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Research on the Impact of Green Bonds on Credit Risk of Urban Commercial Banks

-- Based on the KMV model

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Abstract

Green finance has gradually become an important track for the operation and development of commercial banks after the "double carbon" target is proposed. As an important innovation of green financial instruments in China, green bonds have contributed to China's green development. In order to investigate the impact of green bonds on the credit risk of commercial banks, the article firstly combed through the existing literature on green bonds and commercial banks' credit risk in China, and on this basis, selected 10 urban commercial banks as samples, and conducted empirical analyses by using the KMV model, which showed that green bonds have no clear impact on the credit risk of urban commercial banks. The final findings of the article provide certain policy insights for the high-quality development of green bond market in China.

Keywords

Commercial banks, Green bonds, Credit risk, Kmv model.

1. Introduction

In recent years, the continuous warming of the climate and the frequent occurrence of extreme weather have made mankind understand the consequences of rough economic development, and countries have begun to pay attention to the importance of green development, and China is no exception. 2020, President Xi Jinping proposed at the 75th United Nations General Assembly that China's carbon dioxide emissions will strive to peak in 2030, and to achieve the vision goal of carbon neutrality by 2060. The "dual-carbon" goal has stimulated the development of China's green industry, which in turn has generated huge financing needs, further requiring the financial industry to support the green industry, and therefore, green finance will be an important direction for future development. The development of green financial market promotes the generation of green bonds. Green bonds not only have the basic functions that ordinary bonds should have, but also have the role of the financing specifically for environmental protection and green project development. Green bond market has a huge development space, not only to adapt to the needs of environmental change, but also for commercial banks to open up the blue ocean of future business.

Commercial banks have the advantages of capital deployment, scale effect and risk diversification, and the issuance of green bonds by commercial banks is conducive to improving the effectiveness of capital investment in the green industry. And urban commercial banks and other small and medium-sized banks are an important part of China's commercial banking system, especially for promoting local economic development and growing the scale of local credit plays an important role. At present, the green bonds of commercial banks are in the stage of rapid development, then the risk management of green bonds must be one of the focuses of commercial banks, and there are fewer studies on this at home and abroad, and even fewer of

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urban commercial banks and other small and medium-sized banks as the main research object. Therefore, this paper takes the problems arising from the high-speed development of domestic green bond market as the research background, takes 10 domestic urban commercial banks as the research object, constructs the experimental group and the control group, and applies the KMV model to measure the distance of default and estimate the probability of default of urban commercial banks, in order to test whether the issuance of green bonds has increased the credit risk of urban commercial banks.

2. Literature Review

The article divides the literature review into three areas by combing through past studies: studies on green bonds, studies on credit risk of commercial banks, and studies on the KMV model.

2.1. Study on green bonds

The research on the impact of issuing green bonds on commercial banks is mainly sorted out, and it is found that scholars believe that the issuance of green bonds has a double-edged sword effect on the operation of commercial banks. On the one hand, some scholars hold a positive view that green bonds have a good impact on commercial banks. Li Jing (2017), in view of the current situation of green bond issuance by commercial banks in China, proposes that green bonds can play a role in enhancing the ability of long-term credit investment and active liabilities of banks. Chen Qi and Zhang Guangyu (2017) also believe that the positive significance of the development of green finance in commercial banks lies in the following: it helps enterprises to fulfil their social responsibility, enhances the level of risk management of banks and China's commercial banks are in line with international standards. Chen et al. (2022) point out that for bond issuers, the development of China's green bond market has the inherent advantages that the financing cost of green bonds is lower than that of general bonds, the issuance requirements of green bonds are more lenient, and green bonds can help issuers, such as commercial banks, to obtain reputational gains. On the other hand, some scholars believe that the issuance of green bonds can also have a negative impact on banks. For example, Hu, Jing et al. (2019) argue that in the short term, the cost advantage of issuing green bonds cannot be well demonstrated as the low interest rates due to policy favours may be offset by additional assessment fees. In addition, Ehlers (2016) found that green industry projects due to some non-human factors fail to reach the goals of the contract on time and in quantity, leading to default behaviour of creditors.

2.2. Study on credit risk in commercial banks

I. Causes of credit risk

From the theoretical research, the factors affecting the changes in credit risk of commercial banks are: i) Macroeconomic conditions; Wang Li and Wang Xianshang (2015) found that expected inflation fluctuations reduced by the central bank's expectation management policy increase the risk-taking of commercial banks by estimating the expected inflation fluctuations, which increases the bank's credit risk. Second, information asymmetry theory; since commercial banks cannot know or need high cost to know the real situation of enterprises, this information asymmetry causes enterprises to have incentives to hide their real financial situation, which gives rise to adverse selection and moral hazard problems. Third, internal bank governance problems, i.e., poor bank management and lack of effective risk management strategies, leading to asset and liability maturity mismatches. Some bank managers conceal the bank's true risk profile in order to maintain performance (Wei Gongqi, 2009).

II. Credit risk of green credit

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From the existing studies, the mechanisms by which green credit affects bank credit risk can be divided into two main categories, with one group of studies arguing that green credit reduces bank credit risk and the other arguing that it does not. Scholars holding the first type of opinion believe that carrying out green credit can improve the reputation of banks, which is the fulfilment of the social responsibility of banks as a corporation; and believe that green credit can improve the balance sheet of banks, which in turn improves the bank's efficiency and thus helps to reduce the non-performing loan ratio (Sun Guanglin et al., 2017). In addition, Li Su et al. (2017) found that the credit risk of China's commercial banks decreases with the increase in the amount of green credit allocated and can improve bank performance through regression analysis of panel data from 16 commercial banks. Dissenting scholars are in the minority, in their view, the market has the role of automatic allocation of resources, and the issuance of green credit increases the operating costs of banks and reduces their efficiency.

III. Study on the KMV model

KMV model, as a model for modern credit risk measurement, has more literature studies showing that KMV model has strong reliability in reflecting the real credit risk of enterprises. In foreign research, Altman et al. (1997) compared and analysed the KMV model with the traditional Probit multivariate discriminant model, and the results show that the KMV model is significantly better than the models of other methods in the identification of credit risk.Peter Crodbie (2003) and Navneet Arora (2005) compared the KMV model with the other credit risk models by comparing the KMV model with the other credit risk models in calculating expected default probability with better accuracy. In terms of domestic research, Liu Yingchun (2014) concluded that the KMV model is more effective in measuring the default of a single loan in commercial banks by using three models to analyse the default risk of listed and unlisted companies. Ge Lin et al. (2016) found that green credit policy can reduce commercial bank credit risk to a certain extent by analysing the KMV model and demonstrated the feasibility of the KMV model in the field of green risk credit management.

In summary, although existing studies have explored the impact of green bonds on the business development of commercial banks and the credit risk brought by green credit from a certain perspective, less literature has examined the impact of green bonds on the credit risk of commercial banks. In addition, scholars are more inclined to study enterprises or large commercial banks and pay less attention to small and medium-sized banks such as urban commercial banks. Therefore, the article adopts the KMV model to measure the credit risk changes of 10 urban commercial banks, which complements the research on small and medium-sized commercial banks and improves the quantitative research on the risk of credit entities.

3. Introduction to the KMV Model

3.1. Theories related to the KMV model

The KMV model was created and commercialised by KMV Inc. in the United States, and its origins can be traced back to 1974, when Merton proposed a model that determines the probability of default with the help of the idea of option pricing, and the KMV model further converts the probability of default from Merton's model to the real-world probability of default to predict the likelihood of default of a listed company.

The basic assumptions of the KMV model are, first, that markets are frictionless, the risk-free rate does not move, stocks are not subject to dividend payments, there are no arbitrage opportunities in securities and there is continuity in securities trading. Second, default does not occur when the market value of a firm's assets is higher than the value of its debt; conversely, default occurs. Third, the capital structure of a firm consists of owner's equity, short-term liabilities, long-term liabilities and convertible preferred stock. Fourth, the return on the

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borrower's assets exhibits a normal distribution law and the market value of the firm obeys Brownian motion.

3.2. KMV model calculation ideas

I. Calculate asset value and asset value volatility based on corporate financial data

Estimated using the market value of the firm's equity, the volatility of equity and the book value of liabilities based on the Black-Scholes theory and the Merton option pricing model.

From the option pricing model, the relationship between the firm's equity value and asset value is:

$$E = VN(d_1) - De^{-r(T-t)}N(d_2) \tag{1}$$

Among them.

$$\begin{cases} d_1 = \frac{\ln\left(\frac{V}{D}\right)+(r+\frac{\sigma_v^2}{2})(T-t)}{\sigma_v\sqrt{(T-t)}} \\ d_2 = d_1 - \sigma_v\sqrt{(T-t)} \end{cases} \tag{2}$$

$$\mathrm{N}(d) = \int_{-\infty}^{1} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx \tag{3}$$

Equity value volatilityσ_E and firm's asset value volatilityσ_v The relationship between is given by the equation:

$$\frac{\sigma_E}{\sigma_v} = \frac{V}{E}\mathrm{N}(d_1) \tag{4}$$

Where: E refers to the equity value of the enterprise, andσ_E is the equity value volatility; V is the market value of the firm's assets andσ_v D is the book value of corporate debt, T is the time to maturity, t is the present moment, r is the risk-free interest rate, and N(d) is the standard cumulative normal distribution function.

II. Determine the default point DP and calculate the default distance DD

To determine the default point, the debt structure of the company is taken into account and weights are reasonably assigned to the company's long term liabilities LTD and short term liabilities STD, default point = short term debt + 0.5 x long term debt, i.e.:

$$DP = STD + \frac{1}{2LTD} \tag{5}$$

After determining the value of the firm's assets, the volatility of the asset value, and the point of default, it is possible to measure the default distance, which represents the distance between the market value of the assets and the point of default; the further away the default distance, the less likely it is that a default will occur. The formula is:

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$$DD = \frac{E(V)-DP}{E(V)\sigma_v} \quad (6)$$

Where: E(V) is the expected asset value; DP is the firm's default point.

III. Estimation of expected default probability EDF

If the market value of the firm's assets, V, is assumed to follow a normal distribution, the default distance, DD, corresponds to the corresponding quantile, and the firm's expected probability of default (EDF) is, using the model estimation method:

$$EDF = P_r(E(V) < DP) = N\left(\frac{DP-E(V)}{E(V)\sigma_A}\right) = N(-DD) \quad (7)$$

4. Empirical Analysis

4.1. Sample selection

The article selected 10 listed city commercial banks as samples, and after considering data availability, five banks were finally obtained as the experimental group (i.e., having issued green bonds before 2021), including: Bank of Guiyang, Changsha Bank, Bank of Chongqing, Bank of Nanjing, and Bank of Ningbo; and the control group (city banks that had not issued green bonds before 2021) were: Bank of Chengdu, Bank of Xi'an, Bank of Hangzhou, Bank of Suzhou and Bank of Xiamen. The data used in the model calculations come from the Wind database, Oriental Wealth website and the official annual reports of each bank.

Table 1. Stock Codes of Sample Banks

stock code (computing)	Stock Name	stock code (computing)	Stock Name
SH.601997	Bank of Guiyang	SH.601838	Bank of Chengdu
SH.601577	Changsha Bank	SH.600928	Bank of Xi'an
SH.601963/01963.HK	Bank of Chongqing	SH.600926	Bank of Hangzhou
SH.601009	Bank of Nanjing	SZ.002966	Bank of Suzhou
SZ.002142	Bank of Ningbo	SH.601187	Xiamen Bank

Data source: Oriental Wealth

4.2. Parameter setting

I. Default point DP

According to the idea of the previous KMV model calculation, the point of default is the sum of the short-term liabilities and 1/2 long-term liabilities of a commercial bank.

II. Equity value E

With reference to the scholars' methodology, the equity value of commercial banks is calculated by collecting the closing stock prices of A and H shares, the total share capital of A and H shares, and the market value of the firm's illiquid shares on the last trading day of each year from 2019-2021 for each of the sample banks, viz:

Equity value = number of outstanding shares x closing price + number of non-outstanding shares x net asset value per share (add both if the enterprise is listed in both places (A+H))

III. Risk-free rate r

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The one-year whole deposit rate published by the People's Bank of China for 2019-2021 is used as the risk-free rate, i.e., r = 1.5 per cent.

IV. Time range T

The time horizon is 2019-2021 and the debt maturity is set at one year, i.e. the calculation of the probability of default is set at one year

4.3. Calculation process

I. Calculation of equity value volatilityσ_E

The stock prices of each sample bank for each month of 2019-2021 are collected through Wind database and the monthly logarithmic stock returns are based on the assumption of the KMV model that the stock prices follow a standard normal distribution:

$$\mu_i = \ln\left(\frac{P_{i+1}}{P_i}\right) \tag{8}$$

whereP_i denotes the closing price of month i during the year, andμ_i is the return for month i.

The volatility of monthly stock returns is obtained by calculating the average monthly standard deviation:

$$\sigma = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(\mu_i - \bar{u})^2} \tag{9}$$

Among them. $\bar{u} = \frac{1}{n}\sum_{i=1}^{n}\mu_i$

The annual stock return volatility (i.e., equity value volatility) is derived from the relationship between monthly stock return volatility and annual return volatility:

$$\sigma_E = \sigma \times \sqrt{12} \tag{10}$$

The results of the calculations are shown in the table below.

Table 2. Value of equity in each sample bank ($ million)

Stock Name	2019	2020	2021
Bank of Guiyang	2720100.08	2326556.50	2228318.33
Changsha Bank	3224727.88	3565826.59	3852062.54
Bank of Chongqing	2071494.23	2300418.65	2732893.70
Bank of Nanjing	5929063.34	7152137.07	8450532.32
Bank of Ningbo	14345274.10	19398572.20	24482654.15
Bank of Chengdu	2976733.90	3572191.54	3831645.14
Bank of Xi'an	2436888.89	2471194.17	2495537.59
Bank of Hangzhou	4068164.94	7924440.75	7158687.65
Bank of Suzhou	2777666.67	2528151.04	2577675.72
Xiamen Bank	1529638.52	1982512.87	1898451.46

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Table 3. Volatility of equity value across sample banks

Stock Name	2019	2020	2021
Bank of Guiyang	0.271916	0.209430	0.119293
Changsha Bank	0.356511	0.208891	0.247939
Bank of Chongqing	0.306010	0.301586	0.215896
Bank of Nanjing	0.258218	0.285304	0.383433
Bank of Ningbo	0.179516	0.325119	0.241989
Bank of Chengdu	0.296073	0.347054	0.364438
Bank of Xi'an	0.405962	0.227400	0.128057
Bank of Hangzhou	0.236978	0.454082	0.331603
Bank of Suzhou (Suzhou branch)	0.349033	0.212891	0.106996
Xiamen Bank	--	1.109606	0.280873

II. Calculation of asset value and asset value volatilityσ_v

According to the BSM model, the data of equity value and equity value volatility are imported into the formula and Matlab is used to calculate the asset value and asset value volatility of each sample bank for the year 2019-2021 and the results are shown in the table below.

Table 4. Value of Assets by Sample Banks ($million)

Stock Name	2019	2020	2021
Bank of Guiyang	53953010.54	56136200.13	56865261.18
Changsha Bank	58406551.22	68436651.36	76701516.31
Bank of Chongqing	47644497.09	53491421.43	58855402.97
Bank of Nanjing	129610561.64	145958544.93	168663587.05
Bank of Ningbo	134231519.03	167928559.14	208265820.80
Bank of Chengdu	54473960.91	63300856.75	74396592.16
Bank of Xi'an	27517778.26	30129991.44	33847787.22
Bank of Hangzhou	98789189.31	115128649.57	135271269.89
Bank of Suzhou	33760871.28	37680603.15	43828272.02
Xiamen Bank	24314798.91	27376417.25	32065449.83

Table 5 Asset value volatility across sample banks

Stock Name	2019	2020	2021
Bank of Guiyang	0.013710	0.008680	0.004675
Changsha Bank	0.019721	0.010884	0.012452
Bank of Chongqing	0.013310	0.012974	0.010025
Bank of Nanjing	0.011813	0.013982	0.019283
Bank of Ningbo	0.019185	0.037576	0.028447
Bank of Chengdu	0.016183	0.019614	0.018815
Bank of Xi'an	0.036128	0.018651	0.009441
Bank of Hangzhou	0.009759	0.031625	0.017566
Bank of Suzhou (Suzhou branch)	0.028755	0.014284	0.006293
Xiamen Bank	--	0.119819	0.016631

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III. Calculation of distance to default, estimation of probability of default EDF

According to the data that have been obtained from Table 2 to Table 5, and then solved by Excel function, the default distance and default probability of each bank in 2019-2021 are obtained, as shown in Table 6. And bar charts are made to compare and analyse the credit risk differences of commercial banks that have issued and have not issued green financial bonds before 2021.

Table 6. Distance to Default and EDF for Sample Banks, 2019-2021

typology	name (of a thing)	2019		2020		2021	
		Default distance	EDF	Default distance	EDF	Default distance	EDF
Green financial bonds issued before 2021	Bank of Guiyang	2.631	0.004263	3.106	0.000949	5.276	0.000000
	Changsha Bank	2.075	0.018995	3.471	0.000259	2.880	0.001986
	Bank of Chongqing	2.180	0.014616	2.200	0.013910	3.194	0.000701
	Bank of Nanjing	2.652	0.004005	2.477	0.006633	1.853	0.031970
	Bank of Ningbo	4.867	0.000000	2.718	0.003280	3.664	0.000124
No green financial bonds issued before 2021	Bank of Chengdu	2.494	0.006320	2.150	0.015792	1.975	0.024149
	Bank of Xi'an	2.068	0.019303	3.654	0.000129	6.326	0.000000
	Bank of Hangzhou	2.735	0.003120	1.727	0.042055	2.198	0.013987
	Bank of Suzhou	2.378	0.008692	3.710	0.000104	7.086	0.000000
	Xiamen Bank	--	--	0.253	0.400269	2.705	0.003416

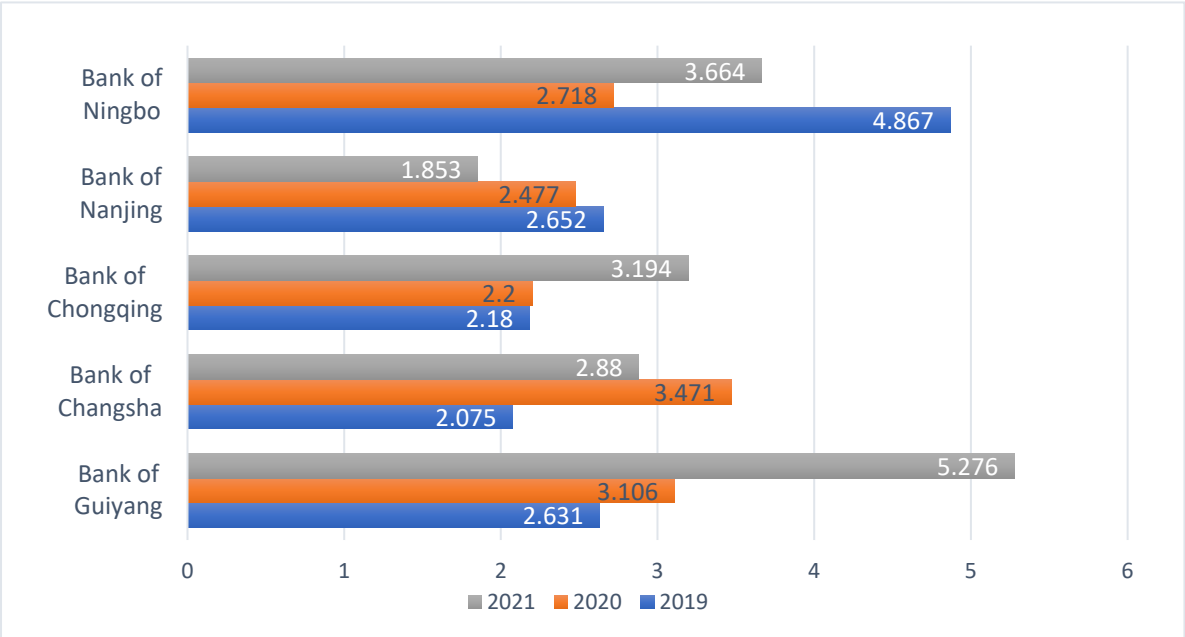

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Figure 1. Default distance for experimental group

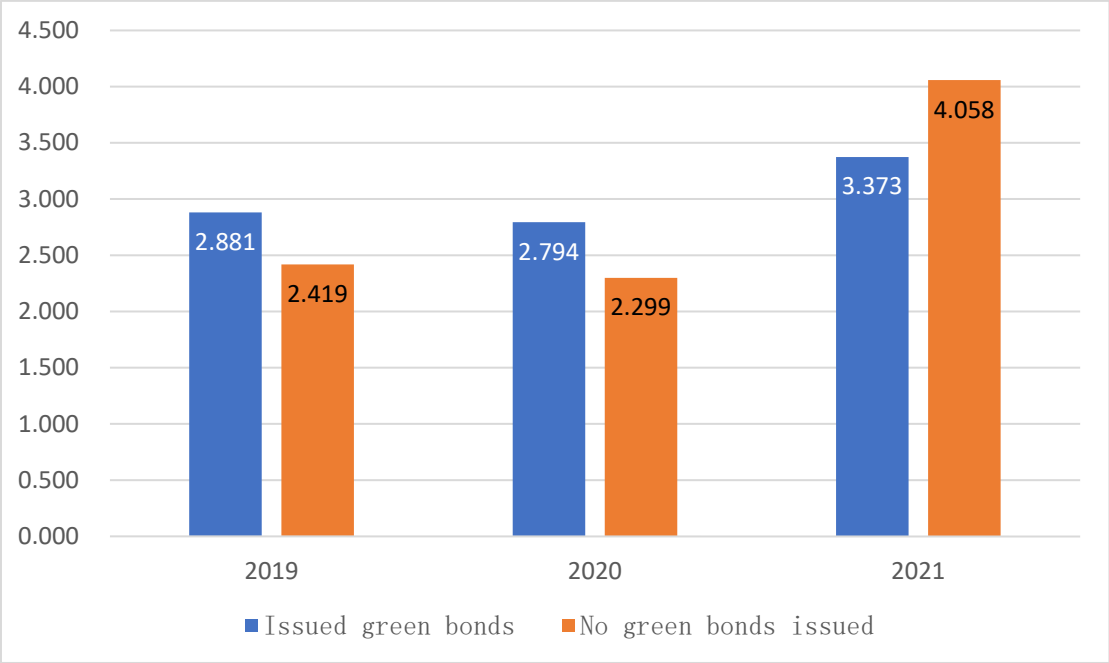

Figure 2. Distance to default for control group

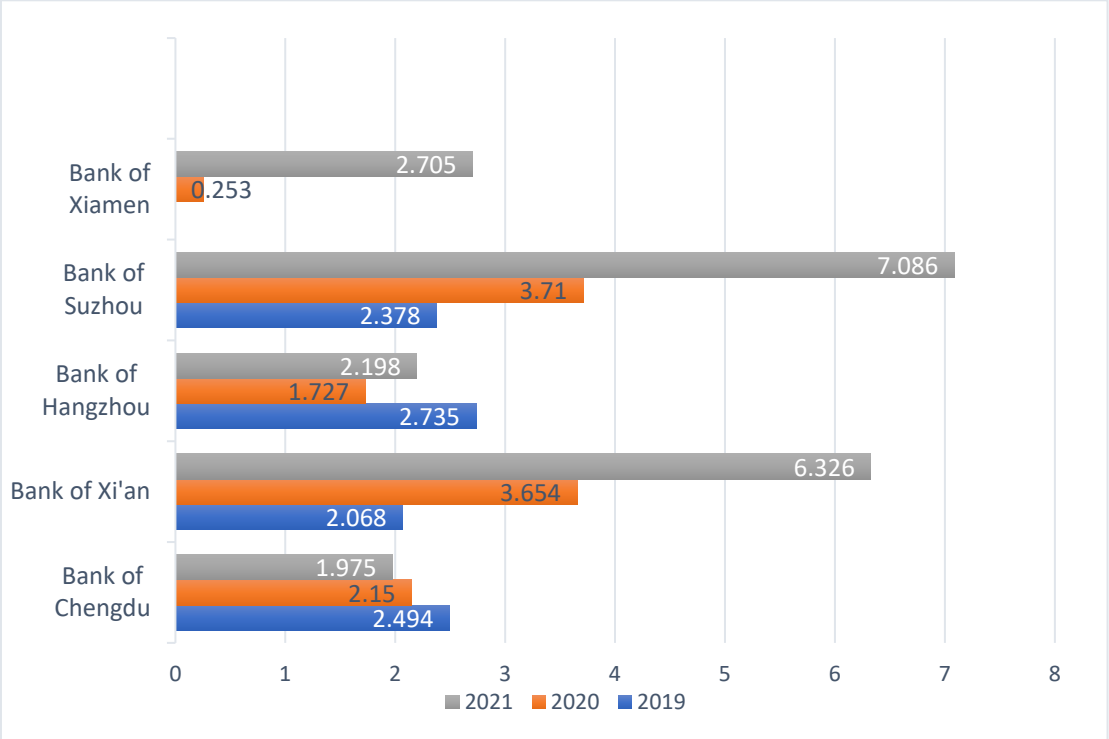

Figure 3. Average distance to default

4.4. Analysis of empirical results

The development cycle of green bonds in China's capital market is still short, and the green bonds issued by various commercial banks have not yet experienced substantial default events. Since the estimation of expected default probability is mostly based on previous default events, according to the situation of China's capital market, there is a lack of relevant data if this indicator reflects the credit status of the subject, so referring to the methodology of existing studies, the article decides to use the distance to default to estimate the credit status of the

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target subject. From the empirical results, the default distance of the experimental group of banks, i.e., commercial banks that have issued green bonds before 2021, is 2.881 in 2019, 2.794 in 2020, and 3.373 in 2021; the default distance of the control group of banks that have not issued green bonds before 2021 is 2.419 in 2019, 2.299 in 2020, and 4.058 in 2021. 4.058 in 2021.Overall, the difference in default distance between commercial banks that have issued green bonds and those that have not is not significant.

Therefore, the empirical results of the KMV model show that there is no significant effect on the main credit risk of commercial banks whether they issue green bonds or not before 2021.

5. Conclusions and Insights

5.1. Conclusion

The article takes 10 domestic city commercial banks as samples, adopts the comparative analysis method, divides them into experimental group and control group, calculates the default distance of the two groups of banks by using the KMV model, and thus explores their credit risk differences. From the empirical process, in order to calculate the default distance, the first thing to do is to count the equity value and volatility data, and calculate the asset value and its volatility through Matlab, which also involves the book value of corporate liabilities and other elements; from the empirical results, the default distance of the credit subjects that have not issued and those that have issued green bonds is more consistent, and there is no particularly noteworthy difference, which indicates that whether or not to issue green bonds is important to the credit risk of small and medium-sized banks such as city commercial banks has little impact. The article argues that the possible reasons are: first, the green bonds issued by city commercial banks are subject to certain restrictions on their issuance method and issuance scale, making them have the same qualities as ordinary bonds, which are a kind of certificate reflecting the borrowing and lending relationship, and the creditors will face the credit risk once the debtors fail to repay the principal and interest on schedule. Second, the KMV model has some limitations. As the risk status of credit subjects is a combination of multiple factors, such as unexpected events, national policies, participants' willingness, etc., all of which will jointly affect the credit risk level of the subject, and the KMV model has different degrees of applicability under different conditions. There is also a lack of effective tests to judge the accuracy of the model's results.

5.2. Revelations

I. Establishment of a credit risk information base for the banking sector

When collecting financial data, it is found that China currently has less data on bank credit records, and the establishment of the inter-banking default database is incomplete, and many missing data lead to the research on some commercial banks can only be interrupted. Therefore, it is necessary to establish a default information database of China's banking industry, which will also enable more metrics such as the KMV model to better serve the subject credit risk measurement of China's green bonds.

II. Improve the basic institutional arrangements for green finance

The implementation of green financial services or products can help to improve the business performance of commercial banks. Commercial banks are not only important intermediaries in China's social and economic development, but also the largest issuers in the green bond market. Although policy documents such as the Opinions on Building a Green Financial System have been issued, the policies are poorly grounded, coupled with the fact that green financial reforms in different regions have different characteristics, so the peer-to-peer promotion of green financial development has yet to be further enhanced. In addition, although China's green bonds have been vigorously developed in recent years, the issuer and other relevant departments

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should be more standardised in terms of information disclosure, etc. Government departments also need to formulate better policies and regulations to guide the healthy and sustainable development of China's green bond market.

III. Advancing green finance in small and medium-sized banks

As the banking industry continues to grow, it is important to pay attention to small and medium-sized banks while focusing on and promoting the development of green finance in large commercial banks, which are, after all, an important force in promoting the development of the local economy. For a long time, the lack of innovation in financial products and narrow channels of funding have been hindering the development of small and medium-sized commercial banks. In the current context of green development, small and medium-sized banks, while taking advantage of the favourable policies of the higher authorities, also need to seize the convenience of the information age, and continue to push forward and actively transform, in order to achieve green innovation in products and services.

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