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Abstract

While the global financial crisis had a cascading effect on all economies and financial sectors of countries, the Indian economy and its finances, particularly its banking system, due to its stringent regulatory and prudent policies. However, in the post crisis period, the scenario changed in the Indian banking because of the mounting pile of bad loans. The main purpose of the study is to estimate the bank specific efficiency utilizing the technical efficiency effect model in the stochastic frontier approach for panel data during the post global financial crisis period, 2009-2018 and find out the factors causing variations in efficiency of Indian banks.

Results indicate that despite the consolidation of information technology efforts, the efficiency of the Indian banking industry deteriorated during the post global financial crisis period. This may be due to the mounting pile of non-performing assets. Interestingly, the public banks seem to be more efficient than their private counterparts. The results also indicate that banks with larger capital adequacy ratio or older banks or banks with more branches are less inefficient in generating interest income.

Keywords: *stochastic frontier, technical efficiency effect, panel data, Indian banks, financial crisis*

JEL Codes: *D24, G21, G34, G28*

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INTRODUCTION

As the financial world has become increasingly interdependent, the global financial crisis has had a cascading effect on almost all economies and finances of nations. However, the Indian economy and its financial sector emerged relatively unaffected due to its stringent regulatory and prudent policies. Many appreciate the Indian financial system, particularly the banking system. However, in the post crisis period, the scenario changed in the Indian banking sector due to a few recent developments, particularly the mounting pile of bad loans (i.e., non-performing assets) despite the consolidation of Information Technology (IT) based efforts.

Although India had the lowest non-performing assets (NPA) ratio among the G-20 nations in 2009, its NPA was the second highest, next only to Russia in 2018.[1] According to the Reserve Bank of India (RBI) website, the NPA (Gross) of Indian banks increased from Rs. 699540 million (2.3 percent) in 2008-09 to Rs. 10396790 million (11.2 percent) in 2017-18. Many banks incurred loss and most of the stressed (i.e., 9 out of 10) banks were public sector banks. The RBI asked all banks before March 2017 to clean up their balance sheets and required them to provide for huge capital in the form of provisioning.[2] The high degree of NPAs and the necessity of provisions could have obviously affected the profitability and liquidity of banks.

Despite the NPA stress, Indian banks worked towards creating a Digital India. Due to the initiatives of Government of India and the RBI, the falling internet costs and increased awareness, in 2012–13, Indian banks deployed technology-intensive solutions to increase their revenues, enhance customer experiences, optimize cost structure and manage their enterprise risks. However, wide variations existed in technology and implementation capabilities of different banks. In addition, these

[1] As per data on world indicators available in: https://data.worldbank.org/indicator.

[2] In his monetary policy speech, Mr. Raghuram Rajan, then Governor of RBI suggested to sell NPAs to asset reconstruction companies to clean up their balance sheets to keep moving forward.

technological advancements have brought new security risks like cybercrime, hacking, etc.

It is expected that the technological transformation through the digital revolution and the mount of pressure due to NPA make the business milieu more uncertain as they bring positive as well as negative impacts. In such an environment, it is essential to examine the performances of Indian banks after the global crisis and ensure the efficient functioning of the banking sector, which is vital for the overall economic development of the nation.

In the literature, two performance measures are used widely, namely, productivity and efficiency. Although they are different, they are interrelated. Among them, the efficiency measure is more popular. The efficiency is measured as the ratio between the actual output of the bank and the bench mark or maximum or frontier output of the bank using the same amount of inputs and technology. Broadly, two alternative methodologies are employed in the literature to measure the efficiency, namely the data envelopment analysis (DEA) and stochastic frontier approach (SFA). While each of them has its own advantages and limitations, the SFA is widely used for panel data and time-varying efficiency.

There are four types of scheduled commercial banks in India. They are: i) the State Bank of India and its associate banks (SBIs), (ii) the nationalized banks (NBs), (iii) private domestic banks (PBs) and (iv) private foreign banks (FBs). While a handful of studies have emerged to provide the estimates of efficiency of Indian banks, they provide the estimates either before the global crisis period or in initial year of the crisis. The main contribution of this study to the banking efficiency literature is that it estimates the technical (in) efficiency of the Indian banks during the post global financial crisis period: 2009-10 to 2017-18. It employs the stochastic frontier methodology for panel data developed by Battese and Coelli (1995), which is called the Technical Efficiency

Effects model. The main advantage of this method is that it facilitates the joint estimation of both frontier production function and inefficiency equations. Thus, this paper provides and compares the efficiency variations across banking ownership groups and identifies the factors determining efficiency variations across banks.

The rest of this study proceeds as follows. The next section provides a short note on the banking industry in India. The subsequent sections provide a brief literature review and the methodology, including the data, the variables and the empirical model used in this study. Then the empirical results of the study are presented and discussed. The final section provides the summary and policy implications of the study.

A NOTE ON INDIAN BANKING INDUSTRY

India has a bank dominated financial system. Its modern banking system has its roots in the late 18th century and primarily catered to the needs of the British Government. After Independence, two waves of nationalization of major private banks happened: the first one in 1969 and the another in 1980. These were important milestones in the Indian banking system, which made banking accessible to the most unbanked population in the country. While the Indian banking industry comprises of SBIs, NBs, PBs and FBs, the public sector banks-SBIs and NBs have acquired the status of prominence in the financial intermediation process. They have also been expanding their geographical coverage, mobilizing savings and providing funds for investments in agriculture and small-scale industry (i.e., priority sectors).

The highly regulatory environment with interest rates, credit allocation and entry being controlled by the RBI favoured the Indian banks to have tremendous achievements. However, most banks suffered from poor profitability or loss, high proportion of non-performing assets and larger administrative expenses during the late 1980s (Shanmugam and Das, 2004). Therefore, the Government of India appointed the

Narasimham Committee to suggest measures to improve the functioning of the financial services industry, including the banks. The committee submitted its recommendations in November 1991. Based on that, the RBI initiated various reform measures to improve the banking efficiency including the entry deregulation, the branch de-licensing and the deregulation of interest rates, and to allow public sector banks to raise their equity in the capital market. These reforms helped Indian banks to improve their profitability through gradual reduction of cash reserve ratio (CRR), statutory liquidity ratio (SLR) and relaxation of various quantitative restrictions on the composition of selected portfolios.

The economic liberalization in the early 1990s supported the emergence of many new private banks. A few foreign banks also started their operations in India. This process led to a competitive environment. Indian banks were quick to leverage the emerging technology and were competitive in attracting customers. They adopted the international best practices. They followed several prudential and provisioning norms. These helped Indian banks to increase their efficiency and decrease their NPAs. Thus, these measures improved the financial health of the banking system.

With their major role in credit intermediation process, payment and settlement system and monetary policy transmission, and additional responsibility of helping the Government's social agenda, the banking industry supported India to achieve a faster growth path..[3] In spite of various acts promulgated by the Government of India and guidelines passed by the RBI, however, the NPAs continued to increase in the Indian banking sector, particularly after the global crisis. The public banks were on the verge of a crisis due to their high NPAs. They accounted for over 90 percent of the total bad loans of the industry. Most of them reported losses.[4] The RBI asked all banks to clean up their

[3] Commercial banks improve allocation of resources by lending money to priority sectors of the economy. They also provide finance to the infrastructure and support the economic growth.

[4]Finance Ministry's 2015-16 Annual Report reveals that Gross NPAs of banks could soar to 6.9 percent by March 2017 in a severe stress scenario.

balance sheets before March 2017 and provide a huge amount of capital in the form of provisioning.

On the technology front, the foremost breakthrough in the banking industry began with the use of Advanced Ledger Posting Machines (ALPM) in 1980s in India. In the late 1980s, the Total Bank Automation (TBA) was introduced, followed by the establishment of mechanized cheque processing systems, using the Magnetic Ink Character Recognition (MICR) technology (Bansal, 2015). Internet banking grew faster in the 2000s. Indian banks continuously invest in the following key innovations in digital banking (DB), namely (i) Digital-only/Virtual Banking, (ii) Biometric Technology, (iii) Artificial Intelligence (AI), (iv) BlockChain Technology, (v) Bitcoin, (vi) Robotics etc. As a result, Indian banks started providing end-to-end services through digital platforms like mobile phones, tablets and the internet. These services are paperless, branchless and signature-less banking offering 24*7 services to its customers.

The consolidation of IT based efforts in banks happened around 2006-07. These efforts include the establishment of data centers, and large scale implementation of core banking systems across various branches of banks. The Government also enacted the Payment and Settlement Systems (PSS) Act in December 2007. The RBI has authorized the payment system operators of pre-paid payment instruments, card schemes, cross-border in-bound money transfers, ATM networks and centralized clearing arrangements. These efforts have resulted in deeper acceptance and penetration of non-cash payment modes in India. However, the development of new products and business practices due to technology advancement has brought out new security risks including cybercrime, hacking, etc. Thus, the adoption of banking technology creates new opportunities as well as challenges. The demonetization announced by the Government of India in 2016 as a surgical strike to uproot black money and to counter terrorism by controlling fake currencies affected many sectors, including the banking sector. It created

greater demand for digital banking services where cashless transactions were prioritized. It has greater influence on management of liquidity and its demand raised by customers in the exchanging of their banned currency notes. Thus, the Indian banking industry has faced an uncertain environment for its operations due to these developments as they have brought positive as well as negative impacts.

A BRIEF REVIEW OF LITERATURE

The modern efficiency measurement concepts for any Decision Making Units (DMUs) like firms, farms, hospitals, banks etc start with Farrell (1957). He defines the economic efficiency (EE) of any DMU as the product of technical efficiency (TE) and allocative efficiency (AE). The AE measures the ability of a DMU or bank to use inputs in optimal propositions, given their respective prices/costs and the TE measures the ability of a bank to produce maximum possible output using a given set of inputs/technology. In a simpler term, the TE is the ratio between the actual output/outcome and the maximum possible or potential output. It suggests whether the actual outcome generated could be achieved with less inputs or whether the same inputs could produce better outcomes.

There are broadly two empirical approaches to measuring (technical) efficiency. They are: (i) mathematical approach or data envelopment analysis (DEA) and; (ii) econometric or stochastic frontier approach (SFA). The DEA includes (i) the non-parametric deterministic model developed by Farrell (1957) later popularized by Charnes *et. al.*, 1978, (ii) the parametric deterministic model by Aigner and Chu (1968), (iii) the probabilistic model by Timmer (1971) and (iv) Corrected OLS . The deterministic model assumes that the actual output produced Q is less than the potential output, $Q^*(=f(.))$, i.e., $Q \leq Q^* = f(.)$. The output gap is: $u= Q^*-Q$, and due to a non-linear relationship, the actual output is written as: $Q = f(.)e^{-u}$. Since u is the ratio between Q and Q^*, it is also called the technical (in) efficiency term. The Linear Programming (LP) method is used to estimate the DEA model. The major limitation of the

DEA is that it ignores the random factors which may influence the outputs of the production units.

Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) independently developed the SFA approach for cross section data, taking in to account the random factors. According to them, the potential output is not deterministic, but stochastic due to random factors and so the actual output is: $Q = f(.)\ e^{-u}\ e^{v} = f(.)\ e^{\varepsilon}$, where v is regular stochastic error term and ε (=v-u) is the composite error term. For estimating this function using the maximum likelihood estimation (MLE) method, the one sided error term u (is always positive) is assumed to follow one of the following four distributional assumptions, namely half normal, truncated normal, gamma and exponential. Jondrow *et. al.* (1982) suggest that the individual specific efficiency can be computed by taking the conditional expectation of e^{-u} given ε.

However, the SFA for cross section data has three serious limitations. First, the measure of inefficiency may not be consistent. One can consistently estimate the (whole) error term for a given observation, but it is the summation of v and u. The variance of the distribution of u term conditional on the ε term does not vanish when the sample size increase (Jondrow *et. al.*, 1982). Second, this approach uses a specific distributional assumption on the inefficiency term. The choice of wrong assumption leads to biased estimates of efficiency. Finally, this assumes that the inefficiency term is independent of regressors included in the model which may not correct.[5]

To overcome these limitations, Schmidt and Sickles (1984) introduced the stochastic frontier models for panel data, by taking account the individual effects. This approach assumes that efficiency is time-invariant. Utilizing the Cobb-Douglas functional form (and lower cases indicate the logarithmic values) the model is specified as: $q_{it} = \alpha +$

[5] If a DMU knows its inefficiency, then it will affect its choice on resource base (inputs).

$x_{it}' \beta + v_{it} - u_i$, where u_i is independently and identically distributed (iid) with mean-μ and variance-σ^2_u. Letting $\alpha_i = \alpha - u_i$ the equation becomes: $q_{it} = \alpha_i + x_{it}' \beta + v_{it}$. The α_i is an individual specific effect (intercept) and the model is estimated using the fixed effects "within" method. α^* [=max (α_i)] is the performance of the Most Efficient Bank and the relative efficiency of i^{th} Bank can be measured as: $u_i = \alpha^* - \alpha_i$. Then, technical efficiency is computed as: $TE_i = \exp(-u_i)$.

Assuming that that the individual specific effects are uncorrelated with the explanatory variables, the random effects model treats them as random and allows them to merge with regular error terms. The estimating equation in this case is: $q_{it} = \alpha + x_{it}' \beta + \varepsilon_{it}$, where $\varepsilon_{it} = v_{it} - u_i$ and feasible GLS method is used to estimate the equation. Then individual effect is obtained as: $\alpha_i = (1/T) \Sigma \varepsilon_{it}$; i=1,2,…N and one can get α^* and $u_i = \alpha^* - \alpha_i$. Then TE is calculated as above. Alternatively one can use MLE method to estimate the equation $q_{it} = \alpha + x_{it}' \beta + v_{it} - u_i$, where u may follow either half normal or truncated normal distribution as in the cross section model to calculate the time-invariant efficiency values.

To estimate the time-varying TE, there are three alternative models developed in the literature: (i) Cornwell *et. al.*, (1990) Model allows for both firm and time (t) effects (in efficiency is modeled as $\alpha_{it} = \theta_{i1} + \theta_{i2} t + \theta_{i3} t^2$); (ii) Kumbhakar *et. al.*, (1990) model uses: $u_{it} = [1+ \exp\{bt+ ct^2\}]^{-1} u_i$, where u_i is a half normal variable and b and c are unknown parameters to be estimated; and (iii) Battese and Coelli (1992) model specifies u as $u_{it} = u_i \eta_{it} = u_i \exp\{-\eta(t-T_i)\}$;i =1,…..,n, $t \in g(i)$; where u_is are non-negative random variables that are assumed to be i.i.d as truncated normal with mean μ and variance σ_u^2, η is an unknown parameter to be estimated and g(i) represents the set of T_i time periods for which observations for state i are available. The MLE technique can be used to estimate the models. If η=0, the model becomes time-invariant.

After estimating the technical efficiency variable in the first stage, it is regressed on various factors to identify its major determinants in the second stage. But this two-stage approach is inconsistent in its assumptions regarding the independence of the inefficiency effects. To overcome this limitation, Batese and Coelli (1995) developed the Technical Efficiency Effects model that assumes the u_{it} to be iid with a truncated normal distribution and a time varying mean, i.e., $u_{it} \sim N (m_{it}, \sigma_u^2)$. It is specified that the individual and time varying mean as $m_{it} = Z_{it} \delta$, where Z is vector of factors explaining the efficiency. For a complete review of these models, see Aigner et. al. (1977), Meeusen and Broeck (1977), Battese and Coelli (1992), Greene (1993), Kalirajan and Shand (1994) and Kumbhakar et. al. (1997).

The above methodologies are widely used to measure the efficiency in various fields. Some studies estimate the output function to measure the technical efficiency, while many others estimate the cost or profit or revenue function to measure the cost efficiency or profit or revenue efficiency. Large numbers of empirical studies have emerged to measure the efficiency of financial institutions in developed nations such as USA, Sweden, and Finland. After reviewing 130 studies on the efficiency of financial institutions/banks from 21 countries, Berger and Humphrey (1997) remarked that 116 studies emerged during 1992-1997and most of them analyzed the efficiency of US banks. They also found that the annual average technical efficiency of these studies was 77 percent (with median of 82 percent).

In the case of financial institutions, particularly banks, the major issue is the selection of inputs and output sets. Past studies employ three approaches: the production (or also called service provision or value added) approach, the intermediation (or asset) approach and the modern approach (Hjalmarsson *et. al.*, 2000; Das and Ghosh, 2006). While the first two approaches apply the theory of producer's behaviour to banking, they differ due to their specification of banking activities.

Benston (1965), the pioneer of the production approach, considers banks as the providers of services to customers. He uses the number of deposits and loan accounts as outputs and labour, material, space or information systems or their associated cost as inputs. Sealey and Lindley (1977) in their intermediation approach views banks as intermediating funds between depositors and creditors. They produce intermediation services through the collection of deposits and other liabilities and their application in interest-earning assets. The intermediation considers both operating and interest expenses as inputs and loans and other major assets as outputs.[6] The modern approach introduces the quality of bank assets and the probability of bank failure in the estimation of costs. This approach is best represented through the ratio-based CAMEL approach. This approach derives the individual components of CAMEL using banks' financial tables and considers them as variables in the performance analysis.[7]

Most studies measuring efficiency of banks in developed nations employ the DEA approach.[8] For instances, Elyasiani and Mehdian (1995) used the intermediation approach to measure the trends in efficiencies of small and large US commercial banks during 1979 to1986 and found that although the efficiency declined over the years, small banks emerged as more efficient. Fecher and Pestieau (1993) found that the average

[6] The production approach focuses on operating cost and ignores interest expenses while the intermediation approach considers both. Elyasiani and Mehdian (1990) argue that the intermediation approach is preferred to other approaches. Due to the controversy on whether deposits to be treated as input or output, the asset, user cost and value added approaches emerged as three variants of intermediation approach. The asset approach considers deposits and other liabilities, labor and capital as inputs, and bank assets such as loans as output (Sealy and Lindley, 1977). The user cost approach argues that if the financial returns on an asset exceed the opportunity cost of the funds, they are considered as outputs; otherwise, they are considered as inputs (Hancock, 1985). The value-added approach uses the balance sheet categories (assets or liabilities) as outputs that contribute to the bank value added (Berger, Hanweck, and Humphrey, 1987).

[7] The operating approach (or income-based approach) considers banks as business units, aiming to generate revenues from the total cost incurred (Leightner and Lovell, 1998). Thus, it considers the total revenue (interest and non-interest income) as output and interest and operating expenses as inputs.

[8] As the empirical studies on measuring banking efficiency are larger, we discuss about only a few, but selective studies in India and other countries.

efficiency of financial services (banking and insurance) for 11 OECD countries from 1971 to 1986 was 0.82 and the efficiency ranged between 0.67 (for Denmark) and 0.98 (for Japan). Maudos and Pastor (2001) estimated the cost and the profit efficiency for 14 countries of the European Union, as well as Japan and the US and found vast variations in the profit efficiency of these countries.

Only a few studies have emerged to measure the efficiency of Asian banks. Analyzing the operating efficiency in Taiwan's banking industry from 1986–89 to 1992–95, Shyu (1998) found improvements in the overall efficiency. Hao, Hunter, and Yang (1999) employed the SFA and the data for 19 Korean banks from 1985 to 1995 and showed that banks with faster growth rates, and an extensive branch network were most efficient. Jaffry *et. al.*(2007) showed that technical efficiency increases and converges across the Indian sub-continent in response to reforms.

In the context of measuring banking efficiency in India, a handful of studies emerged. But most of them employ the DEA approach. Bhattacharya, Lovell and Sahay (1997) using the DEA approach showed that the public sector banks performed well and improved their efficiency in the deregulated environment during 1986-1991. They also showed a temporal improvement in the performance of foreign banks and a temporal decline in the performance of Indian public sector banks. Mohan and Ray (2004) found that the revenue efficiency of Indian banks improved and there was a convergence in the performance between public and private sector banks in the post-reform era.

Das *et. al.* (2005) estimated the cost efficiency, the revenue efficiency, and the profit efficiency of Indian banks during 1997-2003 using DEA and showed that bank size, ownership, and stock exchange listing affected the profit efficiency positively. Das and Ghosh (2006) use three different approaches, viz., (1) intermediation approach, (2) value added approach, and (3) operating approach and DEA method showed

that medium-sized public sector banks performed reasonably well, and banks with less NPAs were technically more efficient during 1992-2003. Gupta *et. al.*, (2008) using the DEA approach showed that the estimated productive efficiency during 1999-2003 increased from 0.901 to 0.925. The SBI group of banks were the most efficient banks, followed by private banks, and nationalized banks.

Ray and Das (2010) applied the DEA method to measure the cost and the profit efficiency of Indian banks during the post reforms period. They showed that public sector banks were more efficient than their private counterparts. Smaller banks (with assets up to Rs.50 billion) mostly operated below the efficiency frontier. Sunil and Gulati (2010) employed the DEA approach to measure and examine the convergence in cost, technical and allocative efficiencies of 27 public sector banks during 1992-93 to 2007-08. They found that deregulation had a positive effect on the cost efficiency of public banks. While the efficiency of public sector banks increased over the years, the allocative efficiency declined. The inefficient public sector banks were catching-up the efficient ones, confirming a strong β convergence in the efficiency levels of Indian public banks.

Dwivedi and Charyulu (2011) used DEA and showed that the mean technical of all banks increased slightly from 95.6 per cent in 2005 to 97.9 per cent in 2010. Jayaraman and Srinivasan (2014) considered four inputs (equity (capital plus reserves and surplus), borrowed funds (deposits and borrowing), number of employees and branches), two outputs (deployed funds including loans and investments and non-interest income) and one undesirable output (gross non-performing assets) to measure the profit efficiency of Indian banks during 2005-2012. But they showed the profit inefficiency was only 2 percent in private banks and 3 percent in public banks. The inefficiency was higher in big and large banks than in small and medium size banks.

Kaur and Gupta (2015) computed the efficiency of 8 SBIs, 19 NBs and 30 PBs during 2009-2013 using the DEA. They found that the mean efficiency score was 91 percent for all banks; 94.5 percent for SBIs; 92 percent for PBs; and 86.9 percent for NBs. Tandon *et. al.*, (2014) applied the DEA method to measure the efficiency of 19 NBs, 15 PBs and 10 FBs during 2009–2012 and showed that 7 out of 44 banks operated on the efficiency level.

Utilizing Battese and Coelli's (1992) SFA for panel data, Shanmugam and Das (2004) showed that that during 1992-1999, the efficiency of raising noninterest income, investments and credits of Indian banks improved. Ataullah *et. al.*, (2004) calculated that the overall efficiency of the banking industry of India and Pakistan improved in the financial liberalization period. Das *et. al.*, (2005) showed that the efficiency of Indian banks, in general, and of bigger banks, in particular, increased during the post-reform period. Mahesh and Rajeev (2006) showed more or less similar results in Shanmugam and Das (2004). While Mahesh and Bhide (2008) showed that deregulation has a significant positive impact on the cost and the profit efficiencies of commercial banks, Das and Ghosh (2009) also found that the liberalization improved the cost and profit efficiencies of banks.

Using hedonic aggregator function, Das and Kumbhakar (2012) found that the efficiency of public sector banks was higher than the efficiency of private sector banks during the post reform period 1996-2005. Bhattacharya and Pal (2013) estimated the technical efficiency of 103 commercial banks during 1989-2009 using a multiple-output generalized stochastic production frontier and intermediary approach. They showed that the average efficiency of Indian banks was 64 percent. Public sector banks were more efficient than private and foreign banks. The review indicates that the efficiency studies on the Indian banks after the post financial crisis period are non-existent.

MODEL, DATA AND ESTIMATION

This study utilizes Battese and Coelli's (1995) TE effects model. Consider the actual production (Y_{it}) function of a bank i for period t as:

$$Y_{it} = f(x_{it};\ \beta)exp\ (v_{it} - u_{it}) \quad (1)$$

where f(.) is the frontier output that could have been produced by the bank with a given level of inputs and technology; x_{it} is a vector of inputs while β is a vector of parameters of inputs; v_{it} is stochastic error term (iid normal with mean 0 and variance σ^2_v) and u_{it} (=TE effect) is a one-sided (non-negative) residual term, which is assumed to be independently distributed such that u_{it} is observed by truncation at zero of the normal distribution with mean $Z_{it}\ \delta$ and variance σ^2. Z_{it} is a vector of factors determining the technical inefficiency of banks over time and δ is a vector of parameters associated with Z variables. Thus, the technical inefficiency effect u_{it} in equation (1) can be specified as:

$$u_{it} = Z_{it}\delta + w_{it} \quad (2)$$

where w_{it} is a truncated normal variable with mean 0 and variance σ^2 and the point of truncation is $-Z_{it}\ \delta$, i.e., $w_{it} \geq -Z_{it}\ \delta$. The maximum likelihood estimation (MLE) can be used to jointly estimate the stochastic frontier equation and the technical inefficiency equation.[9] The TE of bank i for period t is computed as:

$$TE_{it} = \exp(-u_{it}) = \exp(-Z_{it}\ \delta - w_{it}) \quad (3)$$

This study uses the operating (or income based) approach to select outputs and inputs. The total revenue is the output and the total expenses, including interest and operating expenses are inputs. Using them, the stochastic frontier production function is written as:

[9]The likelihood function and its partial derivatives are given in Battese and Coelli (1993).

$$\text{Ln } Y_{it} = \beta_0 + \beta_1 \text{ Ln Interest Expenses}_{it} + \beta_2 \text{ Ln Employee Expenses}_{it} + \beta_3 \text{ Ln Capital Related Operating Expenses}_{it}^{10} + v_{it} - u_{it} \quad (4)$$

where Ln denotes the natural logarithm. The technical inefficiency equation is written as:

$$u_{it} = \delta_0 + \delta_1 \text{ Capital Adequacy Ratio}_{it} + \delta_2 \text{ Age}_{it} + \delta_3 \text{ Bank Branches}_{it} + \delta_4 \text{ Dummy for SBI Group}_{it} + \delta_5 \text{ Dummy for Nationalized Bank}_{it} + \delta_6 \text{ Dummy for Private Bank}_{it} + w_{it} \quad (5)$$

As the total revenue includes interest income and non-interest income, the Y_{it} (total revenue) in equation (4) is replaced with interest income and non-interest income in alternative specifications of the model.[11] Thus, the study considers total revenue, interest income and non interest income as outputs in alternate specification of equation (4). The data on inputs, and outputs and Z variables of commercial banks in India during 2009-10 to 2017-18 has been collected from the Statistical Tables relating to Banks in India published by the RBI. Appropriate deflators are used to convert all monetary values into 2011-12 prices. Due to the missing data, 99 banks belonging to four ownership groups are included in the estimation. The final data set is an unbalanced panel of observations (a total of 754) on inputs, outputs and Z variables. Table 1 presents the descriptive statistics of these study variables.

[10]The capital related operating expenses can be computed by adding rent, taxes, lighting, printing and stationary expenses, depreciation on bank property, repairs, and maintenance and insurance.

[11]Some one may argue that the technology process used for generating the interest income and the non-interest income may be different and so adding them and used as a dependent variable in the production function may be biased.

Table 1: Descriptive Statistics of the Study Variables

Variables	Units of Measurement	Mean	Standard Deviation
Interest Income	Rs. Crore	81134.84	149485.44
Non-interest income	Rs. Crore	12598.35	26133.26
Total Income	Rs. Crore	93733.18	174230.43
Interest Expenses	Rs. Crore	53601.30	97002.23
Employee Expenses	Rs. Crore	9977.27	21349.21
Capital Related Expenses	Rs. Crore	3843.99	7638.83
Capital Adequacy Ratio	Percentage	30.68	46.60
Age	in Years	70.77	53.49
Number of Branches	Numbers	1172.74	2151.10
Dummy for SBI Group	1 for SBI; 0 for others	0.064	0.244
Dummy for Nationalized	1 for Nationalized; 0 for others	0.244	0.430
Dummy for Private Banks	1 for Private; 0 for others	0.240	0.427

Note: Total sample is 754. All monetary values are in 2011-12 prices. Crore=10 million.

EMPIRICAL RESULTS

Table 2 shows the MLE results of the stochastic frontier and technical efficiency models for Indian banks using FRONTIER 4.1 software. Column 1 of the table presents the results of total revenue (=interest plus non-interest income) equation (4). All three inputs have positive and statistically significant effects at 1 percent level. The capital related expenses is a dominant factor in determining the total income of Indian banks as its parameter is the largest (0.37), followed by employee expenses (with 0. 33). Both σ^2 and γ terms are positive and statistically significant at 1 percent level, indicating that the actual level of total income significantly differs from the frontier level of income due to factors which are within the control of banks. The estimated value of γ is 0.94, implying that 94 percent of the difference between actual and frontier output is due to technically inefficient performance of banks.

The estimated coefficients in the inefficiency model in Column (1) of table 2 indicate that the capital adequacy ratio has a positive and significant (at 1 percent level) coefficient. This result implies that the banks with higher capital adequacy ratio are more inefficient than banks with less capital adequacy ratio. The negative and significant (at 1 percent level) parameter of number of bank branches implies that banks with a larger number of branches tend to be less inefficient. The age coefficient is negative, indicating that the older banks are less inefficient than the younger ones. However, this relationship is very weak because this relationship is not supported by t value. As the parameters associated with all three dummies for SBIs and NBs and PBs are negative and statistically significant at 1 percent level, the three groups of banks are less inefficient than the base category, namely the foreign banks.

Column 2 of table 2 presents the estimation results of interest income. As in Column 1, all input parameters are positive and statistically significant at 1 percent level. The employee expenses variable is the dominant factor determining the interest income, followed by capital related expenses and interest expenses. σ^2 and γ terms are positive and statistically significant at 1 percent level. The estimated value of γ reveals that 96 percent of the difference between actual and frontier output of banks is due to technical in-efficiency. In the technical inefficiency model, capital adequate ratio, age and branch variables have a negative and significant impact at 5 percent level, indicating that banks with a larger capital adequacy ratio/older banks/banks with more branches are less inefficient in generating interest income. Like in Column 1, all dummy coefficients are negative and statistically significant at 1 percent level, indicating that the SBI group, nationalized and private banks are less inefficient in generating interest income than foreign banks.

Table 2: Maximum Likelihood Estimation Results of Technical Efficiency Effects Model for Indian Banks (2010 to 2018)

Variables	Total Revenue	Interest Income	Non-Interest Income
	(1)	(2)	(3)
Stochastic Frontier Model			
Constant	3.2213	2.5448	2.4993
	(47.369)	(55.649)	(15.761)
Ln Interest Expenses	0.2151	0.2797	-0.1399
	(21.935)	(44.169)	(-5.512)
Ln Employee	0.3317	0.3626	0.3371
Expense	(14.314)	(18.009)	(5.658)
Ln Capital Related	0.3698	0.3089	0.6903
Expenses	(15.340)	(15.403)	(11.447)
Technical In-Efficiency Model			
Intercept	0.1969	-0.2366	-0.4271
	(1.692)	(-2.092)	(-2.074)
Capital Adequacy	0.0030	-0.0073	0.0181
Ratio	(6.869)	(-3.526)	(18.041)
Age	-0.0004	-0.0024	-0.0011
	(-0.905)	(-2.091)	(-0.764)
Number of Branches	-0.0002	-0.0002	-0.0005
	(-14.087)	(-7.573)	(-3.218)
Dummy for SBI	-0.8596	-3.6857	-0.5651
Group	(-3.985)	(12.032)	(-1.310)
Dummy for	-1.7045	-5.3758	-0.9814
Nationalized	(-4.151)	(-17.485)	(-2.806)
Dummy for Private	-0.3741	-2.5342	-0.2341
	(-4.449)	(-13.649)	(-1.099)
σ^2	0.3112	0.7925	1.412
	(7.439)	(6.873)	(13.992)
γ	0.9384	0.9640	0.8674
	(85.957)	(136.713)	(37.652)
Log-Likelihood	-129.8715	-130.0228	-804.6371
LR test of one-sided error	188.7411	356.0785	270.2594
Mean TE (percent)	72. 47	77.32	57.37
N (Sample)	754	754	754

Note: t-values are in the parentheses.

Column 3 of table 2 shows the estimation results for non-interest income. Both capital related expenses and employee expenses are having a positive and statistically significant impact at 1 percent level on non-interest income of banks. Of these, the former is the dominant factor as it has the larger coefficient (0.69). The interest expense has negative and significant parameter. Both σ^2 and γ terms have positive and statistically significant coefficients. The estimated value of γ indicates that about 87 percent of the difference between actual and potential output is because of technical inefficiency. In the technical inefficiency model, the results of almost all variables are more or less the same with variations in the magnitude of the impact of these variables.

Technical Efficiency Estimates

Table 2 shows that on an average, the sample banks realized only 72.5 percent of their technical abilities in raising total income and 77.3 percent in raising interest income and 57.4 percent of their technical abilities in raising non-interest income. Table 3 shows the time varying mean TE values by banks groups. The overall results indicate that the nationalized banks have the largest mean efficiency values in raising total income, interest income and non-interest income, followed by SBI group banks, private banks and foreign banks. The overall average TE value of banks in raising total revenue (income) increased from 71.5 percent in 2009-10 to 76.7 percent in 2011-12. After that it started declining to reach 68.2 percent in 2017-18. The overall efficiency of raising interest income increased from 74.9 percent in 2009-10 to 80.2 percent in 2012-13 and then declined to 74.4 percent in 2017-18. During 2009-19 to 2017-18, the overall mean efficiency of generating non-interest income declined from 61.3 percent to 54.1 percent.

During 2009-10 to 2017-18, the mean efficiency of raising total revenue of SBI group of banks declined from 85.6 percent to 84.2 percent. For nationalized banks, although the mean efficiency value increased initially and then declined, in 2017-18 their mean efficiency was the same as in 2009-10.

Table 3: Time Varying Mean Efficiency Values by Banks Groups

(Percent)

Year	SBI Group	Nationalized Banks	Private Banks	Foreign Banks	All Banks
Total Revenue					
2009-10	85.57	86.29	68.61	59.99	71.54
2010-11	83.76	87.76	67.91	59.95	70.9
2011-12	87.85	91.68	74.07	67.23	76.66
2012-13	88.54	92.56	76.07	62.25	74.16
2013-14	85.22	91.59	75.17	59.75	72.37
2014-15	86.12	89.18	75.14	62.57	73.47
2015-16	85.06	86.88	74.62	62.21	72.45
2016-17	80.4	86.36	75.94	62.21	72.38
2017-18	84.15	86.29	75.24	56.53	68.18
overall	85.29	88.71	73.64	61.32	72.47
Interest Income					
2009-10	88.79	89.08	77.44	59.89	74.85
2010-11	87.96	90.59	77.12	61.96	75.15
2011-12	90.69	92.87	82.19	67.76	79.48
2012-13	91.00	93.25	84.01	70.34	80.15
2013-14	89.12	93.08	83.47	65.79	77.73
2014-15	89.47	91.28	82.81	68.46	78.70
2015-16	88.87	89.54	83.00	67.89	77.90
2016-17	84.74	88.36	82.90	67.24	77.10
2017-18	87.41	88.49	82.73	63.93	74.37
Overall	88.8	90.71	81.73	66.17	77.32
Non-Interest Income					
2009-10	72.47	72.78	58.92	52.43	61.34
2010-11	69.16	68.80	54.80	52.56	58.58
2011-12	67.77	70.60	57.35	54.26	60.17
2012-13	67.23	72.17	58.88	44.25	55.56
2013-14	65.84	68.80	57.31	44.95	54.73
2014-15	69.04	69.36	60.70	46.09	56.64
2015-16	68.97	67.57	57.19	47.97	56.19
2016-17	72.74	74.15	63.26	48.82	59.89
2017-18	75.46	74.51	60.99	41.33	54.07
Overall	69.26	70.96	58.82	47.61	57.37

For private banks, the mean efficiency increased from 68.6 percent to 75.2 percent. For foreign banks, the mean efficiency declined from about 60 percent to 57 percent. During 2009-10 to 2017-18, the mean efficiency of raising interest income of SBI group banks declined marginally from 88.8 percent to 87.4 percent while the mean efficiency of nationalized banks declined from 89.1 percent to 88.5 percent. At the same time, the mean efficiency of private banks increased from 77.4 percent to 82.7 percent and the mean efficiency of foreign banks also increased from 59.9 percent to 63.9 percent. It is noticed that the mean efficiency values of raising non-interest income of SBI group, nationalized and private banks increased over the years and only for the foreign banks the mean efficiency value declined over the years.

SUMMARY AND CONCLUTION

This study has analyzed the efficiency and its determinants of commercial banks in India during post global financial period 2009-10 to 2017-18 using the standard technical efficiency effect model. The data set employed is an unbalanced panel of 99 banks (a total of 754 observations) belonging to four ownership groups. Following the operating approach, it has considered the total revenue (interest income plus non-interest income) as output and interest expenses, employee expenses and capital related expenses as inputs.

The results of the study indicate the dominants of capital related expenses in raising the total income and also the non-interest income and the dominants of employee expenses in generating interest income. Due to technical inefficiency, the observed outputs of banks are less than their respective frontier output. The average efficiency of banks is 72.5 percent in raising total income, 77.3 percent in raising interest income and 57.4 percent in raising non-interest income. In terms of average TE value of raising all three variants of outputs, the nationalized group ranks first, the SBI group second, the private banks third and the foreign group obtains the last rank. For almost all groups, the average efficiency initially

increased from 2009-10 to two or three years and after that all mean efficiency values declined. This is a clear indication that despite the consolidation of IT efforts, the banking performance in India deteriorated during the post global financial crisis period. It seems that Indian banks are still learning the new technology to reap the maximum possible outputs. Further, the mounting pile of non-performing assets would have caused the declining performance of all groups of banks.

The results also indicate that banks with larger capital adequacy ratio or older banks or banks with more branches are less inefficient in generating interest income. Banks with more branches seem to be less inefficient in generating non-interest income and total income, but banks with a larger capital adequacy ratio are more inefficient in generating non-interest income as well as total income. We hope that the results of this study may be useful to policy makers, international agencies, and other stakeholders in evaluating and increasing the performance of the banking sector in India.

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