“How efficient are public sector banks in India? A non-parametric approach”

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HOW EFFICIENT ARE PUBLIC SECTOR BANKS IN INDIA? A NON-PARAMETRIC APPROACH

Abstract

This study examines the efficiency of Public Sector Banks (PSBs) in India using Data Envelopment Analysis (DEA). Analysis is carried out on a sample of 19 PSBs that are existed during the study period from 2005 to 2018. There are two different aspects deliberated, namely technical efficiency of PSBs and the growth in their productivity. Input variables envisaged for the study are deposits, borrowings, fixed assets, and the number of employees. Loans and advances along with investments act as output variables to measure technical efficiency and productivity. The results indicate that the technical efficiency of PSBs ranges between 97% and 100%. Corporation Bank, Indian Bank, and Oriental Bank of Commerce outperformed their peers with 100% technical efficiency. Productivity growth among the sampled banks during the study period stood between 0.8% and 20%. However, Corporation Bank, Indian Bank, and Oriental Bank of Commerce registered 9.1%, 5.4% and 6.4% productivity growth, respectively. The results reveal that PSBs are working hard to optimize resource utilization. Researchers around the world can use DEA as a tool to measure the efficiency of banks with different input and output variables related to financial, marketing and managerial performance.

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INTRODUCTION

The economic development of any country depends on the financial sector, especially the banking sector. The role of financial intermediation in economic growth has been a widely recognized aspect of empirical research. Finance can stimulate the main drivers of growth, efficiency, and productivity of an economy (Yusifzade & Mammadova, 2015). The Indian banking sector is one of the healthiest performers in terms of competitiveness, growth, efficiency, profitability, and soundness in the world banking industry (Kumar Mishra, 2017). Banks' efficiency depends on a diversified banking system that attracts savings and channelizes them into productive investments to generate income.

Economists like Schumpeter have accepted the indispensable role of the financial system in the development of the economy. He characterized their significance as follows: "He [the banker] stands between those who wish to form new combinations and the possessors of productive means. The banker is a phenomenon of development" (Schumpeter, 1934). However, the banker can achieve development only through the process of efficient and effective financial intermediation. Simultaneously, the banking sector focuses on improving the quality of assets, appropriate capital, and an expectation of higher returns. Three eminent researchers representing The World Bank (Yeyati), Ministry of Finance Chile (Alejandro Micco) and Debt and Development Finance Branch, UNCTAD (Ugo Panizza), respectively,

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reappraised state-owned banks during 2007. Similarly, PSBs in India are not exempt from criticism for their functions and coverage, as in any other country (Yeyati et al., 2007).

Commercial banks in India comprise scheduled and non-scheduled commercial banks. Scheduled commercial banks in India comprise 27 in public sector banks (including SBI and its five associates) and 26 private sector banks. However, PSBs constitute 70% of the total banking assets in India as the principal lending agent (Deb, 2019). Like India, every county has a government-owned banking system to make banking facilities available to everyone at an affordable cost. In 2018, total assets of banks globally amounted to USD 147.9 trillion, whereas total banking assets in India were around USD 2.36 trillion (www.statistica.com). India stands at 56th position with 68.35% in terms of bank assets as percent of GDP (https://www.theglobaleconomy.com/rankings). This statistics clearly explains the importance of the Indian banking system to the world banking system. Ten years after the financial crisis, regulators and banking sectors joined hands and took the initiative to bring back the financial system (McKinsey, 2018). However, over the last couple of years, many fault lines are becoming evident in the PSB's corporate governance (RBI, 2019). With this backdrop, this study investigates the efficiency of PSBs in converting their input resources (deposits, borrowings, fixed assets, and employees) into output (loans & advances and investments) using DEA and MPI, which is a significant method to measure efficiency and productivity. The study examines differences in the technical efficiency and productivity of PSBs, analyzes the reasons for these differences and suggests measures to reduce them.

1. LITERATURE REVIEW

1.1. Evolution of data envelopment analysis and its application

In 1957, US economist Michael Farrell published a critical paper titled "The Measurement of Productive Efficiency," considering single-output/single-input to measure the technical efficiency of decision-making units. Charnes, Cooper and Rhodes improved this method with multiple-output/multiple-input in the year 1978. However, Farrell's seminal work has undergone various improvements, mainly categorized as three schools: Afriat School, Charnes School and Shephard School, as mentioned by Thompson et al. (1993). Allen N. Berger, a senior economist (Federal Reserve System), and David B. Humphrey, an eminent scholar in Banking at Florida State University, investigated efficiency issues in commercial banking in 1992 and concluded that technical efficiency progress was an outcome of a firm's technology (Berger & Humphrey, 1992). Five years later, the same researchers carried out an extensive review of international literature and found that frontier efficiency measurement techniques like "Stochastic Frontier Analysis, Data Envelopment Analysis and Thick Frontier Analysis" were extensively used (Berger et al., 1997). There was a shift from non-parametric methods used to estimate the production frontier to parametric tests. Lovell and Schmidt (1998) investigated and presented a comparative view of these approaches. In 2008, Wade and Larry explored the thirty years of research work using DEA considering four essential models used to measure efficiency, approaches to integrate restrictions on multipliers, considerations about the status of variables and data variation modeling (Lovell & Schmidt, 1998). In 2009, Yang, (2009) evaluated 240 branches of one big Canadian bank in the Greater Toronto Area using DEA. Primary emphasis was on managing the resources to achieve technical efficiency in various branches. Gupta and Garg (2011) applied DEA to examine commercial banks' competitiveness in India and found that 19 out of 49 banks are technical and scale efficient (Gupta & Garg, 2011). In the same year, Kumar and Maurya (2011) investigated the level of technical efficiency, considering globalization and its impact on the banks' ownership pattern. They concluded that Indian banks functioning abroad ranked better than foreign banks operating in India (Kumar et al., 2011). Kumar and Batra (2012) used MPI in their research to analyze panel data and concluded that stagnation in technological progress affected the Indian banking industry (Kumar & Batra, 2012).

Similarly, Singh and Gupta (2012) analyzed top Indian banks' technical proficiency between 2007 and 2011 to know the impact of the sub-prime crisis. They found that the variables changed significantly during the study period. They also emphasized that DEA was an appropriate tool to measure banks' efficiency. Selvam and Kingsly (2013) examined Indian private sector banks' technical efficiency and found that the improper utilization of input resources and obscene scale of operation resulted in technical inefficiency. In 2014, Ghozali, an economist from Indonesia, along with Subandi, an eminent researcher from Indonesia, estimated technical efficiency of banks using DEA. They found that size, type of banks, capital adequacy ratio, loan deposit ratio, operating expenses and net interest margin might significantly impact technical efficiency (Subandi & Ghozali, 2014). A group of researchers from China, Zha et al. (2016) and Liang et al. (2011), evaluated technical efficiency and banks' ownership structure. They found that the ownership structure of the banks influenced efficiency. Researchers from the United States, Badunenko and Kumbhakar (2017) measured the adjustment mechanism adopted by different ownership banks' in response to regulatory changes. They reported that banks of all proprietorships had experienced technological growth. However, foreign banks enjoyed the maximum benefit, followed by state-owned banks. Mezzi (2018) explored the efficiency of Islamic banking in Malaysia and GCC countries and identified that their optimum operation scale determined the scale efficiency. Ofori-Sasu et al. (2019) examined banks' technical efficiency in Ghana and found that Ghanaian banks lacked technical efficiency.

The efficiency and productivity of banks are always a matter of importance since they participate in financial intermediation. Several studies used DEA and SFA to measure the technical efficiency of banks in India, namely, Kumar and Sreeramulu (2007), Mahesh and Rajeev (2009), Sanjeev (2009), Verma and Bodla (2011), Sangeetha and Jain (2013) and Tamatam, et al. (2019). Continuing similar work, eminent researchers across the globe worked on the efficiency analysis, viz., Ajoa and Ogunniyi (2010) studied the technical efficiency of banks in Nigeria. Hon et al. (2011) explored the efficiency of banks in Malaysia to understand the effect of the Financial Sector Master Plan (FSMP) using DEA. They found that FSMP contributed to the efficiency growth of banks in Malaysia. Vinh (2012) analyzed the efficiency and productivity change of twenty Vietnamese commercial banks using DEA and found an increasing trend in TE with 30 percent inefficiency among 20 Vietnamese commercial banks. Analysis of total factor productivity indicates that the average annual growth of the Malmquist index has been positive. Qayyum and Riaz (2012) researched on the productivity changes of banks in an emerging economy. Raphael (2013) measured the productivity change of Tanzanian commercial banks using Malmquist productivity index and found that the banks under study registered progress in technical efficiency. Shah et al. (2019) explored sustainable and non-sustainable banks in various regions such as Asia, Europe, North America and South America using DEA and MPI. The results revealed that the sustainable banks were more efficient than non-sustainable banks.

Since maintaining efficiency in operations and utilizing resources (assets and liabilities) are a continuous requirement for creating sustainable operations, academicians and researchers worldwide are particularly interested in questions of efficiency. Previous research has focused on measuring banks' efficiency based on ownership patterns (public, private and foreign), size, country-specific, and operations during events like financial crises. This study aims to assess the technical efficiency of PSBs in India with the variables relating to the financial intermediation process. Perhaps the methodology adopted (DEA and MPI are worldwide accepted tools to measure efficiency and productivity) in the study is applicable to measure the efficiency of any bank across the globe. Understanding current levels of efficiency will enable banks, government, and policymakers in enhancing the future-readiness of banks. PSBs or state-owned banks in emerging nations hold 70% of the market share. Hence, this study is of direct relevance to further the understanding of the industry and its functioning.

2. METHODOLOGY

2.1. Model specification for data envelopment analysis

Production process can be described as a procedure that can turn a set of resources into attractive outcomes by production units. During this process, efficiency is used to determine how well a

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production unit is performing in using its resources to produce the outcomes. DEA provides a comprehensive analysis of relative efficiencies of multiple input and multiple output situations by evaluating each DMU and measuring its performance in relation to an envelopment surface composed of other DMUs. Those DMUs forming the efficiency reference set are known as the peer group for the inefficient units (Yang, 2009).

Banker et al. (1984) extended the CCR model by relaxing the CRS assumption. The resulting Banker, Charnes and Cooper (BCC) model is used to assess the efficiency of DMUs characterized by Variable Returns to Scale (VRS). The VRS assumption provides the measurement of Pure Technical Efficiency (PTE), TE devoid of the SE effects. If there appears a difference between the TE and PTE scores of a particular DMU, then it indicates the existence of scale inefficiency, i.e., $TE = PTE \cdot SE$. The former relates to the capability of managers to utilize the given resources of banks. In contrast, the latter refers to exploiting the scale of the economy by operating at a point where the production frontier exhibits CRS. The DMUs are homogeneous units whose performance is to be measured (Sekhri, 2011). For this study, DMUs are commercial banks. Technical efficiency score is the total weighted sum of input divided by the total weighted sum of output divided by the ratio of weighted inputs. The efficiency of a bank can be measured as to how efficiently it utilizes its inputs.

The following linear programming equations represent the input-oriented BCC model with VRS assumption:

Thus:

$$Efficiency = \frac{Weighted\ sum\ of\ ouputs}{Weighted\ sum\ of\ inputs} = \tag{1}$$
$$= \frac{u_1 y_1 + u_2 y_2 + u_n y_n}{v_1 x_1 + v_2 x_2 + \ldots . v_n x_n},$$

where u and v are weights for the outputs (y_1 ... y_n) and the inputs (x_1 ... x_n), respectively. The models with CRS to scale are known as the CCR model as it is proposed by Charnes et al. (1978) to estimate the input-oriented technical efficiency of the Korean banking sector.

The CCR model can be formulated as follows:

$$\min l_0 - \varepsilon \left[\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right], \tag{2}$$

Subject to:

$$\sum_{f=1}^{N} \lambda_f x_{if} = l_0 x_{ife} - S_i^-, \qquad \sum_{f=1}^{N} \lambda_f y_{rf} = S_r^+ + y_{rf0},$$

$$\lambda_f \geq 0, f = 1..N,\ S_i^-, S_r^+ \geq 0 \ \forall\, i \text{ and } r,$$

where x_{if} and y_{rf} are the levels of the i-th input and r-th output, respectively, for DMU f; N is the number of DMUs; ε is a very small positive number (non Archimedean) used as a lower bound to inputs and outputs; λ_f denotes the contribution of DMU f in deriving the efficiency of the rated DMU f_0 (a point at the envelopment surface); S_i^- and S_r^+ are slack variables to proxy extra savings in input i and extra gains in output r; and l_0 is the radial efficiency factor that shows the possible reduction of inputs for DMU f_0. If l_0 (optimum solution) is equal to one and slack values at the optimal solution, one can conclude that the corresponding input or output of DMU f_0 is said to be efficient. When S_i^- or S_r^+ are positive values at the optimal solution, one can conclude that the corresponding input or output of DMU f_0 can improve further once input levels have been contracted to the proportion l_0*. This study aims to identify the technical efficiency and technical inefficiency of PSBs.

2.2. Model specification for the Malmquist productivity index

Malmquist productivity index is used to measure the changes in firms/banks' efficiency over some period of time. Productivity indices are resultant of production frontier models. Total Factor Productivity (TFP) has various components to provide a clear understanding of Technical Change and Efficiency Change (Fare et al., 1994). Shifts in the production frontier are measured by technical changes, whereas efficiency change measures shifts in the frontier position of a production unit or bank. In 1992, various researchers from Norway representing banking (Atle Berg, Eilev S. Jansen) and the education sector (Finn R. Forsund) measured the average productivity growth, frontier growth and the spread of growth rates in the banking industry using MPI. They concluded that there were very negligible productivity growth at the frontier and noticeable improvement in most banks' relative efficiency (Berg et al., 1992). Borrowing MPI concepts from the earlier researchers, Economics professor Suleyman Desgirmen in collaboration with a professor from the Business Education department, Benli Yasemin Keskin, attempted to apply DEA based Malmquist Total Factor Productivity Index on Turkish banks (TB). They found that with the advantage of technology, foreign banks outperformed other groups. Further, they specified that the financial crisis had brought a setback in TB's technical efficiency (Benli & Degirmen, 2013).

Economics professors from Australia studied the changes in productivity of financial institutions in Botswana during 2009 and found that both decrease and improvement in productivity were technological regress outcomes. Considering the above research that has used MPI to measure productivity, this study intends to apply the same with the following description of the methodology.

Malmquist productivity Index is defined using distance functions. Suppose the function that describes the technology of production is given as $F(X,Y) = 0$, where $X = (x_1, x_2, x_3, ..., x_m)$ is the input vector and $Y = (y_1, y_2, ..., y_s)$ is the output vector. Caves et al. (1982) provide an alternative interpretation of production technology using the concept of 'distance function'. They defined the output distance function as $D_0(X,Y) = Min\left[\mu : F(X,Y/\mu) = 0\right]$ where μ_Y is the minimum equiproportional change in the output vector. The distance function measures the maximum proportional change in output required to place (X,Y) on the efficiency frontier. If the evaluated production unit is efficient, $D_0(X,Y) = 1$, otherwise $D_0(X,Y) < 1$. A distance function may also be computed with input orientation, with reference to technology in a certain period and with CRS or VRS specification. Let $D_t^0(CRS)$ and $D_t^0(VRS)$ denote the output distance function with period t technology and with CRS and VRS specifications, respectively. The output distance function is the maximum equiproportional increase in output for a given input. This is the output oriented (Farrell, 1957) technical efficiency. Therefore, the distance function can be determined using the DEA method.

Caves et al. (1982) as cited in (Galagedera & Edirisuriya, 2005) define the output-based MPI to compare the performance of a production unit in time period t and $t + 1$ with reference to period t technology as

$$M_0^t\left(X_{t+1},Y_{t+1},X_t,Y_t\right) = \frac{D_0^t\left(X_{t+1},Y_{t+1}\right)}{D_0^t\left(X_t,Y_t\right)}. \quad (3)$$

The output-based productivity index measures the maximum level of outputs that can be produced using a given input vector and a given production technology relative to the observed levels of outputs (Coeli et al., 1998 as cited in Galagedera & Edirisuriya, 2005).

Alternatively, output based MPI can be defined with reference to $t + 1$ technology as

$$M_0^{t+1}\left(X_{t+1},Y_{t+1},X_t,Y_t\right) = \frac{D_0^{t+1}\left(X_{t+1},Y_{t+1}\right)}{D_0^{t+1}\left(X_t,Y_t\right)}, \quad (4)$$

$M_0 > 1$ indicates higher productivity in period t than in period $t + 1$.

Fare et al. (1994) as cited in Galagedera and Edirisuriya (2005) define an index that incorporates Malmquist indices in both periods. They suggest avoiding choice of the period arbitrarily. Fare et al. (1994) specify the output-based Malmquist total factor productivity change index as

$$M_0\left(X_{t+1},Y_{t+1},X_t,Y_t\right) = \left[\left(\frac{D_0^t\left(X_{t+1},Y_{t+1}\right)}{D_0^t\left(X_t,Y_t\right)}\right)\left(\frac{D_0^{t+1}\left(X_{t+1},Y_{t+1}\right)}{D_0^{t+1}\left(X_t,Y_t\right)}\right)\right]^{\frac{1}{2}} = \left(\frac{D_0^{t+1}\left(X_{t+1},Y_{t+1}\right)}{D_0^t\left(X_t,Y_t\right)}\right) \times \left[\left(\frac{D_0^t\left(X_{t+1},Y_{t+1}\right)}{D_0^{t+1}\left(X_{t+1},Y_{t+1}\right)}\right)\left(\frac{D_0^t\left(X_t,Y_t\right)}{D_0^{t+1}\left(X_t,Y_t\right)}\right)\right]^{\frac{1}{2}} \quad (5)$$

where the component outside the square brackets is the change in the output oriented measure of technical efficiency between periods t and t + 1. The other component in equation (6) captures the shift in technology (technological change Index – TCI) between the two periods t and t +

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1. The output based Malmquist total productivity change index is the geometric mean of output-based Malmquist productivity indices with reference to period t and period $t + 1$ technology. The ratio outside the square brackets in equation (6) is often referred to as the boundary shift component. The catch-up term compares the closeness of the production unit in each period to that period's efficient frontier, whereas the boundary shift term represents productivity gain/loss by the industry and not necessarily by the production unit itself. When the boundary shift is equal to 1, the industry has on average registered no productivity gain or productivity loss between period t and $t + 1$ (Thanassoulis, 2001 as cited in Galagedera & Edirisuriya, 2005).

When the efficient production is characterized by variable returns-to-scale, the change in the productivity of a production unit may be impacted by changes in scale size. In that case, the component outside the square brackets in equation (6) can be decomposed into a pure technical catch up component and a scale efficiency catch-up component. Pure technical efficiency catch-up and scale efficiency catch-up are orientation dependent. Now for a given production unit, the indices that capture changes in period $t+1$ relative to period to period t are given by:

Total factor productivity change index (TFPCI)

$$\text{TFPCI} = \left(\frac{D_0^{t+1}\,(CRS)(X_{t+1}, Y_{t+1})}{D_0^{t}\,(CRS)(X_t, Y_t)} \right) \times \left[\left(\frac{D_0^{t}(CRS)(X_{t+1}, Y_{t+1})}{D_0^{t+1}(CRS)(X_{t+1}, Y_{t+1})} \right) \left(\frac{D_0^{t}(X_t, Y_t)}{D_0^{t+1}(X_t, Y_t)} \right) \right]^{\frac{1}{2}}. \quad (7)$$

The indices of MPI are less than one, one and greater than one. One is subtracted from the index to estimate the growth, and then the value is multiplied with 100 to get the growth rate. If the index is more than one, the bank is said to be with growth in TFP, and less than one indicates negative growth. However, each operation of a bank is supported by technical, technological, management and scale/size efficiencies to have better productivity. Collectively a positive change in all these aspects will lead to growth in total factor productivity (TFPCI). This study used MPI to measure the PSB's growth in TFP during the study period.

2.3. DEA application in the banking sector

Eminent researchers from India and various other countries used DEA to measure bank efficiency. Accordingly, this study considered DEA to measure the technical efficiency of PSBs in India taking the support from the research work carried out across globe discussed below. Dash and Charles (2009) assessed the technical efficiency of Indian banks using DEA and found that 59.5% of the banks were proficient. Few other eminent researchers in India, Reddy and Subramanyam (2011), Sinha (2011), Ibrahim (2011) and Thomas (2019), considered DEA as an instrument to assess the efficiency of banks. Economics professors from Italy Favero and Papi (1995) explored a non-parametric DEA to the measure technical efficiency of 174 Italian banks and revealed that the results depend on the specifications of inputs and outputs. They furthered with regression analysis and found that productive specialization and size impacted efficiency more than location. Valadkhani, Moffat, & Harvie, (2009) explored the efficiency and productivity of 10 financial institutions in Bostwana during post financail era and found that technological progress is the main reason for the gain in efficiency as well as productivity. In 2010, a Professor from Uzbekistan Nigmonov applied DEA to measure the efficiency of Uzbek banks and found that there was an improvement in the overall efficiency (Nigmonov, 2010). A group of researchers from Malaysia, Sufian and Habibullah (2010), studied the contributors to efficiency in the banking sector in Thailand. It was revealed that the inappropriate scale of operations contributed more to inefficiency. Various authors from Pakistan, Usman, Wang, Mahmood, and Shahid have attempted to check banks' technical efficiency in Pakistan, categorizing banks based on ownership. They concluded that overseas banks functioned better than the banks with the state ownership (Usman et al., 2010). Researchers from China, Yannick, Hongzhong, and Thierry (2016), analyzed the banking sector in the West African Economic and Monetary Union to measure banks' efficiency (both public and private banks) in transforming the deposits into credits to its clients using DEA. They concluded that private banks were comparatively better than their counterparts due to inappropriate operation (Yannick et al., 2016).

3. DATA AND RESULTS

This section describes the data used for the analysis, its rationale and the findings of empirical investigation. This paper used secondary data of 19 banks collected from the RBI website. It considers the banks that existed during the study period (2005–2018). Due to the merger of all subsidiaries of the State Bank of India on February 15, 2017, the total assets composition undergone a drastic change, hence it is excluded. IDBI bank was incorporated as a Banking Company under the Companies Act 1956 in September 2004, so it has been excluded from the study. The study period (2005–2018) saw various reforms in the regulatory environment. Increasing PSB's capital through private contribution (2004), FDI participation (2005), financial crisis (2008), permission to foreign banks to incorporate subsidiaries of branches (2009), FSDC 2010, Nayak Committee report (2014), Pradhan Mantri Jan Dhan Yojana (PMJDY 2014), New Banks license policy and Payment banks license 2015, demonetization (2016) and introduction of GST (2018) are few of the reforms initiated during the study period. Since these initiatives are taken to mark an improvement in the efficiency of banks, it is appropriate to measure the efficiency and productivity of PSBs. Reviews indicate that DEA can be applied to measure the relative efficiency of public sector banks; also, MPI can be used on the panel data to analyze the productivity and its growth across the period. Hence, DEA and MPI are chosen as a tool to measure efficiency and productivity. Accordingly, variables are chosen to assess the public sector banks' technical efficiency and productivity. Commercial banks' primary operation is to accept deposits and provide loans and advances, which is fundamental for financial intermediation. Hence, deposits, borrowings, number of employees and fixed assets are used as inputs; loans and advances, as well as investment, are used as outputs to carry out the analysis.

Table 1 depicts total banking sector's assets (in USD billion) held by Public Sector Banks (PSBs), Private Sector Banks (PVSBs) and Foreign Banks (FBs) along with descriptive statistics. It is evident that PSBs hold the majority of the share (average 76.94%). Therefore, this study is appropriate to measure the efficiency and productivity of PSBs.

Table 1. Sector wise asset holding by commercial banks in India

Years	PSBs	PVSBs	FBs	Total
2013	1140.20	325.90	104.50	1570.60
2014	1305.00	369.90	122.60	1797.50
2015	1421.40	415.10	123.50	1960.00
2016	1347.90	488.10	121.10	1957.10
2017	1518.46	558.92	125.52	2202.90
2018	1557.04	666.99	134.12	2358.15
2019	1038.76	288.96	22.57	1350.29
Mean	1332.68	444.84	107.70	1885.22
Standard deviation	190.24	134.90	38.57	348.37

A concise explanation about the results and its interpretations is displayed in tabular form. Table 2 exhibits various levels of efficiency and productivity scores as an outcome of DEA.

Table 2. Technical efficiency and MPI scores and its interpretation

Measure	Score	Interpretation
1. Technical efficiency	1	100% efficient
2. Technical efficiency	< 1	Inefficient to the extent of 1 – TE score
3. MPI score	> 1	Growth in productivity
4. MPI score	1 and < 1	No growth, negative growth and loss of growth

Table 3 expresses the individual bank-wise TE score of PSBs during the study period. Table 1 shows that two banks, namely, Corporation Bank and Oriental Bank of Commerce, have emerged as 100% efficient banks throughout the study period. The Corporation Bank and Oriental Bank of Commerce are the references set for the remaining PSBs in India. This finding reveals that these two banks managed and utilized the resources well and had an optimum scale of operations. Another fascinating point to note is that the Corporation Bank and Oriental Bank of Commerce have not wasted their resources during the financial intermediation process. The best practices of these banks form the benchmark for the remaining banks.

Though Indian Bank captured a mean TE score of 1, it had less than 100% (99.3%) during 2011. The TE score of the remaining 17 banks is relatively lower (less than one), indicating scope for improvement in resource utilization and man-

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Table 3. Describing the technical efficiency (TE) scores of public sector banks in India (2005–2018)

No.	Bank name	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
1	ALLAHABAD BANK	1.000	1.000	1.000	0.998	1.000	1.000	0.981	0.987	0.962	0.984	0.970	0.991	0.984	0.945	0.986
2	ANDHRA BANK	0.971	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.979	0.967	0.994
3	BANK OF BARODA	0.930	0.928	0.954	0.979	1.000	1.000	1.000	1.000	0.949	0.968	0.937	0.957	1.000	1.000	0.972
4	BANK OF INDIA	1.000	0.964	0.978	1.000	1.000	1.000	0.956	0.983	0.964	1.000	0.973	1.000	0.954	0.916	0.978
5	BANK OF MAHARASHTRA	1.000	0.979	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998
6	CANARA BANK	1.000	1.000	1.000	1.000	1.000	0.993	0.973	0.944	1.000	0.986	0.940	0.913	0.928	0.969	0.975
7	CENTRAL BANK OF INDIA	0.940	0.904	0.957	1.000	1.000	0.936	0.965	1.000	0.970	1.000	1.000	1.000	1.000	1.000	0.977
8	CORPORATION BANK	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
9	DENA BANK	0.989	1.000	0.981	0.975	1.000	1.000	1.000	0.962	1.000	0.993	0.942	0.944	0.958	0.975	0.980
10	INDIAN BANK	1.000	1.000	1.000	1.000	1.000	1.000	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	INDIAN OVERSEAS BANK	0.980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.973	1.000	1.000	0.974	0.995
12	ORIENTAL BANK OF COMMERCE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
13	PUNJAB AND SIND BANK	1.000	0.944	0.948	1.000	1.000	0.984	0.985	0.965	0.979	1.000	1.000	1.000	1.000	1.000	0.986
14	PUNJAB NATIONAL BANK	1.000	0.905	0.998	1.000	0.981	1.000	0.995	0.995	1.000	0.996	0.957	0.961	0.926	0.922	0.974
15	SYNDICATE BANK	1.000	1.000	0.968	1.000	1.000	1.000	1.000	0.997	1.000	1.000	0.968	0.987	1.000	1.000	0.994
16	UCO BANK	0.954	0.975	0.978	0.981	0.954	1.000	1.000	0.972	0.967	1.000	0.955	1.000	1.000	1.000	0.981
17	UNION BANK OF INDIA	0.982	1.000	1.000	0.991	0.974	0.986	0.992	1.000	1.000	0.999	0.991	1.000	1.000	1.000	0.994
18	UNITED BANK OF INDIA	1.000	0.994	1.000	1.000	0.953	1.000	0.960	0.950	0.988	1.000	1.000	0.930	1.000	1.000	0.984
19	VIJAYA BANK	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.997	0.970	1.000	1.000	0.962	0.981	1.000	0.994
Mean		0.987	0.979	0.987	0.996	0.993	0.995	0.990	0.987	0.987	0.996	0.979	0.981	0.985	0.983	0.988
Standard deviation		0.022	0.034	0.018	0.008	0.016	0.015	0.015	0.019	0.017	0.008	0.024	0.028	0.025	0.028	–

Table 4. Describing total factor productivity change of public sector banks in India (2005–2018)

No.	Bank name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
1	ALLAHABAD BANK	1.360	0.636	0.907	1.143	0.961	0.981	1.040	0.974	1.016	1.005	0.982	0.984	0.964	0.996
2	ANDHRA BANK	1.304	1.262	1.145	1.078	0.896	1.113	1.222	1.163	1.068	1.098	0.798	0.933	0.994	1.083
3	BANK OF BARODA	1.078	1.066	1.077	1.078	1.056	1.132	1.143	1.043	1.083	1.034	0.973	1.061	1.067	1.069
4	BANK OF INDIA	1.038	1.056	1.140	1.105	1.059	1.061	1.078	1.006	1.074	1.018	0.959	1.039	0.981	1.047
5	BANK OF MAHARASHTRA	0.928	1.037	0.964	1.230	1.192	0.542	1.028	0.851	0.963	1.028	1.580	0.756	1.110	1.016
6	CANARA BANK	1.473	0.353	0.827	1.048	1.022	1.024	1.015	1.060	1.067	1.026	0.849	0.992	1.040	0.984
7	CENTRAL BANK OF INDIA	1.005	0.874	0.972	1.574	0.693	1.048	1.077	0.967	1.055	1.006	1.419	0.650	3.361	1.208
8	CORPORATION BANK	1.222	1.154	1.237	1.292	1.003	1.131	1.082	1.147	1.095	1.000	0.988	0.769	1.062	1.091
9	DENA BANK	2.745	0.114	1.044	1.919	0.684	1.144	1.063	1.063	1.036	1.035	0.983	0.980	1.018	1.141
10	INDIAN BANK	1.019	1.078	0.995	1.061	1.002	1.019	1.155	1.209	0.848	1.385	0.943	0.967	1.019	1.054
11	INDIAN OVERSEAS BANK	1.122	1.032	1.015	1.032	1.004	1.050	1.016	1.026	0.999	0.983	1.026	0.974	0.972	1.019
12	ORIENTAL BANK OF COMMERCE	1.140	1.137	1.163	1.264	1.004	1.118	1.337	0.515	1.039	1.148	0.966	0.908	1.088	1.064
13	PUNJAB AND SIND BANK	0.850	0.541	1.021	1.028	1.025	1.023	1.024	1.115	1.138	1.561	0.677	0.903	1.199	1.008
14	PUNJAB NATIONAL BANK	1.005	1.166	1.013	1.005	1.031	1.034	1.019	1.037	0.978	0.973	0.953	0.944	1.007	1.013
15	SYNDICATE BANK	0.991	1.137	1.144	1.169	0.895	1.043	1.014	1.021	1.013	1.006	0.889	1.005	0.998	1.025
16	UCO BANK	1.113	1.026	1.091	1.069	1.049	1.080	1.030	1.023	1.023	0.966	1.069	0.953	1.044	1.041
17	UNION BANK OF INDIA	1.148	1.029	1.003	1.032	1.053	1.069	1.064	1.022	1.009	1.031	0.976	0.997	1.056	1.038
18	UNITED BANK OF INDIA	0.921	0.920	0.986	1.076	1.017	0.916	0.990	1.022	1.141	1.077	1.024	1.096	0.915	1.008
19	VIJAYA BANK	1.104	0.758	0.912	1.188	0.895	1.103	0.991	1.076	1.261	1.009	0.886	0.983	1.032	1.015
Mean		1.145	0.824	1.030	1.162	0.968	1.022	1.070	1.005	1.044	1.065	0.980	0.935	1.096	1.027
SD		0.408	0.304	0.102	0.224	0.122	0.132	0.087	0.145	0.084	0.150	0.200	0.110	0.538	–

agement. Bank of Maharashtra obtained 0.988 as its TE score, meaning it had nearly 100% technical efficiency. Nevertheless, Andhra Bank, followed by Indian Overseas Bank, Syndicate Bank, Union Bank of India, United Bank of India and Vijay Bank, registered 99.5%. The overall mean score of 0.988 indicates that PSBs with less than 100% efficiency have wasted their resources by 2.2%, leaving room for optimizing resources. This means that banks have used more resources than required for financial intermediation. PSBs could have achieved the same output level with 98.8% of inputs (deposits, borrowings, fixed assets and employees).

Nevertheless, the potential reduction of input may vary from bank to bank. For example, to get a 100% TE score, Bank of Maharashtra (being the least TIE scorer) and Bank of Baroda (being the highest TIE scorer) could have reduced their present input levels 0.02 % and 2.7 %. On average, banks with less than 100% could have improved their efficiency by 1.02 times (1/0.959), with the reduced input of fixed assets, deposits, borrowings, and the number of employees. Optimum resource allocation will facilitate the bank's resources to boost financial intermediation by extending banking facilities to more beneficiaries. Also, increased financial intermediation will positively affect the output level of goods and services in the economy.

The standard deviation reveals that dispersion among the banks in a year has been very moderate. This means that the TE scores achieved among all the banks have a very negligible deviation. Low product differentiation in the banking sector can contribute to negligible deviation among the TE scores of banks. All the banks, irrespective of their size and spread, cater to analogous segments and terrestrial populations. Strong product differentiation to satisfy the demands of heterogeneous customers may improve efficiency.

Having grasped TE and TIE of PSBs, it is essential to identify the growth or productivity changes during the study period. For this purpose, MPI is being used to trace the growth in productivity. As per MPI, Total Factor Productivity (TFP) is the outcome of better resource utilization. Table 4 indicates that out of 19 banks considered for study in the PSB group, 17 have registered productivity growth during the study period. Two banks, Central Bank of India and Dena Bank, have recorded a productivity growth rate of 20.8% and 14%, respectively. Out of the 15 remaining banks, 13 have positive growth except for two banks that have shown negative growth. Among the 13 banks, the growth percentage varies between 9% (Corporation Bank) and 0.8% (United Bank of India). However, Allahabad Bank and Canara Bank recorded negative growth (loss of growth) to the extent of 1% to 2%. One of the reasons for growth in productivity or TFP score is the change or improvement in technical efficiency. Deviation observed is very high during 2018, 2006, 2007 and 2016 with 0.538, 0.408, 0.304 and 0.200, respectively.

While comparing the minimum and the maximum number of banks with productivity growth during the study period, 2009 witnessed the best year with all the banks showing growth. However, 2016 and 2017 saw negative growth, indicating a significant impact of demonetization on financial intermediation.

This study evidenced the relationship between efficiency and productivity. Out of 19 banks, 17 banks recorded productivity growth though they had less than 100% TE score. With the current status, only two banks with 100% TE score and the remaining banks with 97% to 99%, 17 banks registered with an increase in productivity. Though 89% of the sample banks (17 banks) were with less than 100% technical efficiency, they all could register productivity growth. This means that PSBs have done the effective channelization of resources in the process of financial intermediation. PSBs ensure a perfect link between the income earners with surplus and market players with the deficit. Through this process, PSBs impact the level of productivity in the economy.

CONCLUSION

This study focused on investigating the levels of technical efficiency and productivity of PSBs. The study period of 2005–2018 (14 years) witnessed tremendous changes in banking regulation. However, the DEA results show that individual banks could achieve an overall 97% to 100% technical efficiency, leaving 3% as inefficiency. This means that PSBs are using more resources than required, also they can achieve the present output level with lesser input. MPI exhibits productivity growth ranging between 0.8% and 20.8%. PSBs with 97% to 100% TE could register productivity growth (17 banks out of 19 banks). This proves that efficiency and productivity are interrelated.

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Perhaps it can be reaffirmed that PSBs have taken all efforts to be the best in the financial intermediation process with optimum use of their resources. The individual banks with less than 100% efficiency should refer to their peers, namely Corporation Bank and Oriental Bank of Commerce, that have 100% TE to improve their performance.

This study considers two economic effects to conclude. Namely, PSBs are government-controlled and preferred banks. Their long established existence in the economy and government regulation makes them work under a fixed framework to maintain efficiency, leading to better productivity. On the other hand, PSBs face a massive challenge by catering to the priority sector's requirement at a nominal rate. PSBs operating under these two regimes have proven that they excel in their operations. However, if they can optimally allocate their resources, that will bring better efficiency and productivity.

Academicians and researchers can adapt the considered research methodology to carry out further research in different regions. Besides, researchers can extend the scope of the study to any ownership structure, size, period and variables. The findings can also be used by policymakers to understand banks' efficiency and productivity level in India to establish additional policies. Moreover, DEA's output can be augmented for a second-stage analysis to scrutinize the significance of the input and output variables in determining bank efficiency.

AUTHOR CONTRIBUTIONS

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Formal analysis: Sangeetha R.
Investigation: Sangeetha R.
Methodology: Sangeetha R.
Resources: Sangeetha R.
Software: Sangeetha R.
Supervision: Sangeetha R.
Validation: Sangeetha R.
Visualization: Sangeetha R.
Writing – original draft: Sangeetha R.
Writing – reviewing & editing: Sangeetha R.

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