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An Empirical Study on the Impact of Green Credit on Financial Performance of China's Listed Banks

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Abstract

The concept of green environmental protection and sustainability is deeply rooted in China. Green credit has become an important social issue in recent years. Most Chinese financial institutions are also actively participating and investing in this field, especially banks. In order to explore the correlation between banks' participation in green credit business and banks' financial performance, this paper collects the green credit balance, green credit ratio, return on total assets, non-performing loan ratio and other data of 16 major listed commercial banks in China from 2011 to 2019. At the same time, econometric modelling is built using the system GMM regression analysis method. This focuses on the impact of commercial banks' green credit business on their profitability. The final research results certify that banks' increasing investment in green credit has a positive impact on promoting profitability, both showed a positive correlation. Therefore, this paper suggests that banks should focus on the development of green credit business, which is beneficial to both the financial performance of banks and the construction of an environmentally sustainable society.

JEL classification numbers: P34.
Keywords: Green credit, Green credit, Bank financial performance.

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1. Introduction

1.1 Background of the study

China's famous business newspaper (The Financial Times), launched the social survey polling called "Hot Topics of the Two Sessions". The survey was published on its website, public app and official microblog, which includes traditional and new media channels, from the end of February to the beginning of March 2022. The aim is to select the most concerned issues among netizens. Nearly 130,000 netizens participated in the online voting through various channels during the survey period. The final results of the survey showed that the "green credit" option accounted for 15.66%, which was the fifth highest in the entire voting list. This indicates the relatively high degree of concern about 'green credit' among individuals.

Green credit refers to the financial sector, such as banks. This means that they will give priority to supporting measures for investment in environmental projects, such as clean energy, green buildings, energy conservation and emission reduction (Hao et al., 2022). Specifically, the financial sector will combine green credit, green bonds, green insurance, green funds and other financial products and services in different fields. Therefore, the combination can promote preferential support in the areas of credit policies, objects and methods development. The requirements of green credit is that the financial sector is responsible to take the basic principle of harmonious with nature (Sun et al. 2019). Aims to build a green credit system with economic and environmental development together through the implementation concepts between promoting green innovation, sustainable development, industrial transformation, supply-side structural reform and other requirements.

At present, the financial institutions that are most concerned about green credit are the banks, which is reflected in the various credit businesses related to the environmental protection industry launched by the banking industry, collectively known as "green credit business" (Bao and He, 2022). China has been concerned about the development of green credit business since 2007, when the three departments of the China Banking Regulatory Commission (CBRC), the People's Bank of China (PBOC) and the State Environmental Protection Administration (SEPA) jointly proposed the Opinions on the Implementation of Environmental Protection Policies and Regulations to Prevent Credit Risks. Since then, the CBRC has issued the Green Credit Guidelines, which require financial institutions, especially banks, to make more efforts in green credit operations.

China issued the "Opinions of the State Council of the Central Committee of the Communist Party of China on the Complete and Accurate Implementation of the New Development Concept and the Good Work of Carbon Peak and Carbon Neutral", which mainly elaborated on the Chinese government's basic stance and key policies on carbon peak and carbon neutral on 22 September 2021 (Hao et al., 2022). It also indicated that supporting green and low-carbon development would become the focus of the financial sector in China in this decade. In 2021, the People's Bank of China issued the "Green Financial Evaluation Programme for Banking Financial Institutions" and the improvement of the incentive and restraint

mechanism of the central bank have further strengthened the initiative and enthusiasm of financial institutions in the aspects of green financial services development and financial sector expansion.

The development of China's green credit business gained momentum in 2021. The green credit of China's banking institutions reached RMB15.9 trillion, an increase of RMB3.86 trillion in the whole year. Meanwhile, it took the top position in the world with a growth rate of 33%. And the non-performing asset rate of green credit in China is much lower than the overall non-performing level of various loans in the same period, and the overall quality of green credit assets shows good characteristics.

1.2 Research Methodology and Research Ideas

This thesis takes green credit, China's listed commercial banks, as the main object of study. Over the decade, the government departments have witnessed that a significant increase in the impact of the development of green credit and the publicity attention. As the successful achievement in green credit can win the strong support from the government. In addition, green credit differs significantly from traditional finance in terms of credit assets. Green credit is an innovative business for banks, and the banking industry in China is also enthusiastic about this business. Firstly, in the theoretical analysis chapter, this paper first explains the green credit business and the financial performance of banks, and then further analyses how green credit affects the profitability of banks in both positive and negative ways. Secondly, in the research design chapter, this paper constructs an econometric model by collecting data related to green credit and financial performance of commercial banks, selecting the variables in the econometric model and adopting the system GMM estimation method to regress in three segments. Then, in the empirical analysis chapter, the paper regresses the designed econometric model, analyses the results obtained and performs robustness tests on the model. Finally, in the conclusion and recommendations section, the paper draws conclusions and makes recommendations based on the theoretical and empirical analysis.

1.3 Review of the literature

Gao and Guo. (2022) used the panel data of 62 commercial banks in China from 2013 to 2020 as the basis of their study, and used the difference-in-difference (DID) model method to study the impact of green credit on the financial performance of commercial banks, and the results of the study indicated that commercial banks could improve their financial performance by increasing their investment in green credit. Jiang et al. (2022) used China's 2012 Green Credit Guidelines as a quasi-natural experiment to identify the causal effect of green credit policy (GCP) on corporate sustainability performance (ESP). ESP integrates the performance of highly polluting enterprises in terms of financial and environmental social responsibility, and the propensity score matching combined with difference-in-difference (PSM-DID) analysis method provided evidence that GCP has a

significant improvement effect on ESP, especially for small and privately owned highly polluting enterprises. In addition, more environmentally friendly innovations result from GCP. Yang and Zhang. (2022) stated the debt financing relationship between green credit and the heavily polluting enterprises performance based on Chinese A-share listed enterprises from 2004 to 2020 through PSD-DID method. They found that the implementation of the GCP has been successful in significantly reducing long-term financing for highly polluting companies, however, it caused the pollution expansion for short-term. Li et al. (2022) used the relevant cross-sectional panel data of China's 30 provinces from 1995 to 2017 as the analysis, and adopted the Augmented Autoregressive Distributive Lags (ARDL) method to co-integrate the influences between green investment, green credit, carbon emissions and business performance. The study suggests that the implementation of green investment is helpful in reducing carbon emission and promoting high business sustainability. The empirical results show that the improvement of green credit has a positive and significant catalytic effect association with business financial performance and socio-economic. Wang and Dong. (2019) construct a random effects variable intercept regression model based on relevant panel data of 12 commercial banks in China from 2010 to 2017, and the results of the empirical analysis show that the development of green credit business has a negative impact on the financial performance of large state-owned banks in China, while the impact on the operating performance of small and medium-sized joint-stock commercial banks in China is not significant.

A comprehensive analysis comparing the existing research shows that scholars have not addressed a concern on whether the impact of green credit on the financial performance of commercial banks is positive or negative. Therefore, the various conclusions are drawn due to the specific empirical analysis methods used by different scholars.

The remainder of the paper is organized as follows. In section 2, the mechanism of the impact of green credit on the profitability of commercial banks is analysed. In section 3 collects and collates data and constructs an econometric model. In section 4, the paper made the empirical study. In section 5, the paper made the Conclusions and recommendations.

2. Theoretical Analysis

2.1 A description of green credit operations and financial performance

Green financial services include green credit, green bonds, green funds, etc. This paper decides to focus on green credit as the focus of the empirical research, based on the scale of each of these services and the availability of relevant data. This is followed by a description of financial performance. Commercial banks are generally guided in their business activities by the so-called "three principles", i.e. "security, liquidity and profitability" of commercial banks. Profitability is central to the business activities of commercial banks because it is a requirement for commercial banks to maximise their profitability, in other words, to maximise their

business results at minimum cost. Therefore, with reference to the existing literature and the availability of data, this paper decides to focus on the profitability of listed commercial banks in China as the focus of the empirical study of their financial performance, that is, to quantify the financial performance of commercial banks into the relevant financial indicators that can indicate the profitability of the banks. In the following, this paper will explore, from a theoretical perspective, the impact of green credit on bank profitability and the mechanism of action that causes the impact.

2.2 Impact of green credit on the profitability of commercial banks

A large number or prior studies have states that the upgrading development of green credit business may affect the profitability of banks in several aspects below.

2.2.1 Expanding new business models

The homogeneity of commercial banks' operating models in China is becoming serious, leading to intense competition among banks in traditional businesses. This means that the green credit business still has huge potential development and cultivation space. In this decade, the Chinese government has been increasingly concerned about environmental protection, which has occupied an important position in China's development. The "two high and one surplus" traditional enterprises experienced a gradual reduction in the amount of loans from banks, which are all resource-based industries with high pollution and energy consumption, and industries with excess capacity. The banks have to face the general environment of a depressed property market. It is imperative for market-oriented commercial banks to exploit and build up potentially profitable areas. Qi et al. (2022) conclude that differentiation is one of the most important competitive strategies. By entering the green credit business and launching the green and environmental protection enterprise lending business, commercial banks can seize the first opportunity to develop in this field, occupy a favourable position, obtain a first-mover advantage, further obtain more high-quality green credit projects, form a differentiated competitive advantage, improve the bank's competitiveness, and ultimately increase the bank's profitability and revenue level.

2.2.2 Improving asset quality

Commercial banks can generally obtain high returns in the short term by granting loans to "two high and one surplus" traditional companies. As the concept of environmental protection is gradually gaining popularity, the government is paying more attention to environmental assessment, supervision and enforcement. The "two high and one surplus" companies may be substandard due to their production flow. Because the surrounding environment is suffered polluted which caused by the companies. Then they will fail to meet the relevant policies and regulations assessment, which may lead them forced to pay certain fines. In this regard the policy may has additional pressure on their operations. Even then these companies

may be ordered to cease operation and rectification. These possibilities are becoming reality as the concept of green development takes up mainstream. If commercial banks grant loans to these companies, the default rate of these will increase, and the possibility of their loans being converted into non-performing assets will rise as well, which will undoubtedly have a negative impact on the banks' business conditions.

In addition, banks may be held jointly and severally liable by the relevant regulatory authorities for granting loans and providing financial services to these polluting companies, which may place a burden on the financial performance of the bank. It even affects the image of the penalised bank in the public mind and further extends the losses of banks. In contrast to the ‘two high and one leftover', green credit business and related policies are required to be monitored by the public, and banks and the government are required to disclose information about the environmental and social impacts of their business, and to make the detection of the environmental impact of enterprises, their pollution control and their ecological protection an important reference rule for banks in granting loans. This will undoubtedly raise the threshold for enterprises to apply for loans. The above-mentioned green credit policy formulation and operations have raised the level of commercial banks' ability to control operational risks. In addition, it will also help to solve the problem of loans issued that have long been difficult for banks to deal with in the past being transformed into non-performing assets such as doubtful and dead loans, reducing the risks faced by banks and ultimately effectively improving the financial performance of commercial banks. Finally, commercial banks' support for green enterprises helps to achieve sustainable development, creating a development environment in which humans and nature live in harmony and sustainable industries, which can also bring positive externalities to banks.

2.2.3 Developing new types of intermediary business

The development of green credit business by commercial banks will not only bring new credit business to the banks directly, but will also give rise to some new intermediate businesses, such as commercial banks can provide some green financial advisory services on green credit, act as financial advisors related to green credit, provide financial leasing services related to green credit and so on. As an emerging business area, with the rapid development of green credit, its intermediate business will also become gradually rich, and commercial banks can also gain revenue from these intermediate businesses. Not only that, the activities of these intermediate businesses will also enhance the diversification of banks' income methods, and according to scholars Phan et al. (2022) on the impact of commercial banks' income structure on their profitability, the diversification of commercial banks' income can significantly improve their financial performance, especially the level of revenue.

2.2.4 Improving the social evaluation of commercial banks

The widespread and increased efforts of commercial banks to develop green credit business can be seen as a manifestation of commercial banks' proactive social responsibility, and this will bring benefits to banks in several ways. Firstly, the initiative of commercial banks to take up social responsibility helps them to establish good cooperation with the government and other social organisations, and according to the results of a study by Li et al. (2022) on the relationship between corporate social responsibility(CSR) and financial performance, the increased awareness of social responsibility and the assumption of social responsibility by enterprises has a positive impact on their financial performance (Zhou et al., 2021). Commercial banks' green credit business strongly supports the country's green and sustainable development strategy, and therefore may enable them to obtain various subsidies as well as preferential measures granted by the government and the central bank, for example, the People's Bank of China has extended the scope of quantitative evaluation of financial institutions to green credit and green bonds in the green credit Evaluation Programme for Banking Financial Institutions released in 2021, in addition, the programme also reserves space in advance for other businesses in green credit such as green insurance, green wealth management, green funds and green trusts. Besides, the People's Bank of China has also developed policies and products to support the reduction of carbon emissions and the refinancing of loans specifically for the efficient and clean use of coal. Secondly, green credit is a way for banks to gain the support of customers who value the environment (Finger et al., 2018). Meanwhile, the concept of green and sustainable living is gaining popularity, and commercial banks taking the initiative to assume social responsibility for environmental protection will gain the favour of customers who are more environmentally conscious and establish an advantageous position for the bank to gain customers. Finally, in addition to customers, commercial banks can also gain the favour of green investors in the capital market by conducting green credit business. The act of engaging in green lending can demonstrate to the capital markets that banks value green-related financial services. In addition, given the important role of green credit business by commercial banks, the expansion of financial resources will demonstrate that they have strong green financial capabilities, to further enhance them attract investment from green investors in the capital markets.

2.2.5 Negative effects

Commercial banks engaged in green credit projects may also experience negative effects on their profitability. This paper examines the negative effects of green credit on commercial banks and the mechanisms of these effects from different theoretical perspectives.

The development of green credit may increase the operating costs of commercial banks, which can be analysed from two aspects: direct costs and indirect costs. In terms of direct costs, as green credit is an emerging field, there is still a certain talent

gap in China's banking industry and financial institutions in this field, and as China's green credit business has been launched relatively late, there is still room for improvement in the degree of specialisation. This will result in certain trial and error costs, which will impose an additional burden on the banks' operations. In addition, as the threshold for green credit is high for enterprises applying for loans, banks need to test and evaluate the environmental standards and pollution control effects of the applicant enterprises, which will cost the banks extra manpower, material and time costs. In addition, green enterprises are mostly projects with long production cycles and high marginal costs in the production process. In order to give green enterprises preferential treatment in order to support their better development, commercial banks may also grant loans at lower interest rates to enterprises that meet green standards. In addition to direct costs, there are indirect costs associated with the development of green credit. As banks have limited funds and resources, increased investment in green credit by commercial banks will inevitably squeeze out the resources invested in traditional credit operations. Despite the rapid development of green credit over the past period, traditional financial services still account for the majority of the total loans granted by commercial banks and are their core business, and the reduction of resources invested in their core business may weaken their core competitiveness. In addition, the reduction of commercial banks' credit to the 'two high and one leftover' enterprises will also add some additional costs. The reduction in bank lending to these enterprises will have a negative impact on the short-term financial performance of banks, which generally earn higher returns in the short term. The reduction of loans to these enterprises will increase the chances of their production and operation difficulties, which will increase the risk of default of the bank's initial investment in these enterprises and make it easier to turn them into non-performing assets, which is detrimental to the bank's risk management. Finally, some of the customers of the 'two high and one leftover' enterprises reduced by commercial banks may turn to rival banks in the same industry, making the banks face increased competition in the market in the short term, which will have a negative impact on the profitability of banks.

In summary, the green credit business can have both positive and negative impacts on the profitability of commercial banks in two different directions, and the final effect of green credit on the financial performance of banks needs to take into account the neutralisation of the two forces of different nature, which requires the use of more precise data for analysis. In the following, a statistical model will be constructed to carry out the empirical analysis.

3. Study Design

3.1 Collecting and collating data

China's green credit policy was first proposed on 12 July 2007, and the disclosure of green credit-related data, such as green credit balance and green credit ratio, by commercial banks in China generally started in 2007. The disclosure of green credit data by most of the listed commercial banks in China was not common in the first

few years after 2007, but after 2010, more and more banks published their green credit business development and the data was gradually improved (Wang, et al., 2020). In this paper, from the perspective of data availability and completeness, we decided to select the development of green credit business of some listed commercial banks in China in the nine years starting from 2011 to 2019. Taking the completeness of the data related to green credit disclosed by listed commercial banks in China as the selection criterion, 16 banks that published complete data on green credit during the period from 2011 to 2019 were selected as the subjects of the empirical study. These listed commercial banks are Ping An Bank (PAB), Bank of Ningbo (BON), Shanghai Pudong Development Bank (SPDB), Hua Xia Bank (HXB), China Minsheng Banking Co. (CMB), Bank of Jangsu (BOJ), Industrial Bank Co. Industrial and Commercial Bank of China (ICBC), China Everbright Bank (CEB), China Construction Bank (CCB), Bank Of China (BOC), and China Citic Bank (CITIC). In this paper, by collecting relevant data disclosed in the financial annual reports and social responsibility reports published on the respective official websites of the above listed commercial banks from 2011 to 2019, we collated and plotted the tables to summarise the balanced panel data with 16 valid observation samples, 9 years and a total of 144 observations.

3.2 Building the econometric model

3.2.1 Selection of explanatory and explained variables

Explained variable: return on total assets. This paper studies the impact of conducting green credit business on the financial performance of listed commercial banks in China, where the financial performance of banks is again mainly related to the indicators of profitability. By referring to the empirical study on the impact of green credit and internal and external policies on the competitiveness of commercial banks done by Lian et al. (2022), this thesis decides to use the return on total assets as an indicator of the profitability of horizontal commercial banks, which is also used as the explanatory variable in this empirical analysis. Return on Total Assets (ROA), abbreviated as ROA, is calculated as the net profit generated by a commercial bank per unit of assets, and its specific formula is as equation (1).

$$ROA = (\text{Net Profit} / \text{Total Assets}) * 100\% \quad (1)$$

Core explanatory variable: green credit balance. The focus of this paper is on the impact of green credit on banks' financial performance in green credit business. Referring to the existing literature on the measurement of commercial banks' investment in green credit, this paper decides to use the green credit balance, which is the sum of loans invested by commercial banks in various energy-saving and environmental protection projects and related service businesses, as a quantitative indicator to reflect the development of commercial banks' green credit business. In addition, considering that the development of green credit business has a certain lag effect on the profitability of commercial banks, this paper decides to use the lagged

period of green credit balance as the core explanatory variable in the empirical study in the model. Green Credit Balance (GCB), abbreviated as GCB, measures the total amount of credit invested by commercial banks in green economic projects.
Control variables: The non-performing loan ratio (NLR), total assets of commercial banks, capital adequacy ratio of commercial banks. One-period lagged return on total assets. From the above analysis, it is clear that there are a number of different paths and ways in which the development of green credit by commercial banks can impact their financial performance, and this paper will introduce control variables to improve the econometric model. First, the quality of assets is an important factor that affects the return on total assets, which is the explanatory variable selected in this paper. Therefore, for the sake of theoretical soundness and completeness, this paper decides to introduce an indicator to quantify the quality of assets in the econometric model. Referring to the study on the impact of green credit on bank operating performance by Wang et al.(2020), this paper selects the non-performing loan ratio as a measure of asset quality and introduces it into the model as a control variable. NPL is calculated as the proportion of non-performing loans to the total loan balance of commercial banks, and is calculated by the equation (2).

NLR= (subordinated loans + doubtful loans + loss loans)/loss loans x 100% (2)

Secondly, the 16 banks selected as the research sample in this paper include both large state-owned banks, such as the four major state-owned banks, and some small and medium-sized local joint-stock commercial banks, and there are certain differences between the different research subjects. Therefore, based on the rigour of the empirical research, this paper decides to introduce the differences in the internal factors of the research subjects as influencing factors in the construction of the econometric model. By analysing the existence of significant and deterministically different financial performance indicators for commercial banks of different sizes, plus drawing reference from the study of Wang and Dong (2019). This paper decides to select the total assets of commercial banks and the capital adequacy ratio of commercial banks as the data indicators for quantifying the internal factors of commercial banks. Finally, in order to make the mathematical model more rigorous and complete, this paper decides to select the one-period lag of the return on total assets as the explanatory variable to be introduced into the econometric model used in the study, considering that the financial performance of commercial banks in previous periods will have certain influence on the financial performance in the current period. Total Assets (TA) of a commercial bank, abbreviated as TA, quantifies all the assets owned or controlled by the commercial bank. The one-period lagged return on total assets, abbreviated as $ROA_{i,t-1}$, Capital Adequacy Ratio (CAR) of commercial banks, is calculated as the ratio of a bank's total capital to its risk-weighted assets, calculated as equation (3).

CAR= (Capital/ Risk Assets)*100% (3)

The core explanatory variable used for robustness testing: the green credit ratio. In addition to using green credit balance as a measure of green credit size in green credit-related studies, some scholars also use green credit ratio as an indicator to quantify the intensity of commercial banks' investment in green credit business, such as referring to the practice of using green credit ratio as the core explanatory variable in the study on the impact of green credit on the heterogeneity of banks' financial performance conducted by Lian et al. (2022). Unlike the aggregate indicator of green credit balance, the green credit ratio is a relative indicator. On balance, this paper decides to introduce the green credit ratio as an alternative variable to the original core explanatory variable of green credit balance in the robustness analysis of the econometric model, in order to make the whole process of empirical analysis more complete and rigorous. The Green Credit Ratio (GCR) is calculated as the proportion of green credit balances (GCB) to total loans (TL) issued by banks, and is calculated as equation (4).

$$\text{GCR= GCB/TL*100\%} \tag{4}$$

3.2.2 Setting up the model

Through the analysis and selection of the explanatory and explanatory variables above, the final empirical analysis model constructed in this paper is shown in equation 5.

$$\text{ROA}_{i,t} = \beta_0 + \beta_1 ROA_{i,t-1} + \beta_2 \ln GCB_{i,t-1} + \beta_3 NL_{i,t} + \beta_4 TA_{i,t} + \beta_5 CA_{i,t} + \varepsilon_i + u_{i,t} \tag{5}$$

Considering that the green credit balance is an aggregate indicator while the return on total assets is a relative indicator, in order to eliminate the undesirable consequences of possible heteroskedasticity in the regression analysis (Zhang et al., 2022), this paper decided to take the natural logarithm of the data for the green credit balance variable to eliminate heteroskedasticity.

In equation 5, different values of the subscript i for each variable indicate different commercial banks and different values of the subscript t for each variable indicate different years of the commercial bank. $\text{ROA}_{i,t}$ indicates the return on total assets of commercial banks, $ROA_{i,t-1}$ indicates the one-period lagged return on total assets of commercial banks, $\ln GCB_{i,t-1}$ indicates the green credit balance of commercial banks after taking the natural logarithm, indicates the non-performing loan ratio of commercial banks, indicates the total assets of commercial banks, indicates the capital adequacy of commercial banks, indicates the unobservable fixed effects in equation 5, indicates the random disturbance term in equation 5. $NL_{i,t}$ $TA_{i,t}$ denotes total assets of commercial banks, $CA_{i,t}$ denotes capital adequacy ratio of commercial banks, ε_i denotes unobservable fixed effects in equation 5 and $u_{i,t}$ denotes random disturbance terms in equation 5.

3.3 Choice of measurement method

Firstly, based on the general econometric model constructed in this paper and the type and characteristics of the data selected, it can be determined that the data used in this study is panel data. Based on the analysis and selection of the explanatory and explanatory variables chosen in the model above, it can be seen that this paper introduces a one-period lag of the explanatory variable total return on assets in the explanatory variables of the econometric model, and therefore the econometric model that should be built in this paper should be that of a dynamic panel. In the regression analysis, it is not possible to use methods such as simple difference and within-group deviation as in a static panel in order to eliminate fixed effects, and ultimately it is not possible to obtain consistent estimates of the coefficients before the explanatory variables, which is also referred to as dynamic panel bias (Nguyen and Liu, 2019). Secondly, from the perspective of the research subjects selected for this paper, there are significant differences in the nature and size of the different commercial banks that are the subject of the study, for example, there are large state-owned banks such as the Big Four, but also some local small and medium-sized joint-stock commercial banks, so there are considerable individual differences in the research sample selected for this paper, which means that when considering the measurement method, we must take into account the possible In other words, when considering the measurement method, this paper must take into account the possible existence of individual fixed effects. By fixed effects, we mean that even though the intercept term of the model may differ between the different samples (in this paper, the 16 commercial banks selected), the intercept does not change over time across the different samples.

In addition, this paper needs to discuss the problem of endogeneity variables that may exist in the setting of the model. The problem of endogeneity refers to the correlation between one or more explanatory variables in the mathematical model and the random disturbance term of the model (Raza et al, 2019). Although this paper will study the impact of the development of green credit business on the financial performance of commercial banks, the theoretical analysis shows that the financial performance of commercial banks may also counteract the development of green credit business of banks, which is also known as the phenomenon of mutual causality, and this will lead to This can lead to endogeneity problems in the model. Therefore, an endogeneity test is needed to check whether the model has endogenous variables.

This paper uses the Hausman test for endogeneity testing of the constructed models, for equation 5 constructed above and for the robustness tests to be constructed below equation (6), i.e. the core explanatory variable green credit balance in equation 5 is replaced with a robustness test model (equation 6) for the green credit ratio and a Hausman test is conducted. The results of the Hausman test are presented in Table 1.

Table 1: Hausmann test results

Name of measurement model	Hausmann test value	P-value
Equation 5	89.45	0.0000
Equation 6	74.47	0.0000

The original hypothesis can be seen by looking at the results of the Hausman test in Table 1. That is, the model does not have endogenous variables and is rejected at the 1% level, then it can be assumed that there are endogenous variables in either equation 5 or equation 6.

In summary, in order to effectively control as well as overcome the individual fixed effects and endogeneity problems of the model, this paper decided to select the system generalised moment estimation model, also known as the system GMM model, as the econometric analysis method used for the study. The method uses an instrumental variable (tentatively set as Z_{it}), uncorrelated with the random disturbance term $u_{i,t}$, i.e. $E\left(Z_{i,t}, u_{i,t}\right) = 0$ of the generalised moment condition to estimate generalised moments for the parameters before the explanatory variables. In addition, the panel data used in this study is a short panel of 16 commercial banks and 9 years of large N and small T data, which is consistent with the applicable prerequisites for dynamic panel generalised moment estimation. The systematic GMM model uses the difference values of the lagged variables of the explanatory variables as instrumental variables for the endogenous explanatory variables in the level equation and the level values of the lagged explanatory variables as instrumental variables for the endogenous explanatory variables in the difference equation, which helps to control for endogeneity problems and individual fixed effects in the econometric model.

4. Estimation of the econometric model and analysis of the regression results

With the mathematical model set up above, the selection of variables in the model and the choice of measures, the following paper will formally begin the regression analysis. The econometric software used to estimate the model in this paper is STATA.

4.1 Model estimation

4.1.1 Descriptive statistics and analysis of statistical results

Firstly, the sample collected by the author was firstly defined for the panel data, as well as the cross-sectional and temporal variables. Secondly, descriptive statistics were conducted and the results of the statistics are shown in Table 2.

Table 2: Descriptive statistics for panel data

Variable name	Variable abbreviations	Average	Standard deviation	Minimum value	Maximum value
Return on total assets	ROA	1.057356	0.195199	0.7134	1.4748
Green Credit Balance	GCB	2344.152	3234.665	5.34	12377.58
Non-Performing Loan Ratio	NL	1.265694	0.406027	0.38	2.39
Total assets	TA	74618.51	73644.47	2604.98	301094.4
Capital Adequacy Ratio	CA	12.86278	1.573643	9.88	17.52
Green Credit Ratio	GCR	4.808348	5.099686	0.09013369	29.37424

As can be seen from Table 2 above, the standard deviation of the return on total assets of the 16 different commercial banks selected for this paper is about 0.20%, and the standard deviation of total assets is about 73,644.5, which indicates that there are large differences in the return on total assets and the scale of the banks among the different commercial banks as the subject of the study, which is also consistent with the theoretical prediction before the analysis. The green credit balance of the 16 commercial banks. The average value of green credit balance of the 16 commercial banks is about RMB234.415 billion and the average value of green credit ratio is about 4.81%, thus it can be seen that the scale of green credit business carried out by commercial banks in China is not large enough and there is still room for improvement. In addition, the standard deviation of green credit balance is about 3234.67, and the standard deviation of green credit ratio is about 5.10, which indicates that there is also a certain difference in the scale of green credit business carried out by these 16 listed commercial banks in China. Moreover, the maximum non-performing loan ratio of the 16 commercial banks in the sample over the nine years from 2011 to 2019 is 2.39%, which is less than 5%, meaning that the likelihood of serious credit risk for the 16 banks during the nine years is low, the asset quality of each bank is relatively healthy, and the banks' control of their business risks is within a reasonable range. The minimum capital adequacy ratio of the 16 banks in the sample over the 9-year period was 9.88%. According to the Basel III Accord issued on 21 September 2010, the capital adequacy ratio of commercial banks should not be less than 4%. In summary, it can be seen that the banks selected for this study have performed well in terms of resisting possible credit risks.

4.1.2 Systematic GMM model estimation and analysis of regression results

After entering a series of program commands for the regression of the OS-specific GMM model in the econometric software STATA, the econometric software regresses the previously constructed model as equation 5.

A systematic GMM regression analysis was carried out and the regression results were summarised and collated and the significant information is shown in Table 3.

Table 3: Equation 5 system GMM model estimation results

Variable name	Parameters to be estimated	Parameter estimates	P-value
$ROA_{i,t-1}$	β_1	0. 743374	0. 000
$lnGCB_{i,t-1}$	β_2	0. 0526519	0.001
NL_{it}	β_3	-0.2205349	0.000
TA_{it}	β_4	-8.11e-07	0. 000
CA_{it}	β_5	0. 0172943	0. 023

Systematic GMM models require over-identification tests and autocorrelation tests in the process of use.

By autocorrelation test, it is meant that one of the applicable conditions for a systematic GMM model is that the random disturbance terms of the model be free from serial correlation. The test for autocorrelation will use the AR(2) test as well as the AR(3) test, which tests whether there is second-order autocorrelation or third-order autocorrelation in the differences of the random disturbance terms, and the results of the AR(2) as well as the AR(3) tests are shown in Table 4.

Table 4: AR(2) test for equation 5 and AR(3) results

Name of measurement model	AR(2) test p-value	AR(3) test p-value
Equation 5	0.088	0.630

As can be seen from Table 4 above, the p-value of the AR(2) test is greater than 5%, which indicates that equation 5 is insignificant at the 5% significance level, i.e. the original hypothesis of the AR(2) test "no autocorrelation of the random disturbance term" is accepted, while the p-value of the AR(3) test is greater than 0.10, which indicates that equation 5 is insignificant at the 10% significance level, i.e. the original hypothesis of the AR(3) test “no autocorrelation of the random disturbance term” is not rejected. This means that equation 5 is not significant at the 10% significance level, i.e. the original hypothesis of the AR(3) test "no autocorrelation of the random disturbance term" is not rejected. In summary, the model is generally consistent with the applicable assumptions of the systematic GMM model and ensures the consistency of the estimation of the parameters of the systematic GMM model.

The over-identification test refers to the use of a systematic GMM model to perform an over-identification test on the appropriateness of the instrumental variables used in the model, i.e. whether the setting of the instrumental variables in the econometric model is reasonable. In this paper, the Sargan test and the Hansen J test will be used for the over-identification test, and the results of the test for equation 5 are shown in Table 5.

Table 5: Sargan test for equation 5 and Hansen J test results

Name of measurement model	Sargan test p-value	Hansen J test p-value
Equation 5	0.212	0.933

As can be seen from Table 5, the p-value of the Sargan test is greater than 0.10, indicating that equation 5 is not significant at the 10% significance level, i.e. the original hypothesis of the Sargan test "instrumental variables are reasonably used and there is no over-identification" is accepted, while the p-value of the Hansen J test is also greater than 0.10(Kiviet and Kripfganz, 2021) This indicates that equation 5 is not significant at the 10% level of significance, i.e. the original hypothesis of the Hansen J test is accepted as "the instrumental variables are used reasonably and there is no over-identification". In summary, it can be judged that the instrumental variables chosen for equation 5 are valid.

In the following, the results of the regression of the system GMM model in Table 3 above will be analysed. From Table 3 it can be seen that the estimated results of the coefficient before the variable $\ln GCB_{i,t-1}$ has a p-value of less than 0.01, indicating that the coefficient is significant at the 1% level of significance. β_2 The estimated value of the coefficient is approximately 0.0527, which indicates that for every 1% increase in the amount of green credit balances invested by listed commercial banks in China in the previous period, the return on total assets of these commercial banks increases by 0.0527%, with other control variables held constant. At the same time, the value of this coefficient is greater than zero, indicating that commercial banks' development of green credit business still has a positive impact on their profitability level, which is the core issue of this paper's research. The estimated p-value of the coefficient of the variable $NL_{i,t}$ before β_3 is less than 0.01, which indicates that this coefficient shows significant at the 1% level of significance. The estimated value of this parameter is approximately -0.221, which indicates that for every 1% increase in the NPL ratio of a commercial bank, the bank's total return on assets decreases by 0.221%, holding all other explanatory variables constant. The estimated p-value of the parameter β_5 preceding the variable $CA_{i,t}$ is 0.023, which is less than 0.05, indicating that the parameter behaves significantly at the 5% level of significance. β_5 The estimated value of is approximately 0.017, which implies that for every 1% increase in the capital adequacy ratio of a commercial bank, the capital adequacy ratio of the bank will increase by 0.017% under the assumption that the other independent variables remain constant. The regression results for the above two parameters also indicate that an increase in the asset quality of commercial banks has a positive effect on their profitability, and this result is consistent with the theoretical analysis as well as common sense logic, further demonstrating that the model does not contradict economic theory and justifying the model previously constructed. The p-value of the regression results for the coefficient of β_4 before the explanatory variable $TA_{i,t}$ is less than 0.01, which can be explained by the fact

that the coefficient behaves significantly at the 1% significance level criterion. β_4 The estimated value of the coefficient is less than 0. This indicates that as the total assets of commercial banks rise, the return on total assets of banks will fall, reflecting a negative correlation between the scale of operations and profitability of commercial banks. The explanation for this regression result is that the sample selected in this paper includes the four state-owned banks and some other listed commercial banks with large asset size, and as the asset size of banks expands, the marginal return of total assets to commercial banks will diminish. In the regression model, there is a negative correlation between the two, i.e. the value of β_4 is less than 0.

4.2 Robustness tests

In order to make the econometric model constructed in the previous section more convincing, robustness tests are conducted in the equation 6. By robustness tests I mean to go through the robustness of the constructed econometric model methodology and the explanatory power of the explanatory variables selected by the model. In this paper, we will start with the selection of variables and look for alternative variables to replace the core explanatory variable of green credit balance in equation 5 $\ln GCB_{i,t-1}$. Based on the previous analysis when conducting the selection of the explanatory variables, this paper will use the green credit ratio $GCR_{i,t-1}$ in place of the green credit balance and ultimately construct equation 6 as follows.

$$\mathrm{ROA_{i,t}} = \alpha_0 + \alpha_1 ROA_{i,t-1} + \alpha_2 GCR_{i,t-1} + \alpha_3 NL_{i,t} + \alpha_4 TA_{i,t} + \alpha_5 CA_{i,t} + \varepsilon_i + u_{i,t} \quad (6)$$

A systematic GMM regression analysis was conducted for equation 6 and the regression results are shown in Table 6 below. In addition, the AR(2) test and AR(3) test were performed on equation 6 and the results are shown in Table 7 below. In addition, the Sargan test as well as the Hansen J test were conducted for equation 6 and the results are shown in Table 6.

Table 6: Equation 6 system GMM model estimation results

Variable name	Parameters to be estimated	Parameter estimates	P-value
$ROA_{i,t-1}$	α_1	0.6923059	0.000
$GCR_{i,t-1}$	α_2	0.0000385	0.021
$\mathrm{NL_{it}}$	α_3	-0.1146441	0.034
$\mathrm{TA_{it}}$	α_4	-8.72e-07	0.075
$\mathrm{CA_{it}}$	α_5	0.0368838	0.000

Table 7: AR(2) test for equation 6 and AR(3) results

Name of measurement model	AR(2) test p-value	AR(3) test p-value
Equation 6	0.062	0.319

Table 8: Sargan test for equation 6 and Hansen J test results

Name of measurement model	Sargan test p-value	Hansen J test p-value
Equation 6	0.997	0.980

The results of the above series of manipulations show that the coefficient before the green credit ratio variable in equation 6 α_2 is greater than zero at the 5% significance level, indicating that an increase in the green credit ratio of commercial banks has a positive impact on the return on total assets of banks, confirming the findings in equation 5 above. In addition, the significance of the remaining explanatory variables did not change significantly from positive to negative. α_3 is less than 0 at the 5% significance level and α_4 is less than 0 at the 0.1 significance level, indicating that the regression results for NPL ratio and total assets show a negative relationship between the two and return on total assets. In contrast, α_5 is greater than 0 at the 1% significance level, indicating a positive relationship between capital adequacy ratio and return on total assets. The results of the regression analysis of equation 5 are generally consistent with the above analysis. The results of AR(2) test for equation 6 indicated that equation 6 accepted the original hypothesis of no autocorrelation of the random disturbance term at the 5% significance level, and the results of AR(3) test indicated that equation 6 accepted the original hypothesis of no autocorrelation of the random disturbance term at the 0.1 significance level. The Sargan test for equation 6 indicates that equation 6 accepts the hypothesis that 'the instrumental variables are used reasonably and there is no over-identification' at the 10% level of significance, and the Hansen J test for equation 6 indicates that equation 6 accepts the hypothesis that 'the instrumental variables are used reasonably and there is no over-identification' at the 10% level of significance. The Hansen J test for equation 6 indicates that equation 6 accepts the original hypothesis of 'reasonable use of instrumental variables and no over-identification' at the 10% significance level. The above tests indicate that the use of equation 6 meets the prerequisites and the reasonableness of the instrumental variables used.

In summary, the good performance of the robustness test results indicates that the econometric model constructed in this paper and the selection of the systematic generalised moment estimation method as the measure is relatively robust.

5. Conclusions and recommendations

5.1 Research findings

The empirical study concludes that there is a positive relationship between commercial banks' increasing efforts in green credit business and their profitability.

5.2 Recommendations for green credit

Based on the findings of the study, this paper gives the following suggestions on how to increase the investment of commercial banks in green credit in China, both from the banks and the government.

5.2.1 Recommendations to the Government

According to the People's Bank of China, the China Banking Regulatory Commission (CBRC), the Environmental Protection Bureau and other government departments have issued many policies and measures to stimulate the development of green credit, but most of these measures are some recommendation-based and initiative-based policies and some guidance documents of moral persuasion, and their legal binding force is weak (Aizawa and Yang, 2010). Therefore, there is still some room for the government to promote commercial banks to fulfil their responsibilities and obligations in terms of green sustainability and to encourage them to invest more in green credit. For example, the CBRC should strengthen its supervision of commercial banks' credit activities, introduce binding laws and regulations on green credit, improve the legal system and policy system on green credit, and strictly restrict banks from lending to enterprises that contradict the concept of sustainable development, such as the so-called "two highs and one surplus". The government should also step up efforts to ensure that the green financial system is not compromised (Ye et al., 2022). Second, the Environmental Protection Bureau and other government agencies should step up their efforts to conduct strict environmental assessments and environmental reviews of banks' corporate and enterprise lending operations, set environmental entry thresholds for lending projects, and give more weight to the environmental impact of companies' production practices in credit policies. In addition, the government should improve or introduce more incentives and rewards for banks to engage in green lending. For example, banks should receive certain subsidies, the government should provide guarantees for green and sustainable projects, and the development of green credit should be included in the evaluation programme for commercial banks. All government departments should coordinate and work together to improve the enthusiasm and initiative of commercial banks to conduct green credit business, so that they will invest more in green credit projects.

5.2.2 Recommendations to banks

China is accelerating the construction of a resource-saving and environment-friendly society, vigorously promoting the comprehensive green transformation of China's economic and social development, and green and low-carbon development

has become the general trend. Commercial banks in China should also strengthen their own sense of social responsibility, so as to contribute to the early realization of ecological priority, green and low-carbon high-quality development path in China, and the completion of carbon peaking and carbon neutrality as scheduled. In addition, according to the findings of this paper, there is a positive correlation between commercial banks' increased efforts in green credit and their profitability, and the fact that banks invest more resources in green projects has a positive impact on their operating conditions, business performance and even social evaluation. Therefore, banks should take the initiative to increase their support for green and sustainable projects, provide more credit and financial resources to enterprises in this field, and discourage the granting of credit to obsolete and highly polluting industries.

To enhance the green credit business development, commercial banks can device more innovative and redundant quality green credit-related products and services. This is benefit to attract quality customers who concerns about green credit through differentiated competition in various aspects. In addition, banks should also improve their internal evaluation and audit systems, strengthen the verification of green credit applicants, train and reserve professional talents who are proficient in green credit business, and reduce their own trial and error costs in the emerging field of green credit.

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