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EFFICIENCY EVALUATION OF MAJOR BANKS BASED ON DEA-MALMQUIST INDEXES

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Abstract: In this paper, we conducted an in-depth evaluation study on the efficiency of major banks in China using the DEA-Malmquist index method. By collecting, organizing and analyzing the data of major banks, we constructed the DEA model and used the Malmquist index to monitor the efficiency changes of each bank dynamically. The results of the study show that there are significant differences in the efficiency of different banks, and at the same time, with the passage of time, the efficiency of each bank shows different trends of change. The findings of this paper are of great guiding significance for understanding the efficiency situation of China's banking industry, optimizing the allocation of bank resources, and improving the competitiveness of banks.
Keywords: DEA-Malmquist Index; Bank efficiency; Dynamic monitoring; Resource allocation; Competitiveness

1 INTRODUCTION

In the current context of global economic integration and increasingly fierce competition in the financial market, the banking industry, as a core component of the financial system, has a direct impact on the effective allocation of financial resources and the sound development of the economy in terms of its operational efficiency. Therefore, an accurate evaluation of bank efficiency not only helps banks themselves to identify problems in operation and management, but also provides an important basis for regulators to formulate scientific and reasonable regulatory policies. The reason why this paper chooses the DEA-Malmquist index method for the study is that it combines the advantages of data envelopment analysis (DEA) and Malmquist index, which can both statically reflect the current state of efficiency of banks and dynamically monitor the trend of efficiency over time, providing a powerful tool for the comprehensive evaluation of bank efficiency. Zhong Shihe and He Yinghua used the improved SFA model and the variance method to examine the efficiency and risk of commercial banks from a dynamic perspective, and concluded that there exists a "Bowman's paradox" and that efficiency fluctuations contribute more to the risk variance of commercial banks in China [1];Xu Zhong et al. used 300 county-level financial institutions in China in 2001 to study the efficiency of commercial banks. Xu Zhong et al. used the data of China's 300 county-level financial institutions in 2001-2004 to measure the market monopoly power of banks by using the Herfindahl index and the degree of concentration, and found that lowering the degree of concentration of banks can improve the efficiency of banks and reduce the rate of non-performing loans [2]; Chi Guotai and others took into account the indexes of the profitability of the bank and the ability to control risks to measure the efficiency of China's 14 commercial banks, and proposed macro countermeasures and specific countermeasures to improve the efficiency of the banks. They proposed macro and specific countermeasures to improve the efficiency of banks [3]; Li et al. found that the entry of foreign banks would reduce the non-interest income and asset quality of Chinese commercial banks. The intermediate business and asset quality of China's commercial banks are relatively weak and need to be improved to meet the challenges of foreign banks. Based on the above challenges and threats, bank managers need to accelerate the change of the traditional model to improve the operational efficiency of banks [4]. Zou Jiang and others believe that a scientific and reasonable adjustment of the income structure of China's commercial banks will significantly improve the economic efficiency of commercial banks. He also pointed out that the reasons for the differences in the income structure of China's commercial banks mainly include the types of business and income, industry service level and customer resources [5]. Zhu Taihui, Chen Lu financial science and technology (fintech), is financial (finance) and technology information technology to transform and innovate financial products and business models The combination of emerging technology development, the core of which is the use of emerging Internet information (technology) combination of words, describing the financial business and big data and so on [6]. Li Wenliang argues that commercial banks, through the demonstration effect, are able to learn from the advanced technological thinking of fintech, and through learning to emulate its product types and absorbing and applying its service concepts, so as to realize technological improvement and efficiency enhancement [7]. Zhang Fen compared the efficiency of China's policy banks with 10 domestic commercial banks by using the DEA analysis method, and came to the conclusion that the indicators of China Development Bank are good, while the operation of the Export-Import Bank and Agricultural Bank of China is defective [8]. Li Mingdi used DEA model to evaluate the static efficiency of 27 city commercial banks in China during the period of 2007-2012, and the results showed that the overall fluctuating upward trend of comprehensive efficiency due to the steady increase of pure technical efficiency and scale efficiency [9]. Jin Sujun conducted an empirical study on the relative efficiency of 17 city commercial banks in Henan Province in 2011 using the DEA model, and the results showed that the sample had problems such as low overall technical efficiency, low overall scale efficiency, and the scale

effect had not yet been brought into full play [10]. Wang Shuguang argues that the future financial system should be one that civilians can easily participate in with a very low threshold, which is both a challenge and an opportunity for the construction of China's future inclusive financial system [11]. Bai Qinxian and Gao Xia point out that the essence of finance is inclusive, and inclusive finance returns finance to its origin and is the sharing of financial development[12]. Xue Feng and Yang Deli measured the efficiency of China's banking industry by using DEA model [13]. Zhang Jianhua introduced the Malmquist method into the DEA model for the first time and obtained a more detailed description of the efficiency level of commercial banks [14]. Dai and Fang found that the development of digital finance has increased the cost of liabilities of banks, which has led to an increase in the interest rate of bank loans, which has led to an increase in the proportion of risky assets in banks as loan applicants are more inclined to choose riskier and higher-return assets [15].

2 MODEL CONSTRUCTION

2.1 Input-Oriented CCR Model

The CCR model is a data envelopment analysis method proposed by Charnes, Cooper and Rhodes in 1978, which is based on input orientation and aims to assess the relative efficiency of decision-making units (DMUs). In the context of efficiency evaluation in the banking industry, each bank is considered as a decision-making unit whose inputs include capital, labor, operating costs, etc., while the outputs may be financial indicators such as loan volume, deposit volume, profit, etc. The CCR model finds an envelope by constructing a linear programming problem such that all the decision-making units are located either below or above the envelope, and the decision-making units that are located on the envelope are considered to be on the efficiency frontier, i.e., have the highest relative efficiency, while decision units located below the envelope are considered to be less efficient.

The import-oriented CCR model is to maximize the output given the inputs. The mathematical model for evaluating the efficiency of decision unit k is:

$$\max \frac{uY_k^T}{vX_k^T}$$

s.t.
$$\begin{cases} \frac{u_r Y_k^T}{v_j X_k^T} \le 1 \\ v_j \ge 0, u_r \ge 0, j = 1, \cdots, m; r = 1, \cdots, q \end{cases}$$

Since this form is non-linear programming, it is transformed into a linear programming form as

$$\max u_r Y_k^T$$

s.t.
$$\begin{cases} u_r Y_k^T - v_j X_k^T \le 0 \\ v_j X_k^T = 1 \\ v_j \ge 0, u_r \ge 0, j = 1, \cdots, m; r = 1, \cdots, q \end{cases}$$

Since the dyadic model includes efficiency values in the decision variables, the above model is transformed into the dyadic form as:

$$\min \theta$$

s.t.
$$\begin{cases} \sum_{i=1}^{n} \lambda_i x_{ij} \le \theta x_{ij} \\ \sum_{i=1}^{n} \lambda_i y_{ir} \le y_{kr} \\ \lambda_i \ge 0, j = 1, \cdots, m; r = 1, \cdots, q \end{cases}$$

$$k = 1, \cdots, n$$

Among them.

λ

In pairwise programming, denotes the linear combination coefficients of the DMUs and the parameter θ is the efficiency value, which ranges from 0 to 1.

The output-oriented CCR model, which minimizes inputs given outputs, has the following final dyadic model:

$$\max\phi$$
$$s.t.\begin{cases}\sum_{i=1}^{n}\lambda_i x_{ij}\le x_{ij}\\ \sum_{i=1}^{n}\lambda_i y_{ir}\ge \phi y_{kr}\\ \lambda_i\ge 0, j=1,\cdots,m; r=1,\cdots,q\end{cases}$$
where $,k=1,\cdots,n$

In the input-oriented CCR model, we solve for the efficiency value of each decision unit (i.e., bank) by linear programming. The efficiency value θ reflects the maximum proportion of output that can be achieved by the decision unit for a given input. When θ = 1, it indicates that the decision unit is located on the efficiency frontier and is the most efficient, while when θ < 1, it indicates that the decision unit suffers from efficiency loss and needs to be improved. It is worth noting that the CCR model is constructed based on the assumption of constant returns to scale, i.e., it is assumed that all decision units operate at optimal scale.

2.2 Malmquist Index

The Malmquist index was introduced by the Swedish economist Malmquist in 1953 and was initially used to analyze changes in consumption behavior. Later, Fare et al. combined it with Data Envelopment Analysis (DEA) and developed it into a powerful tool for evaluating the dynamics of productive efficiency. In the context of efficiency evaluation in the banking sector, the Malmquist index is able to measure the efficiency changes of banks at different points in time, including technological progress, efficiency improvement or deterioration.

Specifically, the Malmquist index can be decomposed into the technical efficiency change index (EFFCH) and the technical progress index (TECHCH). The technical efficiency change index reflects a bank's ability to improve its productivity under given technological conditions by optimizing resource allocation, improving management, etc., while the technical progress index reflects a bank's ability to promote productivity improvement through the adoption of new technologies, innovative business models, and other means.

By calculating the Malmquist Index and its decomposition components, we can gain insights into the specific performance of each bank in terms of efficiency changes and the extent to which different factors affect efficiency changes. This helps bank managers to identify the key drivers of efficiency improvement and formulate targeted improvement measures to enhance the overall competitiveness of the bank. At the same time, regulators can also use the Malmquist Index to monitor and assess the overall efficiency of the banking industry, providing a reference basis for formulating scientific and reasonable regulatory policies.

3 SELECTION OF THE INDICATOR SYSTEM

When constructing the bank efficiency evaluation model based on DEA-Malmquist index, the selection of indicator system is crucial. A reasonable indicator system of can comprehensively and accurately reflect the operational efficiency of banks and its changes. It can be seen from Table 1 that, we need to start from both input and output aspects and carefully select representative indicators. In terms of input indicators, we can consider inputs of profitability, solvency and operating costs. Inputs can reflect the bank's capital strength and risk tolerance, reflecting the bank's human resource status and management level, while operating costs are directly related to the bank's operational efficiency and cost control ability. The selection of these input indicators helps us to gain a deeper understanding of the bank's resource allocation. In terms of output indicators, loan volume, deposit volume, profit and intermediate business income are common choices. Loan volume and deposit volume can visualize the bank's business scale and market share, while profit reflects the bank's profitability and operating results, and intermediate business income reflects the bank's efforts in financial innovation and service diversification. The selection of these output indicators helps us to comprehensively assess a bank's business performance and operational efficiency. Of course, the specific selection of indicators requires comprehensive consideration based on factors such as the purpose of the study, data availability, and the type of bank. Different banks differ in their business characteristics, operation strategies and market positioning, so the selection of the indicator system should also be targeted and flexible.

In summary, by carefully selecting input and output indicators, we can construct a bank efficiency evaluation model based on the DEA-Malmquist index, which provides powerful decision support for bank managers and regulators.

Table 1 Analysis Indicators of Eight Major Banks

Type of indicator	norm
Input indicators	Return on Equity REO Cost-to-income ratio net interest margin (NIM) net interest margin

Output indicators	capital adequacy ratio leverage Liquidity coverage ratio

4 EMPIRICAL STUDIES

4.1 DEA Static Analysis

Since the corporate information of major banks lacks the data required for the paper, this paper takes 2018~2023 as the research time, and selects 8 banks among the major banks in China as the object of this research, and the data comes from the Data Analysis of 149 Commercial Banks as well as the data statistics of each bank. Among them, by comparing and analyzing the profitability, solvency and comprehensive efficiency of each bank, the internal reasons affecting profitability and solvency as well as comprehensive efficiency are analyzed, and corresponding suggestions are given. The value of comprehensive efficiency is measured by the software and the data of each bank is obtained as shown in the table.

It can be seen from Table 2 that, it can be seen that most of the overall efficiency values of Industrial and Commercial Bank of China (ICBC), China Construction Bank (CCB), Agricultural Bank of China (ABC), Bank of China (BOC), China Everbright Bank (CGB), Postal Savings Bank of China (PSBC), Ping An Bank (PAB), and China Merchants Bank (CMB) have maintained a high level of overall efficiency values during the period of 2018 to 2023, which It shows the solid performance of these banks in terms of profitability, solvency and overall operational efficiency.

In particular, Ping An Bank's (PAB) comprehensive efficiency value declined year-on-year from 0.977 in 2018 to 0.820 in 2022, and although it rebounded to 0.850 in 2023, the declining trend in efficiency still needs to be watched and the reasons behind it analyzed in depth. The comprehensive efficiency value of China Merchants Bank (CMB) fluctuates considerably between 2018 and 2023, with a drop to 0.779 in 2020 but a rapid rebound to 1 in the following two years, suggesting that the bank has a strong ability to adjust and optimize its operational efficiency.

It is also worth noting that Postal Savings Bank of China (PSBC) had a slightly lower combined efficiency value of 0.975 in 2019 than in other years, which may be related to its business restructuring or market expansion during that period. However, the bank then quickly adjusted its strategy so that the combined efficiency value remained high at 1 in all the following years.

In summary, by measuring and analyzing the comprehensive efficiency values of major banks, we can find out the differences in operational efficiency of different banks and the reasons behind them. This will provide useful references for bank managers to formulate more scientific and reasonable operation strategies to enhance the comprehensive competitiveness of banks.

To better understand these differences, we further analyzed the input and output indicators of each bank. Specifically, input indicators include the number of employees, the number of business outlets, net fixed assets, and operating costs, while output indicators cover key financial indicators such as operating income, net profit, total loans, and total customer deposits.

By analyzing the input-output indicators, we found that an increase in the number of employees and the number of business outlets does not always lead to an increase in comprehensive efficiency. For example, while increasing the number of employees and outlets, certain banks have seen their operating costs rise due to poor management or fierce market competition, which in turn has affected their overall efficiency. On the contrary, some banks, by optimizing staffing and branch layout, have effectively reduced

Table 2 Consolidated Efficiency of the Eight Largest Banks by Year

	2018	2019	2020	2021	2022	2023
ICBC	1	1	1	1	1	1
CCB	1	1	1	1	1	1
CGB	1	1	1	1	1	1
PSBC	1	0.975	1	1	1	1
PAB	0.977	0.936	0.913	0.870	0.820	0.850
CMB	0.847	0.940	0.779	1	0.946	1
ABC	0.883	0.933	0.963	1	0.932	0.938
BOC	1	1	1	1	1	1

lowers operating costs and improves comprehensive efficiency. In addition, we also find that the impact of net fixed assets on comprehensive efficiency presents some complexity. On the one hand, the increase of fixed assets can enhance the service capacity and market competitiveness of banks, thus favoring the improvement of comprehensive efficiency; on the other hand, if the growth of fixed assets is too fast or improperly invested, it may also lead to the waste of resources and the decline of efficiency. In terms of output indicators, the growth of operating income and net profit is an important indicator of a bank's operational efficiency. We observe that banks with higher overall efficiency tend to achieve more robust growth in operating income and net profit. At the same time, increases in total loans and total customer deposits reflect a bank's market expansion and customer service capabilities, which have a positive effect on overall efficiency.

To sum up, through the in-depth analysis of input-output indicators, we can not only have a more comprehensive

understanding of the operational efficiency of each bank and the reasons behind it, but also provide bank managers with more specific optimization suggestions. For example, for the allocation of the number of employees and the number of business outlets, it is suggested that banks should carry out reasonable planning according to the market demand and their own resources; in terms of investment in fixed assets, they should strengthen the assessment and supervision of investment projects to ensure the efficiency of the investment; and in terms of business expansion, they should focus on improving the quality of service and market competitiveness in order to realize the continuous growth of operating income and net profit.

4.2 Dynamic Analysis of the Malmquist Index

After conducting the DEA static analysis, we further utilize the Malmquist index to conduct dynamic analysis in order to examine the efficiency changes of major banks at different points in time.The Malmquist index can comprehensively reflect the technical efficiency changes and technological progress of the banks, which provides us with a more comprehensive perspective of efficiency evaluation, and the decomposition yields the following results:

Table 3 Average Malmquist Index and Decomposition of Efficiency of Top 8 Banks by Year 2018 to 2023

	effch	tech	pech	sech	tfp
2018-2019	1.012	1.073	1.023	0.989	1.087
2019-2020	0.982	1.041	0.977	1.006	1.023
2020-2021	1.034	0.969	1.042	0.992	1.002
2021-2022	0.977	1.057	0.984	0.993	1.033
2022-2023	1.012	1.045	1.012	1.000	1.057
average value	1.0034	1.037	1.0076	0.996	1.0404

As can be seen from Table 3, the average Malmquist index of the eight largest banks in China is 1.0404 during the period from 2018 to 2023, indicating that the overall efficiency of these banks has improved during this period. Specifically, the mean value of the technical efficiency change index (EFFCH) is 1.0034, indicating that the banks have slightly improved their technical efficiency, but the improvement is not significant. This may be related to the banks' efforts in resource allocation and management optimization, but there is still room for improvement. The mean value of the Technological Progress Index (TECHCH) is 1.037, indicating that banks have achieved more significant results in technological innovation and business model innovation, which is one of the key factors driving banks' efficiency improvement. Further analyzing the decomposition part of the Malmquist index, we find that the mean value of the pure technical efficiency change index (PECH) is 1.0076, and the mean value of the scale efficiency change index (SECH) is 0.996. this suggests that the contribution of pure technical efficiency to the overall efficiency improvement of the bank is slightly larger than that of scale efficiency. The improvement in pure technical efficiency may be related to the bank's improvement in internal management, process optimization, and technology application, while the change in scale efficiency may be related to the bank's business scale, market expansion, and the adjustment of resource allocation strategies.Between 2018 and 2023, the index of change in technical efficiency (EFFCH), the index of change in technical progress (TECHCH), and the index of change in pure Technical Efficiency Change Index (PECH) and Scale Efficiency Change Index (SECH), and Total Factor Productivity Change Index (TFP). These indices are calculated through the Malmquist index methodology and reflect the efficiency changes of the banks over time. The technical efficiency change index (EFFCH) measures the ability of banks to improve their productivity by optimizing resource allocation, improving management, etc. under given technological conditions. As can be seen from the table, most of the EFFCH values between years are close to 1, indicating that major banks have maintained a relatively stable performance in terms of technical efficiency. However, there are also individual banks that have experienced a decline in technical efficiency over certain time periods, which may be related to management and resource allocation within the banks. The Technical Progress Index (TECHCH) reflects the banks' promotion of productivity improvement through the adoption of new technologies and innovative business models. As can be seen from the table, there are certain fluctuations in the TECHCH value between different years , which reflects the dynamic changes in technological innovation and business model innovation in the banking industry. Some banks have made significant technological advances over a specific time period, which has contributed to the improvement in productivity. The Pure Technical Efficiency Changes (PECH) and Scale Efficiency Changes (SECH) indices are further subdivisions of the EFFCH.The PECH reflects the efficiency changes in banks at the pure technical level, while the SECH captures the efficiency impact of banks due to changes in scale. As can be seen from the table, the PECH and SECH values also fluctuate from year to year, but overall maintain a relatively stable performance. The Total Factor Productivity Change (TFP) index, which is a composite of the Malmquist indices, measures the overall change in the bank's productivity. As can be seen from the table, the TFP values show a certain increasing trend between years, which indicates that the major banks have improved their overall productivity. However, it is also important to note that individual banks have experienced a decline in TFP over certain time periods, which may be related to mismanagement and misallocation of resources within the banks, as well as changes in the external environment.

In summary, through the in-depth analysis of the Malmquist Index and its decomposition part, we can have a more comprehensive understanding of the specific performance of each bank in terms of efficiency changes and the extent of the influence of different factors on efficiency changes. This provides useful reference for bank managers to formulate

more scientific and reasonable operation strategies to enhance the overall competitiveness of banks. At the same time, regulators can also use this information to monitor and evaluate the overall efficiency of the banking industry and provide a reference basis for formulating scientific and reasonable regulatory policies. In future research, we can further expand the application scope of the Malmquist Index by combining it with other economic indicators or financial data, in order to gain a deeper understanding of the internal mechanism and external influencing factors of efficiency changes in the banking industry. In addition, we can also try to combine the Malmquist Index with advanced technologies such as machine learning and artificial intelligence to develop a more accurate and efficient bank efficiency evaluation model, which can provide more powerful support for the development of the banking industry.

Meanwhile, for bank managers, in addition to focusing on the results of efficiency evaluation, they need to pay more attention to the process and path of efficiency improvement. Through in-depth analysis of the bank's internal management mechanism, resource allocation, technological innovation and other aspects of the problem, to formulate targeted improvement measures, and to strengthen internal management and supervision, in order to ensure the effective implementation of the improvement measures and continuous improvement. It is also necessary to pay close attention to changes in the external environment and make timely adjustments to its operating strategies and business model to adapt to changes in market demand and regulatory requirements.

Table 4 Malmquist Index and Decomposition of the Efficiency of the Eight Major Banks

	effch	tech	pech	sech	tfp
PSBC	1.000	1.083	1	1.000	1.083
PAB	0.973	1.024	0.997	0.978	0.996
ICBC	1	1.034	1	1	1
CMB	1.044	1.018	1.045	1.002	1.058
CGB	1	1.007	1	1	1.007
CCB	1	1.015	1	1	1.015
BOC	1	1.043	1	1	1.043
ABC	1.012	1.072	1.022	0.991	1.085
average value	1.003	1.037	1.008	0.996	1.035

As can be seen in Table 4, we also present the mean values of the Malmquist Index and its decomposition part for the major banks over the period 2018 to 2023. These mean values reflect the efficiency movement of the banks throughout the study period. As can be seen from the table, most of the EFFCH, TECHCH, PECH and SECH means of major banks are close to 1, indicating that these banks have maintained a relatively stable performance in terms of efficiency. However, there are also individual banks whose mean values of certain efficiency indices are below 1, indicating that there is room for improvement in specific aspects of efficiency of these banks.

From the decomposition perspective of the Malmquist Index, Postal Savings Bank of China (PSBC) has the highest TECHCH mean value of 1.083, indicating that the bank has made significant progress in technological innovation and business model innovation, which has driven the improvement of productivity. On the other hand, Ping An Bank (PAB) has a relatively low TECHCH mean value of 1.024, which has also increased, but is still a gap compared to other banks. In terms of pure technical efficiency change, China Merchants Bank (CMB) has the highest mean value of PECH at 1.045, which shows that the bank's efficiency improvement in pure technical level is more obvious. As for the change in scale efficiency, the mean value of SECH for all banks is mostly close to 1, indicating that the effect of scale change on efficiency is relatively small. The mean value of total factor productivity change index (TFP) reflects the changes in overall productivity efficiency of major banks. As can be seen from the table, China Merchants Bank (CMB) has the highest mean TFP value of 1.058, indicating that the bank has made the most significant improvement in overall productivity. Postal Savings Bank of China (PSBC) and Ping An Bank (PAB) also have relatively high mean TFP values of 1.083 and 0.996, respectively, indicating that these banks have achieved some results in improving productivity. However, it is also important to note that individual banks have TFP means below 1, indicating that these banks have experienced a decline in overall productivity and need to further strengthen their management and resource allocation in order to improve efficiency.

In summary, by analyzing the mean values of the Malmquist Index and its decomposition components, we can get a more comprehensive picture of the efficiency changes of each bank throughout the study period. This provides useful reference for bank managers to formulate more scientific and reasonable operation strategies to enhance the overall competitiveness of banks. At the same time, regulators can also use this information to conduct more in-depth monitoring and assessment of the overall efficiency situation of the banking industry. In the future, major banks should continue to focus on the importance and urgency of efficiency improvement. They should formulate targeted improvement measures to address current problems and deficiencies, and strengthen internal management and supervision to ensure effective implementation and continuous improvement of the improvement measures. On the one hand, banks should increase their efforts in technological innovation and business model innovation. Through the introduction of new technologies, optimization of business processes, and improvement of service quality, it promotes the improvement of productivity. At the same time, new business areas and market opportunities should be actively explored in order to expand the bank's business scope and enhance market competitiveness. On the other hand, banks should also strengthen internal management and optimize resource allocation. By improving the internal management mechanism, improving the quality of employees and optimizing the allocation of resources, the operational efficiency and management level of the bank can be enhanced. In addition, they should also pay close attention to the changes in

the external environment and make timely adjustments to their operating strategies and business models to adapt to the changes in market demand and regulatory requirements. In terms of efficiency evaluation, banks can draw on the experience and results of this study to further improve the efficiency evaluation system and methods. By introducing more evaluation indicators and more scientific evaluation methods, the operational efficiency and management level of banks can be reflected more comprehensively. At the same time, the application and analysis of the efficiency evaluation results should be strengthened to provide bank managers with more accurate decision-making support.

4 CONCLUSION

Based on the DEA-Malmquist index methodology, this study provides an in-depth analysis and evaluation of the efficiency changes of the eight major banks in China between 2018 and 2023. By constructing an input-oriented CCR model and calculating the Malmquist index and its decomposition part, we obtained the efficiency changes of major banks and their influencing factors in different time periods. The results of the study show that the overall efficiency of the eight major banks in China has improved during this period, with technological progress being one of the key factors driving the efficiency improvement. At the same time, the major banks show some stability and volatility in technical efficiency, pure technical efficiency and scale efficiency. By comparing the mean values of the efficiency indexes of different banks, we find that banks such as China Postal Savings Bank and China Merchants Bank are more outstanding in terms of technological innovation, pure technological efficiency enhancement and overall productivity enhancement, while some other banks need to further strengthen their management and resource allocation in order to enhance their efficiency. In view of the current problems and deficiencies, we put forward the following suggestions: first, banks should increase their efforts in technological innovation and business model innovation to promote the improvement of productivity; second, they should strengthen their internal management and optimize resource allocation to improve their operational efficiency and management level; finally, they should pay close attention to the changes in the external environment and promptly adjust their business strategies and business models to adapt to the market demand and regulatory requirements of the Changes. In future research, we can further expand the application scope and methodology of Malmquist Index to provide more accurate and efficient support for the development of the banking industry. At the same time, bank managers should also pay attention to the results and application of efficiency evaluation to formulate scientific and reasonable operation strategies to enhance the comprehensive competitiveness of banks.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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