Performance of Commercial Banks in China Based on Data Envelopment Analysis (DEA)

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Abstract

China is at a stage where it encourages the inflows of international funds and accelerates its initiatives in the opening up of its financial market. The initiatives encompass of encouraging international funds and financial establishments to join the local financial market, and improving the financial system's competitiveness and vigour. As banks are the main player in financial industry, their performance and efficiency attract the interest of scholars and practitioners. At the same time, in recent years, the overall performance data of the banking industry is insufficient, and there is no systematic statistical analysis. This study will examine the overall performance of Chinese commercial banks through data from selected banks. Data during the years 2010-2019 from 29 commercial banks comprising of large, joint-stock and city banks are examined. The DEA method has been employed to calculate the performance score of bank operation, and identify the influencing factors of the operating performance. This study uses preliminary input indicators to finally determine that the input indicators are total assets and total operating expenses, and the output indicators are loans and net income. The results indicate that big commercial banks have higher performance scores as compared with joint-stock banks and city commercial banks; while joint-stock banks record better performance scores than city commercial banks.

Keywords: Commercial bank; Performance; Data envelopment analysis; China

INTRODUCTION

The financial industry is mainly comprised of banks. The operating efficiency of banks does not only have a direct correlation with the financial industry's robust progress, but it also significantly affects a nation's economy. In line with China's extensive financial transformation as well as the gradual opening of the financial market, competition in the financial market has become increasingly fierce. The joining of China into World Trade Organization (WTO) in 2001, following the 2008 Beijing Olympic Games, then the World Expo held in Shanghai in 2010 and the G20 summit held in Hangzhou in 2016 are among examples of major international events occurred in China. During 2019, China's total exports accounted for 13.2 percent of the world's total exports and 10.8 percent of the world's total imports, thus it is the world's largest trading country.

China has entered a stage of rapid development, and China's connection with the world has become closer now than before. As competition turns more intense, China's financial industry including commercial banks is facing various pressures from home and abroad. Many foreign banks have established their operations in China, which in turn increases the pressure on China's financial market

and caused China's commercial banks to face arduous challenges. Therefore, clarifying the performance of banks can help the development of commercial banks themselves, and is very important and meaningful to the stability of China's economy and society.

Bank performance refers to a bank's input to output ratio, or cost to revenue ratio, in its banking activities. It illustrates a bank's capability in allocating its resources, as well as the bank's capability in carrying out its operation; whereby it is the main component in measuring a bank's competitive advantages. The comparative analysis on the commercial banks' efficiency had been conducted. The study had also constructed a reasonable mathematical model, and measured the banks' degree of efficiency. There will also be a discussion on the main factors affecting efficiency. It is expected that the findings will provide decision-making basis for bank management and macro-control policy makers. Data Envelopment Analysis (DEA) had been utilized for the measurement and analysis of the performance of 29 commercial banks in China for a ten-year period from 2010 to 2019. The DEA approach was introduced by Charnes et al. (1978) and the technique was first used by Sherman and Gold (1985) in their analysis on the banking sector. Subsequently, the DEA technique had been used by many researchers in their estimations and analyses of bank efficiency. (Berger et al., 1997; Paster,1999; Hassan, 2002; Lin et al., 2009; Eken et al.,2011; Anastasios et al., 2012; Nguyen et al., 2016; Afsharian et al., 2016).

As China gradually opens its financial market, the understanding of its banking sector's performance is becoming even more crucial for the banks and the country. Acknowledging its importance and recognizing that studies in this area are new in China, in this study's goal to analyze China's commercial bank performance. After a series of data analyses on the performance of commercial banks, will help the development of commercial banks and will provide commercial banks with an overall industry reference, which is conducive to avoiding risks. Through the comparative comparison of the selected commercial banks, we can use the data results to analyze the performance of each commercial bank more accurately. this study will use secondary data for the performance indicators were analyzed using the DEA method. In the next section, the literature review is discussed, followed by methodology, finding, and conclusion.

LITERATURE REVIEW

Studies on the performance of commercial banks mainly focus on the evaluation of commercial banks' performance, and they have proposed a variety of evaluation methods. More traditional performance research methods include DuPont analysis, Standard & Poor's Bank rating analysis, camel rating, and balanced scorecard methods have been widely used around the world. Charnes and Copper (1978) made a series of improvements to non-parametric statistical methods from the perspective of input-output and the first to propose DEA. This method has since then been widely applied by scholars as the performance evaluation method of commercial banks.

Sherman and Gold (1985) had examined the banking industry's performance through the DEA technique. Emrouznejad et al. (2008) argued that commercial bank performance evaluation is one of the most widely used areas of DEA. Around year 2000, the assessment on the banking industry had widely utilized the DEA model, and in the process of its application, the model was continuously improved. Saha and Ravisankar (2000) had employed the DEA method in their analysis of India's commercial banks' efficiency. Not only through vertical comparison, by measuring various commercial banks' efficiency in India between 1992 and 1995, it was concluded that their efficiency had improved. Sathye (2003) used horizontal comparison through the DEA model for the estimation of output efficiency for various categories of India's banks, as well as the banking industry's average efficiency. It was discovered that the privately owned banks in India were not as efficient as other banks. However, the banking sector's average efficiency is better compared to the world's average.

Zenios et al. (2000) argued, there are three elements that impact the financial sector's performance and those are environment, company strategy, and degree of strategic execution. Halkos

et al. (2004) conducted an empirical research and found that commercial banks' performance differs according to asset size. It was discovered that the higher the asset size, the better the efficiency of the banks' operation; hence resulting in an increase in the performance of commercial banks. It was concluded that when there is reduction in the number of non-large banks through reconfiguration or merger, there will be an improvement in the commercial banks' performance.

Ariff and Can (2008) summarized factors affecting performance of commercial bank for the period of 1995-2004, based on Bank of China's financial statement data. The study discovered that there are several variables impacting the commercial banks' performance such as bank type, bank size, bank asset, asset security, preventing and controlling risk, and outside influence. Staub et al. (2010) used DEA method in calculating the scores for efficiency where the Brazilian banks' efficiency in terms of technology, distribution and cost from data between 2000 and 2007 were analyzed. It was discovered that banks in Europe and America had better cost (economic) efficiency than the banks in Brazil. During the turbulent economic condition (2000 to 2002), the banks in Brazil had experienced unfavorable economic efficiency. Nonetheless, this was a primarily the result of technical inefficiency instead of distribution inefficiency.

More scholars have proved through empirical research that the DEA method performs well and is practical in bank performance. Raghoober et al. (2017) analyzed the performance of ten banks that had their operations based in Mauritius. The DEA technique was used and data of 2011-2015 were utilized. Wanke et al. (2018) selected 15 Angolan banks from 2006 to 2014, calculated the average efficiency score through the DEA method, re-evaluated the efficiency level of Angolan banks, and discussed in depth the management significance of Angolan banks. Adeabah et al. (2019) analyzed from annual reports of 21 banks for the period from 2009 to 2017 to examined the determinate of bank efficiency. Ruinan (2019) compared the performance of banks in the United States and Canada based on DEA. Ofori-Sasuet al. (2019) examined the effect of funding structure on the technical efficiency of banks in Ghana, between 2011 and 2016. and the results present new evidence. Chen et al. (2020) focused on risk factors and analyzed the data of Taiwan Bank of China through the DEA technique where the domestic banks' performance was evaluated. Through DEA approach Amowine et al. (2019) analyzed the banks in Africa. Zhu et al. (2020) analyzed the banks in Pakistan. Lartey et al. (2021) analyzed banks in UK.

In addition, through the DEA technique, scholars have concluded that the performance of different types of banks is different. Wanke et al. (2017), based on the DEA technique calculated the performance of virtual bank mergers, and discussed on the suitability of M&A strategies in South African banks. The study's results showed that bank type will affect virtual banks' efficiency. Henriques et al. (2018) evaluated the performance of 37 banks in Brazil using data between 2012 and 2016 through the DEA method. They analyzed the performance of those banks through the BCC and CCR models. They found that different banks will produce different performance. The large banks performed well from the pure technical efficiency aspect, but cannot achieve the best economies of scale. It also can be concluded that the largest bank is not necessarily the most efficient bank. The DEA technique had been utilized by Shaddady et al. (2019) to understand the impact on bank performance from the perspective of bank supervision. The results showed that the performance of commercial banks, small banks and banks of developing nations is different. Shaddady et al. (2019) found that bank supervision and bank performance are positively correlated. Czerwonka (2019) studied 12 listed banks in Poland from 2013 to 2018, and the results showed that the large banks were very efficient on average. Goyal et al. (2019) analyzed data to make Indian banks internationally competitive and improve industry efficiency. Analyzing the data of 66 banks in 2015 and 2016, it proves that the performance of different banks is very different. Partovi et al. (2019) examined the performance level of Turkish banks between 2002 and 2017 using the DEA method where it was assumed that there is constant return to scale. The study's findings showed that Turkish banks have different performance levels, and the dissimilarities are primarily caused by ownership structure.

There are also scholars focusing on the performance of Islamic banks. Basri et al. (2018) estimated the Malaysian Islamic banks' efficiency through DEA. The study also compared the

performance of local and international Islamic banks to measure the contribution of foreign Islamic banks to Malaysian Islamic banking sector's progress for impact assessment. The findings showed that local Islamic banks had greater efficiency level compared to their foreign counterparts. Kamarudin et al. (2019) studied the Malaysian Islamic banking sector where they employed DEA to assess income efficiency and investigate factors that may affect internal (external banks) and external (macroeconomic) determinants. The results show that the international Islamic banks had better income efficiency compared with their local counterparts. Determination of these efficiency concepts enable efficiency level of Islamic banks be obtained. Moreover, through the comparison between profit efficiency and cost efficiency, the impact on bank profit by income efficiency could be determined. The above literature shows that the DEA approach is widely used in bank performance. Wasiaturrahma et al. (2020) analyzed the difference in performance between conventional banking system and Islamic banking system in Indonesia, where they focused on Bank Perkreditan Rakyat (BPR) and Bank Pembiayaan Rakyat Syariah (BPRS). It was concluded based on the DEA method both those financial institutions were not efficient as intermediaries. Nonetheless, they were both not inefficient from the production perspective.

METHODOLOGY

DEA was originally proposed by Farell (1957). The DEA method has two classic models, namely the CCR and BCC models. Charnes, Cooper and Rhodes introduced the CCR model in 1978. The model studies the relative efficiency in the making of decisions where constant returns to scale is assumed. Banker, Charnes and Cooper introduced the BCC model in 1984. It removes the fixed return to scale factor in the CCR model and adds the variable return to scale factor for the estimation of relative efficiency where the scale returns differ.

In cases where there are multitude of output and input, the DEA approach will be used. The sample's optimal individual is analyzed from the selected decision-making unit (DMU). The estimated value obtained by such a study is more similar to the effective state. The DEA method can evaluate the overall status or performance level of a DMU that has multitude of output and input. The evaluation and analysis of various factors can be carried out, and then the quantitative index of the comprehensive efficiency of each DMU can be obtained. Specifically, the comprehensive efficiency can include the technical efficiency reflecting the input-output structure and the scale efficiency of the overall scale. Finally, the index weight of each DMU in the DEA method model is a variable, which is finally calculated by the model according to the optimal principle, rather than pre-assumed. This will lead to avoidance of inaccurate conclusion risk caused by subjective factors, conform to the principle of objective and fairness, and make research conclusions more accurate and scientific.

According to DEA theory, efficiency is mainly divided into: scale efficiency, technical efficiency, pure technical efficiency and configuration efficiency. The actual output--ideal output ratio under the premise that the DMU input remains unchanged is known as technical efficiency (TE). The technical efficiency often has a value from 0 to 1. When the score of technical efficiency equals to '1', then DMU has managed to generate the maximum output under prevailing level of input, i.e., technically effective. When the score of technical efficiency does not reach 1, then DMU is not producing optimally, whereby the preferred output level is yet to be attained.

Allocation efficiency (AE) is DMU overall efficiency-technical efficiency ratio given a certain output level. The overall efficiency represents the minimum DMU cost-actual cost ratio. The overall efficiency takes into account the pricing factor of each element of input. When the value approaches '1', the DMU actual cost is near to the ideal value. Should the allocation efficiency value equal to '1', the DMU is effectively allocated.

Pure technical efficiency (PTE) measures the gap between production frontier and the actual unit produced where the variable is return to scale. Scale efficiency (SE) refers to CCR efficiency-BCC efficiency ratio. Among them, CCR efficiency means global technical efficiency, and BCC efficiency

means local pure technical efficiency. Therefore, the scale efficiency could also be regarded as the ratio of the technical efficiency of the DMU (where there is constant return to scale) to the technical efficiency (where there is variable scale). If the value of scale efficiency equals to '1', then there is scale effective DMU. Should the scale efficiency equal to a value not exceeding '1', then there is scale invalid DMU.

CCR model with constant returns to scale

Charnes, Cooper and Rhodes (1978) introduced CCR which is a fundamental DEA model. In the model, it is assumed that there are *n* banks, and each bank is a decision unit, that is, DMU, where *m* is number of inputs and *s* is number of outputs.

The input and output data for every bank are represented by X_{ij}, Y_{rj}.

X_{ij} = input of decision unit j (denoted as DMUj) to the i-th input, xij>0.

Y_{rj} = input of decision unit j (denoted as DMUj) to the r-th output, yrj>0.

v_i=A measure (or weight) for the i-th input.

u_r=A measure (or weight) for the r-th output.

$i = 1,2, \dots, m$

$j = 1,2, \dots, n$

$r = 1,2, \dots, s$

Record as

$X_j^T = (x_{1j}, x_{2j}, \dots x_{mj}.)^T, j = 1,2, \dots, n.$

$Y_j^T = (y_{1j}, y_{2j}, \dots y_{sj}.)^T, j = 1,2, \dots, n.$

$v = (v_1, v_2, \dots v_m.)^T$

$u = (u_1, u_2, \dots u_s.)^T$

Among them, X_i and Y_i are the input vector and output vector of DMU_j. It can be obtained from historical data or statistical data and it is a constant, and v and u are weight vectors corresponding to m inputs and s outputs, and are variables. When it is necessary to obtain the most suitable input-output ratio for each sample, seek the most input-output weights, calculate the most efficient index, and obtain the effective production possibility boundary. Among them, the input-output ratio:

$$\text{No.1 } h_0 = \frac{u_0}{v_o} = \frac{\sum u_r y_{r0}}{\sum v_i x_{i0}}$$

Where v_i, u_r are the input and output weight vectors, $v_i, u_r \geq 0$. Finally, using the length between each DMU and the effective production possibility boundary, it can be determined whether the DMU is effective. When the exponents in X_j^T, Y_j^T are constraint boundaries, assuming that the scale efficiency is unchanged, the most weighted vector can be solved through the CCR model, as follows:

$$\text{No. 2} \quad max\, h_0 = \frac{\sum u_r y_{r0}}{\sum v_i x_{i0}}$$

Constraint conditions:

$$\text{No. 3 } \sum_r u_r y_{rj} / \sum_i v_i\, x_{ij} \leq 1$$

In order to avoid finding infinite solutions, constraints can be added:

$$\text{No. 4 } max\, h = \sum_{r=1}^{s} u_r y_{r0}$$

Constraint conditions:

$$\text{No. 5} \begin{cases} \sum_{r=1}^{s} u_r y_{r0} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 \\ \sum_{i=1}^{m} v_i x_{ij} = 1 \\ u_r v_i \geq 0 \end{cases}$$

According to the definition of Farrell (1957), assuming that θ is the technical efficiency value of the bank under investigation (that is, DMU_j), satisfying $0 \leq \theta \leq 1$ Applying the duality principle of linear programming to transform the above model into the corresponding duality model, the equivalent envelope form can be obtained:

$$\text{No. 6 } \theta^* = min\, \theta$$

Constraint conditions:

$$\sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{i0}$$

$$\sum_{j=1}^{n} y_{rj}\, \lambda_j \geq y_{r0}$$

$$\lambda_j \geq 0 \quad j = 1,2, \dots, n$$

$$\text{No.7} \qquad min\, \theta = \varepsilon(\kappa_1^T S^- + \kappa_2^T S^+)$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + S^- = \theta x_{ij}$$

$$\sum_{j=1}^{n} \lambda_j y_{ij} - S^- = y_{ij} \lambda_{ij} \geq 0, \quad S^- \geq 0, \ S^+ \geq 0$$

Where κ_1^T and κ_2^T are m-term and s-term unit vectors, S^- is the input relaxation variable of m-term, S^+ is the output relaxation variable of s-term, λ_j is the effective DMU Combination ratio. θ represents the relative efficiency value of the bank. Repeat this n times to get the efficiency values of all sample banks. When θ<0, it means that the DMU is inefficient and the input of its elements is wasted. It is necessary to reduce the use of its input proportionally. The smaller ratio is 1- θ. When θ<1, it means that the decision unit is non-deterministic DEA effective, When $\theta = 1$ and $S^- = S^+ = 0$, it means that the efficiency is on the boundary of the feasible area, that is, the bank is in a technically valid state, When $\theta = 1$and $S^- \neq 0$ or $S^+ \neq 0$, it indicates that DMU is deterministic and DEA is weak-effective, at this time, the optimal allocation of resources can be achieved by adjusting the ratio of input and output during the operation. If contact all θ values of DMU_j, so will get overall situation of the technical efficiency of each bank.

Determination of variables

The selection of items for output and input in the calculation process is critical. Early literature on financial institutions used a single-output method, which did not conform to the actual situation of banking, such as Schweiger and McGee (1961), Bell and Murphy (1968), and Benston (1972). Then researchers began to adopt multiple output methods when choosing input and output variables, including production method, intermediary method and asset method. Benston (1965) proposed that the production method to regard commercial banks as a production institution that produces financial products. The input is the resources that need to be invested in the operation process, and the output is financial products or services. The intermediary method was proposed by Sealey and Lindley (1977); and Benston, Hanweck and Humphrey (1982) had enhanced the technique. The intermediary method regards a commercial bank as an intermediary institution, which absorbs savings or deposits through its own capital and labor capital, and obtains interest income through loans and investments. The asset

method is a variant of the intermediary method. The asset method considers commercial banks as institutional investors in the financial market, regardless of input factors. The liability account on the balance sheet is the input variable when measuring performance, and the asset account is the output variable. Fethi and Pasiouras (2010) believed that DEA is an extensively employed approach in measuring bank efficiency. Their investigation proves that the input-output mix of the corresponding research is not consistent.

For the three methods described above, Humphrey and Berger (1997) believed that there has to be separate consideration. The production technique is a better approach in analyzing the commercial banks' branches. The rationale is that, only the branches are directly processing the customer's business records, and the fund adjustment between the branches has little effect on the entire banking system. However, since interest is used as an output indicator, the intermediary method is more applicable to the entire bank (Maudos and Pastor, 2003; Cook et al., 2005; Delis and Papanikolaou, 2009). Nonetheless, the above three methods have few shortcomings. None of them reflects the dual characteristics of commercial banks as capital circulation medium, that is, collecting social idle funds and distributing the collected funds to those in need.

This study combines production method, intermediary method and asset method to select nine preliminary input and output indicators, including total assets, fixed assets, other assets, net income, return on assets, return on equity, loans, total customer deposits, and operating expenses. Considering the correlation between indicators, several variables were removed. At the same time, considering that the data will affect the measurement results when they negative, indicators that have negative values are eliminated. This is because the presence of negative values will reduce the validity of DEA calculations (Master,1993). Scholars' opinion differs on whether deposits are used as an input or output variable (Fare et al., 1989; Resti, 1997; Fukuyama and Weber, 2008). In this study, deposits are not the actual initial investment of commercial banks, they are used as an intermediate variable. Therefore, the final input indicators are total assets and total operating expenses, and the output indicators are loans and net income. Table 1 presents the descriptive statistics of input-output indicators.

Table 1: Descriptive statistics of input-output indicators

Input	Total asset	X1	Bank's total assets at the end of the year	7,978.86	8722.14	43.36	30,109.44
	Total operating expense	X2	Bank annual operating expenses	74.12	74.59	0.38	220.84
Output	Net income	Y1	Bank's annual after-tax profit	93.33	103.52	0.13	313.36
	Loans	Y2	Total bank loans at the end of the year	4,161.11	4628.09	20.62	16,326.55

RESULTS AND DISCUSSION

Based on China Banking Regulatory Commission report, there are eighteen types of domestic banking financial institutions in China. When determining the scope of the data, this article considers the comprehensiveness of the data, the degree of bank development, and the relative geographic location. In the end, this study chose 29 banks from three categories (city commercial banks, large commercial banks, and joint-stock banks). This study's data are between the period of 2010 and 2019. Meanwhile, Bankscope database provides the bank-related data. Table 2 lists the 29 banks included in this study.

Table 2: Lists of sample banks

No.	Bank	No	Bank
1	Industrial and Commercial Bank of China Limited (ICBC)	**16**	China Bohai Bank Co., Ltd (CBB)
2	China Construction Bank Corporation (CCB)	**17**	Hengfeng Bank Co., Ltd (HB)
3	Agricultural Bank of China Limited (ABC)	**18**	Beijing Bank
4	Bank of China Limited (BOC)	**19**	Shanghai Bank
5	Bank of Communications Co., Ltd (BCM)	**20**	Nanjing Bank
6	China Merchants Bank Co.,Ltd (CMB)	**21**	Tianjin Bank
7	Industrial Bank Co., Ltd (IB)	**22**	Guangzhou Bank
8	Shanghai Pudong Development Bank Co., Ltd. (SPDB)	**23**	Chengdu Bank
9	China Citic Bank Corporation Limited (CCBC)	**24**	Chongqing Bank
10	China Minsheng Banking Corp., Lt(CMBC)	**25**	Dalian Bank
11	China Everbright Bank Co., Ltd (CEB)	**26**	Ningxia Bank
12	Hua Xia Bank Co., Limited (HXB)	**27**	Changsha Bank
13	China Guangfa Bank (CGB)	**28**	Qingdao Bank
14	China Zheshang Bank Co., Ltd (CZB)	**29**	Luoyang Bank
15	Ping An Bank Co., Ltd. (PAB)		

Based on the input-output indicators, DEA-solver-Lv software had been employed in the calculation of relative performance of commercial banks taken as samples. This research is in accordance to the input data of the DEA-CCR model, and the output data of CCR-I. The results are summarized as the performance scores of 29 commercial banks from 2010 to 2019. Further analysis provides the performance scores of five big commercial banks, twelve joint-stock banks, and twelve city commercial banks.

Table 3: Performance score of 29 commercial banks from 2010-2019

Bank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ICBC	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CCB	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ABC	0.80	0.82	0.85	0.87	0.88	0.86	0.87	0.86	0.88	0.88
BOC	0.92	0.96	0.97	0.99	1.00	1.00	0.98	0.96	0.96	0.96
BCM	0.93	1.00	1.00	1.00	0.99	0.95	0.91	0.87	0.86	0.87
CMB	0.98	1.00	1.00	0.98	0.94	0.90	0.97	1.00	1.00	1.00
IB	0.84	0.81	0.87	0.76	0.84	0.80	0.80	0.85	0.88	0.90
SPDB	0.92	1.00	0.98	1.00	1.00	0.97	0.98	0.98	1.00	1.00
CCBC	1.00	0.97	1.00	0.97	0.95	0.92	0.90	0.96	1.00	0.94
CMBC	0.95	0.97	0.85	0.93	0.84	0.83	0.77	0.84	0.90	0.91
CEB	0.94	0.94	0.83	0.90	0.86	0.88	0.90	0.90	0.97	0.95
HXB	0.83	0.85	0.85	0.88	0.90	0.92	0.92	0.95	1.00	0.98
CGB	0.93	0.99	0.93	0.88	0.86	0.83	0.85	0.91	0.95	0.94
CZB	0.86	0.85	0.83	0.83	0.79	0.75	0.68	0.79	0.93	0.97
PAB	1.00	0.88	0.80	0.81	0.83	0.85	0.89	0.90	0.98	0.93
CBB	0.57	0.62	0.56	0.62	0.60	0.70	0.73	0.79	0.92	1.00

HB	0.79	0.72	0.75	0.73	0.68	0.69	0.65	0.73	0.72	0.68
Beijing Bank	0.85	1.00	1.00	1.00	1.00	0.99	0.97	0.98	1.00	1.00
Shanghai Bank	0.97	0.96	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00
Nanjing Bank	0.79	0.75	0.85	0.72	0.68	0.72	0.68	0.71	0.86	0.90
Tianjin Bank	0.76	0.79	0.93	0.88	0.93	0.92	0.80	1.00	0.94	0.80
Guangzhou Bank	1.00	0.94	1.00	1.00	1.00	1.00	0.93	0.77	0.87	0.88
Chengdu Bank	0.85	0.89	0.84	0.84	0.83	0.78	0.69	0.75	0.93	0.99
Chongqing Bank	0.91	0.93	0.91	0.83	0.77	0.79	0.90	0.99	0.97	0.98
Dalian Bank	0.70	0.80	0.70	0.76	0.87	0.97	0.86	0.73	0.73	0.76
Ningxia Bank	1.00	1.00	1.00	1.00	0.94	0.79	0.76	0.75	0.79	0.77
Changsha Bank	0.78	0.74	0.71	0.73	0.76	0.76	0.68	0.70	0.77	0.78
Qingdao Bank	0.73	0.75	0.80	0.73	0.71	0.77	0.63	0.73	0.67	0.78
Luoyang Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.85	0.88
Average	**0.88**	**0.89**	**0.89**	**0.88**	**0.88**	**0.87**	**0.85**	**0.88**	**0.91**	**0.91**
Maximum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Minimum	**0.57**	**0.62**	**0.56**	**0.62**	**0.60**	**0.69**	**0.63**	**0.70**	**0.67**	**0.68**
Standard deviation	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.10**	**0.12**	**0.11**	**0.09**	**0.09**

From Table 3, it can be seen that the 29 banks have a minimum performance score of 0.56 in 2012. Although the minimum value increased in 2013 and 2014, the performance score is lower compared to other years. In the years 2017, 2018 and 2019, their minimum values are 0.70, 0.67, 0.68 respectively. The standard deviation remained at 0.11 between 2010-2014, and in 2017. In other years, standard deviation is recorded at 0.09 in 2018 and 2019, 0.10 in 2015 and 0.12 in 2016. Based on these scores, it can be inferred that bank performance fluctuated between 2012-2014, and subsequently showed an upward trend. In more recent years, the commercial banks had not only improved their performance but also increased their operational stability.

Study by Czerwonka (2019) found that large banks are very efficient on the average. Henriques et al (2018) however concluded that big banks are not automatically efficient. Further analysis on performance of banks in China based on its classification is reported in this study.

Table 4: Performance score of 5 large commercial banks from 2010-2019

Bank	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
ICBC	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CCB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ABC	0.86	0.87	0.87	0.87	0.88	0.86	0.87	0.86	0.88	0.90
BOC	0.98	0.97	0.98	0.99	1.00	1.00	0.98	0.96	0.96	0.98
BCM	1.00	1.00	1.00	1.00	0.99	0.95	0.91	0.87	0.86	0.92
Average	**0.97**	**0.97**	**0.97**	**0.97**	**0.97**	**0.96**	**0.95**	**0.94**	**0.94**	**0.96**
Maximum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Minimum	**0.86**	**0.87**	**0.87**	**0.87**	**0.88**	**0.86**	**0.87**	**0.86**	**0.86**	**0.90**
Standard deviation	**0.06**	**0.06**	**0.06**	**0.06**	**0.05**	**0.06**	**0.06**	**0.07**	**0.07**	**0.05**

From Table 4, we could observe that the scores of five large commercial banks' performance are stable with little fluctuation. The five large commercial banks have the advantage due to their state-owned assets background, huge assets, strong strength, comprehensive business, system norms, and long history of development. Halkos et al. (2004) found that the commercial banks' performance directly varies in accordance to asset size. As we can see both ICBC and CCB have reached technical effectiveness in these ten years. BCM gradually changed from technically effective to less than ideal.

BOC reached technical effectiveness in years 2014 and 2015, and are relatively close in other years. Even though ABC has not achieved technical effectiveness in the past ten years, the scores are relatively stable without much fluctuation. From the standard deviation range of 0.01-0.02, it can be said that the scores of large commercial banks are stable, which implies that the technology of large commercial banks is effective. Findings from this study are consistent with Czerwonka (2019), which showed that the large banks are very efficient on average. Ariff and Can (2008) found that a factor influencing commercial banks' performance is size.

Table 5: Performance score of 12 joint-stock banks from 2010-2019

Bank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CMB	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
IB	1.00	1.00	1.00	0.97	0.96	0.94	1.00	1.00	1.00	1.00
SPDB	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CCBC	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.94
CMBC	0.95	0.99	0.93	1.00	0.96	0.98	0.85	0.92	0.92	0.93
CEB	1.00	0.98	0.88	0.94	0.93	0.98	0.96	0.95	0.99	0.96
HXB	0.83	0.86	0.85	0.90	0.96	1.00	0.97	0.99	1.00	0.98
CGB	0.93	0.99	0.93	0.91	0.91	0.90	0.90	0.95	0.95	0.94
CZB	0.86	0.85	0.84	0.87	0.80	0.78	0.81	0.83	0.93	0.97
PAB	1.00	0.92	0.80	0.82	0.89	0.92	0.93	0.93	0.98	0.93
CBB	0.57	0.62	0.60	0.71	0.66	0.76	0.79	0.82	0.92	1.00
HB	0.89	0.98	0.97	1.00	0.80	0.76	0.77	0.73	0.72	0.69
Average	**0.92**	**0.93**	**0.90**	**0.93**	**0.91**	**0.92**	**0.91**	**0.95**	**0.97**	**0.94**
Maximum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Minimum	**0.57**	**0.62**	**0.60**	**0.71**	**0.66**	**0.76**	**0.77**	**0.82**	**0.92**	**0.69**
Standard deviation	**0.12**	**0.11**	**0.12**	**0.09**	**0.10**	**0.10**	**0.09**	**0.07**	**0.03**	**0.08**

Performance scores of 12 joint-stock banks and 12 city commercial banks are presented in Table 5 and Table 6, respectively. Judging from the results of performance scores, it is quite different from the performance scores of large commercial banks. The comparison of these three types of banks also proves that the research is reasonable for in its choice of banks. In addition to 5 large commercial banks and 12 joint-stock banks, the remaining 12 city banks are selected according to the development of different cities in China, which enables a more comprehensive analysis on commercial banks' performance. Shaddady et. al. (2019) also showed that the performance of commercial banks, small banks, and banks operating in developing nations is different.

Table 6: Performance score of 12 city commercial banks from 2010-2019

Bank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Beijing Bank	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shanghai Bank	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00	1.00
Nanjing Bank	0.79	0.76	0.86	0.74	0.69	0.81	0.75	0.79	0.97	0.97
Tianjin Bank	0.77	0.82	0.93	0.88	0.93	0.92	0.83	1.00	0.94	0.84
Guangzhou Bank	1.00	0.94	1.00	1.00	1.00	1.00	0.95	0.86	0.97	1.00
Chengdu Bank	0.88	0.91	0.86	0.91	0.92	0.98	0.86	0.81	1.00	1.00
Chongqing Bank	0.96	1.00	1.00	0.91	0.87	0.98	0.97	1.00	1.00	1.00
Dalian Bank	0.79	0.89	0.81	0.86	1.00	1.00	1.00	0.93	0.88	0.91
Ningxia Bank	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.95	0.97	0.93
Changsha Bank	0.79	0.74	0.71	0.73	0.77	0.87	0.76	0.78	0.95	0.95
Qingdao Bank	0.82	0.85	0.89	0.83	0.86	0.97	0.75	0.74	0.82	0.93
Luoyang Bank	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88	0.92

Average	**0.89**	**0.91**	**0.92**	**0.91**	**0.92**	**0.96**	**0.90**	**0.91**	**0.95**	**0.95**
Maximum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Minimum	**0.77**	**0.74**	**0.71**	**0.73**	**0.69**	**0.81**	**0.75**	**0.74**	**0.82**	**0.84**
Standard deviation	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**	**0.06**	**0.11**	**0.10**	**0.06**	**0.05**

From Tables 5 and 6, the observation on standard deviation shows that city commercial banks' performance is not as stable as the joint-stock banks. Based on the minimum performance score, the highest value of minimum joint-stock banks score is 0.92. Meanwhile, the city banks' highest value for the minimum score is 0.82. However, from the perspective of the overall minimum value, the overall minimum value of city banks exceeds the joint-stock banks. Partovi et al. (2019) showed that the differences in performance levels have a correlation with the banks' ownership composition. The fundamental purpose of establishing City Bank is to serve the development of local finance and SMEs. Compared with joint-stock banks, there are no distinctive advantages. It is also closely related to the development of local cities. Therefore, the performance of city commercial banks in different regions varies greatly. For example, the 10-year performance of the Bank of Beijing is stable and basically remains at 1.00. At the same time, the highest performance score of Bank of Nanjing is 0.97. A study by Ariff and Can (2008) found that a factor influencing commercial banks' performance includes bank type.

CONCLUSION

This study utilized the CCR model of the DEA method for performance measurement of 29 commercial banks in China. The research estimates and analyzes the technical efficiency of 3 categories of commercial banks (large commercial banks, joint-stock and city commercial banks) in China. The study has found that the most dynamic and technically efficient banks are large commercial banks. The city commercial banks are the most inefficient where their service scope is only within certain locality. The technical efficiency evaluation on joint-stock banks indicates that there are fluctuations over the years. The study also observes that city commercial banks, especially those located in first-tier cities, have significantly better technical efficiency than city commercial banks in other cities. However, it is also possible for some city commercial banks operating in second-tier or third-tier cities to also reach the state of technological effectiveness. Some joint-stock banks, even if they have great advantages over city commercial banks, did not perform as good as city commercial banks from the technical efficiency aspect. This shows that joint-stock banks' technical efficiency still needs to be improved and further developed.

Technological progress is a vital element that affects commercial banks' efficiency, in which it is an indispensable approach towards improving the commercial banks' efficiency. Commercial banks can carry out financial innovations based on current business types, open up new business areas, use electronic technology, increase the types of financial products, diversify their services, reduce costs, and improve efficiency. In addition, market competition is also the way to promote the efficiency of commercial banks, to survive through market forces, to retain advanced management systems and technical levels, and to promote the reform of the banks themselves. This research makes a contribution to the study area through insights into bank performance in China, And through the data analysis of the performance of different banks, obtained comparative data. So as to contribute to the research field, provide data reference, and see the performance level of the entire industry. It provides empirical evidence on the performance of the financial industry in China for bank management, policymakers and researchers. Further studies may expand the scope to include more samples and employ qualitative methods to explain the performance of banks in China.

REFERENCES

Adeabah, D., Gyeke-Dako, A., & Andoh, C. (2019). Board gender diversity, corporate governance and bank efficiency in Ghana: a two-stage data envelope analysis (DEA) approach. *Corporate Governance (Bingley)*, 19(2), 299–320.

Afsharian, M., Ahn, H. and Neumann, L. (2016). Generalized DEA: an approach for supporting input/output factor determination in DEA. *International Journal of Benchmarking*, 23(7):1892-1909.

Amowine, N., Ma, Z., Li, M., Zhou, Z., Asunka, B. A., & Amowine, J. (2019). Energy efficiency improvement assessment in Africa: An integrated dynamic DEA approach. *Energies*, *12*(20).

Anastasios, D.V. and Stella, S. (2012). Efficiency evaluation of Greek commercial banks using DEA. *Journal of Applied Operational Research*, 4(4):183-193.

Ariff, M. and Can, L. (2008). Cost and profit efficiency of Chinese banks: A non-parametric analysis. *Journal of China Economic Review*, 19(2): 260-273.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis. Management Science, 30(9):1078-1092.

Basri, M.F., Muhamat, A.A. and Jaafar, M.N. (2018). The efficiency of Islamic banks in Malaysia: Based on DEA and Malmquist productivity index. *Journal of Emerging Economies and Islamic Research*, 6(3):15.

Bell, F.W. and Murphy, N.B. (1969). Costs in commercial banking: A quantitative analysis of bank behavior and its relation to bank regulation. *Journal of Financial and Quantitative Analysis*, 4(1):100-103.

Benston, G.J. (1965). Branch banking and economies of scale. *Journal of finance, American Finance Association*,20(2).312-331.

Benston, G.J. (1972). A microeconomic approach to banking competition: comment. *Journal of Finance*, 27(3):722-723.

Benston, G.J., Hanweck, G.A. and Humphrey, D.B. (1982). Scale economies in banking: A restructuring and reassessment. *Journal of Money, Credit, and Banking*, 14(4):435-456.

Berger, A.N. and Humphrey, D.B. (1997). Efficiency of financial institutions: International survey and directions for future research. *European Journal of Operational Research*, 98(2):175-212.

Chen, Y.C., Chiu, Y.H. and Chiu, C.J. (2020). The performance evaluation of banks considering risk: an application of undesirable relation network DEA. *International Transactions in Operational Research*, 27(2), 1101–1120.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research, 2*(6):429-444.

Cook, W.D., Hababou, M. and Liang, L. (2005). Financial liberalization and efficiency in Tunisian banking industry: DEA test. International Journal of Information Technology and Decision Making, 4(3):455–475.

Czerwonka, L. (2019). Efficiency in Polish listed commercial banks: a DEA approach. *Prace Naukowe Uniwersytetu Ekonomicznego We Wrocławiu,* 63(5), 7–18.

Delis, M.D. and Papanikolaou, N.I. (2009). Determinants of bank efficiency: evidence from a semi-parametric methodology. *Journal of Managerial Finance*, 35(3):260–275.

Eken, H.M. and Kale, S. (2011). Measuring bank branch performance using data envelopment analysis (DEA): The case of Turkish bank branches. *African Journal of Business Management*, 5(3):889-901.

Emrouznejad, A. and Yang, G.L. (2018). A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016. *Journal of Socio-Economic Planning Sciences*, 61: 4-8.

Emrouznejad, A., Parker, B. R., and Tavares, G. (2008). Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-Economic Planning Sciences*, *42*(3), 151–157.

Fare, R., Grosskopf, S. and Weber, W.L. (2006). Shadow prices and pollution costs in U.S. agriculture. *Journal of Ecological Economics*, 56(1):89-103.

Farrell, M.J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A,* 120(3): 253–281.

Fethi, M.D. and Pasiouras, F. (2010). Assessing bank efficiency and performance with operational research and artificial intelligence techniques: A survey. European Journal of Operational Research, 204(2):189–198.

Fukuyama, H. and Weber, W.L. (2008). Estimating inefficiency, technological change and shadow prices of problem loans for regional banks and Shinkin banks in Japan. *The Open Management Journal*, 1, 1-11.

Goyal, J., Singh, M., Singh, R., & Aggarwal, A. (2019). Efficiency and technology gaps in Indian banking sector: Application of meta-frontier directional distance function DEA approach. *Journal of Finance and Data Science*, *5*(3), 156–172.

Halkos, G. and Salamouris, D. (2004). Efficiency measurement of the Greek commercial banks with the use of financial ratios: A Data Envelopment Analysis approach. *Management Accounting Research*, 15(2): 201-224.

Harker, P. and Zenios, S. (2000). The performance of financial institutions (2nd ed). *Cambridge University Press.*
Hassan, M.K. and Isik, I. (2002). Technical, scale and allocative efficiencies of Turkish banking industry. *Journal of Banking and Finance*, 26(4):719-766.
Henriques, I.C., Sobreiro, V.A., Kimura, H. and Mariano, E. B. (2018). Efficiency in the Brazilian banking system using data envelopment analysis. *Journal of Future Business*, 4(2). 157–178.
Kamarudin, F., Sufian, F., Nassir, A.M., Anwar, N.A.M. and Hussain, H.I. (2019). Bank Efficiency in Malaysia a DEA Approach. *Journal of Central Banking Theory and Practice*, 8(1):133–162.
Lartey, T., James, G. A., & Danso, A. (2021). Interbank funding, bank risk exposure and performance in the UK: A three-stage network DEA approach. *International Review of Financial Analysis*, *75*.
Lin, T.T., Lee, C.C. and Chiu, T.F. (2009). Application of DEA in analyzing a bank's operating performance. *Expert Systems with Applications*, 36(5): 8883-8891.
Maudos, J. and Pastor, J.M. (2003). Cost and profit efficiency in the Spanish banking sector (1985–1996): A nonparametric approach. *Journal of Applied Financial Economics*, 13(1):1-12.
Mester, L. (1993). Efficiency in the savings and loans industry. *Journal of Banking and Finance*, 17(2-3):267-286.
Nguyen, T.P.T., Nghiem, S.H., Roca, E. and Sharma, P. (2016). Bank reforms and efficiency in Vietnamese banks: evidence based on SFA and DEA. *Journal of Applied Economics*, 48(30):2822-2835.
Ofori-Sasu, D., Abor, J. Y., & Mensah, Lord. (2019). Funding structure and technical efficiency: A data envelopment analysis (DEA) approach for banks in Ghana. *International Journal of Managerial Finance*, 15(4), 425–443.
Partovi, E. and Matousek, R. (2019). Bank efficiency and non-performing loans: Evidence from Turkey. *Research in International Business and Finance*, 48, 287–309.
Paster, J.M. (1999). Efficiency and risk management in Spanish banking: A method to decompose risk. *Journal of Applied Financial Economies,* 9(4): 371-384. 14.
Raghoober, K., Babajee, R.B., Ramdhany, N.G. and Seetanah, B. (2017). An Analysis of the Efficiency of the Mauritian Banking Sector Using the Data Envelopment Analysis (DEA). *Theoretical Economics Letters*, 07(05). 1423–1430.
Resti, A. (1997). Evaluating the cost-efficiency of the Italian Banking System: What can be learned from the joint application of parametric and non-parametric techniques. *Journal of Banking and Finance,* 21(2): 221-250.
Ruinan, L. (2019). Comparison of Bank Efficiencies between the US and Canada: Evidence Based on SFA and DEA. *Journal of Competitiveness,* 11(2), 113–129.
Saha, A. and Ravisankar, T.S. (2000). Rating of Indian commercial banks: a DEA approach. European Journal of Operational Research. 124(1):187-203.
Sathye, M. (2013). Efficiency of banks in a developing economy: the case of India. *European Journal of Operational Research,*148(3):662-671.
Schweiger, I. and McGee, J.S. (1961). Chicago banking. *Journal of Business,* 34(3):203-366
Sealey, C.W. and Lindley, T.J. (1977). Inputs, outputs, and a theory of production and cost at depository financial institutions. *Journal of Finance,* 32(4):1251-1266.
Shaddady, A. and Moore, T. (2019). Investigation of the effects of financial regulation and supervision on bank stability: The application of CAMELS-DEA to quantile regressions. *Journal of International Financial Markets, Institutions and Money,* 58, 96–116.
Sherman, H.D. and Gold, F. (1985). Bank branch operating efficiency: Evaluation with data envelopment analysis. *Journal of Banking and Finance,* 9(2): 297-315.
Staub, R.B., Silva, Souza, G. and Tabak, B.M. (2010). Evolution of bank efficiency in Brazil: A DEA approach. *European Journal of Operational Research,* 202(1):204–213.
Wanke, P., Barros, C.P. and Emrouznejad, A. (2018). A comparison between stochastic DEA and fuzzy DEA approaches: Revisiting efficiency in angolan banks. *RAIRO- Operations Research,* 52(1), 285–303.
Wanke, P., Maredza, A. and Gupta, R. (2017). Merger and acquisitions in South African banking: A network DEA model. *Research in International Business and Finance,* 41, 362–376.
Wasiaturrahma, Sukmana, R., Ajija, S.R., Salama, S.C.U. and Hudaifah, A. (2020). Financial performance of rural banks in Indonesia: A two-stage DEA approach. *Journal of Heliyon,* 6(7).
Zhu, N., Shah, W. U. H., Kamal, M. A., & Yasmeen, R. (2020). Efficiency and productivity analysis of Pakistan's banking industry: A DEA approach. *International Journal of Finance and Economics*.