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Research on the Macro and Micro Factors Affecting the Credit Spread of ESG Bonds in China

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Abstract

Based on the Lasso algorithm and a bidirectional fixed multiple linear regression model, this study comprehensively investigates the impact of macro and micro factors on the credit spread of ESG bonds in China. Research has shown that the credit spread of ESG bonds is negatively correlated with macro factors such as regional per capita GDP, local fiscal revenue, money supply, stock market returns, as well as micro factors such as total issuance amount, entity rating, debt rating, guaranteed delivery, state-owned equity certification, and green certification. Meanwhile, the credit spread is positively correlated with factors such as RMB exchange rate, fuel oil price, and urban investment bond certification. Further heterogeneity analysis indicates that ESG bonds are more significantly impacted by external factors after the epidemic, and the safety of state-owned bonds is further highlighted. The default rate of ESG urban investment bonds in the southwest region is relatively high, and the key to reducing their credit spread is to obtain green certification for establishing a positive market image. The above research conclusions provide important references for optimizing the bond pricing mechanism and reasonably evaluating the risks of ESG concept financing projects.

Keywords

Lasso, Macro Factors, Micro Factors, ESG Bonds, Green Bonds, Urban Investment Bonds

1. Introduction

Credit spread refers to a bond issuer providing investors with higher returns than risk-free bonds to compensate for default risk, in order to attract investors

and facilitate financing. It is an important indicator for measuring bond risk and determining bond issuance prices.

With the growing progress of the dual carbon goals, the green bond market has gradually developed. Green bonds refer to the securities issued in accordance with legal procedures and repaying the principal and interest as agreed, including but not limited to green finance bonds, green enterprise bonds, green corporate bonds, green debt financing instruments and green asset-backed securities, which are used to support green industries, green projects or green economic activities that meet the specified conditions. Compared to the global market, China's green bond market started relatively late, and the relevant institutional construction began with the release of the "Green Bond Issuance Guidelines" in 2015. In recent years, policies related to green bonds have become increasingly sound in terms of issuance approval, supervision, performance evaluation, etc., and China's green bond market is gradually aligning with international standards. In April 2021, the "Catalogue of Green Bond Support Projects" was released, further adjusting relevant green projects. In July 2022, the China Green Bond Standards Committee released the "China Green Bond Principles", marking the official establishment of a green bond standard that is initially unified domestically and in line with international standards.

Green bonds play an important role in solving ecological and environmental problems and promoting sustainable development. Therefore, as an increasingly important component of the bond market, the necessity of studying the credit spread of green bonds cannot be ignored, which has practical significance for reasonably assessing the risks of green projects, promoting the issuance of green bonds, and optimizing corporate financing costs.

2. Literature Review and Research Assumptions

Currently, many scholars have directly or indirectly studied the macro influencing factors of green bond credit spreads. **Firstly, in terms of macroeconomic situation,** Doğan et al. (2023) studied the impact of economic policy uncertainty on the green bond market, and the results showed that during periods of high uncertainty, the risk of green bonds is relatively small (i.e., they have relatively small credit spreads), making them suitable risk avoidance assets; Dong et al. (2023) found that when the level of macro risk (including geopolitical risk, economic policy uncertainty, climate policy uncertainty, etc.) is high, green bonds have better performance and lower credit risk, so they can be included in diversified investment portfolios for risk hedging; The study of Cicchiello et al. (2022) showed an increase in the credit spreads of green bonds compared with conventional ones in the aftermath of pandemic's outbreak. **Secondly, in terms of financial markets,** based on the theory of financial contagion, Tiwari et al. (2023a) found that price fluctuations in the fintech market exacerbate the fragility of green bonds, and the development of fintech can increase the credit spread of green bonds to some extent; Mishra et al. (2023) studied the contemporaneous

growth of green bonds and sever S&P sectoral indices; Tiwari et al. (2023b) found the relatively weak impact of green stocks on green bonds, so under bear market conditions, green bonds can serve as an effective tool for risk diversification and hedging of environmental portfolios; Jin et al. (2020) found that the green bond index is the best hedge for carbon futures; Xiang and Cao (2023) found a long-term high correlation between green bond performance and oil prices; Wei et al. (2023) observed positive effects of both supply-driven and demand-driven oil shocks on the green bond market at most quantile levels, indicating that the impact of oil prices has increased the risk of the green bond market presented as an overall increase in the credit spread.

Besides, some scholars also focused on the micro influencing factors of green bond issuance and credit spreads. Jankovic et al. (2022) empirically confirmed the significant effect of transparency on green bond yields; The sampling survey results of Zeng et al. (2022) indicate that the credit rating of issuers can significantly affect credit spreads, and green bonds of state-owned enterprises are more competitive than those of semi-enterprises; Zenno and Aruga (2023) found that higher bond credit ratings tend to increase Beijing investors' willingness to pay of green bonds, and an increase in demand usually leads to a decrease in credit spreads; García et al. (2023) found that companies with a higher proportion of women in their boards are more likely to issue green bonds; Su et al. (2023) found a negative correlation between the reputation of bond underwriters and the issuance cost of green bonds based on the Chinese market data in 2022, indicating that an increase in the credit ratings of underwriters will reduce the issuance risk and credit spread of green bonds.

Two major gaps can be found after reviewing the literatures above. Firstly, there are relatively little researches on micro influencing factors, and there are even less literatures taking both macro and micro influencing factors into consideration. Secondly, in terms of sample selection, most studies focus on only green bonds. However, with the popularity of ESG, concepts such as corporate responsibility, corporate governance, and sustainable development are also closely related to environmental protection and green concepts, indicating that non-green bonds with ESG concepts are also worth studying. Therefore, this article will study both macro and micro influencing factors of ESG bond credit spread, and conduct heterogeneity analysis for further supplements. **A series of hypotheses can be proposed and briefly analyzed as follows.**

Firstly, considering macro factors, the credit spread of ESG bonds is generally negatively correlated with regional per capita GDP, local fiscal revenue, money supply and stock market returns, while positively correlated with factors such as economic policy uncertainty, RMB exchange rate, and fuel oil price. On the one hand, per capita GDP and local fiscal revenue measure the economic development level of a certain region. Regions with better performance usually have strong public finances and a stable economic environment, and the bond market is more mature and standardized. In addition,

the ESG concept has advantages in social image enhancement, making investors more willing to purchase these bonds, thereby reducing bond credit spreads. When money supply increases, funds in the market become sufficient, and investors will have more money available to purchase bonds, which will lead to an increase in bond prices and a decrease in bond yields. During periods of economic prosperity, an increase in stock market returns usually reduces the attractiveness of bonds, resulting in a decrease in bond yields. **On the other hand,** economic policy uncertainty may come from factors such as the instability of government policy formulation and changes in the domestic and international political environment, which is likely to cause investors to have pessimistic expectations of future economic situation, leading to an increase of risk premiums in the bond market. The rise in the RMB exchange rate (RMB depreciation) is usually caused by government budget deficits, capital outflows, and other reasons, resulting in an overall risk premium or credit spread increase in the bond market. Most of the companies issuing ESG bonds belong to high-carbon industries such as construction and railways. The rise in fuel oil price will increase their production costs and operational risks, and thus lead to an increase in default probability and bond credit spreads.

Secondly, considering micro factors, the credit spread of ESG bonds is generally negatively correlated with total issuance amount, entity rating at the time of issuance, debt rating at the time of issuance, guaranteed delivery, state-owned equity certification and green certification, while positively correlated with factors such as bond maturity and urban investment bond certification. On the one hand, a larger total issuance amount indicates a company's strong ability to repay principal and interest, good credibility, strong market absorption ability, and usually a smaller credit spread. The credit rating of the issuing entity takes various internal and external factors into consideration. The higher the rating, the stronger the issuer's long-term and short-term debt repayment ability in the future, and the smaller the credit spread. The guarantee terms require a third party to provide guarantee for the payment of interest and principal, so secured bonds have an additional level of security protection and a smaller credit spread compared to the unsecured ones. For state-owned enterprises, government support and endorsement can enhance their credibility, reducing the risk of bond defaults and enabling them to obtain lower credit spreads when issuing bonds. From the perspective of investors, the use of funds through green certified bonds has characteristics such as environmental protection and low-carbon, indicating high quality and low risk features of the underlying asset. Therefore, bond issuers tend to receive lower credit spreads. **On the other hand,** under a normal interest rate term structure, the term of a certain bond is positively related to its yield premium. Issuing urban investment bonds is an immature financing method, many local governments excessively expand their debt through borrowing from urban commercial banks and issuing bonds, resulting in debt ratios far exceeding the risk warning level. Therefore, urban

investment bonds tend to have high credit spreads compared with government bonds.

3. Methodologies

We adopt a multivariate linear regression model with bidirectional control, which is shown as follows:

$$y = \alpha + \sum \beta_i x_i + \sum \beta_j year_j + \sum \beta_k area_k + \mu$$

Among them, α is the intercept term, β is the coefficient of the explanatory variable corresponding to each macro and micro influencing factor, year and area respectively represent the dummy control variables of the issuing years and the issuing regions. To prevent multicollinearity, the number of dummy variables of year and area is the total number of issuing years minus 1 and the total number of issuing regions minus 1, respectively.

If a large number of variables are introduced into the regression model, the credibility of the regression results will be low if not effectively processed. Therefore, variables need to be screened to realize dimensionality reduction before regression.

This article adopts Lasso algorithm. Regression coefficients can be solved using the Lagrange multiplier method. When the adjustment coefficient λ is small, Lasso regression will compress the coefficients of certain variables to 0 for reducing the model dimension. Compared to Ridge algorithm, the advantage of Lasso is that it introduces the L1 penalty term, while Ridge introduces the L2 penalty term, the former has a smaller computational complexity.

$$\hat{\beta}_{Lasso} = \min \sum_{i=0}^{n} \left(Y_i - X_i^{\mathrm{T}} \beta \right)^2 + \lambda \sum_{j=1}^{m} \left| \beta_j \right|$$

$$\hat{\beta}_{Ridge} = \min \sum_{i=0}^{n} \left(Y_i - X_i^{\mathrm{T}} \beta \right)^2 + \lambda \sum_{j=1}^{m} \beta_j^2$$

The steps of regression are as follows. Firstly, standardize all the dependent and explanatory variables; Secondly, screen them by Lasso algorithm; Thirdly, construct models based on the screened variables; Fourthly, conduct robustness tests and further heterogeneity analyses.

4. Empirical Analyses

4.1. Data and Variables

The data source of this article was the bond data browser of Wind Database. The time series ranges from 2016 to 2023. The research object was set as ESG bonds (including green, social, and sustainable development linked categories), and bonds issued by Hong Kong, Macao, Taiwan entities or having insufficient data were removed. Finally, 562 observations were obtained. Specific explanations for the dependent variable, macro explanatory variables, micro explanatory variables and control variables are shown in Table 1 below. The data period of most explanatory variables is one year (or month) prior to the bond issuance announcement, which can help alleviate endogeneity issues.

Table 1. Variable explanation.

Variables	Name	Symbol	Definition
Dependent	Bond's yield spread	YieldSpread	The difference between the yield to maturity of ESG bonds at the time of issuance and the yield of government bonds in the corresponding period
Macro Explanatory	Regional per capita GDP	pGDP	Logarithmic data
	Regional fiscal revenue	Fiscal	Logarithmic data
	CPI	CPI	Year on year %
	Broad money supply	M2	Year on year %
	Economic policy uncertainty index	Uncertain	News index
	HS 300 Index	HS	Yield %
	China securities green bond index	GBI	Yield %
	RMB to USD exchange rate	USD	Daily median price, taking the average on a monthly basis
	Futures fuel oil settlement price	Oil	Yield %
Micro interpretation	Total Issuance Amount	Amount	-
	Term	Term	(Due date − value date)/365
	Entity rating at the time of issuance	MainScore	Uniformly graded, minimum A^- = 1, maximum AAA = 6
	Debt rating at the time of issuance	DebtScore	Uniformly graded, minimum A^- = 1, maximum AAA = 6
	Guarantee delivery	Secure	Dummy variable, yes = 1, no = 0
	State-owned equity?	Soe	Dummy variable, yes = 1, no = 0
	Green bonds?	Green	Dummy variable, yes = 1, no = 0
	Urban investment bonds?	City	Dummy variable, yes = 1, no = 0
Control	Regional controls of issuing entities	area	7 dummy variables East/South/North/Central/Northwest/ Southwest/Northeast China
	Annual controls of issuance	year	8 dummy variables years from 2016 to 2023

4.2. Descriptive Statistics

From the descriptive statistical results in Table 2, it can be seen that the average credit spread is 1.8337, the maximum value is 6.0905, and the minimum value is −2.7259, indicating significant differences in credit spreads among different ESG bonds. The average value of Secure is 0.7562, indicating that most ESG bonds are guaranteed delivery bonds. The average value of Soe is 0.9680, indicating that most of them are issued by central or local state-owned enterprises; The average value of Green is 0.6566, indicating that more than half of the bonds in the sample

Table 2. Descriptive statistics.

Variables	Number	Mean	S. dev	Min	Max
Term	562	5.5409	2.4732	1.0000	20.0000
Amount	562	10.2284	11.0546	0.3000	200.0000
Secure	562	0.7562	0.4297	0.0000	1.0000
Soe	562	0.9680	0.1762	0.0000	1.0000
Green	562	0.6566	0.4753	0.0000	1.0000
City	562	0.5480	0.4981	0.0000	1.0000
MainScore	562	5.1192	0.9221	1.0000	6.0000
DebtScore	562	5.5107	0.6917	4.0000	6.0000
YieldSpread	562	1.8337	1.2803	−2.7259	6.0905

are green bonds. The average value of City is 0.548, indicating that the number of urban investment bonds and non-urban ones in the sample is equivalent; The average value of both the entity rating and the debt rating are higher than 5 with small volatilities, showing the initial good credit status of most bonds.

4.3. Benchmark Model Results

The regression results of the benchmark model are shown in the first column of Table 3. Four indicators including CPI, Uncertain, GBI, and Term are dropped by Lasso, so their statistics are not reported. It can be seen that the regression coefficients of most variables are roughly consistent with previous assumptions.

Specifically, in terms of macro factors, the coefficients of pGDP and Fiscal are significantly positive at the level of 10%, indicating that ESG bonds issued by regions with high economic development and strong public finances usually have low credit spreads. The coefficient of USD is positive and significantly positive at the 5% level, indicating that the depreciation of the RMB will increase the overall risk premium of the ESG bond market. The coefficient of M2 is negative but not significant, which may be due to the delay in the transmission of monetary policy to the bond market. The coefficients of HS and Oil are consistent with our expectations but not significant, which can be explained by the different purposes of investors when choosing ESG and ordinary bonds. For the former, investors tend to value their prospects for promoting sustainable development more than investment returns. Therefore, they are less affected by financial trading markets such as securities and futures (Liu and Jiang, 2023).

In addition, in terms of micro factors, the regression coefficients of Amount, MainScore, DebtScore, Secure and other variables are significantly negative at the 1% level, indicating that the credit spreads of ESG bonds with large issuance amount, high credit ratings and security guarantees are generally small. The coefficient of Soe is significantly negative at the 1% level, indicating that central

Table 3. Regression results.

Variables	Basic model	Stability test
	z_YieldSpread	z_YieldSpread
z_Amount	−0.1597***	−0.1600***
	(−6.956)	(−6.993)
Soe	−0.4741***	−0.5189***
	(−2.666)	(−2.653)
Green	−0.0492	−0.0353
	(−0.907)	(−0.644)
City	0.1277**	0.1278**
	(2.174)	(2.102)
Secure	−0.2871***	−0.2817***
	(−4.174)	(−3.971)
z_MainScore	−0.3755***	−0.3839***
	(−9.458)	(−9.056)
z_DebtScore	−0.2198***	−0.2233***
	(−6.906)	(−6.501)
z_M2	−0.0527	−0.0413
	(−1.243)	(−0.954)
z_pGDP	−0.0829*	−0.0795
	(−1.697)	(−1.563)
z_Fiscal	−0.0912*	−0.0881
	(−1.741)	(−1.587)
z_HS	−0.0231	−0.0279
	(−0.880)	(−1.041)
z_Oil	0.0297	0.0301
	(1.062)	(1.078)
z_USD	0.0943**	0.0920**
	(2.056)	(1.978)
Constant	0.4622	0.9801***
	(1.622)	(3.242)
Observations	562	522
R-squared	0.737	0.740
Region FE	YES	YES
Year FE	YES	YES

Note: robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

and local state-owned enterprises usually receive lower credit spreads when issuing bonds. The coefficient of City is significantly positive at the 5% level, indicating that the debt risk and credit spread of urban investment ESG bonds are usually high; The coefficient of Green meets previous expectation but is not significant, possibly because green ESG bonds and other ESG bonds (such as social responsibility bonds and sustainable development linked bonds) have similar financing goals, so differences between them are gradually decreasing.

4.4. Robustness Test

To demonstrate the stability of the research results, the sampling period is shortened to 2018-2022. New regression results are shown in column 2 of **Table 3**. It can be seen that the new model is generally consistent with the basic model, indicating the robustness of the research conclusions. Specifically, there are no changes in the signs of the regression coefficients. For variables that are statistically significant, the impacts of Secure and USD decrease slightly (from 0.2871 to 0.2817 and from 0.0943 to 0.0920, respectively), while those of the remaining factors increase to small extent.

4.5. Further Heterogeneity Analyses

We employ two heterogeneity analyses for further exploring the impact of macro and micro factors on the credit spread of ESG bonds in different periods and categories.

Firstly, the time span is from 2016 to 2023, and time intervals before and after the epidemic is relatively balanced, making it suitable for heterogeneity analysis. Comparative regression results are shown in the first two columns of **Table 4**. First, the regression results of most variables are consistent with the overall regression results, which verifies the robustness of the previous conclusions. Secondly, the coefficient of Soe is negative before and after the epidemic, the coefficient of City is positive before and after the epidemic, but both changed from insignificant to significant. This indicates that in the circumstances of epidemic impact and economic downturn, the safety of state-owned bond is more prominent, while the high-risk characteristics of urban investment bonds are further exposed. Finally, the coefficient of USD is always positive, but turns from insignificant to significant, with the value increases significantly from 0.0009 to 0.1365, indicating that in the context of globalization, the impact of COVID-19 will intensify the shock of financial markets and strengthen the risk linkage between regions.

Secondly, according to the survey results of China Chengxin International Research Institute in 2022, eight provinces and cities including Guizhou, Henan, Hunan, Inner Mongolia, Shaanxi, Sichuan, Tianjin, and Yunnan are involved in non-standard default of urban investment in the previous year. Among them, three are southwest provinces, and Guizhou was the "severely affected area" for default with 29 enterprises, accounting for nearly 70%. **Figure 1** shows the

Table 4. Heterogeneity analysis.

Variables	Non-Covid	Covid	Non-WSCity	WSCity
	z_YieldSpread	z_YieldSpread	z_YieldSpread	z_YieldSpread
z_Amount	−0.1602***	−0.1521**	−0.1172**	−0.4092**
	(−12.052)	(−2.482)	(−2.186)	(−2.096)
Soe	−0.3480	−0.4710*		
	(−1.193)	(−1.890)		
Green	0.0707	−0.0609	0.0153	−0.3916**
	(0.626)	(−0.999)	(0.193)	(−2.210)
City	0.0931	0.1276*		
	(0.837)	(1.850)		
Secure	−0.4675***	−0.2427***	−0.1314	−0.2998
	(−3.145)	(−2.910)	(−1.551)	(−1.645)
z_MainScore	−0.3775***	−0.3739***	−0.4048***	−0.5315**
	(−4.728)	(−7.393)	(−8.306)	(−2.119)
z_DebtScore	−0.3356***	−0.1931***	−0.2020***	−0.3705***
	(−5.273)	(−5.297)	(−4.847)	(−5.998)
z_M2	0.1031	−0.0739	−0.0194	−0.1197
	(0.714)	(−1.596)	(−0.263)	(−0.895)
z_pGDP	0.0291	−0.1131*	−0.3025***	−0.1122
	(0.294)	(−1.885)	(−3.361)	(−0.463)
z_Fiscal	−0.2897*	−0.0751	0.0113	0.0513
	(−1.862)	(−1.321)	(0.123)	(0.353)
z_HS	−0.0790	−0.0197	−0.0527	0.0140
	(−1.231)	(−0.677)	(−1.337)	(0.143)
z_Oil	0.0511	0.0394	0.0207	−0.1183
	(0.991)	(1.214)	(0.499)	(−0.914)
z_USD	0.0009	0.1365**	0.0173	0.1834
	(0.013)	(2.437)	(0.291)	(1.509)
Constant	0.1369	0.6253*	0.3373	1.0468**
	(0.293)	(1.876)	(1.306)	(2.118)
Observations	110	452	244	64
R-squared	0.863	0.720	0.718	0.722
Region FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Note: robust t-statistics in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

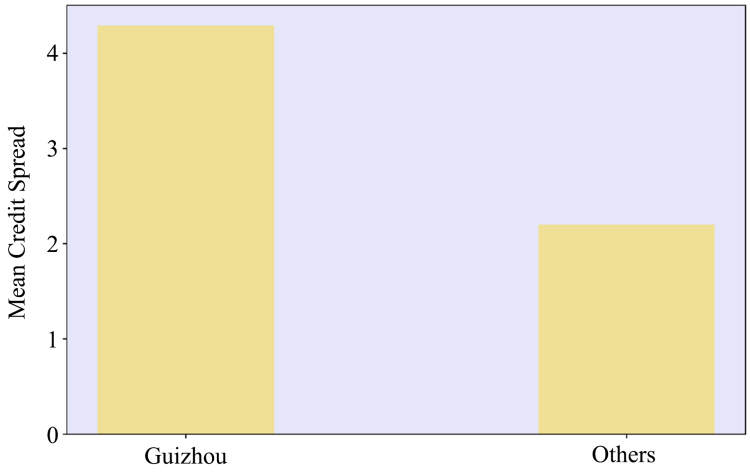

Figure 1. Urban investment bonds-credit spread between Guizhou and other regions.

comparison of the average credit spreads between urban investment bonds in Guizhou and other regions. It can be seen that the former is nearly twice as high as the latter, which is in line with the research conclusions.

Comparative regression results of urban investment bonds in the southwest and non-southwest regions are shown in the last two columns of **Table 4**. Due to the state-owned nature of all urban investment bond issuers, the unnecessary variable Soe is removed from the regression. By comparing the values of the regression coefficients, it can be found that all significant micro variables have greater impacts on the credit spread of urban investment bonds in the southwest region, which confirms the existence of heterogeneity. In addition, it is worth noting that for ESG urban investment bonds in the southwest region, the increase in per capita GDP and fiscal revenue does not significantly improve their credit situations. However, bonds certified green has notably smaller credit spreads, reflecting the difference between ordinary urban investment bonds and ESG urban investment bonds in high-risk areas. The key to reducing the credit risk of the former is to boost regional economy and fiscal strength, while the crucial point for the latter is to obtain green certification and establish a positive market image.

5. Conclusions and Suggestions

This article uses a combination of Lasso algorithm and multiple linear regression to comprehensively study the effects of macro and micro factors on the credit spread of ESG bonds in China. The main conclusions are as follows. Firstly, basic regression results show that the credit spread of ESG bonds is negatively related to macro factors such as regional per capita GDP, local fiscal revenue, money supply, stock market returns, as well as micro factors including total issuance amount, entity rating, debt rating, guarantee delivery, state-owned equity certification, and green certification. Meanwhile, it has positive correlations with macro factors including RMB exchange rate, fuel oil price, and micro factors

such as urban investment bond certification. Secondly, the narrowed interval regression results are generally consistent with those of basic regression, indicating the robustness of the above conclusions. Finally, heterogeneity analyses show that ESG bonds are more significantly impacted by external shocks after the epidemic, and the safety of state-owned bonds is further highlighted. Moreover, the impact of micro variables on ESG urban investment bonds in the southwest region is more significant than in non-southwest regions, and the key to reducing their credit spread is to obtain green certification for establishing positive market images.

Based on the above research conclusions, we briefly propose following suggestions from both supply and demand perspectives. Firstly, for issuers of ESG bonds, when setting coupon rates, they should not only pay attention to the macroeconomic environment and examine changes in indicators such as exchange rates, but also choose objective rating agencies and underwriters to evaluate the rationality of their pricing, in order to avoid problems such as increased financing costs caused by excessive credit spreads and financing difficulties resulted from small credit spreads. For ESG urban investment bond issuers in high-risk areas, obtaining green certification is an effective way to reduce credit spreads and improve market image. Secondly, whether individual or institutional investors, when investing in ESG bonds, they should comprehensively examine the regional macroeconomic situation, basic issuance information and credit qualifications of the bond issuer, in order to purchase reasonably priced bonds and control potential investment risks.

ESG bonds are important financial instruments for sustainable economic development. In order to better study this topic in the future, several potential deficiencies of this article are summarized. Firstly, due to the later development of China's ESG bonds markets compared with other developed countries, insufficient samples may lead to biases in the regression results. Secondly, only cross section analyses are put forward, while the impacts of macro and micro variables from a time series perspective are also worth exploring. Moreover, the effectiveness of these variables in asset pricing, bonds selection and quantitative investment can be further studied.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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