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# Influencing Factors of Green Credit Efficiency in Chinese Commercial Banks

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This paper is applied the Tobit panel model to analyze the driving factors of green credit efficiency by using Chinese commercial banks' data from 2009 to 2019. Based on the undesirable-SBM-DEA model, this paper is attempted to construct the green credit evaluation index by incorporating carbon emissions, and evaluating the green credit efficiency of Chinese commercial banks. The result shows that the green credit efficiency of Chinese commercial banks is low currently. Moreover, there is a mutually significant relationship between the efficiency and profitability of commercial banks' green credit funds. Our findings suggest that the commercial banks should pursue the scale of green credit capital and improve the efficiency of green credits to help China achieve carbon neutrality goals.

**Keywords: green credit, capital efficiency, environmental performance, commercial banks, China**

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## 1 INTRODUCTION

With the frequency of extreme global climate events, increasing number of countries have reached the consensus of reducing environmental pollution and mitigating climate emergencies. In 2002, the Equator Principles was proposed by the International Finance Corporation and the ABN AMRO Bank, which is a benchmark for financial institutions to identify, assess and manage environmental and social risks for financing projects. In recent years, the Chinese government released numerous green finance policies to encourage financial institutions to protect the environment through investments or green credit. For example, China first implemented green credit policies in 2007, which was required commercial banks to take corporate emission reductions account to decide for the loans' issuance. In 2012, the CBRC issued the "Green Credit Guidelines" to further regulate commercial banks' green credit and guided financial institutions to invest more in green industries. In the future, the Chinese commercial banks will gradually withdrawal of funds to energy-intensive and heavily polluting industries, and increasingly issuing credit funds to support low-carbon and energy conservation projects.

Based on the guidance of a series of green finance policies, the scale of the Chinese green credit market has been continuously expanding. By the end of 2021, the balance of Chinese green credit was 15.9 trillion RMB yuan, ranking first in the world[1]. However, according to "The Adaptation Finance Gap Report (2016)," the annual costs of adaptation to climate change in developing countries are range from US$140 billion to US$300 billion by 2030, and between US$280 billion and US$500 billion by 2050 (Puig et al., 2016; Dong et al., 2020). China still needs funds to adapt

[1]Source: "Statistical Report on Loan Investment of Financial Institutions in 2021" released by the People's Bank of China

to climate change. Scholars began to pay attention to the green credit efficiency of banks to analyze whether financial institutions actual efficienctly use green credit or not. For example, Zhang B. et al. (2011) presented that green credit was not fully implemented and the efficiency level of implementation was far from the expectations. However, most studies only focused on the effects of implementing green credit, but had different conclusions (Yao et al., 2021; Zhang et al., 2021; Zhou et al., 2021b; Tian et al., 2022). Analyzing the Influencing factors of China's green credit efficiency and improving the efficiency is important to banks for green developments. Therefore, this paper constructed an indicator system to evaluate green credit efficiency and considered the carbon emisssion to identify the potential carbon dioxide emission reduction in Chinese commercial banks. We analyzed the influencing factors of green credit efficiency in Chinese commercial banks, such as bank's return on assets, loan-deposit ratio, capital adequacy ratio and so on. Given on that, we attempt to explore the methods to improve Chinese green credit efficiency.

The academic contributions of this paper are as follows: First, China has implemented many green credit policies but has not formed an evaluation system for its efficiency. Thus, we construct a general indicator system to evaluate green credit efficiency in this paper. Second, the main purpose of green credit is to help commercial banks play a leading role in emission reductions in China. We considered the carbon emissions and applied the Undesirable-Slack-Based Measure-Data Envelopment Analysis (Undesirable-SBM-DEA) model as the most suitable model to evaluate green credit efficiency for Chinese commercial banks. Third, we use the Tobit panel model to analyze the influencing factors of green credit efficiency and to identify methods to improve the green credit efficiency of Chinese commercial banks.

The structure of this paper is as follows. The second part presents the related literature review. The third part proposes the research hypotheses about what factors affect the green credit efficiency in Chinese commercial banks. The fourth part introduces the econometric model and data. The fifth part shows and discusses the empirical results, and the sixth part is the research conclusions.

## 2 LITERATURE REVIEW

Green credit innovated is aimed to economic development and environmental protection through the rational allocation of credit resources (Zhu et al., 2020; Dong et al., 2022). For commercial banks, it is important to evaluate the efficiency of implementing green credit. By evaluating the efficiency of green credit, the commercial bank could clearly know their shortcomings in the process of implementation and improvement. Therefore, this section first reviewed the existing literature in two key areas: climate change and commercial banks, and appropriate model to evaluate the efficiency of green credits.

### 2.1 Commercial Banks and Climate Change

Climate change and environmental protection have become hot topics in recent years. According to the FRBSF Economic Letter, climate change is a source of financial risk (Rudebusch, 2021; Ren et al., 2022a; Wang et al., 2022). Banks and other financial institutions may also face different risks caused by climate change, such as valuation risk, credit risk, legal risk, business risk, etc. China has the most dynamic economy and is one of the largest energy consumers and carbon emitters (Tian et al., 2022) in the world. The scope and scale of its industrial activities, assets, and population make financial institutions' businesses highly exposed to the effects of climate change.

The risks caused by climate change include physical risks and transitional risks. The former usually refers to natural disasters and extreme weather events related to climate change (i.e., typhoons, floods, droughts, hurricanes, and forest fires) (Dikau and Volz, 2021). The latter generally refers to uncertainty related to changes in policies, prices and technologies that may occur in climate change mitigation and carbon emission reduction (Chenet et al., 2021; Semieniuk et al., 2021; Ren et al., 2022b; Wen et al., 2022). Physical risks, the most important risk over the next 30 years (Stroebel and Wurgler, 2021), may directly affect commercial banks, or indirectly affect banks' operating profit performances through credit risks and collateral depreciation risks of enterprises and insurance companies, which cause enormous economic losses. NGFS (Network for Greening the Financial System) (2019) [2] pointed out that transition risks may lead to capital stranding (asset-grade capital face depreciation risk) or value stranding. For example, when the environmental policy is in transition to net zero, the development of electric vehicles will be likely to disrupt traditional car manufacturers (Krueger et al., 2020). In addition, climate change will limit the growth of bank assets, weaken the growth basis of bank liabilities, and the quality of loans in industries that are strongly affected by climate change tends to deteriorate.

Climate change not only causes threat for individual and social wealth, but also affects the stability of the financial system (Dietz et al., 2016; Dikau and Volz, 2021; Dou et al., 2022; Ren et al., 2022c). Therefore, Chinese commercial banks are facing huge pressures of transition and competition which force them to consider the best way for sustainable development. They need to enhance their "green" awareness as soon as possible to effectively avoid risks. As early as in 2004, Thompson and Cowton (2004) highlighted the need for banks to incorporate environmental factors into their standard processes for offering loans and investment strategies. Commercial banks, as financial intermediaries, should undertake own social responsibilities and actively respond to national policy requirements.

Currently, the Chinese government is actively encouraging commercial banks to develop green credit and the policy has basically similar with international green credit standards (Wen et al., 2021). Green credit is expected to rationally allocate credit funds through differentiated credit services, eventually lead to

[2]NGFS denotes for Network for Greening the Financial System.

coordinated progress between finance and environmental protection (He et al., 2019; Deng et al., 2022b; Ren et al., 2022b). It plays an increasingly important role in encouraging the development of environment-friendly enterprises. Cilliers et al. (2011) found green credit helped commercial banks to improve their long-term operating performance, and had a significant effect on the overall core competence of the banking industry (Luo et al., 2021). However, this also is brought stress to banks (Wright and Rwabizambuga, 2006).

## 2.2 Method Selection

The DEA method has been widely used in energy efficiency and environment efficiency. In energy efficiency, Han et al. (2015) analyzed energy efficiency for ethylene production systems in chemical industry based on the DEA model. In environment efficiency, Bian and Yang (2010) extended Shannon-DEA procedure to comprehensively measure resource and environment efficiencies. Sueyoshi et al. (2017) pointed out that it is important for China to evaluate environmental peformances by using DEA model to its energy policy, environmental policy, and economic planning. Therefore, the DEA method is also very commonly applied in China's efficiency analysis in recent years, especially in green economic efficiency. Shuai and Fan (2020) applied the super-efficient DEA model to measure China's green economy efficiency and further examined the impact of environmental regulations on China's green economic efficiency. Wu D. et al. (2020) used the DEA method to evaluate green economic efficiency in Chinese regions and analyze its dynamic evolution based on panel data from 2008 to 2017. Song et al. (2021) who employed the super-efficiency data envelopment analysis (DEA) and spatial econometric model, found that green credit could improve high-efficiency utilization of energy. Moreover, there are some other studies also on green innovation efficiency (Li and Zeng, 2020; Lv et al., 2021).

Tone (2004) and Zhou et al. (2006) extended the SBM-DEA model to incorporate undesirable outputs. Therefore. some studies began to consider the impact of unexpected outputs in analyzing energy efficiency (Honma and Hu, 2008; Zhang C. et al., 2011; Wu H. et al., 2020; Dong et al., 2021; Duan et al., 2021; Zhou and Li, 2021a) and environmental efficiency (Chen and Jia, 2017). In general, the undesirable outputs refer to the amount of carbon dioxide emission, chemical and pollution substances, and various types of waste discharges (Sueyoshi et al., 2017). For example, Bian et al. (2013) used carbon dioxide as an undesired output to test the potential energy saving and carbon dioxide emission reduction of provinces in China based on the DEA model. Wang et al. (2021) chose sulfur dioxide and carbon dioxide as unexpected output in this study and applied the DEA model to evaluate regional energy efficiency of China based on data from 2007 to 2019. Therefore, we also incorporate the amount of carbon dioxide emission as the undesirable output in this paper.

We found that although there has been a growing number of studies on green finance in recent years, most of them focus on the impact of developing green credit. However, It still has space to explore. For example, the few studies have directly analyzed the potential influencing factors of green credit efficiency in Chinese commercial banks. As a response, in this article, we investigate the green credit efficiency in Chinese commercial banks based on the Undesirable-SBM-DEA model and analyze its influencing factors applying the Tobit panel model. It would be more helpful for China to develop green credit, which will ensure that it achieved the carbon dioxide peaking and carbon neutrality goals as planned.

# 3 RESEARCH HYPOTHESIS

Commercial banks need to assess borrowers' environmental performances and redeign the loan requirements when implementing green credits. Therefore, green credit involves many subsquence evaluation activites, such as project management, qualification, post-loan management, among many others. These require a great deal of capital, which increase the operating cost for the commercial banks. Moreover, implementing green credit will make commercial banks lose some original customers because of limited credit capital. This will affect their profit. If commercial banks are profit seekers, they may delay provide green credits. However, the commercial banks with higher profitability have stronger awareness of social responsibility and actively to develop green credit (Yin et al., 2021). These banks also have relatively mature management systems and have lots of technical experience, which is better for reducing the costs associated with trial and error and improving green credit efficiency for them. Yin et al. (2021), who took 20 banks in China from 2011 to 2018, pointed out that commercial banks with higher profitability will expand the capital scale of green credit. Based on the above analysis, we select return on assets (ROA) to represent the profitability of commercial banks and propose the following hypotheses:

H1: The profitability of Chinese commercial banks will affect green credit efficiency.

The loan scale is representative by the loan-deposit ratio (LTD), will affect the capital available for green credit businesses in commercial banks. Banks with high LTD ratios have less capital to invest in green credit, because most of their capitals have been already invested in other areas, which will affect their green credit efficiency eventually. The capital adequacy ratio reflects the risk tolerance of commercial banks. The higher the capital adequacy ratio, the stronger is their risk-resistance capacity. One of the reasons for commercial banks to develop green credit is to avoid environmental risks (Campiglio et al., 2018). Therefore, a bank with a higher capital adequacy ratio may have stronger risk-resistance capacity and delay implementing green credit businesses, which will affect green credit efficiency. Meanwhile, bank's scale will also affect green credit efficiency. Commercial banks with larger scales, which have sufficient credit capital resources, can provide more green credit capitals. Combined with the above analysis, we observe that all kinds of commercial banks do not improve green credit at the same time (Deng et al., 2022a). It is particularly noteworthy that

**TABLE 1 |** Carbon emission values of major carbon-containing bunkers in China.

| Bunkers | Coal | Oil | Kerosene | Diesel oil | Fuel oil | Natural gas |
|---|---|---|---|---|---|---|
| cc (t/TJ) | 27.28 | 18.90 | 19.60 | 20.17 | 21.09 | 15.32 |
| cv (TJ/0.1 Bkg) | 192.14 | 448.00 | 447.50 | 433.30 | 401.90 | 3839.10 |
| cor (%) | 92.30 | 98.00 | 98.60 | 98.20 | 98.50 | 99.00 |

*This table shows the carbon emission values of major carbon-containing bunkers in China, which was reported by the National Development and Reform Commission Energy Research Institute (2007). Notably, cc is the carbon content contained in every trillion joules of heat, cv is how many trillion joules of heat were contained in every 100 million kilograms of fuel, and cor refers to the conversion rate of various fuels into carbon emissions.*

**TABLE 2 |** Green credit efficiency index of commercial bank in China.

| Index | First-level indicators | Second-level indicator | Calculating method |
|---|---|---|---|
| Input index | Green credit input | Green credit capital | (Green credit balance in current period + green credit balance in prior period)/2 |
| | Operating input | Human input | Salaries and welfare payable disclosed in bank's annual report |
| | | Daily operation input | Handling charges and commissions expenses and operating costs |
| | | Capital input | Fixed assets disclosed in bank's annual report |
| Normal output index | Profitability | Interest-earning capacity | Net interest income disclosed in bank's annual report |
| | | Earning capacity | Net profit disclosed in bank's annual report |
| Undesirable output index | Environmental pollution | The amount of CO2 emissions | The balance of two high and one surplus disclosed in banks' social responsibility report *0.203 kg/RMB yuan |

*This table shows the green credit efficiency index system evaluation used in this paper and reports specific calculating methods of the indicators. Notably, green credit input and operating input are the input index. Profitability is the output index. Environmental pollution is the undesirable output index.*

urban or rural commercial banks starting late and lack enough experience in identifying green projects (Luo et al., 2021), will affect green credit efficiency. Based on the above analysis, we propose the following hypotheses:

H2: The loan-deposit ratio of Chinese commercial banks will affect its green credit efficiency.
H3: The capital adequacy ratio of Chinese commercial banks will affect its green credit efficiency.
H4: The total assets of Chinese commercial banks will affect its green credit efficiency.

Green credit efficiency not only reflects the profitability, safety, and liquidity of banks but also increase their environmental benefits. Commercial banks can optimize the structure of borrowers and reduce environmental risks by reducing the scale of credit for polluting companies and increasing it for green companies (Yao et al., 2021). The former may be penalized for created environmental problems, which may lead to their failures to repay the loans and, as a result, bringing credit risks. Therefore, optimizing their customers' structures can reduce the credit risks of commercial banks.

Moreover, with the continuously stronger of social environmental awareness, commercial banks actively undertake social responsibilities and develop green credit businesses, which can improve their reputation (Zhou et al., 2021b). This can be benefits for the core competitiveness and profitability of commercial banks (Luo et al., 2021). In addition, with the increasingly homogenization of commercial bank businesses, the banks also create more intermediary business and credit products relating to green credits, which could bring new profit growth drivers and improve their financial performances (Jatana and Jain, 2020). Based on the above analysis, we propose the following hypothesis:

H5: Improving green credit efficiency can improve the profitability of banks.

# 4 EMPIRICAL STRATEGY

## 4.1 Method

There are many methods to evaluate banks' efficiency. The frontier analysis method is the main methodology used to analyze efficiency and can be divided into the parametric and non-parametric approaches. The former is estimated efficiency frontier through statistical methods, whereas the latter generated efficiency frontier through linear programming without considering random influence. Charnes, Cooper and Rhodes (1978) first used mathematical programming to apply the data envelopment analysis (DEA) method in the computable non-parametric method. Scholars also developed the DEA model, such as Constant Returns to Scale (CRS) model, Variable Returns to Scale (VRS) model, Slack-Based Measure-Data Envelopment Analysis (SBM).

Furthermore, the profits of commercial banks are from interest and non-interest incomes, and it is difficult to describe it by the production function. Moreover, the main purpose of green credit is to reduce carbon emissions through capital allocation. If commercial banks blindly expand the

**TABLE 3 |** List of symbols.

| Variable name | Symbols | Definition |
|---|---|---|
| Green credit efficiency | GE | Calculated from the previous contents |
| Return on assets | ROA | Bank annual report |
| Loan-deposit ratio | LTD | Bank annual report |
| Capital adequacy ratio | CAR | Bank annual report |
| Non-performing loan ratio | NPL | Bank annual report |
| Total assets | LnAsset | The logarithm of banks' total assets |

*This table shows the list of symbols about the empirical analysis on the impact of green credit efficiency on profitability in **Equations 3**, **4**. Notably, green credit efficiency is divided into total sample commercial bank green credit efficiency (TGE), state-owned commercial bank and joint-stock commercial bank green credit efficiency (NGE), urban (rural) commercial bank green capital efficiency (UGE). The term return on assets (ROA) equals is the net income divided by total assets for the same period, which is an efficiency measure of how well a bank is using its assets. The Loan-deposit ratio (LTD) is the ratio of a bank's total loans to its total deposits for the same period. The capital adequacy ratio (CAR) is a measurement of a bank's available capital expressed as a percentage of a bank's risk-weighted credit exposures. The Non-performing loan ratio (NPL) refers to the proportion of non-performing loans of a bank in the total loan balance for a specified period. The LnAsset is the logarithm of banks' total assets. According to the risk basis, the loans issued by banks are divided into five categories: normal, concern, subprime, doubtful and loss, among which the latter three categories are collectively referred to as non-performing loans.*

scale of green credit capital without monitoring, the carbon emissions may continue to increase, which obviously violates the purpose of green credit. While evaluating the green credit efficiency of commercial banks, we choose the amount of carbon emissions representing the undesirable output index in the method of efficiency evaluation. Therefore, the Undesirable-SBM-DEA model is the most appropriate approach to reach our research objective. The specific model is as follows:

We consider a production possibility set containing undesirable output:

$$P = \left\{ \left( x, y^g, y^b \right) \middle| x \geq X\lambda, y^g \leq Y^g\lambda, y^b \geq Y^b\lambda, L \leq e\lambda \leq U, \lambda \geq 0 \right\} \quad (1)$$

where x denotes the input, $y^g$ represents normal output, and $y^g$ denotes undesirable output. The expression of Undesirable-SBM-DEA model is:

$$\rho^* = min \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s}\left( \sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g} + \sum_{r=1}^{s_2} \frac{s_r^b}{y_{r0}^b} \right)} \quad (2)$$

$$subject\ to \begin{cases} x_0 = X\lambda + s^- \\ y_0^g = Y^g\lambda - s^g \\ y_0^b = Y^b\lambda + s^b \\ L \leq e\lambda \leq U \\ s^-, s^g, s^b, \lambda \geq 0 \end{cases}$$

where $x_0$, $y_0^g$ and $y_0^b$ denote the targets[3].

[3]Notably, $\frac{1}{m}\sum_{i=1}^{m} \frac{s_{i0}^-}{x_{i0}}$ presents the inefficiency of imput, $\frac{1}{s}\sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g}$ presents the inefficiency of normal output, and $\frac{1}{s}\sum_{r=1}^{s_1} \frac{s_r^g}{y_{r0}^g}$ presents the inefficiency of undesirable output. Meanwhile, $X$, $Y^g$ and $Y^b$ are the target value.

## 4.2 Econometric Model

### 4.2.1 Empirical Analysis on the Influencing Factors of Green Credit Efficiency in Chinese Commercial Banks

According to our research hypothesis, **Eq. 3** is our basic regression specification, which tests the influence of various factors on green credit efficiency, as follows:

$$GE_{it} = \alpha + \beta Expl_{it} + \mu_{it} \quad (3)$$

where, $\mu_{it}$ is an error term for mixing time series and cross section. In **Equation 3**, $GE_{it}$ denotes the green credit efficiency of the sample commercial bank i at year t. $\alpha$ is the constant term of the regression. $Expl_{it}$ refer to the main explaining variables that affect the green finance level of banks, including banks' return on assets (ROA), banks' loan-deposit ratio (LTD), capital adequacy ratio (CAR) and the logarithm of total assets (LnAsset).

### 4.2.2 Empirical Analysis on the Impact of Green Credit Efficiency on Profitability in Chinese Commercial Banks

According to the research hypothesis, **Eq. 4** is also our basic regression specification, which analyses the impact of green credit efficiency on the profitability of the commercial banks.

$$Pro_{it} = \alpha + \beta Expl_{it} + \gamma Con_{it} + \mu_{it} \quad (4)$$

where, $\mu_{it}$ is an error term for mixing time series and cross section. In **Equation 4**, $Pro_{it}$ denotes the sample commercial bank i's ROA at year t. $\alpha$ is the constant term of the regression. $Expl_{it}$ is the main explaining variable, $GE_{it}$. $Con_{it}$ refer to the control variables, including bank loan-deposit ratio (LTD), capital adequacy ratio (CAR) and non-performing loan ratio (NPL).

## 4.3 Variable Selection

Because most of Chinese commercial banks did not disclose their private green credit information, we collected 42 commercial banks' data after checking all the available information for listed commercial banks' financial and social responsibility reports. Our observations include six state-owned commercial banks, twelve joint stock commercial banks, and sixteen urban and rural commercial banks from 2009 to 2019. The data is collected from the RESSET data source and commercial bank corporate social responsibility reports.

### 4.3.1 Green Credit Efficiency Index System

The main purpose of green credit is to control environmental pollution and guide companies to reduce carbon emissions. In order to evaluate the banks' green credit efficiency, we should consider their economic outputs and the environmental benefits they aim to. No matter how environment friendly companies are, they are all directly or indirectly responsible for carbon emissions. Therefore, we are going to use carbon as the proxy variable to measure the impact of green credit on the environment.

Taking into consideration the current amount of green credit capital, we used the mean of the beginning balance

**TABLE 4** | Descriptive Statistics of input-output Indicators from 2009 to 2019.

| Index | Sample size | | | Mean | | | Max | | | Min | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | A | B | C | A | B | C | A | B | C | A | B | C |
| Fixed assets | 55 | 68 | 84 | 1389 | 182.5 | 35.66 | 2535 | 652.7 | 87.34 | 258.4 | 36.94 | 3.86 |
| salaries and welfare payable | 55 | 68 | 84 | 273.2 | 83.16 | 15.89 | 504.7 | 177.4 | 54.61 | 56.73 | 32.20 | 0.43 |
| Daily operation input | 55 | 68 | 84 | 2364 | 709.6 | 113.0 | 4806 | 1603 | 295.7 | 571.3 | 199.9 | 19.12 |
| Green credit capital | 55 | 68 | 84 | 4574 | 1083 | 101.2 | 12950 | 9280 | 828 | 739.4 | 21.32 | 5.11 |
| Net interest income | 55 | 68 | 84 | 3271 | 817.4 | 152.8 | 6070 | 1730 | 375 | 850 | 244 | 29.5 |
| Net profit | 55 | 68 | 84 | 1664 | 384.2 | 71.76 | 3134 | 934.2 | 203.3 | 391.7 | 109.7 | 10.76 |
| The amount of CO2 emissions | 55 | 68 | 84 | 823.45 | 170.66 | 27.97 | 1942.7 | 452.1 | 144.9 | 124.3 | 27.93 | 1.37 |

*This table shows the descriptive statistic of input-output indicators used in this paper. Notably, A represents state-owned commercial banks, B represents joint-stock commercial banks, and C represents urban (rural) commercial banks. Additionally, the unit of carbon emission is tons, and the unit of other variables is million yuan.*

**TABLE 5** | Correlation analysis results.

| Correlation | ROA | LTD | CAR | NPL | LnAsset |
|---|---|---|---|---|---|
| ROA | 1 | | | | |
| LTD | -0.1671*** | 1 | | | |
| CAR | 0.1969*** | 0.0131 | 1 | | |
| NPL | -0.5141*** | 0.2365*** | -0.0981* | 1 | |
| LnAsset | 0.3221*** | 0.232*** | 0.0179 | 0.0159 | 1 |

*This table shows the correlation of the symblos used in this paper. Notably, ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.*

and the ending balance from the commercial banks. Besides providing green credit, commercial banks also have a lot of investments in human capital and equipments to meet the daily operational needs. Therefore, we divided the operational input into three parts: human capital input, capital input, and daily operation input. We used their salaries and welfare payable to denote the human capital input index. Banks' capital is used not only for issuing loans but also for investing in expansion to set up more branches. The local branches help banks know more about local companies, which contribut to develope the green credit businesses. Therefore, we chose fixed assets as the capital input index. We evaluated the daily operation input index as commission expenses and operating costs tied to the business and management of banks. **Table 2** shows the details of the indexes.

Commercial banks should not consider the costs relating to emission reductions as their expenses for their profitability. Thus, we chose net profits as the earning capacity index. It reflects the deposit and loan income, intermediate business income, ability to control cost, and performance levels of commercial banks.

However, Chinese commercial banks do not provide information regarding to all credit capital. They still offer loans to resource-intensive industries with high pollutions and high energy consumptions and industries with overcapacities (two high and one surplus[4]). These industries emit a large amount of carbon while carrying forward their productions and operations, which will have negative externality in the environment. In addition, the capital available for lending is limited, because the credit capital mainly comes from account holders' deposits. Therefore, commercial banks should focus on reducing carbon emissions resulting from lending to two high and one surplus industries. Thus, we referred to Bian et al. (2013) to calculate carbon emissions and considered more different types of fossil energies.

The calculation of carbon emissions was based on the measurement method issued by the Intergovernmental Panel on Climate Change (IPCC):

$$CO_2 = \sum_i fc^i \times cv^i \times cc^i \times cor^i \times (44/12) \tag{5}$$

where i was the fossil fuel type of carbonaceous material, $fc^i$ was the consumption of fuel i, $cv^i$ was the average calorific value of fuel i, $cc^i$ was the carbon content of per unit fuel i heat, $cor^i$ was the carbon oxidation rate of fuel i. The indicator values under different fuels could be seen in **Table 1**.

The above was the measurement method of the total carbon emissions per year. Then, the following is about how to measure the annual indirect carbon emissions for each bank. We selected the loan balance of "two high and one surplus" industries to calculate the ratio of each bank, accounting for all banks[5]. Then, we multiplied this ratio by the total indirect annual carbon emissions of each bank. However, we also found that in the same year, the ratio of two high and one surplus loans multiplied by each bank was the same. Therefore, this paper selected the two high and one surplus loan amount instead, which did not appear to affect the efficiency calculation.

[4]The two high industries refer to resource-intensive industries with high pollution and high energy consumption, and the one surplus refer to industries with overcapacity. It mainly includes steel, paper, electrolytic aluminum, flat glass, wind power and photovoltaic industries. The specific classification can be found in the "Green Credit Guidelines".

[5]These banks Include: PingAn Bank; Zhongyuan Bank; Guangzhou Rural Commercial Bank; Tianjin City Commercial Bank; Jiangxi Bank; Bank of Ningbo; Bank of Zhengzhou; Bank of Qingdao; Bank of Suzhou; HuiShang Bank; Harbin Bank; Bank of Jiujiang; Shanghai Pudong Development Bank; Huaxia Bank; China Minsheng Bank; China Merchants Bank; Wuxi Rural Commercial Bank; Bank of Jiangsu; Bank Of Hangzhou; Bank of Xi'an; Bank of Nanjing; Chongqing Rural Commercial Bank; Industrial Bank; Bank of Shanghai; Agricultural Bank of China; Bank of Communications; Industrial and Commercial Bank of China; Bank of Changsha; Postal Savings Bank of China; China everbright bank; China zheshang bank; China Construction Bank; Bank of China; Bank of Guiyang; China CITIC Bank.

**TABLE 6 |** Descriptive Statistics of crs green credit efficiency from 2009 to 2019.

| Index | Sample size | | | | Mean | | | | Max | | | Min | | | Standard deviation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | T | A | B | C | T | A | B | C | A | B | C | A | B | C | A | B | C |
| 2009 | 5 | 3 | 1 | 1 | 0.391 | 0.242 | 0.230 | 1 | 0.295 | 0.230 | 1 | 0.184 | 0.230 | 1 | 0.055 | - | - |
| 2010 | 8 | 4 | 3 | 1 | 0.683 | 0.518 | 0.797 | 1 | 1 | 1 | 1 | 0.328 | 0.390 | 1 | 0.323 | 0.352 | - |
| 2011 | 12 | 5 | 5 | 2 | 0.707 | 0.505 | 0.791 | 1 | 1 | 1 | 1 | 0.307 | 0.440 | 1 | 0.281 | 0.288 | 0 |
| 2012 | 13 | 5 | 5 | 3 | 0.773 | 0.588 | 0.821 | 1 | 1 | 1 | 1 | 0.342 | 0.547 | 1 | 0.258 | 0.246 | 0 |
| 2013 | 18 | 5 | 7 | 6 | 0.808 | 0.658 | 0.786 | 0.959 | 1 | 1 | 1 | 0.386 | 0.484 | 0.755 | 0.315 | 0.266 | 0.099 |
| 2014 | 18 | 5 | 7 | 6 | 0.853 | 0.700 | 0.903 | 0.923 | 1 | 1 | 1 | 0.457 | 0.505 | 0.535 | 0.276 | 0.189 | 0.190 |
| 2015 | 19 | 5 | 7 | 7 | 0.831 | 0.715 | 0.814 | 0.930 | 1 | 1 | 1 | 0.492 | 0.434 | 0.510 | 0.263 | 0.262 | 0.185 |
| 2016 | 23 | 5 | 8 | 10 | 0.622 | 0.369 | 0.589 | 0.776 | 0.512 | 1 | 1 | 0.310 | 0.343 | 0.363 | 0.083 | 0.273 | 0.292 |
| 2017 | 27 | 6 | 8 | 13 | 0.620 | 0.460 | 0.550 | 0.736 | 1 | 1 | 1 | 0.293 | 0.323 | 0.327 | 0.271 | 0.284 | 0.301 |
| 2018 | 29 | 6 | 8 | 15 | 0.799 | 0.728 | 0.681 | 0.891 | 1 | 1 | 1 | 0.387 | 0.498 | 0.370 | 0.302 | 0.217 | 0.207 |
| 2019 | 35 | 6 | 9 | 20 | 0.652 | 0.492 | 0.525 | 0.757 | 1 | 0.689 | 1 | 0.369 | 0.348 | 0.296 | 0.147 | 0.120 | 0.285 |

*This table shows the descriptive statistics of crs green credit efficiency from 2009 to 2019. Notably, T represents the whole commercial banks, A represents state-owned commercial banks, B represents joint-stock commercial banks, and C represents urban (rural) commercial banks.*

This table shows the carbon emission values of major carbon-containing bunkers in China, which was reported by the National Development and Reform Commission Energy Research Institute (2007). Notably, cc is the carbon content contained in every trillion joules of heat, cv is how many trillion joules of heat were contained in every 100 million kilograms of fuel, and cor refers to the conversion rate of various fuels into carbon emissions.

We obtained data on the balance of two high and one surplus in commercial banks and equated the amount of carbon emissions to that balance multiplied by the bank's carbon emission intensity. **Table 2** is for the specific calculation.

### 4.3.2 Variable Selection of the Empirical Analysis

The list of symbols about the empirical analysis on the impact of green credit efficiency is shown as **Table 3**.

## 4.4 Data

### 4.4.1 Descriptive Statistics

**Table 4** shows the descriptive statistical results of the data. According to the scale and nature of property rights, we classified Chinese commercial banks into three types: state-owned commercial banks (A), joint stock commercial banks (B), and urban(rural) commercial banks (C). **Table 4** shows that the sample sizes of A, B, and C are 55, 68, and 84, respectively. Here, C accounts for a substantial proportion of Chinese commercial banks. The mean of A's fixed assets is 138.9 billion RMB yuan, which is higher than B and C. The scale of Chinese commercial banks is in the following order: A > B > C.

In addition, three types of commercial banks have obvious intraclass agglomeration in scale, which can also be found by comparing the payroll payable index and daily operation input index. There are obvious differences among the scale of various kinds of commercial banks. For the green credit capital, the mean of A, B, and C are 457.4 billion RMB yuan, 108.3 billion RMB yuan, and 10.12 billion RMB yuan, respectively. This data shows that although the sample size of A is the smallest, it provides the majority of green credit capital. Comparing the net interest income index and net profit index, we can find that the highest mean is A and the smallest mean is C. This shows that A has the best profitability, B is in the middle, and C is the worst. However, we can also observe the mean of the amount of carbon emissions. To elaborate, C only emits 27.97 million tons, which is far lower than A and B. In general, when A

**TABLE 7 |** Descriptive Statistics of vrs green credit efficiency from 2009 to 2019.

| Index | Sample size | | | | Mean | | | | Max | | | Min | | | Standard deviation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | T | A | B | C | T | A | B | C | A | B | C | A | B | C | A | B | C |
| 2009 | 5 | 3 | 1 | 1 | 0.918 | 1 | 0.590 | 1 | 1 | 0.590 | 1 | 1 | 0.590 | 1 | 0 | - | - |
| 2010 | 8 | 4 | 3 | 1 | 0.945 | 0.889 | 1 | 1 | 1 | 1 | 1 | 0.724 | 1 | 1 | 0.136 | 0 | - |
| 2011 | 12 | 5 | 5 | 2 | 0.956 | 0.894 | 1 | 1 | 1 | 1 | 1 | 0.645 | 1 | 1 | 0.158 | 0 | 0 |
| 2012 | 13 | 5 | 5 | 3 | 0.939 | 0.898 | 0.944 | 1 | 1 | 1 | 1 | 0.599 | 0.721 | 1 | 0.174 | 0.125 | 0 |
| 2013 | 18 | 5 | 7 | 6 | 0.961 | 1 | 0.899 | 1 | 1 | 1 | 1 | 1 | 0.551 | 1 | 0 | 0.181 | 0 |
| 2014 | 18 | 5 | 7 | 6 | 0.951 | 1 | 0.936 | 0.929 | 1 | 1 | 1 | 1 | 0.554 | 0.573 | 0 | 0.169 | 0.174 |
| 2015 | 19 | 5 | 7 | 7 | 0.925 | 1 | 0.867 | 0.930 | 1 | 1 | 1 | 1 | 0.496 | 0.512 | 0 | 0.229 | 0.184 |
| 2016 | 23 | 5 | 8 | 10 | 0.936 | 1 | 0.916 | 0.919 | 1 | 1 | 1 | 1 | 0.632 | 0.556 | 0 | 0.156 | 0.171 |
| 2017 | 27 | 6 | 8 | 13 | 0.943 | 0.930 | 0.952 | 0.943 | 1 | 1 | 1 | 0.582 | 0.616 | 0.542 | 0.93 | 0.136 | 0.144 |
| 2018 | 29 | 6 | 8 | 15 | 0.910 | 0.929 | 0.860 | 0.930 | 1 | 1 | 1 | 0.578 | 0.627 | 0.408 | 0.172 | 0.193 | 0.185 |
| 2019 | 35 | 6 | 9 | 20 | 0.865 | 0.924 | 0.889 | 0.836 | 1 | 1 | 1 | 0.546 | 0.494 | 0.394 | 0.185 | 0.186 | 0.236 |

*This table shows the descriptive statistics of vrs green credit efficiency from 2009 to 2019. Notably, T represents the whole commercial banks, A represents state-owned commercial banks, B represents joint-stock commercial banks, and C represents urban (rural) commercial banks.*

**TABLE 8 |** Influencing factors of green credit efficiency in Chinese commercial banks.

| | (1) | (2) | (3) |
|---|---|---|---|
| | TGE | NGE | UGE |
| ROA | 0.4469*** | 0.4798*** | 0.5537*** |
| | (0.1095) | (0.1720) | (0.1698) |
| LTD | -0.0034* | -0.0056** | 0.0006 |
| | (0.0018) | (0.0024) | (0.0029) |
| CAR | 0.0220* | 0.0500** | -0.0251 |
| | (0.0127) | (0.0204) | (0.0186) |
| LnAsset | -0.0619** | -0.0497 | -0.0652 |
| | (0.0245) | (0.0690) | (0.0494) |
| cons | 2.0489*** | 1.4407 | 2.4213* |
| | (0.6567) | (1.9469) | (1.3377) |
| sigma_u | 0.1872*** | 0.2086*** | 0.1729*** |
| | (0.0284) | (0.0538) | (0.0383) |
| sigma_e | 0.1777*** | 0.1832*** | 0.1535*** |
| | (0.0097) | (0.0130) | (0.0142) |
| Obs | 207 | 123 | 84 |

*This table shows the results of the influencing factors of green credit efficiency. Our sample period is 2008–2019, and "ROA" is the core explanatory variable, and the positive its value is, the more profitability the green credit efficiency will be. Notably, the dependent variable from column (1) to column (3) is the green credit efficiency of different samples. TGE presents the green credit efficiency of whole Chinese banks, NGE presents the green credit efficiency of state-owned commercial banks and joint-stock commercial banks, and UGE presents the green credit efficiency of urban (rural) commercial banks. Sigma_u is the standard deviation of the individual effect, and sigma_e is the specific error of individual effect. At last, significance levels are represented by "***" (1%), "**" (5%) and "*" (10%).*

provides most of the green credit capital, the banks will emit a large amount of carbon. Thus, we cannot evaluate green credit efficiency by relying on descriptive statistics alone and need further analysis.

### 4.4.2 Correlation Analysis

We conducted a correlation analysis on banks' LTD, CAR, NPL, LnAsset and ROA. **Table 5** shows the results of this analysis. From the results, we can observe that the correlation between each regression variable is small and that there is no collinearity problem.

# 5 RESULTS AND DISCUSSION

## 5.1 Results of Green Credit Efficiency

### 5.1.1 Results of CRS

Due to the policy and geographical restrictions in operations, Chinese commercial banks cannot adjust their scale optionally. In this case, the results reflect green credit efficiency in the current state.

As shown in **Table 6**, the sample size has been increasing since 2009, which implies that Chinese commercial banks did not start to implement green credit at the same time. Comparing the sample size each year, we found that A implements green credit early, which is about 60% of the total sample. On the other hand, B and C start later. In the early stage of green credit implementation, some commercial banks did not realize its importance and take social responsibilities promptly. With the strict implementation of green credit policies carried out, commercial banks gradually had awareness of the climate change. At the same time, they have begun to gradually implement green credit for the purpose of meeting the needs of the policies.

In terms of the mean of whole sample (T), green credit efficiency gradually increased from 2009 to 2015 but started to decrease after 2015. In 2016, The People's Bank of China issued the "Guidelines on Building a Green Financial System." Chinese commercial banks have improved their requirements for a green credit business, resulting in the decline of green credit capital efficiency. We see that the efficiency mean of A is lower than the overall mean every year, but the efficiency mean of C is the highest. The average

**TABLE 9 |** Impact of green credit efficiency on profitability in commercial banks.

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| TGE | 0.2336*** | | | 0.1429*** | | |
| | (0.0399) | | | (0.0324) | | |
| NGE | | 0.2561*** | | | 0.1615*** | |
| | | (0.0496) | | | (0.0418) | |
| UGE | | | 0.2231*** | | | 0.1765*** |
| | | | (0.0664) | | | (0.0469) |
| CAR | | | | 0.0042 | -0.0086 | 0.0244*** |
| | | | | (0.0056) | (0.0075) | (0.0078) |
| NPL | | | | -0.2080*** | -0.1724*** | -0.2866*** |
| | | | | (0.0190) | (0.0235) | (0.0325) |
| cons | 0.6977*** | 0.7873*** | 0.6289*** | 0.9880*** | 1.1807*** | 0.7421*** |
| | (0.0424) | (0.0569) | (0.0627) | (0.0808) | (0.1038) | (0.1245) |
| Obs | 207 | 123 | 84 | 207 | 123 | 84 |

*This table shows the results of the impact of green credit efficiency on profitability. Our sample period is 2008–2019, and "TGE", "NGE" and "UGE" are the core explanatory variables, and the positive its value is, the higher green credit efficiency the more profitability will be. Notably, TGE presents the green credit efficiency of whole Chinese banks, NGE presents the green credit efficiency of state-owned commercial banks and joint-stock commercial banks, and UGE presents the green credit efficiency of urban (rural) commercial banks. The dependent variable from column (1) to column (6) is the bank's profitability, ROA. Columns 4–6 report the results of the impact of green credit efficiency on profitability after adding control variables, CAR and NPL. At last, significance levels are represented by "***" (1%), "**" (5%) and "*" (10%).*

efficiency of C is 1 from 2009 to 2012, showing that C reached optimal efficiency. According to **Table 6**, A invested a large amount of green credit capital. However, that does not point towards the presence of high efficiency. Commercial banks cannot evaluate the implementation of green credit by relying on the scale alone. They should pay more attention to green credit efficiency and avoid "greenwashing." The standard deviations of three types of commercial banks are all lower than 0.4, which indicates there is intraclass agglomeration in green credit efficiency.

### 5.1.2 Results of VRS

Assuming that the scale is variable, green credit efficiency reflects the banks' ability to reduce carbon emissions. **Table 7** summarizes the descriptive statistical results of green credit efficiency from 2009 to 2019 in the case of a variable scale.

In **Table 7**, compared with **Table 6**, the mean, maximum, and minimum of three types of commercial banks have increased every year, which shows that all banks have the ability to accurately identify green projects and apply green credit capital for the reduction of carbon emissions. However, the mean of the whole sample is not equal to 1. This indicates Chinese commercial banks need to further improve green credit efficiency. Commercial banks that improved green credit later did not have enough experience in assessing the borrowers' environmental performance and risks. They are also lack of the abilities to use their green credit capital, resulting in low green credit efficiency. With the sample size expanding, the new entrants lower the average efficiency. The standard deviation of three types of commercial banks is small every year, which is all lower than 0.3. The only exception to this is that A reached 0.97 in 2017. Therefore, the interclass difference is small in green credit efficiency.

## 5.2 Empirical Results on Influencing Factors of Green Credit Efficiency

According to **Eq. 4**, **Table 8** presents the empirical results of the influencing factors of green credit efficiency in Chinese commercial banks.

Columns 1–3 of **Table 8** shows that the coefficients of ROA are significantly positive at the 1% level. This implies that the profitability of Chinese commercial banks has a significant positive effect on green credit efficiency. The improvement of profitability improves commercial banks' operating capacity. Commercial banks with higher profitability have sufficient capitals and the capacities to establish a more complete green credit review mechanisms, which makes it easier for them to invest limited green credit capital in the area of high carbon intensity reduction. The increasing of ROA means the increases of income earned by commercial banks per unit of assets. Higher capital operation efficiency of commercial banks will promote the improvement of green credit capital efficiency.

In Columns 1 and 2, the loan-deposit ratio is significantly negative at the level of at least 10%. This shows that for state-owned banks and joint stock banks, the increase of the loan-deposit ratio inhibits the improvement of green credit efficiency. The higher the current LTD, the commercial banks will invest less in new funds in green areas. As a result, the carbon reduction will be less effective. The LTD will have a negative impact on green credit efficiency. We found that the coefficients of CAR are significantly positive at the level of at least 10%. For state-owned banks and joint stock banks, improving CAR has a significantly positive effect on green credit efficiency.

Commercial banks with high CAR will pay more attention to safety in daily operations and choose green projects more carefully to prevent "greenwashing", thus improving green credit quality and efficiency. The coefficient of LnAsset is significantly negative at the 5% level, which shows that total assets have significantly negative effects on the green credit efficiency of commercial banks. Commercial banks with larger total assets cannot quickly observe the transformation of credit capital, resulting in lower green credit efficiency. Compared to Column 1, the results in Columns 2 and 3 show that the total asset within the group has no statistical impacts on green credit efficiency, which may be caused by the fact that there is no significant difference in the total asset of the sample groups.

**Table 9** reports the empirical results. Columns 1 to 3 showed that the coefficient of green credit efficiency is significantly positive at the 1% level. This shows that for the three types of commercial banks in this study, improving green credit efficiency is conducive to improve the profitability of commercial banks. Combined with **Table 9**, we found that green credit efficiency and banks' profitability has positively relationship with each other. The positive externality of green capital can help banks effectively to avoid environmental risks and improve profitability. As green development is addressed in Chinese national policies, banks with higher profitability could actively develop the green business, which will improve green credit efficiency. Columns 4–6 show that the above conclusions still hold unchanged after adding control variables.

The results of **Tables 8**, **9** show that after adding the control variables, there is a mutually reinforcing relationship between the efficiency and profitability of commercial banks' green credit funds. The improvement of the efficiency in green credit funds by commercial banks will improve the return on assets, and the improvement of the return on assets will largely increase the green credit funds of commercial banks. However, as financial intermediaries, the capital efficiency of the commercial bank is not only related to their own inputs and outputs but also closely related to the borrowers of the funds. The production and operation behaviors of the enterprises will have direct impact on the greenhouse gas emissions, such as carbon dioxide, and generating environmental costs, which will further affect the level of risk faced by enterprises. This will eventually be reflected in the repayment ability of the enterprise. The conclusion only shows that the limited investments of green credit funds by commercial banks will lead to increase the current income. Specifically, the efficiency of the green credit funds of commercial banks can improve the profit level but the efficiency of green credit funds needs to be further measured broadly.

## 6 CONCLUSION

This study constructed an evaluation system of green credit efficiency in Chinese commercial banks and comprehensively analyzed the green credit efficiency. Moreover, we analyzed the factors that affected green credit efficiency and the approaches of the green credit efficiency of Chinese commercial banks can be improved.

The results are as follows: First, the Chinese commercial banks present low level of efficiencies in green credits investments. State-owned commercial banks invested a large amount of green credit capital, but the green credit efficiency is the lowest. Blindly expanding the amount of green credit capital is incapable of improving green credit efficiency. Moreover, if the scale is flexbility, the three types of the commcerical banks will improve in the green credit's efficiency. It all depends on whether the commercial banks can refine their abilities to accurately identify green projects and truly implement green credit capital. Second, there are many factors affecting China's green credit efficiency. There is a significant mutual positive relationship between green credit efficiency and profitability in Chinese commercial banks. For state-owned banks and joint-stock banks, the CAR has a significantly positive effect on green credit efficiency, while the loan-deposit ratio has a negative effect on efficiency. The total assets has a significantly negative effect on the green credit efficiency in Chinese commercial banks. The limitation of the research is the Undesirable-SBM-DEA model we used involves a static analysis and cannot analyze the changes in the efficiency of the bank itself. This question would entail an interesting and relevant endeavor that we will leave for future research.

## DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: Wind database.

## AUTHOR CONTRIBUTIONS

XD: Conceptualization, Data Analysis, Writing—Original draft preparation, Methodology. HH: Data Collection, Data Analysis. MC: Software, Writing—Original draft preparation. XR: Conceptualization, Supervision, Writing—Editing and Writing—Reviewing. LW: Writing—Editing.

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