological change on banking sector.

Literature Review

Bhatia (1978) examined the financial performance of Indian banking during 1950-68. He concluded that the profitability of the banking sector was satisfactory and banking indicators like deposit concentration and the number of bank offices had an insignificant impact on the bank's performance.

Angadi and Devraj (1983) estimated Indian banks' productivity from 1970-80. Results from 1970-75 showed a decline in productivity in the banking system and between 1970-78 there was productivity improvement but again in 1979, it witnessed a decline in productivity. The public sector banks have indicated a decline of 45.5 percent from 53.3 in 1970 while the productivity of private sector banks improved in 1977 but it was lower than public sector banks. Foreign banks had registered higher productivity than other banks group. They suggest that after nationalization the rapid expansion of bank branches in semi-urban and rural areas with no significant growth of bank business leads to a deceleration of bank productivity.

Vashist (1987), examined the performance of public sector banks in India and measure the six parameters namely net profit, advances, branch expansion, deposit credit, and differential rate of interest from 1971 to 1983. The study concluded that Indian Overseas Bank was performing at the front line while Dena Bank was performing at bottom of the line. The researcher suggested a marketing strategy for banks to improve their performance.

Subramanian and Swami (1994) studied the comparative performance of public and private and foreign banks in India years 199-97. They considered a sample of 6 public sector banks, 4 private sector banks, and 3 foreign banks for study purposes. The authors estimated the operational efficiency in terms of salary and business expenditure per employee. Studies had revealed that a higher level of salary per employee did not result in to decline in bank efficiency. Baroda bank had indicated most efficiency score among Public sector banks while Indus Bank registered higher efficiency among private sector banks and Citi Bank in foreign banks. There was registered much efficiency variation in Nationalised Banks.

Keshari and Pau (1994) study empirically examines whether foreign banks operate with higher efficiency by using the econometric frontier approach where they consider total advances and deposits as output capital, material, and labor input. The results indicated that domestic banks are one percent more efficient than foreign banks while the standard deviation of technical efficiency of domestic banks is slightly less than that of the foreign bank.

Bhattacharya (1997) took a study period of six years from 1984 to 1991 and examined the productive efficiency of 70 commercial banks in Indian. The author applied the stochastic frontier approach to estimate the efficiencies. Output is measured as investment, deposit, and advances, and input is measured in operating expenses and interest expenses. The average efficiencies of the banking industry, public banks, private banks, and foreign banks were found 80.30,87.40,75.88 and 75.37 respectively. They also got no trend in the performance of private banks but saw a temporal improvement in foreign banks' performance there is also found a temporal decline in public banks' performance.

Ramamoorthy(1997) examined the productivity of commercial banks in India from 1991-96 by taking business per employee as a proxy for measuring the productivity of banks. The results indicated that after reform productivity has increased in all banks group. The nationalized banks which were suffering from loss before 1990 have registered the most significant productivity. He argued that the productivity of foreign banks and new private sector banks were not comparable due to their limited operational network and class banking character. He concluded that productivity from the business per employee did not reflect the actual profile and business of banks qualitative and quantitatively. Therefore, productivity should be estimated by considering the different criteria and approaches.

Sarker and Das (1997) studied the productivity, profitability, and financial indicators of the Indian banking system and it included public, private, and foreign banks in year1994-95. They concluded that Public sector banks had performed least as compared to private and foreign banks. However, they suggested that no concrete conclusive inference could be made on basis of a single year of study.

Das. A (2000) investigated the efficiency of Indian public sector banks in the year 1998. He revealed that the State Bank of India group had registered higher efficiency than nationalized banks. The study proposed that banks had to improve their asset quality, congestion of labor, and manage portfolios. Banks would practice the strategy of disbursing risk-free loans.

Prashanta Athma (2000), studied the performance of public sector banks from 1980-94. The study examined customer satisfaction, the growth of basic bank Indicators, and the asset structure of banks. The author found

healthy progress in banking parameters during this period. Banks deposit had registered impressive growth and banks were moving toward risk-free investment.

P.Ganesan (2001) studied the determinants of banks profitability of public sector banks in India. He had concluded that significant determents were a credit to assets, the interest cost, deposit per branch, and interest cost. He also recommended improvement in these determinants for making banks profit more profitable.

T.T.Ram Mohan (2002) had studied the deregulation and performance of public and private sector banks and measure the profitability of banks. He had concluded that public sector banks had improved their profitability but they had not registered much progress in attracting public deposits at the best interest rates. Public sector banks were much behind in the progress of information technology as compared to private sector banks.

Singh (2003), examined the profitability and management of banks during deregulated environments with considering some important banking parameters. He had taken all banks of the Indian banking industry except cooperative and rural regional banks. The study revealed that banks' profitability declined during the deregulation environment. He suggested improving profitability by increasing the source of non-interest income.

Sathye (2003), estimated the efficiency of developing banks in the financial year 1997-98 and applied the DEA model. The author included 27 public sector banks, 33 private sector banks, and 34 foreign banks. The Study had taken staff number and deposit as input variables while non-interest income net loans as output variables in the first model. In the second model income and non-interest income as output variables while expenses and non-interest expenses as input variables. The first model found that public sector banks had registered lower efficiency than foreign banks but more efficiency than private banks. The second model revealed that public sector banks had higher efficiency as compared to both private and foreign banks. The author also concluded that Indian banks had depicted less efficiency than the world's mean efficiency.

Kumbhakar and Sarkar (2003) took the stochastic cost frontier analysis to estimate the efficiency of the banking system in India using panel data for the period 1986-2000. They used a trans log specification of the cost frontier to examine the efficiency of the individual banks. The data was set to 27 public sector banks and 23 private sector banks. The results showed that Indian banks, on average, exhibit evidence of cost inefficiency in their function and operations. However, there is also a tendency for inefficiencies to decrease over time. Further, they found that deregulation in the Indian banking sector resulted in an increase in the cost inefficiency of the Indian banks and a decline in the rate of inefficiency reduction.

De, P. K (2004) examined the 'Other Income of the Banks' and evaluated the trend and progress from 1993-94 to 2001-02. The results from this study revealed that the bank's Other Income had increased at a faster pace as compared to interest income and income from transactions also increased steadily. Researchers concluded that there was the entry of new private sector banks due to rapid growth in the income of these banks. In 2001-02 there had been a tremendous increase in Other Income of the banks.

K. R. Shanmugam, (2004) measured the technical efficiency of Indian banks from 1992 to1999. The study used panel data and applied stochastic frontier analysis(SFA). Net interest margin, credit, investment, and non-interest income were taken as output variables while fixed assets, labor, deposit, and borrowing as input variables. The researcher selected 94 banks from different ownership namely SBI group, nationalized,

private and foreign banks. The finding revealed that private banks and the SBI group had performed better than other groups.

Rajesh Chakrabarti, (2005) studied the efficiency of scheduled commercial banks in India post-liberalization in the years 1990 to 2002. The researcher also investigated the trend in financial indicators during this period. He had considered 70 commercial banks which included 8 SBI group banks,19 public sector banks,28 private sector banks, and 15 foreign banks, and also applied at least 5-year operational criteria of banks. Operation expenses and interest expenses took as input variables while deposit, investment, and advances were used as output variables. The study revealed that foreign banks were doing more profitable business than other groups but based on operational volume foreign banks were performing worst.

Das, Nag, and Ray (2005) studied the output-oriented technical efficiency, cost efficiency, revenue maximizing efficiency, and profit efficiency of Indian (public, private, and foreign) banks for the period 1997 to 2003. They took four inputs for their study borrowed funds (deposits and other borrowings), number of employees, fixed assets and. The results obtained by Das, Nag, and Ray show that the Indian banks are still not much differentiated in terms of output or input-oriented technical efficiency or cost efficiency. However, they differ sharply in respect of profit and revenue efficiencies.

Chatterjee and Sinha (2006) estimated the cost efficiency of commercial banks in India using the Data Envelopment Analysis(DEA) taking the loan as the output measure. Several bank branches and borrowed capital were taken as inputs. The results were for 1996 97,1998-99, 2000-01 and 2002-03 respectively. The results of the cost-minimizing DEA indicated that the mean cost efficiency of the commercial banks decreased in 2002-03 significantly.

Das and Ghosh (2006) evaluated the performance of scheduled commercial banks in India after post banking sector reform. They estimated multiple efficiency scores of individual banks by applying non-parametric DEA techniques. The study used three different approaches namely the value-added approach, operating approach, and intermediation approach in deciding input and output vectors.

Mahesh and Rajeev (2006) estimated the deposit efficiency of scheduled commercial banks in India from 1985 to 2004. They applied stochastic frontier analysis (SFA) to measure deposit efficiency. The result had shown that on average scheduled commercial banks in India were 75 percent efficient as compared to the best DMUs or individual banks in the sample. Public sector banks had registered the highest efficiency among all banks group. The authors have concluded that deregulation and competition had significantly led to the deposit efficiency in Indian banks.

Sanjeev, (2006) measured the technical efficiency of Indian banks after reform1997 to 2001. The researcher used the DEA technique to estimate the efficiency of public, private, and foreign scheduled commercial banks. The author selected a sample of 27 public banks,33 private banks, and 38 foreign banks in the study. Input variables were selected from the intermediation approach where interest income and fee, brokerage charge, and commission were considered while non-interest and interest expenses were taken as an input variable. The finding revealed that all banks' efficiency had improved while foreign banks had performed outstandingly. Sonali private and IndusInd foreign banks were found most efficient individual banks.

Sinha, (2006) conducted a study on the relative efficiency of public and private sector banks in India from 1996 to 2003. The researcher used a non-parametric model where he applied the DEA technique and estimated technical cost and allocative efficiencies. Bank's advances are considered output variables while the number of branches and borrowed capital is input variables. The finding observed that public sector banks had registered less efficiency than private sector banks.

Ali Ataullah and Hang Le (2006) studied the economic reform and bank efficiency of developing countries. The researcher tested the hypothesis of the relationship between three indicators namely, financial reform, private investment, fiscal reform, and efficiency of banks. The results found a positive and significant relationship between bank competition and efficiency while a negative relationship had been indicated in the case of foreign banks. Further, the study concluded the negative impact of fiscal deficit on bank efficiency.

Chatterjee, (2006) studied the efficiency of banks in India and applied a parametric approach for estimation. The stochastic frontier analysis (SFA) had been used to estimate the bank's efficiency. In this study, the author considered 10 banks including 4 banks from the SBI group,2 nationalized banks, 2 new private banks, and 2 foreign banks. The input variable considered labor wage and borrowed funds while the output variable was treated as deposits and advances. Results indicated that SBI group banks were the most efficient however the difference in efficiency among various groups had been narrowed down during this study period.

Rajeev, (2007) estimated the Total Factor Productivity (TFP) of scheduled commercial banks from the 1985 to 2004 period. Banks were categorized on an ownership basis namely SBI Group, Nationalized banks, private banks, and foreign banks. The researcher used Malmquist Index to measure the TFP and they further decompose TFP into technical and efficiency changes. This study used three input variables namely loans, investment, and deposit while fixed capital, material cost, and labor took as input variables. The results had shown that the TFP of scheduled commercial banks in India had increased after a post-liberalization period. Foreign banks had shown the highest TFP growth while SBI Group had registered negative TFP growth. The researcher suggested that the growth in TFP was due to technological change. The results also suggested that the TFP growth is mainly due to technological change than efficiency change.

Pratap, (2007) measured the asset quality of 28 scheduled commercial banks in India and it included 20 public sector banks and 8 private sector banks from the year 2000-01 to 2005-06. Performing assets and assets quality of banks took as output variables while the number of branches, net worth, borrowed capital, and labor was used as input variables. The private sector had showed higher technical efficiency than public sector banks.

Sinha, (2007) examined the comparison of fund-based and non-fund-based efficiency and performance of Indian banks during 2002-03 to 2004-05. The author selected a sample of 20 public banks and 8 private banks for study purposes. He applied a super-efficient approach for the estimation of the efficiency score. The study observed that there was a decline in technical efficiency and the private sector had shown more efficiency than public sector banks. Here, the bank's balance sheets were used as output variables while branches, net worth, and labor were considered as input variables.

Kusum W. Ketkar (2008) studied the productivity growth and efficiency of the schedule commercial banks in India during 1990-95. The researcher used the DEA model for estimating the efficiency of banks and selected only 39 banks. Findings revealed that foreign banks had achieved higher efficient scores than other banks and

the private sector had shown a decline in pure technical efficiency while other banks remained stable. This study suggested that public sector banks need improvement in efficiency scores through the introduction of information technology, improved human skills, and amalgamation of banks.

Das and Ghosh, (2009) examined the financial performance of commercial banks in India during the years 1998 to 2002. The focus of the study was to measure the financial ratios of banks and evaluate the strategy of privatization concerning public banks. The author suggested the strategy of healthy competition and cooperation for the banking sector.

B S Bodla, (2010) measured the efficiency and targets of 29 private sector banks in India from 1998-99 to 2005-06. The researcher used the input-oriented model of the DEA technique and NPASs, interest income, and non-interest had taken as input variables while investment, advances, and deposit had taken as output variables. Bank's efficiency was estimated with CRS and VRS assumptions, a researcher suggested some majors reduce inefficiencies.

Uppal,(2010) investigated the entry of new private banks and their challenge to other sector banks from 1997 to 2008. A researcher focused on estimating the productivity and profitability of banks along with other financial indicators. From the results, it was observed that new private sector banks had higher productivity as compared to public sector banks and this would result from higher competition to public sector banks. On liquidity position, private and foreign banks performed well than public sector banks. Productivity side, private sector banks also performed well as compared to other group banks.

Chhikara et al. (2012) estimated the efficiency of 26 public sector banks in India during the years 2010-11. The study measured the various efficiencies namely, scale, pure and technical. The author revealed that public sector banks on average operated at 98.7 technical efficiencies while seven banks had found inefficient on-scale efficiency and four banks had shown inefficiency on the ground of pure efficiency. Canara Bank and The State Bank of India (SBI) were found to be the worst and the best performers among all the public sector banks.

Ravinder,(2012). examined the performance of 20 Nationalized banks and studied for five years from 2006 to 2010. The researcher considered various parameters namely management efficiency, liquidity, assets management, assets quality, and capital adequacy. Canara Bank and Central Bank of India had performed best and worst in capital adequacy positions. Bank of Baroda and Andhra Bank had registered high and low positions in asset quality indicators. In management efficiency, the Central bank of India got positioned at the bottom and Punjab & Sindh Bank at the top position. Punjab National Banka and Indian Bank are positioned at the top and bottom for earning quality. For the liquidity parameter, the Bank of Baroda got the top place while Union Bank listed last. In the overall ranking, Andhra Bank positioned at the top position and the Central Bank of India stood at last place.

Reddy, (2012) examined the relative positions of scheduled commercial banks using panel data from years 1999 to 2009. A researcher had taken a sample of 26 public banks,19 private banks, and 16 foreign banks. This study used CAMEL ratio analysis and estimated each ratio. Results had shown that 18 banks improved their performance and 19 banks registered deteriorated positions. The study also concluded that post-reform period there were significantly improved indicators of investment and increasing competition.

Ravinder, (2012) studied the performance of Indian banks and took a sample of 20 nationalized banks during 2005-06 to 2009-10. The researcher estimated the composite rank for the individual as well as group ranks. SBI bank had found top rank in this research.

Nandi, (2013) highlighted the financial performance of the schedule commercial banks in India during 2001-02 to 2011-12. Ten public and private sector banks had been considered in this study and applied CAMEL methodology for ratio estimation. Karur Vysya Bank held first place while the Central bank of India at the last position in the capital adequacy indicator. In the overall ranking, the Bank of Baroda stood at first place while ICICI bank positioned the top place among private sector banks, and the Central bank of India and Karnataka Bank were listed at the bottom place from respective groups. The mean score of the CAMEL model rating was higher in public sector banks as compared to private sector banks.

Gupta, (2014) evaluated the financial performance and position of public sector banks in India year from 2009 to 2013. The researcher included 26 banks and used the CAMEL approach with applied one-way ANOVA for analysis. He had considered five indicators namely liquidity, assets quality, capital adequacy, earning quality, and management efficiency. It was observed that there was a significant difference between the mean value of CAMELS ratios. The results revealed that Andhra Bank was the best-performing bank among all public sector banks.

Rajveer Rawlin, (2014) studied the profitability and internal factors of HDFC and SBI banks for ten years from 2004-13. The internal factors included net and gross NPAs, bank size, profit per employee, return on assets, business per employee, operating profit, capital adequacy ratio, and interest and non-interest income. The researcher used step-wise multiple regression for finding empirical relationships. The study revealed that net and gross NPAs, deposits, total assets, and business per employee had positively correlated with profit while non-interest income and working fund were negatively correlated with net profit. The results also concluded that the major profit determinants of HDFC were bank size and advances while SBI bank profit determinant was business per employee.

Gupta and Kaur (2015) measured the financial performance of five public and five private sector banks from 2009 to 2014. The CAMEL model was used to evaluate the financial ratios of banks. The finding from this study revealed that total advance and deposit, CAR, and profit per employee were the most determining factors of a bank's performance.

DATA SOURCES, MEASUREMENT OF VARIABLES AND PERIOD OF THE STUDY

In this study data has been taken from RBI statistical table related to banking. The study period has been considered from 2005-2018. Output variable or dependent variable has been measured in total earning and input variable or independent variable are interest income and non-interest income has been taken.

Methodology

Total Factor Productivity (TFP)

A stochastic frontier approach has been used to decompose TFP may arise, either due to technical progress or due to improvement in technical efficiency. The decomposition of TFP introduced in production function by Aigner, Lovell, and Schmidt (1977) independently proposed the stochastic frontier production

$$\boldsymbol{y_{it} = f(x_{it}, \beta, t)\exp(v_{it})\exp(u_{it})} \qquad \textbf{(1)}$$

Where y_{it} is the maximum possible output produced by i th bank (i= 1, 2, N) in the t th period (t=1, T); with f(.) being the production frontier; $X_{i,}$ is the input vector used by the *ith* bank; β is the vector of technology parameter; *t* is a time trend that used as a proxy for technical change; and $u_{it} \geq 0$ is output-oriented technical inefficiency. The random error, v_{it} measuring the error and all other random factors outside the control of the bank, such as fiscal policy, IMF, and World Bank policy, etc, these are likely to affect the bank's maximum possible output, along with the combined effects of unspecified input variables in the production function. This can be indicated from equation (1) that the technical inefficiency in equation (1) varies over time.

The production function is differentiated with respect to time to get

$$\boldsymbol{\frac{d\{\ln(f(x_{it}, t))\}}{dt} = \frac{\partial\{\ln(x_{it}, t)\}}{\partial t} + \sum_j \frac{\partial\{\ln(x_{it}, t)\}}{\partial x_j} \times \frac{dx_j}{dt}} \qquad \textbf{(2)}$$

The first and second terms on the right-hand side of equation (2) measure the change in frontier output caused by Technical progress (TP) and by a change in input use respectively. From the output elasticity of input j,

$\boldsymbol{\varepsilon_j = \frac{\partial\{\ln(x_{it},t)\}}{\partial \ln x_j}}$, the second term can be expressed as $\boldsymbol{\sum_j \varepsilon_j \dot{x}_j}$ where a dot over a variable depicts, its rate of change so equation (2) can be written as

$$\boldsymbol{\frac{d\{\ln(f(x_{it},t))\}}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j} \qquad \textbf{(3)}$$

Differentiating the logarithm of y_{it} in equation (1), with respect to time and using equation (3), the change in production frontier can be expressed as

$$\boldsymbol{\dot{y}_{it} = \frac{d\{\ln(f(x_{it}))\}}{dt} - \frac{du}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j - \frac{dv}{dt}} \qquad \textbf{(4)}$$

The productivity change is not just affected by TP and changes in input use, but also by changes in technical inefficiency. TP is negative (positive) if the exogenous technical change shifts the production frontier downward (upward), for a given level of input. If $\boldsymbol{du/dt}$ is positive (negative) then TE (deteriorates) improves over time,$\boldsymbol{(-\frac{du}{dt})}$ can be interpreted as the rate at which an inefficient bank catches up with the production frontier.

To examine the effect of TP and a change in efficiency on TFP growth is

$$\dot{TFP} = \dot{y_{it}} - \sum_j S_j \dot{x_j} \quad (5)$$

Where S_j is input j' s shares in production cost

By substitution equation (4) into (5) we get

$$\dot{TFP} = TP - \frac{du}{dt} + \sum_j (\varepsilon_j - S_j)\, \dot{x_j}$$

$$= TP - \frac{du}{dt} + (RTS - 1) \sum_j \lambda_j \dot{x_j} + \sum_j (\lambda_j - S_j)\, \dot{x_j} \quad ....(6)$$

where $RTS = \sum_j \varepsilon_j$ shows the measurement of return to scale, and

$\lambda_j = \frac{f_j x_j}{\sum_l f_l x_l} = \frac{\varepsilon_j}{\sum_l \varepsilon_l} = \frac{\varepsilon_j}{RTS}$. The last term in equation (6) measures inefficiency in resource allocation resulting from the deviation of input prices from the value of their marginal product. Therefore in equation (6), TFP growth can be decomposed into TP, and the technical efficiency change$\left(-\frac{du}{dt}\right)$,

scale components $SC = (RTS - 1) \sum_j \lambda_j \dot{x_j}$, and the allocative efficiency change is denoted by $\sum_j (\lambda_j - S_j)\, \dot{x_j}$, In the present study TFP growth is not adjusted for allocative efficiency change. The decomposition formula in equation (6) is drawn from Kumbhakar and Lovell(2000)

Econometrics

The most widely used approach of analysis for estimating technical efficiency is the frontier production function approach. We have considered the time-varying stochastic production frontier which is originally proposed by Aigner, Lovell, and Schmidt (1977) in translog form as

$$ln\, y_{it} = a_0 + \sum_j \alpha_j\, ln(x_{jit}) + \alpha_t t + \frac{1}{2} \sum_j \sum_l \beta_{jl}\, ln(x_{jit})\, ln(x_{lit}) + v_{it} - u_{it} \quad (7)$$

The efficiency error u_{it} represent production loss due to bank-specific technical inefficiency, thus it is always greater than or equal to zero ($u_{it} \geq 0$) and this is assumed to be independently and identically distributed as $N(0,\sigma^2_v)$

The translog frontier function as specified in equation (7) is rewritten for two inputs *interest extended* and *operating expenses.*

$$ln(TE_{it}) = \alpha_0 + \alpha_1\, ln(IE_{it}) + \alpha_2\, ln(OE_{it}) + \alpha_3 t + \alpha_4 \frac{1}{2} (ln\, OE)^2 + \alpha_5 \frac{1}{2} (ln\, IE)^2$$
$$+ \alpha_6 \frac{1}{2} (t)^2 + \alpha_7\, ln(IE)\, ln(OE) + \alpha_8\, ln(IE)\, t + \alpha_9\, ln(OE)\, t \quad (8)$$

Where TE_{it} are the total earnings, $IE_{it,} OE_{it}$ are two inputs *interest extended* and *operating expenses* respectively i is individual bank and t is a year.

The above specification is used for estimating both technical progress or change and time-varying technical efficiency. The translog parameterization of the stochastic frontier model is used for non-neutral technical progress (TP). Technical progress will be neutral if all $\beta_{i,j}$.'s are equal to zero and the production function will be reduced to the Cobb-Douglas function with neutral TP if all the $\beta' s$ are equal to zero. The distribution of technical inefficiency effects, μ is taken to be positive truncation of the normal distribution N (μ, σ_μ^2), modeled, following (Battese & Coelli 1992) to be the product of an exponential function of time as

$$\boldsymbol{\mu_{it} = \eta_t u_i = exp[-\eta(t-T)]u_i \ , \qquad i = 1, 2 \ldots\ldots, N; t = 1, 2 \ldots\ldots T} \qquad \textbf{(9)}$$

Here, the rate of change in technical inefficiency is represented by the unknown parameter η and the positive random variable u_i, is the technical inefficiency effect on *i the* bank's production unit in the last year. It is, the technical inefficiency effects in earlier periods are a deterministic exponential function of the inefficiency effects to the corresponding forms in the final period, given the data for *ith* production unit are available in the final period. So the production unit with a positive η is going to improve its efficiency level over time and vice versa. The value of η =0 implies technical inefficiency is time-invariant or has no change in η. However, the estimates of technical efficiency are sensitive or volatile to the choice of distributional assumption, so we have considered truncated normal distribution for general specifications of one-sided error μ_{it}.

Technical efficiency of *unit i* at time t ($TE_{i,t}$), defined as the ratio of the actual output to the potential output determined by the production frontier, can be written as follows,

$$\boldsymbol{TE_{it} = \exp(-u_{it})} \qquad \textbf{(10)}$$

Results

Total Factor Productivity

In figure-1 there has been shown the estimated results of total factor productivity across bank groups by estimating cobb –Douglas(CDPF) and trans log(TLPF) production functions. The private sector banks group has indicated higher total factor productivity both in cobb –Douglas(CDPF) and trans log(TLPF) production function as compared to the public sector banks group. During 2005-2018 the average total factor productivity of the public sector bank group is almost equal to zero in CDPF and TLPF but the private sector banks group depicted approximately 6 percent total factor productivity in TLPF estimation. In other words, there is an absence of total factor productivity in the public sector bank group.

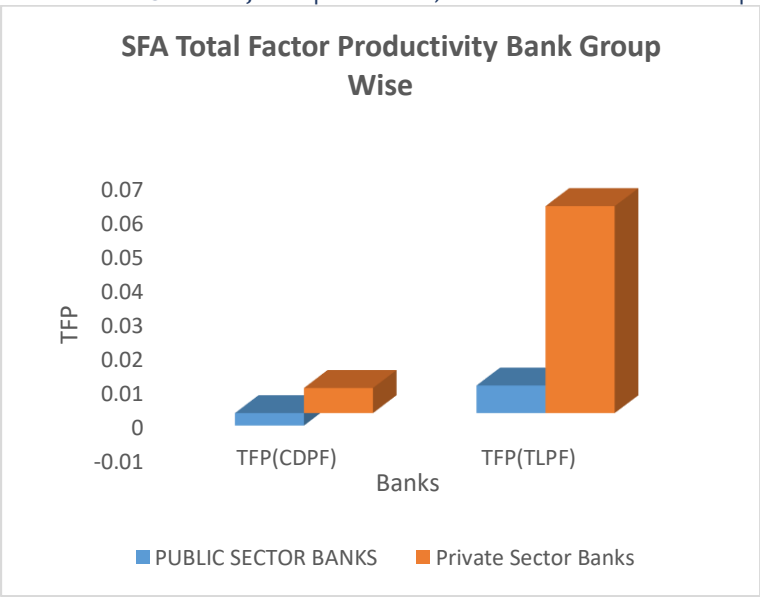

Figure 1. SFA Total Factor Productivity Bank Group Wise

Source: Author Estimation based on STATA and RBI Data

The public sector individual bank also indicated the absence of average total factor productivity during 2005-2018 except for SYNDICATE BANK which showed 1 percent TFP in TLPF depicted in figure-2 where each bank's total factor productivity has been estimated by both CDPF and TLPF.

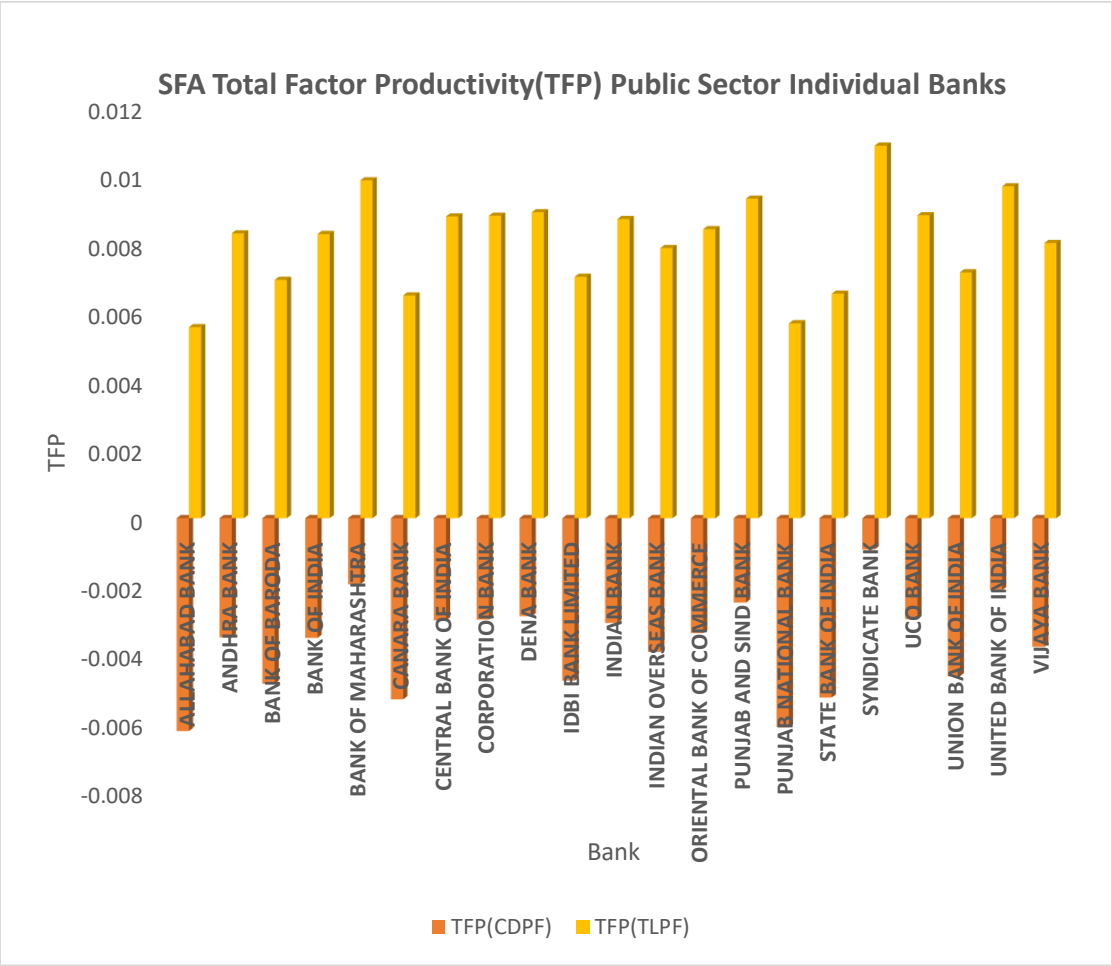

Figure 2. SFA Total Factor Productivity(TFP) Public Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

In figure-3 depicted the TFP of private sector individual banks during 2005-2018 where each bank has more or less the same TFP in both CDPF and TLPF. AXIS BANK has shown the highest average TFP in TLPF almost 7 percent. However, for all private sector individual banks, an average TFP is positive which indicates their competitive environment.

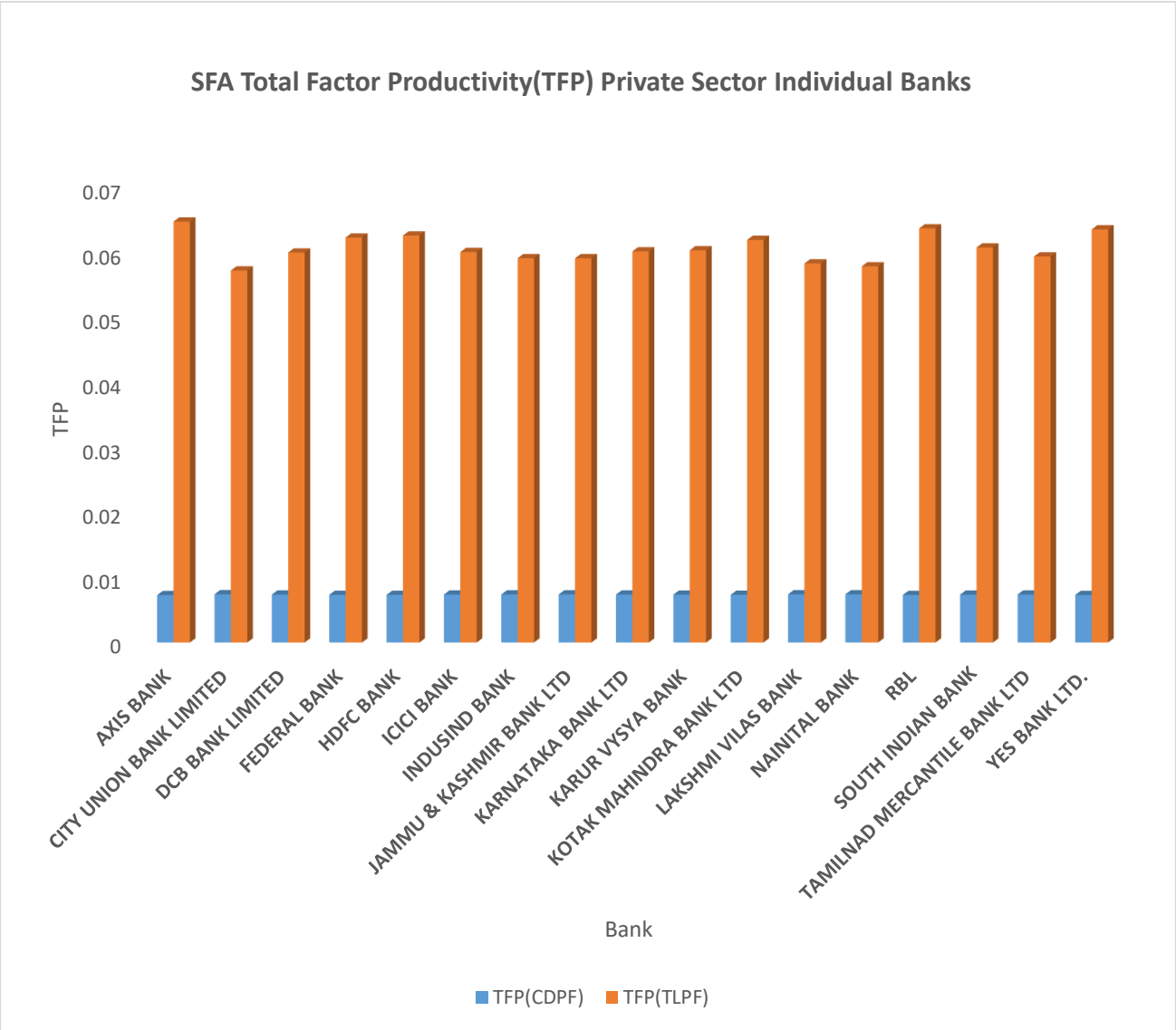

Figure 3. SFA Total Factor Productivity(TFP) Private Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

Technical Change

Technical change, which is the first component in equation (2) the empirical result shown in figure-4 across banks group shows that in CDPF estimation TC is not exit for any bank group. The TLPF estimation indicates a significant TC change in the private sector banks group that is approximately 6 percent but there is no evidence of TC exists for the public sector banks group.

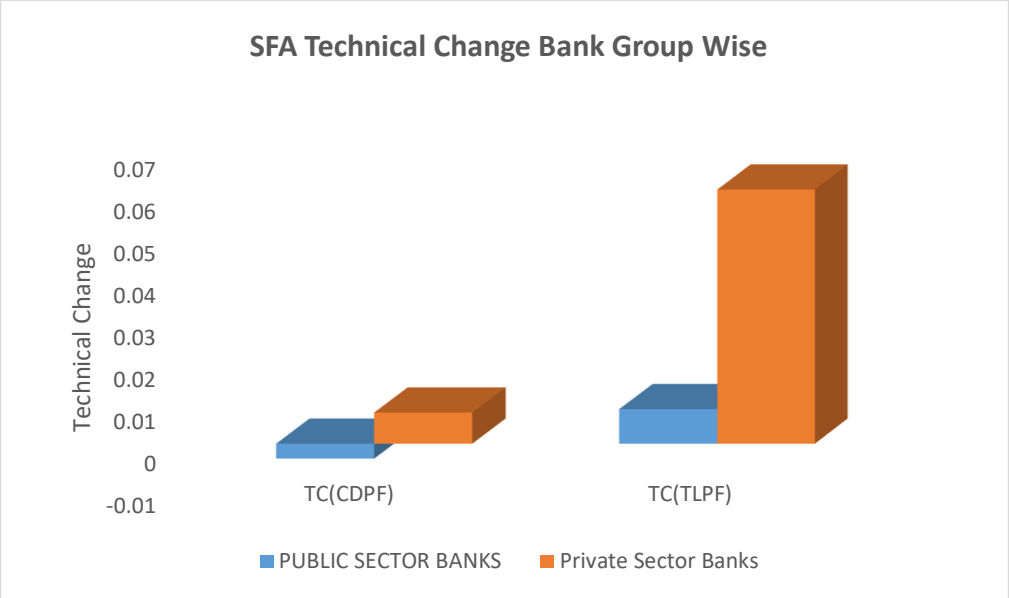

Figure 4. SFA Technical Change Bank Group Wise

Source: Author Estimation based on STATA and RBI Data

There is also no evidence of technical change across individual banks in public sector banks. Figure -5. shows a clear picture of the result and indicates no technical change.

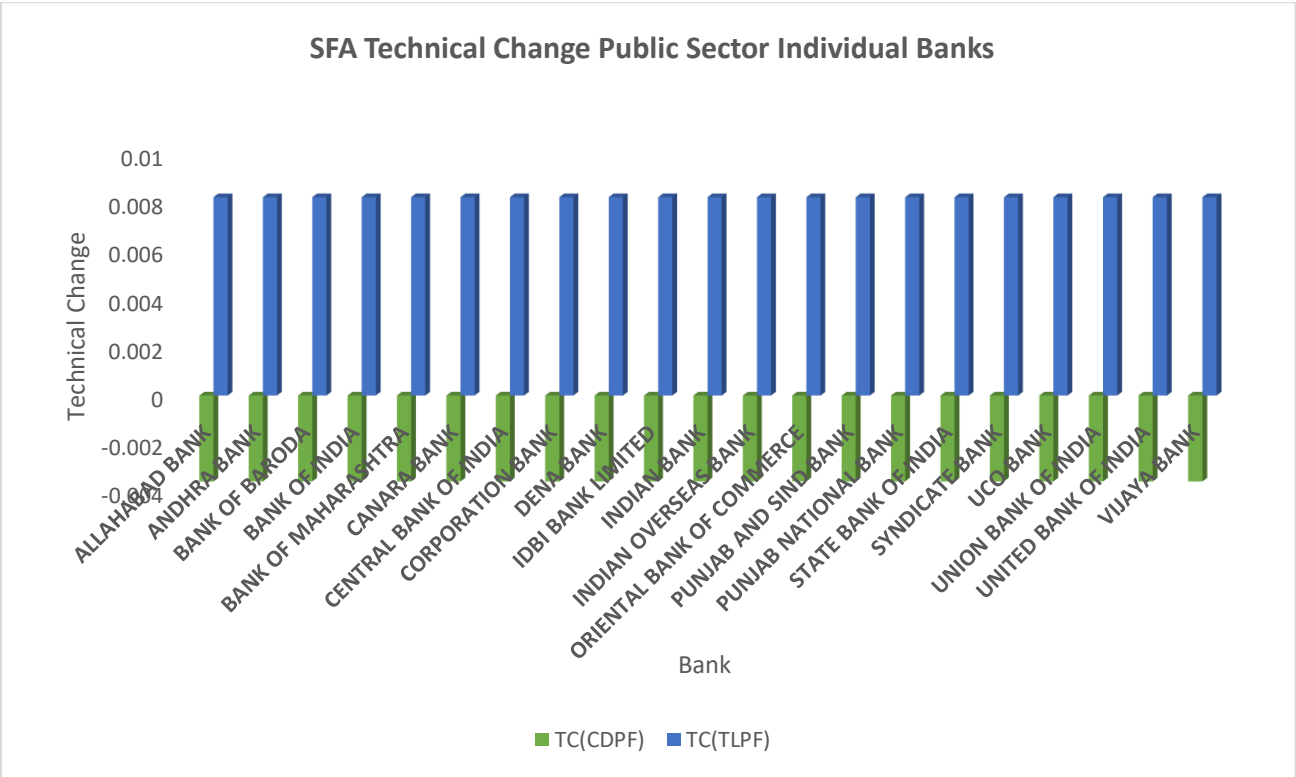

Figure 5. SFA Technical Change Public Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

The private sector individual bank's technical change result in figure-6 indicates that in all individual banks in the private sector equal technical change(TC) exists. It is approximately 1.6 percent in CDPF and TLPF respectively during 2005-2018.

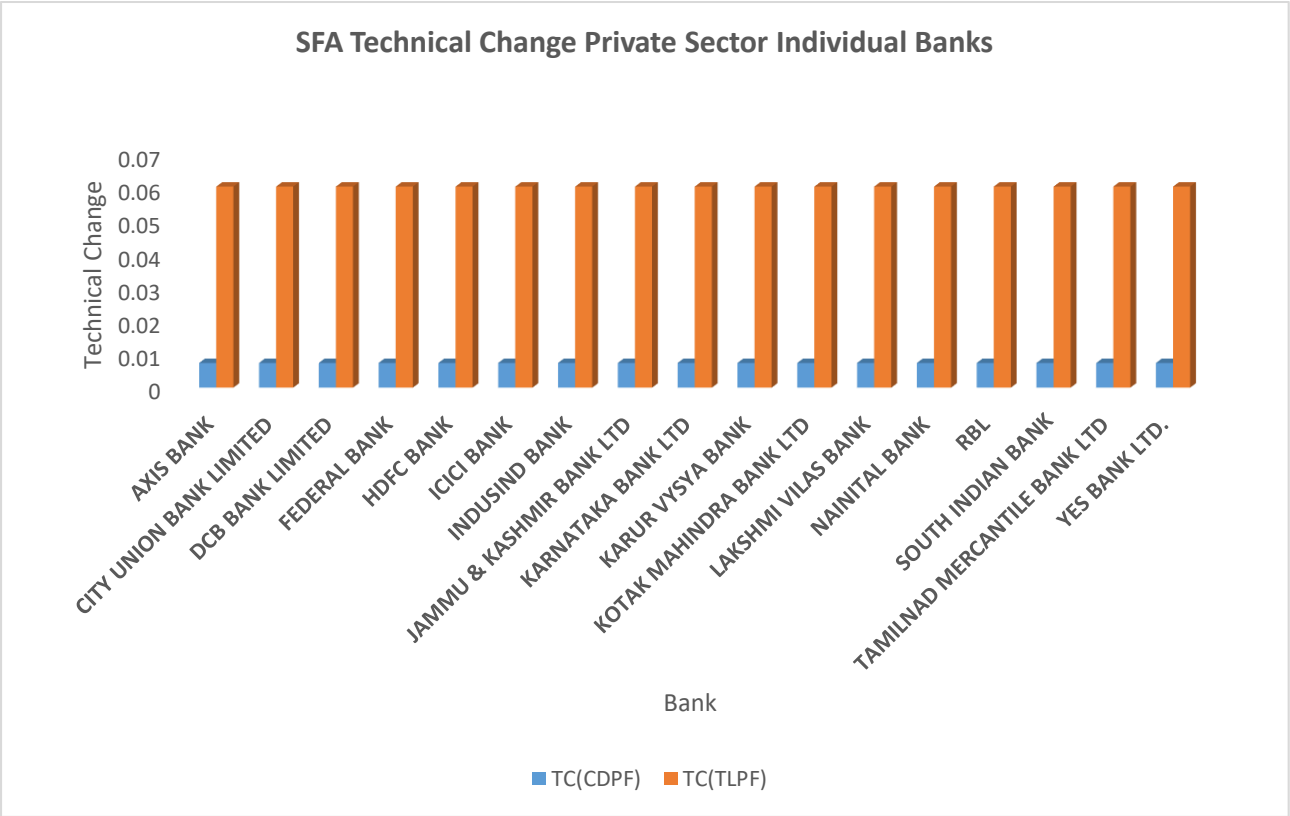

Figure 6. SFA Technical Change Private Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

Scale Efficiency

The result of scale efficiency in equation (6) is depicted in figure-7, figure-8, and figure 5.9 it is much obvious from the results that there is no scale efficiency available across banks group and also within individual banks across public and private sector banks

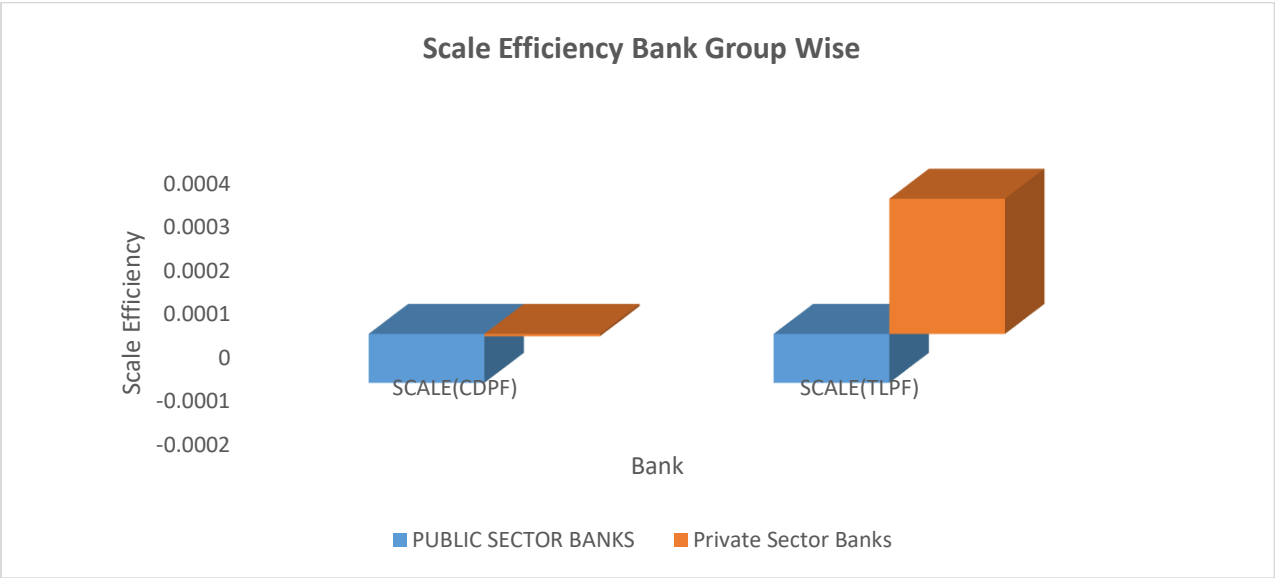

Figure 7. SFA Scale Efficiency Bank Group Wise

Source: Author Estimation based on STATA and RBI Data

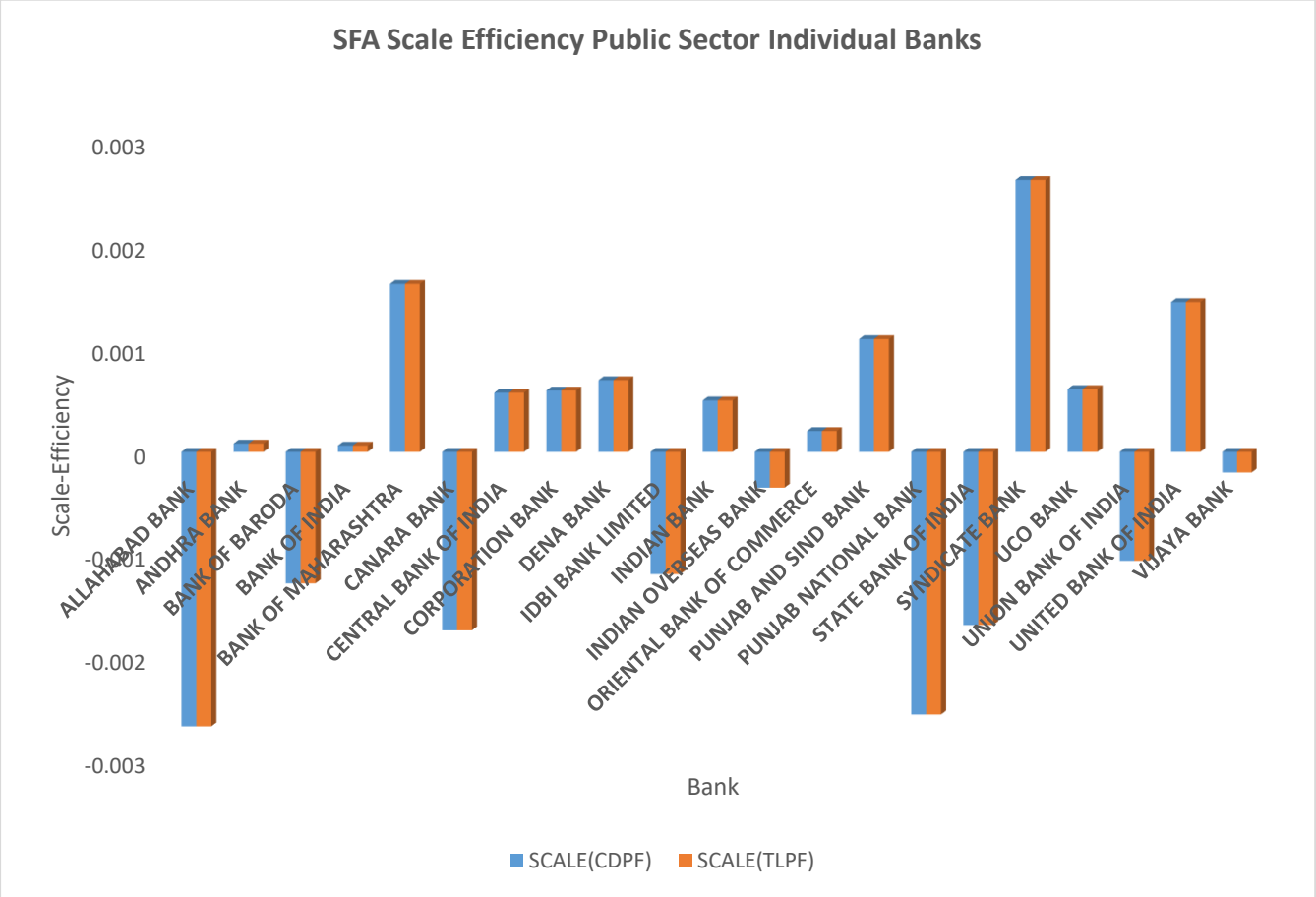

Figure 8. SFA Scale Efficiency Public Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

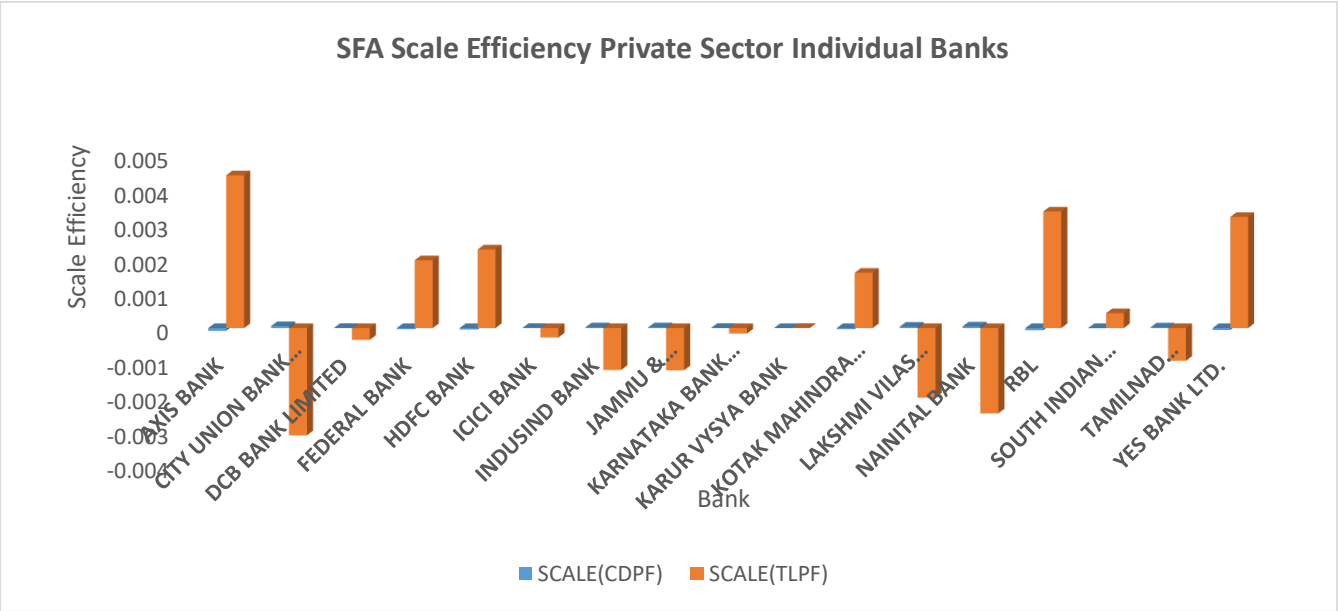

Figure 9. SFA Scale Efficiency Private Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

Technical Efficiency

In research methodology, we have defined the technical efficiency in equation (10) which is simply the ratio of actual output to the potential output or maximum possible output. The empirical result of technical efficiency

across bank groups has been shown in figure-10 where we have estimated the technical efficiency of both CDPF and LTPF by the Stochastic frontier approach. The results indicate that the average TE from 2005 to 2018 in the public sector bank group is 0.82,0.70 percent by CDPF and TLPF respectively and for the private sector bank group it is found to be 0.83,0.83 percent by CDPF, TLPF which conclude that public sector bank group is behind the private sector bank group.

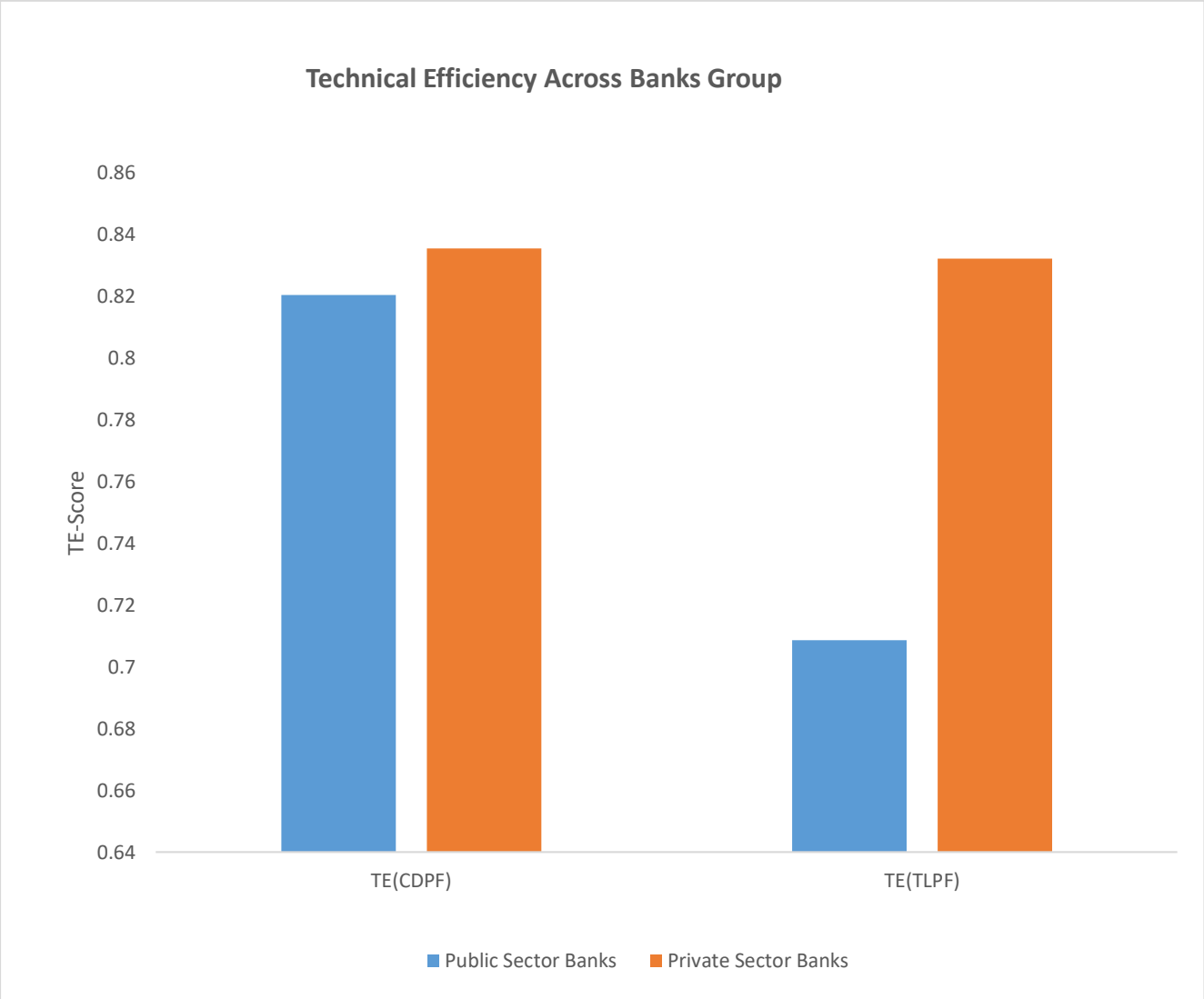

Figure 10. SFA Technical Efficiency Bank Group Wise

Source: Author Estimation based on STATA and RBI Data

The technical efficiency of an individual bank in the public sector showed in figure-11 for CDPF and TLPF. CORPORATION BANK is operating most efficiently at 88.75 percent in CDPF and TLPF respectively on the other side CENTRAL BANK OF INDIA is operating at least level from its potential level at 75.65 percent in CDPF and TLPF respectively. CDPF indicated more average technical efficiency than TLPF during 2005-2018.

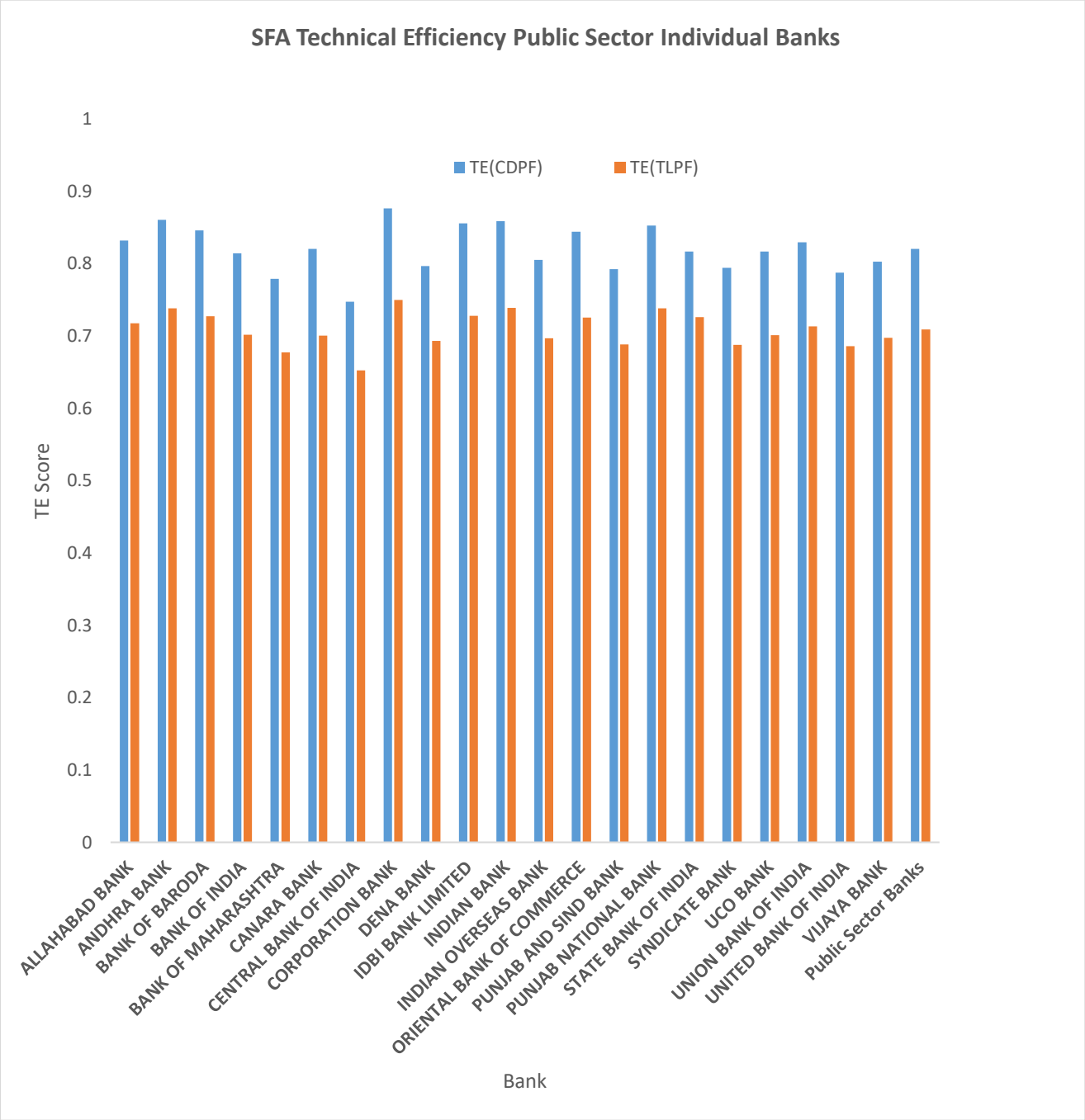

Figure 11. SFA Technical Efficiency Public Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

In private sector banks, figure-12 indicates that the average technical efficiency of *CITY UNION BANK LIMITED* is high among all private banks that is 91.3 and 91 percent in CDPF and TLPF respectively. *DCB BANK LIMITED* shows the least technical efficiency which is 9 and 9 percent respectively in CDPF and TLPF. The technical efficiency indicated by CDPF and TLPF is approximately equal in private individual banks.

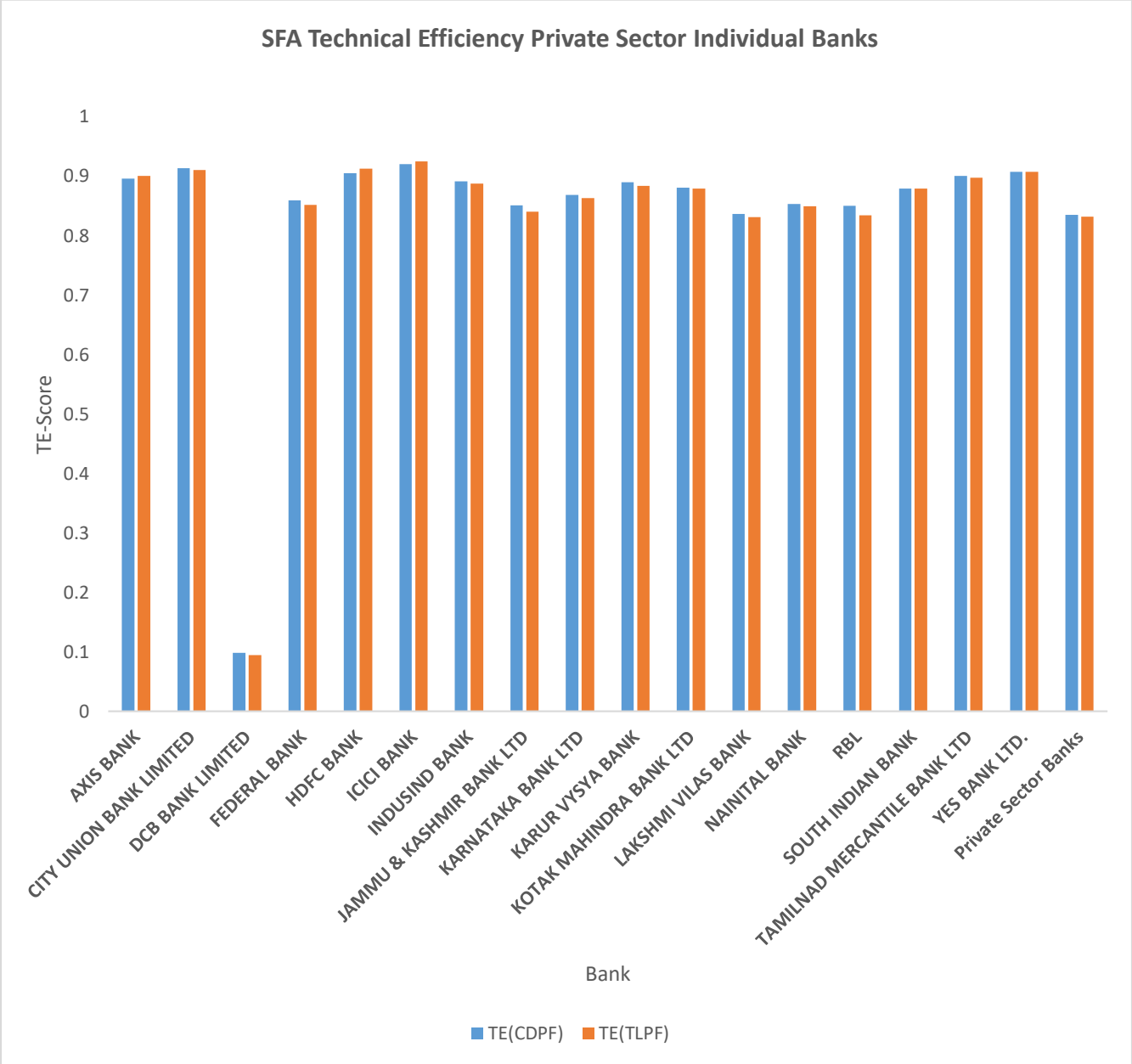

Figure 12. SFA Technical Efficiency Private Sector Individual Banks

Source: Author Estimation based on STATA and RBI Data

Time-varying decay Inefficiency Model

In this section, we have estimated the regression equation (8) which is mentioned in the methodology section. Table 1 is showing the descriptive summary of both bank groups where all value is mentioned in crore except the number of observation which is just an ordinary number. The data used here panel data where public sector banks have higher variable values as compare to private sector banks because public sector banks have more extension of bank branches compared to private sector banks. Summary table-1 also shows that the variability or deviation in variables data is lower in private sector banks as compared to public sector banks and this may be due to higher completion within private banks as compared to lower competition within public sector banks.

Table 1. Descriptive Statistics Summary

Public Sector Banks					
Variable	**Obs**	**Mean**	**Std.D**	**Min**	**Max**
TE(Total Earning)	294	21348.64	29533.24	1419.573	265100
IE(Interest Extended)	294	12941.41	16468.17	668.9881	145645.6
OE(Operating Expenses)	294	4063.963	6508.797	453.9624	59943.45
Private Sector Banks					
Variable	**Obs**	**Mean**	**Std.D**	**Min**	**Max**
TE(Total Earning)	238	9615.699	16424.55	48.1469	95461.66
IE(Interest Extended)	238	4833.167	7683.736	11.8489	40146.49
OE(Operating Expenses)	238	2102.529	3679.654	22.2575	22690.38

Source: Author Estimation based on STATA and RBI Data

For the estimation of the stochastic frontier Time-varying decay model we have used the logarithmic transformation here, we have seen the stochastic frontier in six different models in models M_1 to M_6 for public sector banks and M_1' to M_6' for private sector banks. In Tables - 2 and 3 the variance parameter $\gamma = \frac{\sigma_u^2}{\sigma_s^2}$ and $\sigma_s^2 = \sigma_u^2 + \sigma_v^2$ .Models M_1 to M_4 are time variant inefficiency decay models and M_5 to M_6 are the ordinary model of the production function. Here we will see which model will be the most fitted model for the bank's group. Table 2 shows that model M_2 is the best-fitted model where the inefficiency estimation μ is positive and depicting inefficiency and η is the negative giving signal to an increasing rate of inefficiency in the public sector bank group. Model M_6 is also the best-fitted model for public sector bank groups when we not considering the decay model.

Table 2. Time-Varying Decay Inefficiency Model Estimation Public Sector Banks

Independent Variables	**Total Earning (Dependent Variable)**					
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**
Constant	1.174**	1.854*	1.272**	1.163*	1.756*	2..688*
	(2.56)	(3.56)	(3.14)	(4.86)	(2.71)	(2.97)
Ln(IE)	0.515*	0.676*	0.385*	0.510*	0.510*	0.679*
	(3.82)	(67.38)	(4.46)	(3.82)	(3.82)	(68.05)
Ln(OE)	0.313***	0.328*	0.615*	0.610	0.310**	0.384*
	(1.88)	(26.49)	(6.59)	(6.88)	(1.89)	(27.81)
T	0.011	-0.003**		0.003	0.011	-0.005*
	(0.45)	(-1.81)		(0.72)	(0.44)	(-3.96)
$0.5(\ln IE)^2$	-0.007		0.022	0.045	-0.007	
	(-0.18)		(0.58)	(1.12)	(-0.17)	
$0.5(\ln OE)^2$	-0.014		-0.054	-0.020	-0.013	
	(-0.26)		(-1.08)	(-0.38)	(-0.26)	
$0.5t^2$	-0.006**			-0.005**	-0.001*	

	(-1.83)			(-1.85)	(-1.90)	
ln(IE)ln(OE)	-0.021		0.014	-0.013	0.021	
	(-0.45)		(0.33)	(-0.30)	(0.47)	
ln(IE)t	0.008**				0.009*	
	(2.38)				(2.47)	
ln(OE)t	-0.107**				-0.010*	
	(-2.53)				(-2.64)	
σ^2	-5.276*	-5.344*	-5.814*	-5.381*		
	(-7.03)	(-9.75)	(-28.17)	(-9.36)		
Γ	0.796	0.542*	0.266	0.576		
	(0.73)	(0.62)	(0.55)	(0.64)		
μ	0.014	0.048*	0.344**	0.030**		
	(0.20)	(1.00)	(1.33)	(0.61)		
H	-0.005	-0.045**	-0.024	-0.021*		
	(-0.26)	(-1.90)	(-1.04)	(-0.91)		
Log-likelihood	504.21*	492.00*	498.18*	500.37*	504.16*	490.59*
The values in parentheses below the coefficients indicate the t-statistics.						
*, **, ***, depict the 1 percent, 5 percent, and 10 percent levels of significance respectively.						

Source: Author Estimation based on STATA and RBI Data

Table-2 highlights the stochastic frontier econometric results for the private sector bank group, after analysis of the model results we have found the M_3' model is the best-fitted model the inefficiency parameter μ is also found *positive and significant*. The rate of inefficiency which is measured by η is *negative and significant* other than the decay models the M_5' and M_6' models are the best-fitted model for the private sector bank group.

Table 3. Time-Varying Decay Inefficiency Model Estimation Private Sector Banks

Independent Variables	**Total Earning (Dependent Variable)**					
	M_1'	**M_2'**	**M_3'**	**M_4'**	**M_5'**	**M_6'**
Constant	O.797	1.054*	0.905*	0.875*	0.424*	0.688*
	(3.60)	(15.58)	(4.16)	(4.05)	(26.81)	(15.87)
Ln(IE)	0.584*	0.540*	0.626*	0.599*	0.817*	0.615*
	(3.75)	(15.16)	(4.30)	(4.10)	(74.38)	(338.78)
Ln(OE)	0.498	0.456*	0.421	0.447*	0.217*	0.417*
	(3.14)	(13.08)	(2.78)	(2.95)	(18.43)	(229.66)
t	0.024	0.007**		0.028***	0.851*	0.006*
	(1.56)	(1.66)		(1.71)	(32.06)	(30.99)
$0.5(\ln IE)^2$	-0.139		-0.151	-0.180***	-0.347*	

	(-1.15)		(-1.40)	(-1.65)	(-52.31)	
$0.5(\ln OE)^2$	-0.186		-0.168	-0.200	-0.241*	
	(-1.23)		(-1.13)	(-1.34)	(-25.99)	
$0.5t^2$	-0.063			-0.002	-0.215*	
	(-1.65)			(-1.34)	(-17.08)	
ln(IE)ln(OE)	0.153		0.905	0.185	0.058*	
	(1.87)		(4.16)	(1.46)	(72.41)	
ln(IE)t	-0.013				0.058*	
	(-0.83)				(72.41)	
ln(OE)t	0.016				-0.046*	
	(1.11)				(-58.94)	
σ^2	4.686*	4.724*	4.569*	4.657*		
	(359.76)	(363.74)	(353.41)	(358.97)		
γ	8.05*	8.01**	7.85*	7.97*		
	(85.00)	(85.23)	(83.57)	(84.65)		
μ	-0.387*	-0.395*	-0.367*	-0.383*		
	(-0.45)	(-0.65)	(-10.99)	(-21.24)		
η	-0.629*	-0.644*	-0.653*	-0.629*		
	(-10.99)	(-10.15)	(-10.99)	(-10.91)		
Log-likelihood	45.73*	45.04*	42.02*	44.53*	-7523.23*	-4960.36*
The values in parentheses below the coefficients indicate the t-statistics.						
*, **, ***, depict the 1 percent, 5 percent, and 10 percent levels of significance respectively.						

Source: Author Estimation based on STATA and RBI Data

Conclusion

From the above result of this chapter, there are many interesting and valuable findings we have got here. The first interesting finding is in public and private sector banks there is very low total factor productivity exist in private banks there is some evidence of TPF but in public sector banks, there is hardly any evidence of TFP. The technical progress and scale efficiency components of TPF in the public sector banks group are almost zero in private sector banks TFP is mainly derived by the technical change/progress and scale efficiency is almost equal to zero. One thing we can conclude is that the growth rate of public and private banks in the Indian banking industry is simply input derived growth rate, there is a very low scope of technical progress exits in the banking sector.

The second finding gives a signal that the private sector bank group is harvesting higher output or technical efficiency as compared to public sector banks but both sector banks are not harvesting their potential output.

The third finding in time-variant decay frontier models where we have observed there is inefficiency exists in both public and private sector banks group and the rate of inefficiency is increasing in both sector banks group.

In conclusion, we have seen that the public sector banks are performing relatively low as compared to private sector banks but private sector banks are still behind the efficiency. So in public sector banks government has to put special attention to public banks, in recent times the government has taken concrete measures to make public sector banks competitive like merging as well as amalgamation plans. In private sector banks, there is also a need of getting more attention because they are only just better than public sector banks but inefficiency still exists in private sector banks. So this paper has shown more evidence other than the NPAs ratio that private sector banks are operating better than public sector banks.

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