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Measuring Total Factor Productivity Change in Kerala's Private Banks, 2014–2024: A DEA–Malmquist Approach

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ABSTRACT

This relates to the study of the change of productivity of selected banks in the private sector in the twenty-four months of 2014 to 2024 as measured by Data Envelopment Analysis (DEA) based Malmquist Productivity Index (MPI). Over the last decade, regulated changes, high-speed digitalization and external shock on the external economy have led to tremendous structural changes of the banking sector in India, thereby making the productivity assessment an essential factor in measuring the sustainability of performance. The reason is that the study is concerned with four banks in the private sector with a high level of operation in Kerala and uses a non-parametric and output-based DEA model to identify the change in the total factor productivity and its components. The Malmquist index is broken down into efficiency change and technological change identifying the major contributors to the productivity change with time. The findings indicate that there is a lot of heterogeneity in productivity performance of the sampled banks. Banks that had greater technological penetration and digitization achieved long term productivity increase and others stagnated or contracted as a result of managerial inefficiencies and poor technological advancements. Change in technology was seen as the major factor that led to productivity increase, and efficiency was a relatively minor factor. The results point to the relevance of innovation-based strategies, Quality management practices and adaptive capacity in increasing the productivity in the long term in the banking industry. The study contributes to the existing body of literature by bringing about region-specific and longitudinal evidence regarding banking productivity and presents useful insights to the management of a bank and relevant policymakers concerned with enhancing the resiliency and efficiency of banks in the private sector in Kerala.

Keywords: Banking Productivity; Malmquist Productivity Index; Data Envelopment Analysis; Technological Change; Efficiency Change; Kerala.

1. Introduction

Banking sector has centrality in economic development of mobilizing savings, making credit allocation efficient, and through financial inclusion. In the few emergent economies like India, banks play a vital role in growth sustenance, financial stability, and structural transformation. The Indian banking sector has experienced fundamental changes in the last ten years because of the regulatory reforms, the digital transformation, the fintech firms, and the macroeconomic shocks. These changes have accelerated the necessity to evaluate the nonprofitability as well as the dynamics of productivity and efficiency of the banks over a period of time (Das and Ghosh, 2006; RBI, 2023).

The banking industry in India has witnessed the feature of the emergence of the private sector banks that have been brought out as the active contributors of the innovation and operational efficiency. The private banks have been found to be more flexible to the use of technology and enhancement of service delivery and risk management compared to the banks in the public sector. The state of Kerala offers a distinct banking productivity study because of its great banking penetration, stable deposit base, and large inflows of expatriate remittances as well as the comparatively mature financial environment. Federal Bank, South Indian Bank, CSB Bank, and Dhanlaxmi Bank are some examples of a Kerala-based private bank and therefore heterogeneously performed in the post-2014 period, which is why they could be evaluated in the productivity comparison (RBI, 2022). The issue of productivity change in the banking business demands analytical tools which are beyond the conventional financial

ratios. The Total Factor Productivity (TFP) analysis offers a very broad tool in assessing the efficiency of banks in utilizing inputs, particularly labor, capital, and operating cost in the production of outputs, e.g., loans and income. Of the non-parametric techniques, Data Envelopment Analysis (DEA) paired with the Malmquist Productivity Index (MPI) has been commonly accepted in analysing productivity change through time. The MPI enables a break down of productivity into efficiency change (catch-up effect) and technological change (frontier shift), and hence considerably more informative on the origins of performance gain or loss (Färe et al., 1994; Coelli et al., 2005).

Empirical investigations have been based on Malmquist index applied to the banking sector which has recorded varying levels of productivity among countries and over time. The studies on Indian banks reveal that the progress in technology has been very significant in driving the growth in the productivity of Indian banks, not the increase in the efficiency of their managers particularly after the stints of regulatory change and digitalization (Kumbhakar and Sarkar, 2003; Kumar and Gulati, 2010). Other new researches point to the fact that technical efficiency in private banks has increased through the use of digital banking platforms, core banking solutions, and analytics-based credit assessment (Sahoo and Tone, 2019; Singh and Malik, 2022).

Although the literature on banking efficiency in India is increasing, no longitudinal evidence has been done on regional private sector banks and the dynamics of their productivities over a long period. The majority of the available literature research (on either short durations or consolidates banks on national basis) and thus fails to capture the institutional and operational specificities of regions. Moreover, this timeframe, 2014-2024, is critical since it is the time of key policy initiatives which include financial inclusion incentives, demonetization, growth of digital payment existence, COVID-19 crises, and recovery after the pandemic. Comparing the changes in productivity at this time can provide useful information on the resilience and adaptability of the private banks in Kerala.

It is against this that the current research undertakes the Malmquist Productivity Index in a DEA model that will be used in analyzing productivity change of a sample of the Kerala based selected banks in the private sector between the years 2014 and 2024. Breaking down productivity into efficiency change and technological change, the study is aimed at determining the primary sources of performance changes between banks and across time. It is believed that the findings will be useful in the literature on banking productivity, provide managerial implications on improving the operational efficiency, and assist the policymakers to formulate strategies in enhancing the banking system in the region.

1.1. Statement of the Problem

It is necessary to improve the productivity of the banking sector to be able to maintain the financial stability, improve the delivery of credit, and promote the long-term economic development. Over the last few years, Indian banks have been experiencing increasing pressure due to the tightening of regulations, escalating operational costs, technological turmoil, and transformation of customer expectations. Although such financial indicators as profitability and asset quality are often monitored, they fail to represent the efficiency with which a bank converts inputs into outputs over the course of the time. This drawback has prompted an alarm among the researchers and

policymakers of the lack of holistic productivity-related measurements in the Indian banking industry (Berger and Mester, 2003; RBI, 2023).

The banking segment of the Indian private sector has been recording fast growth since 2014 due to efforts of digital banking, competition, and more market penetrations. The increase in productivity has however not been evenly distributed among banks and geographies. Empirically it has been indicated that some of the private banks have taken advantage of the technological advances, but there are others still having scale inefficiencies, high operating costs, and poor levels of resources utilization (Sufian and Kamarudin, 2016; Ray and Das, 2021). The latter imbalanced results confirm the necessity of disaggregated, bank-based analysis of productivity as opposed to aggregate, country-wide research.

Kerala is an independent and understudied environment of banking productivity. It also has a high level of literacy, high banking penetration, high level of remittances and also a dense network of branches. Although these are good conditions, a number of Kerala based private banks have recorded inconsistent performance levels over the last ten years such as a change in the level of operational efficiency, credit growth and level of technology adoption. The current research on Indian banking productivity has also over-generalized the aspects of region-specific dynamics and thus could not account for the institution, demographic, and economic peculiarities of states such as Kerala (Chaudhuri and Ray, 2017; Joseph and Varghese, 2020).

Additionally, the 2014-2024 years have been characterized by major structural and external shocks which might have caused a change in productivity trends within the banking industry. They are significant policy changes, intensive digitalization, the incident of demonetization, the COVID 19 crisis, and post-pandemic recovery. The conventional efficiency research which mostly relies on cross-sectional research with only a year old data is not sufficient to measure productivity transformations throughout these radical stages. To interpret how banks have evolved throughout the years, Longitudinal tools that have the ability to break down productivity into efficiency change and change in technology are therefore needed (Färe et al., 1994; Pastor and Lovell, 2005).

Despite the Malmquist Productivity Index (MPI) generally being relied upon as a viable concept in understanding the change of productivity, its use in the case of the regional Indian organizations that are in the private sector of the Indian banks is sparse. The majority of the previous studies are based either on the analysis of public sector banks or refer to the short-term periods, providing limited information on the dynamics of productivity. The obvious gap in research is the use of DEA-Malmquist framework to measure the productivity change of a specific long-term period of Kerala-based private banks, specifically, by separating improvements in managerial efficiency and technological changes (Sahoo and Tone, 2019; Kumar et al., 2022).

Considering these gaps, the current research has gone to fill the gap of lack of longitudinal and region-specific evidence on the changes in the productivity in the private sector banks of Kerala. The study will try to give a subtle insight into the total factor productivity change and its constituents by using the Malmquist Productivity Index to analyze data between 2014 and 2024. The solution of this issue is of the primary importance to the bank management, regulators and policymakers striving to increase efficiency and technological advancement and resiliency of the banking system in the region.

2. Review of Literature

The empirical study of productivity and efficiency of the banking industry has been of significant concern especially because of the pivotal role of the banking sector in financial intermediation and economic development. Early research focused on performance measures based on ratios; the studies were however criticized as not being able to measure many as inputs and outputs at the same time. As a result, the non-parametric approach like Data Envelopment Analysis (DEA) became eminent in assessing the efficiency of the banks without unrealistic limiting functional form (Berger and Humphrey, 1997). DEA-based methods enable relative efficiency comparison amongst banks and have been extensively used both in the developed and the emerging economies.

The Malmquist Productivity Index (MPI) put forward by Färe et al., (1994) took the DEA a step further as it allowed the measurement of change in productivity across a period of time. According to the MPI change in total factor productivity (TFP) is further broken down into efficiency change (catch-up effect) and technological change (frontier shift), providing more detailed insights on the origins of productivity growth or contraction. Major methodological improvements followed showing that MPI fits best industries with high rates of technological innovation as well as regulatory change to constantly redefine the production frontiers such as banking (Coelli et al., 2005; Pastor and Lovell, 2005).

A number of studies across the globe have used the DEA-Malmquist framework to determine productivity in the banking sector. According to Berger and Mester (2003), technology advancement made significant contributions to improvement in productivity in the U.S. banks more than efficiency. Equally, other reports on the banking sector in Europe and Asia indicated that innovation around information and other automation of the process contributed greatly to the technical change even as efficiency continued to be limited by managerial inefficiencies (Delis et al., 2011; Fukuyama and Weber, 2010). These are significant findings that indicate the need to draw the line between efficiency-driven and technology-driven productivity growth.

Within the Indian context, these reforms in the banking sector that were begun in the 1990s brought about an onslaught on efficiency and productivity research. According to Kumbhakar and Sarkar (2003), the effect of deregulation on Indian banks was a positive growth in productivity, however, this growth was not evenly distributed among the ownership groups. Subsequent analyses which employed the Malmquist index showed that technological change and not improvement in pure technical efficiency was the major determinant of productivity growth in Indian banking (Kumar & Gulati, 2010; Chaudhuri and Ray, 2017). Such a trend demonstrates the greater investments in the base banking systems, digital channels, and risk management technologies.

Comparisons done among the public and the private sector banks in India give the indication that the private sector banks tend to give better results as far as efficiency and productivity factors are concerned as compared to the public sector banks. Sahoo and Tone (2019) determined that private banks showed to have a high TFP growth owing to the fact that they were more flexible to change in technology and suggested cost management. Ray and Das (2021) also observed that scale efficiency and innovation-based growth favoured in the case of the private banks whereas the public sector banks had limited organizational structures and increased the levels of non-performing assets.

Recent works have laid emphasis on how the digital transformation has impacted the productivity of banking. As was established by Singh and Malik (2022) the adoption of digital banking also contributed immensely to technical efficiency and productivity growth among the Indian banks in the post-2016 period. On the same note, Kumar et al. (2022) indicated that the banks that had greater non-interest income and the use of technology to deliver their services reported greater effects of technical change. These researches highlight the rising role of digitalization as a change factor in the productivity of the banking industry.

Although the research on the banking productivity is widespread on a national level, there is limited research on region-specific analysis of banking productivity. Kerala specifically has a institutional and economic environment, which is unique in the form of high literacy, robust remittances inflows and high bank networks. Hardly any research has studied the effectiveness and the productivity of the Kerala-based private sector banks, and the ones that do are cross-sectional or restricted in duration (Joseph and Varghese, 2020). This makes the absence of longitudinal data to capture productive dynamics of these banks through significant economic and policy transitions.

Moreover, the years 2014-2024 include such critical events as demonetization, a surge in the spread of digital payments, the COVID-19 pandemic, and post-pandemic control. These structural shocks have not been adequately addressed in the existing literature on how they contributed to productivity change in the private banks in the region over time. Malmquist-based studies of this transformative decade are critical in the long run to heed the concept of resilience, adaptability and performance sustainability in the banking industry.

Overall, though the studies made before confirm the utility of DEA-Malmquist methods in the analysis of the banking productivity, there are still numerous gaps in the research process that are inconsistent with regional and long-term studies and the capacity to identify the drivers of productivity. Filling these gaps, specifically the case of the Kerala private sector banks can yield some worthy contribution to the literature and guide policy and managerial decision making.

3. Methodology

3.1. Research Design

The current research is based on a quantitative longitudinal, non-parametric research design in order to assess the productivity variation in the target banks within the private sector that are based in Kerala in the year 2014-2024. The Malmquist Productivity Index (MPI) based on the Data Envelopment Analysis (DEA) measures the change of productivity. The DEA-Malmquist model is more appropriate in the analysis of the banking sector because it is in a position to simultaneously consider the various inputs and outputs without any form of restriction of the production technology.

The longitudinal aspect of the study allows evaluating dynamic productivity changes over the years, and not the efficiency level in one year. This is of particular interest considering the time of research, as it was the time of significant structural changes in the Indian banking, including digitization, regulatory transformation, the process of demonetizing, and the COVID-19 shock.

3.2. Sample Selection

The research will be devoted to four banks of the private sector in Kerala, i.e. Federal Bank, South Indian Bank, CSB Bank, and Dhanlaxmi Bank. The choice of these banks was based on the following criteria:

- Based or in the past in Kerala.
- Constant operation throughout the research term (2014- 2024).
- Access to regular financial information annually.
- Retail banking and credit intermediation.
- The DEA framework has each bank as a Decision Making Unit (DMU).

3.3. Data Sources

The research solely uses secondary data obtained through credible and publicly available data to achieve transparency and reproducibility. The main sources of data will be:

- Publications of the Reserve Bank of India like Trend and Progress of Banking in India and Report on Currency and Finance.
- Respective bank annual reports that have been audited.
- Bank-wise performance released by RBI on statistical tables.
- Each monetary value was normalized and cross-verified among sources to make sure that they are consistent. The data set represents a balanced panel that is a set of ten successive financial years.

3.4. Input and Output Specification

One of the most important conditions of the DEA analysis is the clear identification of input and output variables. Based on the intermediation approach that treats banks as financial intermediaries that convert the deposits and resources into earning assets, the current research designates the following variables:

3.4.1. Input Variables

- Total Deposits- proxy of mobilized financial resources.
- Operating Expenses - indicates efficiency in cost and management work.
- Employee Count - is an input of labor.

3.4.2. Output Variables

- Total Loans and Advances- main earning asset of banks.
- Interest Income- income earned through core lending activities.
- Non-Interest Income - fee income, commission income and other service based income.
- These variables are also selected as the existing literature on banking efficiency would reply and make them

comparable to existing DEA-based research.

3.5. Reasoning behind Output-Oriented DEA Model

The model that has been utilized in the study is the output-oriented DEA model because the short-run goal of banks is to maximize outputs as inputs are available, but not to minimize inputs. Regulatory, contractual and operational limitations make inputs in the Indian banking system very rigid in terms of size of labor force, infrastructure of branches plus deposits.

4. Statistical Objectives of the Study

Objective 1

To measure the change in Total Factor Productivity (TFP) of selected private sector banks in Kerala during 2014–2024 using the Malmquist Productivity Index (MPI).

Statistical Tool:

- Data Envelopment Analysis (DEA)
- Malmquist Productivity Index (MPI)

Objective 2

To decompose Total Factor Productivity change into Efficiency Change (EFFCH) and Technological Change (TECHCH) for selected private sector banks in Kerala during the study period.

Statistical Tool:

- DEA-based Malmquist Decomposition
- CRS and VRS Models

Objective 3

To compare the productivity performance of selected private sector banks in Kerala based on average MPI and its components during 2014–2024.

Statistical Tool:

- Mean comparison of MPI components
- Trend and comparative analysis

5. Analysis Using DEA–Malmquist approach

Objective 1: Total Factor Productivity Change (MPI)

The results of the Malmquist Productivity Index (MPI) reveal that there is significant fluctuation in total factor productivity of the sampled Kerala based privately owned banks over the 2014 to 2024 period. Data that has an MPI above unity indicates productivity increase whereas a figure below unity indicates productivity decrease. The findings indicate that Federal Bank and CSB Bank recorded the value of MPI of over one within most of the plot

period meaning that the productivity had been continuously improving. It indicates that these banks could increase their output levels in comparison with the use of inputs in the course of time and it is an indication of good management of resources and an improvement in the operations.

Table 1. Malmquist Productivity Index (TFP Change) of Selected Private Sector Banks (2014–2024)

Year	Federal Bank	South Indian Bank	CSB Bank	Dhanlaxmi Bank
2014–15	1.032	0.981	1.014	0.956
2015–16	1.045	0.964	1.026	0.943
2016–17	1.061	0.952	1.038	0.931
2017–18	1.074	0.947	1.049	0.918
2018–19	1.058	0.969	1.041	0.924
2019–20	1.036	0.983	1.022	0.947
2020–21	1.019	0.991	1.015	0.962
2021–22	1.048	1.006	1.033	0.979
2022–23	1.067	1.021	1.052	0.993
2023–24	1.081	1.034	1.068	1.012
Mean MPI	**1.052**	**0.985**	**1.036**	**0.957**

However, South Indian Bank had the MPI values that varied around unity with few years recording values below one. This trend shows little growth and low productivity on the first few years up to a slow progress in the later years. In the case of Dhanlaxmi Bank, MPI values of less than one were also a constant feature in most of the period of the study meaning sustainability of productive decline. These tendencies lead toward inefficiency in the organization of the structure, poor use of resources, and the inability to respond to emerging market and regulatory environments. In general, the MPI analysis shows that productivity in private banks based in Kerala is disproportionate, and bank-specific.

Objective 2: Decomposition of Productivity Change

A further breakdown of the Malmquist Productivity Index into Efficiency Change (EFFCH), and Technological Change (TECHCH) can give more detailed information regarding the origins of the variation in productivity. Efficiency change indicates the capability of a bank to shift towards the best-practice frontier by the enhanced performance of managers, and technological change reflects the changes in the production frontier in innovation and in the progress of technologies. The findings show that Federal Bank and CSB Bank showed an increase in productivity which was more as a result of technological advancement than an increase in efficiency.

Table 2. Decomposition of Malmquist Index – Efficiency Change and Technological Change (Mean Values)

Bank	Efficiency Change (EFFCH)	Technological Change (TECHCH)	MPI (TFP Change)
Federal Bank	1.018	1.033	1.052
South Indian Bank	0.992	0.993	0.985
CSB Bank	1.011	1.025	1.036
Dhanlaxmi Bank	0.968	0.989	0.957

The values of TECHCH of these banks are more than unity, indicating that an investment in digital banking systems, automation, and the recent risk management systems was a key factor that caused the production frontier to shift higher. On the other hand, the TECHCH values of South Indian Bank and Dhanlaxmi Bank were almost under unity which implies low technological advancement in the given period of study. Furthermore, the efficiency change element with regard to Dhanlaxmi Bank was still lower than one, which indicates that there were still managerial inefficiencies and poor internal processes. Such results and uphold that technological progress, instead of just cost management is extremely important in a contemporary banking setting as a factor of increasing productivity.

Objective 3: Further Decomposition of Efficiency Change

Additional factorization of efficiency change into Pure Efficiency Change (PECH) and Scale Efficiency Change (SECH) bring to the fore the importance of effectiveness and optimal scale of managerial performance. The pure efficiency change measures the progress in management practices, decisions and operations processes whereas the scale efficiency change indicates if the banks are operating optimally or not. The analysis shows that Federal Bank and CSB Bank were able to make gains in both pure efficiency and scale efficiency, which implies good managerial discipline and ability to scale the operations.

Table 3. Pure Efficiency Change and Scale Efficiency Change (Mean Values)

Bank	Pure Efficiency Change (PECH)	Scale Efficiency Change (SECH)
Federal Bank	1.012	1.006
South Indian Bank	0.987	1.005
CSB Bank	1.008	1.003
Dhanlaxmi Bank	0.961	1.007

There was slight improvement in scale efficiency and a decrease in pure efficiency in South Indian Bank which indicated that this bank might have maximised its operational scale but still had to cope with issues surrounding managerial and internal process efficiency. The loss of pure efficiency change at Dhanlaxmi Bank shows that there are major weaknesses in the performance of the managers even though there is a slight improvement on scale efficiency. This means that increased or altered operations on their own cannot be sufficient to maximize productivity without also internal management and streamlining of the processes.

6. Findings of the Study

Malmquist Productivity Index (MPI) analysis reflects that the performance of the selected banks in the Kerala private sector in terms of productivity is not even and is bank-specific in the years 2014-2024. Federal Bank and CSB Bank would still register higher values of MPI than unity which means total factor productivity has been continually improving during the study period. This observation indicates that these banks had been effective in increasing their output rates in relation to the inputs that were used in their operations, meaning that they effectively utilized the resources they used and adopted responsive operation tactics.

South Indian Bank had uneven productivity performance which showed that MPI values varied about unity. Although the bank had suffered some cases of productivity decline in the preceding years of the research, a

progressive increase was registered in the later years and specifically after 2021. This signifies a partial recovery and implies that new strategic efforts and technological improvements might have helped stabilize the level of productivity.

Most of the time Dhanlaxmi Bank registered low MPI figures which signify that the bank was experiencing continued productivity decline. This observation indicates structural inefficiencies, inefficient way of utilizing resources, and inflexibility to technological and regulatory changes. Although the bank performance improved marginally in the later years, overall the productivity performance of the bank in comparison to the peers was weak.

The analysis of the breakdown effect of the productivity change reveals that technological change (TECHCH) was a strong factor in growth of productivity of high-performing banks. The TECHCH values of Federal Bank and CSB Bank were more than unity that shows that the development of digital banking structure, automation, and technology-oriented, which provides services, moved the production frontier significantly up. Conversely, the less productive banks had a minimal technology development.

The results in efficiency change (EFFCH) show that there were small increases in the efficiency of managers in reference to the sample of banks. Although Federal Bank and the CSB bank showed some improvement in efficiency, South Indian bank and Dhanlaxmi bank did not show any improvement or some efficiency growth, the efficiency of the banks. This conclusion indicates that the effect of innovation and adoption of technology in the banking sector has a stronger correlation with productivity increase as compared to the role of managerial efficiency increase.

Additional breakdown into pure efficiency change (PECH) and scale efficiency change (SECH) would show that the important role of the managerial effectiveness contributed to performance differentiation in banks. Federal Bank and CSB Bank were reflecting better performances on pure efficiency, which means improvement of management practices and optimization of internal processes. The banks also experienced some marginal gains in the efficiency of scales, although they did not make adequate improvements that could counter the losses in pure efficiency as was the case of Dhanlaxmi Bank.

The analysis has also shown that the biggest economic and policy events in the study period had the effect of impacting the trends of productivity. The growth of productivity slowed during economic disruption times and it has since rebounded in post pandemic years in banks that are better technologically equipped. It is significant in that resilience and adaptive capacity continues to maintain productivity when there are external shocks.

Comprehensively, the results indicate that the increase in productivity of the Kerala private sector banks over the years 2014122024 happened more due to the advancement in technology than a efficiency catch up. Banks who invested in digital transformation and innovation stood in a better position to realize sustained productivity gains and those that lagged behind were faced with perpetual productivity problems.

7. Scope for Further Study

Current research analyses the productivity level of performers in the Kerala state of the chosen banks of the private sector applying the DEA Malmquist Productivity Index in 2014-2024. Although the results are informative, there are still a number of directions in which the future research can be developed. The scope of the future studies could be enlarged with a bigger sample of banks, with the inclusion of public sector banks, foreign banks, or small finance banks, which may perform their activities in Kerala. The comparative analysis of this sort would permit a deeper insight into productivity differentials in varying ownership structures and models of banking.

Future studies can expand the scope of time beyond the year 2024 to capture productivity patterns in the post-digital and post-pandemic period. Longitudinal studies in the long periods of time may help to bring a more insight into structural shifts in productivity and efficiency as banking technology and the organization of regulation continues to develop. Also, the sub-period analysis (emphasizing significant policy interventions, namely demonetization, reforms of digital payments, and some pandemic-related regulatory measures) might be used to isolate the effect of these particularly on productivity dynamics.

The current work is based on non-parametric DEA-Malmquist model that fails to consider the effect of statistical noise. The research could take a parametric approach in the future by adopting Stochastic Frontier Analysis (SFA) or DEA-SFA in order to compare the estimations of productivity. It can also be enhanced by incorporation of bootstrap techniques that enhance the robustness of the efficiency and productivity measurements and make a statistical inference.

The determinants of change in productivity may also be studied in future, whereby the second-stage regression analysis is used to integrate it. Modifying factors could be considered to explain variation in efficiency and technological change based on corporate governance, asset quality, non-performing assets, and capital adequacy, and macroeconomic variables. This would help researchers to change the measurement into causal analysis.

The other avenue that shows promise is the incorporation of the unwanted output or those that are not contributing to productivity like non-performing loans or credit risk. Using more sophisticated models of DEA that take into consideration risk and sustainability dimensions would offer a better explanation of the performance of banks. Also, research on green banking activities and investments associated with ESG may be considered in the future to determine its impact on productivity enhancement.

Lastly, the qualitative research methodology may include the use of case studies, interviews with bank managers, and policy analysis as a supplement to quantitative results and provide the contextual information on strategic and managerial drivers of productivity change. These types of mixed-method would make the research findings more profound and relevant to practitioners and policymakers.

8. Conclusion

The current research investigated productivity change in chosen private banks in the state of Kerala during 20141624 with the help of Data Envelopment Analysis Malmquist Productivity Index model. The analysis, which breaks down total factor productivity into change in efficiency and change in technology, gives an overall

perception of how banks have actually changed inputs to outputs over a decade of regulatory reform, high rates of digitalization, and substantial economic shocks. Long-term productivity trends and short-term fluctuations were identified due to the use of a longitudinal approach of DEA–Malmquist.

Findings indicate that there is heterogeneity in the performance of productivity of the banks of the Kerala-based privates. There was persistent increase in the total factor productivity in banks that continuously made investments on digital infrastructure, automation, and new service delivery mechanisms. Banks that were trailing in the technological adoption and managerial efficiency on the contrary suffered stagnation or lack of productivity. On the whole, technological change has become the leading accelerator of increment in productivity, with efficiency gain comparatively minor contribution. This highlights the increasing role of innovation-based strategies with regards to the productivity of the banks.

The breakdown efficiency change also brings about an aspect that suggests that managerial effectiveness and optimization of internal processes are essential in attaining productivity gains. Although the increase in the scale efficiency improved in some banks, it was not only enough to counter any drops in pure technical efficiency in the weaker-performing banks. This observation implies that effective scaling should be enhanced with an efficient governance and management culture and continuous skills enhancement to provide significant productivity gains.

The paper also illustrates that productivity followed external shocks and policy interventions in the course of the period of study. Banks that had more technological power and flexible capacity to endure disruptions and recuperate faster, highlighted the significance of resilience in maintaining the long-term growth in productivity. This information is of great importance to the policymakers and the management of the banks to outline the measures to improve competitiveness and stability in the banking system of the area.

Finally, the paper has added to the literature on the topic by offering long-term, region-specific evidence on bank productivity based on a well-calibered DEA-Malmquist model. The findings draw the focus on the fact that long-term productivity growth within the banking sphere is not only based on expansion or scope, but it is mainly a matter of technological advancement and efficiency in the managerial processes. The enhancement of the digital capabilities and improvement of operational processes and innovation are thus critical in increasing productivity and long-term sustainability of the private sector banks in Kerala.

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Consent for publication

Both the authors contributed to the manuscript and consented to the publication of this research work.

Availability of data and material

Supplementary information is available from the authors upon reasonable request.

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