Typhoon Risk, Green Bond Resilience and Credit Spread Pricing: Empirical Evidence from the Green Bond Market in China

Zhongmou Sun

Nanjing-Helsinki Institute in Atmospheric and Earth System Sciences, Nanjing University, Suzhou, China
241380056@smail.nju.edu.cn

Abstract. In response to the insufficient consideration of physical climate risks, such as typhoons, in most current green bond risk-assessment systems, this paper takes typhoons as an example and uses GIS-based spatial analysis to quantify the typhoon exposure of project locations and examine its impact on green bond credit spreads. Using green bond issuance data from southeastern coastal China, this paper further constructs a provincial typhoon-risk index based on typhoon frequency and wind-force intensity. The results show that, after controlling for bond maturity, issuer rating, the debt-to-asset ratio, and regional GDP growth, the typhoon risk index does not significantly increase credit spreads. The current sample does not support the hypothesis that "typhoon risk significantly increases green bond credit spreads." Green bond pricing may be jointly shaped by physical risk exposure and resilience mechanisms such as preference for green assets, policy support, and project adaptation capacity. This finding suggests that green bonds may show certain resilience under acute physical climate risks.

Keywords: Typhoon impact, Physical climate risk, Green bonds, Credit spread, Green resilience.

1 Introduction

Driven by both the intensification of global climate risks and China's "dual carbon" goals, China's green bond market has expanded rapidly and has become an important financing instrument for sustainable development. However, frequent extreme weather events such as typhoons pose direct threats to asset security and cash-flow stability for green projects in coastal regions. Current investment risk-assessment systems for green bonds have not yet systematically incorporated historical typhoon-track and disaster-probability information for project locations. As a result, investors and rating agencies find it difficult to quantify the actual effect of climate risk on credit pricing, which also constrains the high-quality development of the green bond market. According to conventional credit-risk pricing logic, physical climate risk increases issuers' risk premia through asset damage, operational disruption, and cash-flow volatility. Yet green bonds may also exhibit stronger financing resilience because of their green

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attributes, policy support, and responsible investment preferences. Therefore, whether typhoon risk necessarily increases green bond credit spreads requires further empirical testing.

Existing studies mainly focus on the traditional determinants of green bond credit spreads or separately examine the effects of typhoon disasters on capital markets. Few studies have systematically linked specific data such as typhoon-track frequency and damage potential indices to green bond credit spreads. The literature shows that physical climate risk may enter bond pricing and affect financing costs. However, green bonds and conventional bonds differ in risk exposure, investor structure, and policy support; therefore, their credit-spread responses to acute physical risks such as typhoons are not necessarily the same. Existing research still lacks direct matching and empirical testing between refined spatial indicators, such as typhoon-track frequency and wind-damage potential, and credit spreads in China's green bond market.

Against this background, this paper takes typhoons as the research object. Using typhoon-track data from China Weather Network and GIS-based spatial analysis, it quantifies typhoon crossing frequency and the damage potential index at project locations. It then combines these measures with credit-spread information from the Chinese green bond database to systematically analyze the association mechanism between typhoon risk and green bond credit spreads and to test whether typhoon risk significantly affects green bond credit spreads. The empirical results show that the typhoon risk index does not significantly increase credit spreads at green bond issuance, suggesting that the pricing effect of physical climate risk in the green bond market may be offset by factors such as preference for green assets and policy support.

2 Literature Review

Green bonds are debt securities issued in accordance with statutory procedures and with agreed principal and interest payments, where the proceeds are dedicated to supporting green projects that meet specified eligibility criteria. As a core measure of bond credit risk, the credit spread is the difference between the bond's yield to maturity and the yield on a risk-free Treasury bond of the same maturity. In essence, it is the risk premium required by investors for bearing credit risk. Typhoon-related physical climate risk refers to the negative impact of typhoons on asset value through physical damage, operational disruption, and related channels. This paper quantifies typhoon exposure at project locations using average annual typhoon crossing frequency and a wind-damage potential index.

At the theoretical level, climate finance theory emphasizes that climate risk is an important dimension of financial asset pricing, and that extreme weather can be transmitted to financial markets through real-economy channels. Credit-risk pricing theory further indicates that bond credit spreads depend on the issuer's probability of default and loss given default. Typhoon disasters can directly increase default risk by damaging fixed assets and interrupting project cash flows, thereby affecting credit spreads. At the same time, green bonds may be influenced by green investment preferences, policy support, information-disclosure requirements, and the resilience of

green projects, which may reduce or stabilize risk premia. Therefore, the impact of typhoon risk on green bond credit spreads involves two competing mechanisms: the "physical risk exposure effect" and the "green resilience effect." The ultimate direction must be determined empirically.

The existing research on green bond credit spreads can be divided into three broad strands. The first strand focuses on the traditional pricing factors of green bonds and argues that bond maturity, credit rating, and issuer quality are important foundations affecting green bond credit spreads and issuance costs. The second strand incorporates climate risk into the bond-pricing framework and finds that climate risk may enter the pricing process of bond credit spreads by affecting corporate cash flows, default risk, and financing constraints. Fatica et al. provide key evidence for incorporating climate factors into bond pricing by verifying the significant impact of country-level climate risk on green bond issuance costs [1]. Based on EU market data, Bartolini et al. further find significant heterogeneity in exposure to physical climate risk between green and non-green corporate bonds [2]. Hu Jinyan et al. further examine the relationship between natural-disaster exposure and green bond default risk [3]. Li Zheng et al. confirm that extreme climate events affect corporate bond credit spreads using panel data for Chinese prefecture-level cities [4]. The third strand of research focuses on the impact of tropical cyclones such as typhoons and hurricanes on the financial sector. Huesler examines the effect of hurricane strikes on bond returns from the perspective of sovereign bonds [5], while MSCI discusses the financial materiality of hurricane-related physical risk using corporate bond data [6]. Overall, the existing literature provides a basis for understanding and explaining how climate risk affects bond pricing, but the specific response direction of green bonds may still be moderated by green attributes and investor preferences.

In conclusion, the previous studies have confirmed that climate physical risks have a significant impact on bond pricing. However, there are still two shortcomings. The first issue is the lack of systematic verification that links detailed spatial indicators such as the frequency of typhoon paths and the potential for wind damage to the credit spreads of green bonds. The second issue is the insufficient discussion regarding whether green bonds will exhibit greater risk resilience due to their green attributes and policy support. This paper therefore tests whether typhoon risk significantly increases green bond credit spreads, and discusses the possible mechanisms of the resilience of green bonds based on the fact that the results do not support the original hypothesis.

3 Research Design

In terms of data sources, core meteorological data, such as typhoon tracks and wind-force levels, mainly come from the Northwest Pacific tropical cyclone track dataset released by the Shanghai Typhoon Institute of the China Meteorological Administration and the publicly available global tropical cyclone observation dataset released by the World Regional Meteorological Centre. Information on green bond issuance, credit spreads, and bond characteristics is obtained from the Wind database and ChinaBond, and green bond samples issued within the study region are screened accordingly.

Corporate financial indicators and prefecture-level macroeconomic control variables are obtained from the CSMAR database, the National Bureau of Statistics, and provincial and municipal statistical yearbooks.

In the variable design, the dependent variable is the credit spread at green bond issuance, calculated as follows:

$$Spread_i = \left(YTM_i - Rf_[i,T]\right) \times 10000 \tag{1}$$

where YTM_i denotes the yield at issuance or estimated yield to maturity of bond i, and Rf_[i,T] denotes the risk-free Treasury yield matched to the maturity of that bond. Spread_i is measured in basis points (bp; 1 bp = 0.01%). The core explanatory variable is the typhoon-risk exposure index. Following studies on typhoon-disaster risk assessment, typhoon hazard risk is typically characterized jointly by occurrence frequency and disaster intensity, and composite risk indices are generally constructed using an "indicator standardization–weighted synthesis" method [7-9]. On this basis, this paper measures regional typhoon risk using average annual typhoon impact frequency and average wind-force scale. Frequency reflects the long-term exposure probability of a region, while wind-force scale reflects potential damage intensity. Because this paper focuses on the effect of long-term physical climate risk on green bond credit spreads, the frequency indicator better captures persistent exposure and is therefore assigned a higher weight. The typhoon risk index is constructed as follows:

$$\begin{aligned} TyphoonRisk_i &= 0.6 \times Normalized\ Frequency_i \\ &+0.4 \times Normalized\ Wind\ Force_i \end{aligned} \tag{2}$$

Table 1. Typhoon risk index and measured green bond credit spreads in five southeastern coastal provinces/municipalities (2014–2023).

Region	Average Annual Typhoon Landfall Frequency (times)	Average Wind Force Scale (level)	Standardized Frequency (frequency/6)	Standardized Wind Force (wind force/16)	Typhoon Risk
Guangdong	4.6	10.28	0.767	0.643	0.717
Fujian	3.5	11.97	0.583	0.748	0.649
Zhejiang	2.2	12.50	0.367	0.781	0.533
Jiangsu	1.6	12.56	0.267	0.785	0.474
Shanghai	1.8	12.30	0.300	0.774	0.490

The control variables include bond maturity, corporate debt-to-asset ratio, and regional economic growth, which are included to exclude the pricing effects of other factors. The resulting measurements are reported in Table 1.

In terms of methodology, following studies on credit-spread pricing and green bond risk premia, bond credit spreads are generally affected by factors such as bond maturity, credit rating, issuer financial condition, and the macroeconomic environment [10,11].

At the same time, studies of climate risk and bond pricing show that physical climate risk may enter the pricing process of bond credit spreads by affecting corporate cash flows, default risk, and financing constraints [12]. Accordingly, this paper adopts an OLS multiple linear regression model as the baseline framework to test the impact of typhoon risk on credit spreads at green bond issuance. The baseline model is specified as follows:

$$Spread_i = \alpha + \beta_1 TyphoonRisk_i + \beta_2 Term_i + \beta_3 Rating_i + \beta_4 Lev_i + \beta_5 GDP_i + \varepsilon_i \quad (3)$$

4 Empirical Results and Analysis

Table 2. Baseline regression results for the effect of typhoon risk on green bond credit spreads.

Variable	Coef.	Std. Err.	t-statistic	P-value	95% Confidence Interval
TyphoonRisk	-26.745	27.818	-0.961	0.336	[-81.267, 27.777]
Bond maturity (years)/Term	4.285	0.990	4.329	0.000	[2.345, 6.225]
Issuer rating score/Rating	-57.577	5.336	-10.791	0.000	[-68.034, -47.119]
Debt-to-asset ratio/Lev	-0.254	0.151	-1.675	0.094	[-0.551, 0.043]
GDP	1.749	1.278	1.368	0.171	[-0.756, 4.254]
Constant	602.363	44.690	13.479	0.000	[514.772, 689.954]
Sample Size	585	—	—	—	—
F-statistic	41.528	—	—	—	—
Prob > F	0.0000	—	—	—	—
R-squared	0.3413	—	—	—	—
Adjusted R-squared	0.3356	—	—	—	—
Residual standard error	68.873	—	—	—	—

From the descriptive results, the typhoon risk index of the five provinces/municipalities and the credit spread at green bond issuance do not show a stable monotonic positive relationship as shown in the Table 2. Guangdong has the highest typhoon risk index, at 0.717, with an average credit spread at issuance of 97.64 bp for valid samples. Fujian has a typhoon risk index of 0.649 and an average credit spread of 73.19 bp. The typhoon risk indices of Zhejiang, Jiangsu, and Shanghai are 0.533, 0.474, and 0.490, respectively, while their average credit spreads are 118.75 bp, 121.66 bp, and 140.95 bp, respectively. These results indicate that green bond credit spreads are affected not only by regional typhoon risk but also by multiple factors such as issuer rating, maturity

structure, issuer characteristics, and the macroeconomic environment. Financing costs therefore cannot be judged solely on the basis of regional typhoon risk exposure.

The baseline regression results show that, after controlling for bond maturity, issuer rating, the debt-to-asset ratio, and regional GDP growth, the regression coefficient of the typhoon risk index is -26.745, with a robust standard error of 27.818 and a P-value of 0.336 and it does not pass the significance test. This means that, under the current provincial-level typhoon risk index and green bond sample specification, there is no evidence that typhoon risk significantly increases credit spreads at green bond issuance. By contrast, the coefficient on bond maturity is 4.285 and is significant at the 1% level, indicating that longer maturities are associated with higher credit spreads. The coefficient on issuer rating score is -57.577 and is highly significant, indicating that higher ratings are associated with lower credit spreads at issuance. The debt-to-asset ratio and regional GDP growth do not pass conventional significance tests in the baseline model. The model has an R-squared of 0.3413 and an adjusted R-squared of 0.3356, indicating that it has a certain degree of explanatory power for credit spreads.

In summary, the empirical results do not support the research hypothesis that "physical typhoon risk significantly increases green bond credit spreads." One possible reason is that, while typhoon risk increases the risks of physical damage to green projects and interruptions to cash flows, green bonds may also be affected by green investment preferences, policy support, and the resilience of green projects, thereby offsetting part of the risk premium. The current results are more appropriately interpreted as follows: provincial-level typhoon risk has not yet been fully and consistently priced into credit spreads at green bond issuance, and green bonds may exhibit some resilience under physical climate-risk shocks.

5 Conclusion

This paper empirically examines the impact of typhoon physical risks on the credit spreads of green bond issuances based on the green bond samples from five provinces in southeastern China from 2014 to 2023. The research has reached the following conclusions. First, the typhoon risk index does not significantly increase credit spreads at green bond issuance. The coefficient is -26.745 and the P-value is 0.336 in the baseline regression, which fails to pass the significance test. Second, bond maturity and issuer rating still remain the key factors affecting green bond credit spreads. Longer maturities are associated with higher credit spreads, while higher issuer ratings are associated with lower credit spreads. Third, the response of green bond credit spreads to typhoon risk may be influenced by offsetting effects arising from green attributes, investor preferences, and policy support, suggesting that green bonds may have a degree of resilience under physical climate risk.

Based on the research findings, three practical implications are proposed. First, bond rating agencies should not mechanically assume that such risks necessarily increase green bond credit spreads when incorporating physical climate risks such as typhoons. Instead, they should also examine the adaptive capacity of green projects, the quality of information disclosure, and the strength of policy support. Second, investors should

comprehensively consider the typhoon risk of project locations, issuer ratings, bond maturity and issuers' financial conditions when allocating green bonds in southeastern coastal regions, avoiding judging risk premia solely on the basis of disaster exposure. Third, regulators should promote the standardization of climate-risk information disclosure for green bonds and encourage issuers to disclose project locations, disaster exposure, disaster-prevention measures and insurance arrangements, thereby improving the market's pricing efficiency for physical climate risks.

This paper can still be extended in several ways. First, the typhoon risk index is mainly based on average provincial-level exposure. Future studies can further improve the precision of risk matching by combining prefecture-level city data or project-coordinate data. Second, this paper focuses on a sample of green bonds. Subsequent research can introduce conventional bonds as a control group to compare more systematically the pricing differences between green and conventional bonds under physical climate risk. Third, this paper mainly analyzes credit spreads at issuance. Future studies can incorporate secondary-market yields, liquidity indicators, and event-study methods to further examine the dynamic impact of typhoon shocks on green bond pricing.

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