

Article

Navigating Geopolitical Risks: Deciphering the Greenium and Market Dynamics of Green Bonds in China

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Abstract: This study investigates whether green bonds have an issuance cost advantage over conventional bonds (greenium), examines the impact of geopolitical risks on their price dynamics, and explores the industry-specific effects of such risks in the financial sector. Using a dataset of 270 green bonds and 667 conventional bonds from May 2018 to August 2021, this study applies a two-step panel estimation method to analyze the influence of geopolitical risks on green bond pricing. The findings indicate that green bonds in China have an issuance cost advantage compared to traditional bonds, with a premium of 10–12 bps. Additionally, both recent and historical geopolitical risks, including GPR threats and GPR acts, significantly reduce green bond financing costs, with the China-specific geopolitical risk index having the most substantial impact, lowering costs by up to 17.4 bps. This study also highlights the financial sector, where green bonds do not display an issuance premium, and geopolitical risk has a slightly lower effect compared to the overall market. These results provide a comprehensive analysis of the impact of geopolitical risks on the pricing of Chinese green bonds, utilize strict screening criteria and the latest two-stage panel estimation method for more reliable analytical conclusions, and establish green bonds as reliable tools for sustainable investment.

Keywords: green bonds; geopolitical risk; green premium; financial sector; sustainable finance



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1. Introduction

As a novel financing tool dedicated to funding environmentally friendly projects, green bonds have rapidly surged into a global ‘green bond boom’ since their inception (Morgan Stanley (see <https://www.morganstanley.com/ideas/green-bond-boom>, accessed on 22 July 2024), [1] (see <https://www.climatebonds.net/market/explaining-green-bonds>, accessed on 22 May 2024)).

Green bonds, developed from traditional fixed-income securities, are labeled bonds similar to other environmentally friendly bonds [2]. However, unlike conventional bonds, they aim to improve environmental performance and social welfare, requiring third-party certification and supervision by specialized teams to ensure the intended use of proceeds. For first-time issuers, the process of issuing green bonds is more intricate and complex than that of ordinary bonds, potentially leading to higher issuance costs. Nonetheless, these bonds are typically associated with sustainable investment programs, attracting a distinct investor base compared to conventional bonds and operating under unique favorable policy environments, such as fiscal subsidies and fast-track issuance procedures. Issuing green bonds serves as a positive commitment for companies engaging in environmentally friendly operations. From the signaling theory perspective, the cost of mimicking this signal is high for companies with low credibility [3], enabling investors to identify firms genuinely committed to environmental protection and thereby ‘vote with their feet’, reducing the financing costs of green bonds and achieving a green premium. Due to the inherent contradictions brought about by the unique characteristics of green bonds, examining the financing costs of green bonds has become a primary focus.

Theoretically, green bonds are more susceptible to geopolitical risks compared to conventional bonds. This can be understood from two perspectives.

Firstly, from the bond's perspective, the inherent 'greenness' of these bonds ties them to sustainable investment projects and products, making them highly dependent on corresponding environmental policies and regulations. Geopolitical shifts often have widespread impacts on various policies, including environmental regulations, which directly affect the prices of green bonds. Moreover, green bonds are issued based on eligible green projects closely linked to sustainable development goals. Any geopolitical risk that alters government sustainability targets can influence market perceptions of the future cash flows of green bonds, thereby affecting their current prices.

Secondly, from the market perspective, green bonds attract global investors focused on environmental sustainability. These investors rely on smooth international cooperation and investment channels. Geopolitical risks, such as economic sanctions, can hinder these conditions, affecting investors' willingness to engage in specific markets or high-risk projects, leading to fluctuations in green bond values. Additionally, most green bond projects depend on global supply chains and international cooperation in terms of technology, personnel, and raw materials. Geopolitical tensions can disrupt these supply chains or cooperative efforts, directly impacting investments in green bonds.

Despite the increasing issuance and popularity of green bonds, the understanding of how geopolitical risks influence their pricing and market behavior remains limited. Existing literature primarily focuses on the relationship between green bonds and geopolitical risks based on specific indices of green bonds [4–8]. As a result, the micro-level nuances of the green bond market under geopolitical uncertainty have not been fully explored. Addressing this issue is crucial, as it affects the decision-making processes of various stakeholders, including fund demanders, market investors, policymakers, and regulators, within a rapidly growing and increasingly important market aligned with global sustainable development goals.

This study aims to address two research questions: (1) Do green bonds have an issuance cost advantage compared to conventional bonds? (2) Do geopolitical risks increase the prices of green bonds, thereby promoting a green premium? Additionally, does the impact of such exogenous shocks exhibit industry-specific characteristics in the financial sector?

Since the issuance of the first 'Climate Awareness Bond' by the European Investment Bank in 2007, the green bond market has grown for sixteen consecutive years. In 2021, the Climate Bonds Initiative (CBI) reported a record USD 517.4 billion in new green bonds issued globally, marking the first time the market surpassed the USD 500 billion threshold and achieving a decade of continuous high growth [9]. By March 2022, China's green bond market, one of the fastest-expanding, reached a stock size of over 1.8 trillion CNY, positioning it as a leading participant in the global green bond market, second only to Germany.

Research on green bond pricing yields mixed results. Baker et al. [10] and Zerbib [11] found evidence of a green bond premium, suggesting that investors are willing to accept lower yields for environmentally beneficial assets. However, numerous other studies have not identified such a premium [12–17]. Moreover, the impact of geopolitical risk on the green bond market remains underexplored, with existing studies using varying methodologies and reaching inconsistent conclusions [7,18]. Geopolitical risks, including international conflicts, terrorism, and national tensions, introduce complexities and uncertainties that can affect investor confidence and market stability.

This study utilizes a dataset comprising 270 green bonds and 667 conventional bonds obtained from the Wind Economic Database and corporate financial reports, covering daily trading data from May 2018 to August 2021. First, a sample pool of green bonds was selected, and then a comparable pool of conventional bonds was constructed through a rigorous matching process. The baseline regression was conducted using the two-step method by Kripfganz and Schwarz [19]. To examine the impact of geopolitical risk on green bond

pricing, this study incorporated the global Geopolitical Risk Index (GPR), the Geopolitical Threats Index (GPRT), the Geopolitical Acts Index (GPRA), and the China Geopolitical Risk Index (GPR-China). Further analysis focused on the financial sector to explore the unique challenges and opportunities for green bond financing under geopolitical uncertainty.

Descriptive statistics indicate that green bonds constitute 28.8% of the total sample, with Chinese green bonds generally having higher ratings and larger issuance sizes. The empirical results reveal a green issuance premium of 10–12 basis points for green bonds compared to conventional bonds, indicating a significant pricing advantage in the Chinese market. Additionally, both recent and Historical GPR indices further reduce the financing costs of green bonds, with the China GPR index having the most substantial impact, lowering costs by up to 17.4 basis points. Analysis of the financial sector shows that green bonds do not exhibit any issuance premium, and the influence of geopolitical risk is slightly lower than in the overall market.

This study introduces three main innovations. Firstly, this study provides a comprehensive analysis of the impact of geopolitical risks on the pricing of Chinese green bonds. From the micro-perspective of bonds and issuers, this study contributes to the existing literature. By leveraging extensive microdata, this study explores the potential of green bonds as stable investment tools during periods of geopolitical uncertainty, reinforcing their role in sustainable finance. Secondly, the use of strict screening criteria and the latest two-stage panel estimation method allowed more reliable analytical conclusions by pairing each green bond with a structurally similar conventional bond issued by the same entity, thereby eliminating multiple factors that could render them incomparable. This rigorous matching process advances the study of green bond pricing to a more precise level. The use of the latest two-stage panel estimation method, supplemented by various robust tests, enables us to draw more reliable analytical conclusions. Thirdly, we establish green bonds as reliable tools for sustainable investment and put forward several viable political recommendations. Regarding the study's conclusions, this research highlights the significant reduction in financing costs for Chinese green bonds due to geopolitical risks. It demonstrates both the green premium (issuance pricing advantage) and the risk-mitigation capability of green bonds under geopolitical uncertainty, establishing them as reliable tools for sustainable investment. These insights provide valuable guidance for policymakers, investors, and issuers in managing and mitigating these risks. For example, policymakers can enhance measures to reduce issuance costs and promote green bond market development, while investors can leverage the hedging capabilities of green bonds to achieve lower financing costs and greater environmental benefits.

The remainder of this study is organized as follows. Section 2 reviews the existing literature and develops the hypotheses. Section 3 details the research design, including the process of constructing the data pool and selecting variables. Section 4 discusses the empirical findings and robustness checks. Finally, Section 5 provides a conclusion.

2. Literature Review and Hypothesis Development

2.1. Green Bond Market

Since the European Investment Bank (EIB) issued the first 'Climate Awareness Bond' in 2007, green bonds have not only seen a continuous rise in total issuance but also an expansion in variety and geographic reach. For instance, Poland issued its first green sovereign bond in December 2016, followed by France in 2017. In the same year, the U.S.'s Fannie Mae issued USD 24.9 billion in green mortgage-backed securities. June 2017 marked Malaysia's issuance of the world's first green sukuk. Additionally, the range of issuers has broadened beyond the initial entities like the World Bank and International Finance Corporation to include commercial banks, non-bank financial institutions, and large corporations. Financial enterprises have played a pivotal role as frontrunners in adopting and advancing green bonds.

In the realm of publicly issued green bonds, financial institutions and corporations are the principal issuers, albeit with slightly different approaches to green bond functionality.

Corporate green bonds are typically designated for financing the issuer's own projects. Hence, they often have specific eligibility criteria for these projects. In contrast, financial entities such as commercial banks, investment firms, insurance companies, and diversified banking institutions generally use their green bonds to provide green loans to other companies. This model involves indirect investment in other firms' projects without direct involvement in green project construction, thus adhering to more general standards for green initiatives.

China's green bond market, which commenced at the end of 2015, has grown rapidly. In just one year, 2016, the issuance volume of China's green bonds surpassed one-third of the global total. By 2023, the domestic issuance reached CNY 854.854 billion across 481 issues. By the end of 2023, the cumulative issuance in China's domestic market reached 2192 issues, totaling CNY 3.46 trillion. Globally, China's issuance volume is second only to Germany, ranking second worldwide. This provides a solid empirical foundation for this study (Figure 1).

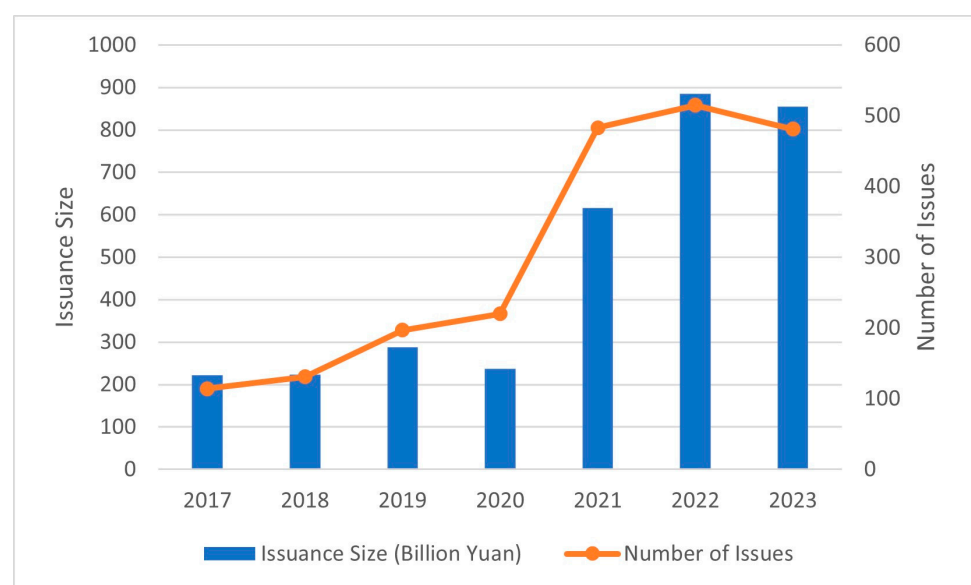


Figure 1. Green bond issuance trends in China (2017–2023). This figure shows the issuance size and volume of green bonds in China on an annual basis.

2.2. Exploring the Greenium: Pricing Green Bonds

The International Capital Markets Association (ICMA) characterizes a green bond as 'a debt security specifically intended to finance or refinance, in part or in full, new or existing eligible green projects' [20].

Green bonds inherently embody certain contradictions. On one hand, despite being fixed-income securities similar to conventional bonds, green bonds have distinct advantages. Their environmental attributes can expand the investor base and potentially secure longer-term, lower-cost capital. Beyond issuer benefits, from an investor perspective, green bonds not only fulfill green mandates but also enhance ESG ratings. On the other hand, green bonds also have inherent disadvantages. Issuers face higher initial costs and reputational risks, such as green certification, disclosure requirements, and the need for specialized personnel or teams. Regulators also encounter challenges due to the lack of a unified global standard for identifying green bonds, making oversight and enforcement a work in progress. The fragmented standards and labels may introduce uncertainty for investors, potentially slowing market growth. However, the difficulty in implementing a broadly accepted standard is understandable given the disparities in cultural, institutional, and economic development across regions. Additionally, while due diligence on environmental impacts is crucial for debt financing, investors, limited to indirect involvement in green projects, often rely on piecemeal information from corporate disclosures or third-

party verification, which can affect the market's trust in the environmental performance of green bonds.

Truly, the contradictions mentioned above contribute to the elusive international consensus on the pricing advantage of green bonds over conventional bonds. Research on green bond pricing reveals divergent views.

The first strand of literature identifies a willingness among market participants to pay a premium for environmentally beneficial assets, suggesting investors accept lower yields relative to conventional bonds. Baker et al. [10] initially introduced an asset pricing model that factored in green preferences and validated a 6 bps green premium in after-tax yields for US municipal green bonds. Similarly, Zerbib [11] discovered a modest yet significant 2 bps premium in the global secondary market through synthetic matched bond pairs and a DID approach. This foundational research prompted further studies by Febi et al. [21], Nanayakkara and Colombage [22], and Hyun et al. [23], who explored varying green premiums across different markets.

Conversely, a second group argues against the existence of a green premium. Karpf and Mandel [16], along with Larcker and Watts [24], found no green premium in the US municipal debt market, a finding echoed by Flammer [13] in the US corporate sector. Further research by Tang and Zhang [17] supported the absence of premiums in the global market. Meanwhile, a third category of studies, including those by Fatica et al. [25] and Kapraun and Scheins [26], presents mixed results, indicating an ongoing debate within the financial academic community regarding the valuation of green bonds.

Previous studies on green bonds have significant limitations, including improper comparisons between taxable and non-taxable bonds and a focus on specific European and U.S. markets that are not directly applicable to China due to distinct economic and financial environments. Additionally, research on China's green bond market often lacks large sample data and rigorous sample selection, limiting insights into recent developments.

Following the analysis, this study presents the subsequent competitive hypotheses:

Accounting for variables impacting credit spreads,

H_{1a}. *Green bonds and conventional bonds have equivalent pricing (green at par).*

H_{1b}. *Green bonds are priced above conventional bonds (green premium).*

H_{1c}. *Green bonds are priced below conventional bonds (green discount).*

2.3. The Geopolitical Risks and Green Bonds

As a novel sustainable investment tool, green bonds have garnered widespread attention. Green bonds not only help finance environmental projects but also provide economic returns for investors. However, as the global geopolitical environment becomes increasingly complex, the impact of geopolitical risk on the green bond market has become a focus of research.

Caldara and Iacoviello [27] describe geopolitical risk as the uncertainty stemming from international conflicts, terrorism, and national tensions, which disrupt the normal development of global relations. The European Central Bank's April 2017 Economic Bulletin and the International Monetary Fund's October 2017 World Economic Outlook both highlight geopolitical uncertainty as a major threat to the economic landscape, deepening these concerns.

Dong et al. [28] and Jernnäs and Linnér [29] elaborate on geopolitical risk, attributing it to complex economic, social, and political interactions between countries. These include political upheaval, trade conflicts, and policy changes, profoundly affecting global relations and stability. Geopolitical risks manifest in various forms: political instability (regime changes, internal unrest, and conflicts), trade conflicts (tariffs, sanctions, and protectionism), economic policy changes (currency fluctuations, sanctions, and financial crises), and security threats (terrorism, military conflicts, and territorial disputes), all impacting regional stability and global security.

Economic and policy uncertainties have garnered significant attention from investors and policymakers. These uncertainties, such as ambiguous government spending and monetary policy regulations, are linked to systemic financial risks [30]. Early scholars speculated that such uncertainties could potentially reduce market investment volumes [31]. In recent years, with the advancement in global economic and financial integration, frequent international trade and exchanges have led to increased conflicts and risks. Consequently, economic policy uncertainties have intensified, motivating investors to diversify risks by optimizing their portfolios. In this context, geopolitical risk, encompassing multiple uncertainty factors, has a complex and varied impact on the green bond market. This complexity helps explain why, despite numerous studies examining the performance of green bonds and other financial instruments, a definitive and consistent relationship between green bonds and geopolitical uncertainty has yet to be established.

This study will investigate the potential impact of geopolitical risks on green bond prices from two perspectives. This study explores both the negative and positive influences, considering various factors that may affect investor behavior and market dynamics.

On the one hand, several studies show that geopolitical risks may have a negative impact on green bond prices.

Firstly, geopolitical risks can negatively impact green bond prices by creating an atmosphere of uncertainty, which affects investor confidence. Adebayo et al. [32] and Rumokoy et al. [33] highlight that such uncertainty leads to increased investor caution and risk aversion, thereby reducing demand for bonds. He [34] notes that adverse geopolitical developments foster pessimism, prompting investors to adopt more risk-averse strategies. Bhatia [35] emphasizes that heightened geopolitical risks generally make investors more cautious, affecting bond market volatility. Hailemariam et al. [36] and Lee et al. [4] also point out that geopolitical risks negatively influence investor sentiment and bond market volatility.

Secondly, the impact of geopolitical risks on green bonds may be more pronounced compared to conventional bonds. Hachenberg and Schiereck [14] assert that green bonds, due to their close ties with environmental policies and regulations, are more susceptible to geopolitical tensions. Doğan et al. [37] further explain that geopolitical risks can influence environmental policies and regulations, directly affecting the value of green bonds. Ballouk et al. [38] note that geopolitical risks deter international green investors, leading to reduced liquidity in green bond investments.

Moreover, regulatory uncertainty induced by geopolitical risks can hinder the development of the green bond market. Falcone [39] suggests that regulatory changes triggered by geopolitical events affect investor confidence in the green bond market. Iyke et al. [40] emphasize that uncertainties in international capital flows due to geopolitical risks can limit the growth prospects of the green bond market.

On the other hand, geopolitical risks can also positively impact green bond prices. Despite the potential negative impacts, several studies suggest positive outcomes.

Zerbib [11], Baker et al. [10], and Flammer [13] argue that investing in green bonds not only offers high returns but also improves environmental performance. Huynh et al. [41] indicate that green bonds diversify investors' portfolios, providing economic benefits while supporting environmental protection. Kanamura [42] finds that green bonds outperform conventional bonds, making them valuable sustainable investment assets.

During periods of geopolitical uncertainty, green bonds emerge as a more stable investment choice. Li et al. [43] and Li and Cheng [44] note that green finance provides more stable investment opportunities during geopolitical uncertainties, encouraging investors to shift toward sustainable and alternative investments to mitigate risks. Guo and Zhou [45] also observe that green bonds outperform conventional bonds in terms of environmental and social impacts, attracting more environmentally conscious investors.

Additionally, green bonds offer certain advantages in addressing geopolitical risks. Flammer [13] and Pástor et al. [46] state that green bonds send positive environmental signals to the market, attracting both institutional and retail investors. Lee et al. [5] Re-

boredo [47], Duan et al. [48], Nguyen et al. [49], Dutta et al. [50], Le et al. [51], and Arif et al. [52] believe that green bonds can serve as effective hedging tools against geopolitical risks. Wang et al. [53] believe that the easing of GPR has boosted renewable energy cooperation and increased the demand for green bonds. Yang and Yang [54] and Marques et al. [55] note that high geopolitical risks prompt governments and corporations to accelerate the transition to renewable energy, thereby enhancing the returns on green bonds. Therefore, based on the eco-friendly nature of green bonds, this study hypothesizes that geopolitical risks are likely to increase green bond prices, reduce their yields, and further promote the attainment of greenium.

H₂. *Geopolitical risks could increase green bond prices, lower their yields, and further promote the attainment of greenium.*

From a comprehensive financial market perspective, geopolitical risks affect various asset classes differently. Broadstock and Cheng [56] highlight that macroeconomic indicators, including geopolitical risks and economic policy uncertainties, significantly impact financial markets. Gozgor et al. [57] emphasize that geopolitical risks profoundly influence investment decisions, thereby affecting the returns of related financial instruments. Apergis et al. [58] and Caldara and Iacoviello [27] note that the effects of geopolitical risks are particularly severe in countries experiencing heightened geopolitical turmoil.

In contrast, green bonds may exhibit relative stability under geopolitical risks compared to other financial instruments. Chopra and Mehta [59] investigated the hedging role of green bonds against U.S. equity sectors during the COVID-19 crisis and found that green bonds provided strong hedging benefits during this period. Wei et al. [60] employed wavelet analysis to examine the quantitative impact of economic policy uncertainty on green bond performance, discovering an asymmetric causal relationship. These studies suggest that green bonds offer certain hedging capabilities during periods of geopolitical uncertainty.

Based on these findings, this paper proposes the following hypothesis:

H₃. *In the financial industry, the impact of geopolitical risks on green bond prices is lower than the market average.*

Despite the significant influence of geopolitical risks on the overall financial market, green bonds, as a stable and sustainable investment tool, may demonstrate relative stability during periods of geopolitical uncertainty, making them a crucial choice for investors seeking to hedge and diversify their investments.

In conclusion, existing research examining the influence of geopolitical factors on the yield advantage of green bonds at a micro-level remains limited. Most studies have broadly analyzed the green bond market through related indices, with few focusing on individual bonds and issuers within emerging economies. Additionally, the diversity of research methodologies has led to a lack of consensus regarding the extent to which geopolitical risks impact green bond market price dynamics, despite substantial attention from both academia and industry. Consequently, this study proposes three hypotheses, based on the literature review, to further investigate the specific effects of geopolitical risks on the green bond market. The subsequent empirical analysis will test these hypotheses individually, offering critical insights for investors and policymakers.

3. Research Design

3.1. Sample Selection and Data Sources

The sample of 270 green bonds and 667 conventional bonds, sourced from the Wind Economic Database and corporate financial reports (annually, quarterly, and monthly), was compiled through a two-step process based on the methodologies used in prior research [10,11,13,24]. First, data-cleaning techniques refined the green bond sample according to established criteria, and then a closely matched sub-sample of conventional bonds was created. The Wind Economic Database provides detailed tranche-level bond issuance

data and is considered the most comprehensive repository for green securities in China. The final dataset covers daily trading data from May 2018 to August 2021, encompassing 6043 and 60,497 trading days for green and conventional bonds, respectively. This approach minimizes selection bias and establishes a robust database for further analysis.

After excluding floating and progressive rate bonds, green bonds issued by Chinese companies on overseas exchanges, bonds with structured terms, private placement and tax-exempt bonds, and those missing key indicators resulted in a pool of 270 green bonds from 136 issuers, covering 2010 months of valid data.

Second, this study established the conventional bond pool using Crabbe and Turner [61] matching methodology. Each green bond is matched with non-green bonds that have similar structure and bond characteristics, including currency, credit rating, interest rate type, coupon variety, tax rate, interest calculation, and repayment order. Bonds with special terms like cross-protection clauses or early repayment options are excluded. The remaining maturity variance between green and conventional bonds is limited to two years, and issuance dates cannot differ by more than six years, with exact matches preferred. A green bond can be matched with multiple conventional bonds if all criteria are met. Conventional bond issuance amounts range between one-fourth and four times the green bonds' value, and coupon rates vary within $\pm 0.25\%$. The final pool includes 667 conventional bonds covering 8904 months of valid data.

Finally, this study uses the China Securities Index (CSI) as the default-free bonds and applies the cubic spline interpolation method, similar to Karpf and Mandel [16], to create a corresponding matched pool for the green and vanilla sample bonds.

3.2. Variable Selection

3.2.1. Dependent Variable

Following previous studies [17,62,63], this study compares the yield to maturity of a green bond with that of a default-free bond with the same remaining maturity. The difference is used as the main dependent variable. In the robustness tests, we substitute the yield spread for the yield to maturity (YTM).

3.2.2. Independent Variable

To select green bond pricing determinants, this study draws from Campbell and Taksler [62], Chen et al. [63], Fama and French [64], and Badoer and James [65]. The independent variable, a green bond dummy, is labeled as 'Green'.

3.2.3. Moderating Variables

This study employs the Global Geopolitical Risk Index (GPR) developed by Caldara and Iacoviello [27] for empirical analysis. The index, based on news information, measures adverse geopolitical events and associated risks. It includes samples from about 25 million news articles published in mainstream English newspapers since 1900. The Recent GPR Index and the Historical GPR Index include approximately 30,000 and 10,000 monthly articles, respectively. The Recent GPR Index starts in 1985, while the Historical GPR Index dates back to 1900, with the latter covering a narrower range of newspapers (specifically, the Recent GPR Index is derived from automated text searches of the electronic archives of ten newspapers: the Chicago Tribune, the Daily Telegraph, the Financial Times, the Globe and Mail, the Guardian, the Los Angeles Times, the New York Times, USA Today, the Wall Street Journal, and the Washington Post. The Historical GPR Index, on the other hand, is based on searches of historical archives from three newspapers: the Chicago Tribune, the New York Times, and the Washington Post).

Furthermore, for the GPR and GPRH indices, this paper also decomposes them into derivative indices, the geopolitical acts index (gpra; gprha) (the names within parentheses represent the forms used in the empirical section of this paper) and the geopolitical threats index (gprt; gprht) for further analysis. Increases in these sub-indices, respectively, reflect

the occurrence or escalation of current adverse events and the anticipation and threats of future adverse geopolitical events.

Lastly, since the aforementioned indices are global, encompassing 39 countries and regions, and the green finance data originate from China, this study further employed the China Geopolitical Risk Index (GPRC-China, abbreviated as chn and chnh in this paper) to conduct additional analyses. Figure 2 shows the time trend graphs of the monthly geopolitical risk indices used in the sample of this paper.

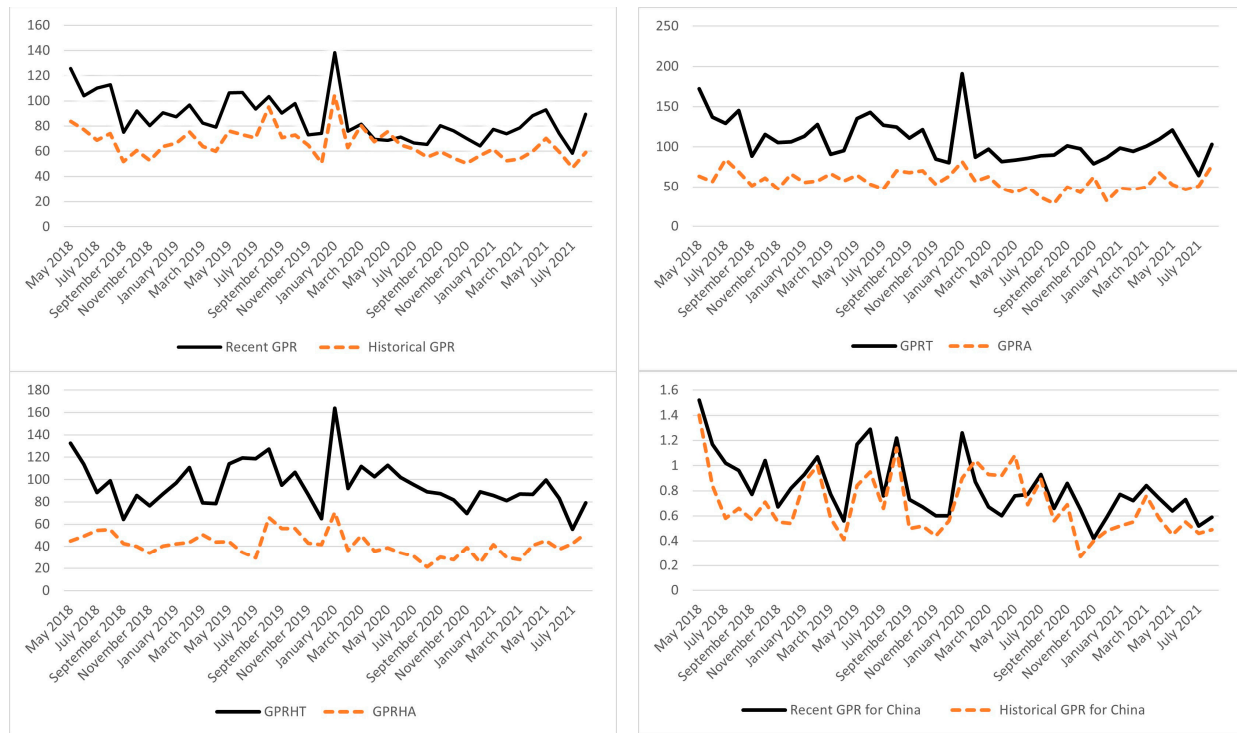


Figure 2. GPR index trend figure (May 2018–August 2021).

3.2.4. Control Variables

Factors influencing the credit spread of green bonds include the bonds' green attributes and essential control variables, categorized into bond and issuer characteristics, and macroeconomic conditions. The selection of control variables follows prior research [24,62,63,65,66].

The first category of control variables covers basic bond characteristics: maturity ($L_{maturity}$), rating ($Rating_2$), third-party certification ($certified$), liquidity ($Turnover$), volatility (MIR), and the log of total initial issuance ($Bondsize$).

The second category of control variables includes basic issuer characteristics, such as the log of the firm's age ($LnFage$) and monthly issuance ($IssueSize$ (the monthly bond issuance size proportion ($IssueSize$) is a widely used control variable in the study of green bond premiums. It is generally used to represent the cross-sectional differences in bond liquidity and is calculated as the proportion of the monthly issuance volume to the total issuance volume up to and including the current month, expressed in deciles)).

The third type of control variable reflects macroeconomic trends, represented by the benchmark treasury yield, which also indicates the interest rate term structure.

All continuous variables are winsorized at the 1% and 99% levels (alternative thresholds (0%, 2%, 5%, 10%, 20%, and 25%) were tested before selecting a 1% threshold. This study's results are not significantly affected by varying screening thresholds), and value variables are adjusted to constant prices with May 2018 as the base period to eliminate price factor effects (Table 1).

Table 1. Variables.

Basic Char.	Indicators	Descriptions
Dependent variable	Ysprd1	The yield to maturity of a bond minus that of a default-free bond with the same remaining maturity
	YTM	The yield to maturity of a bond
Independent variable	Green	Green = 1, if the bond is labeled as green bond; otherwise, Green = 0
Moderating variables	gpr	Recent Global Geopolitical Risk (GPR) Index
	gprh	Historical GPR Index
	gprrt	Geopolitical threats index
	gprra	Geopolitical acts index
	chn	GPR for China
	chnh	Historical GPR for China
	gprrht	Historical GPR threats index
	gprrha	Historical GPR acts index
Control Variables	Lmaturity	The logarithm of the bond's maturity
	Rating2	Policy bank bond = 6, aaa = 5, aa+ = 4, aa = 3, aa− = 2, a+ = 1, etc.
	Certified	Certified = 1 (got a third-party certification); otherwise = 0
	Bondsize	The total initial issuance
	Turnover	Monthly bond turnover (liquidity)
	MIR	CSI 300 Index Avg. Monthly Return
	Issers	LnFage IssueSize The logarithm of the firm's age Monthly issuance
	Macroec.	Treasury The benchmark treasury yield indicator

3.3. Model Specification

Even bonds issued by the same issuer (green versus conventional) can differ in quantitative aspects (such as issuance volume or duration) and qualitative factors (including specific clauses), making direct comparisons challenging. To address these issues and assess price differentials between green and conventional bonds, this study adopts a standardized yield-generating equation. Building on the asset pricing model developed by Baker et al. [10], which incorporates green preferences inspired by Fama and French [64], this study examines the green bond premium. Additionally, drawing on research by previous scholars [11,13,24,63], this study sets the econometric model as follows:

$$Y_{i,b,t} = \beta_0 + \beta_1 Green_{i,b,t} + \beta_2 \vec{X}_{i,b,t} + \sigma_i + \eta_t + \varepsilon_{i,b,t} \quad (1)$$

$Y_{i,b,t}$ represents the yield to maturity or yield spread at issuance for bond b by issuer i at time t . The variable $Green_{i,b,t}$ indicates whether a bond is a Green Bond (1) or not (0). $\vec{X}_{i,b,t}$ encompasses characteristics influencing the yield. This study accounts for time-varying market factors with time fixed effects η_t and control for issuer-specific characteristics using issuer fixed effects σ_i . The error term is denoted by $\varepsilon_{i,b,t}$. Standard errors are clustered at the issuer level.

To further analyze the impact of geopolitical risks on the premium of green bonds, this study constructed the following econometric model:

$$Y_{i,b,t} = \beta_0 + \beta_1 Green_{i,b,t} + \beta_2 \vec{Z}_{i,b,t} + \beta_3 Green_{i,b,t} \times \vec{Z}_{i,b,t} + \beta_4 \vec{X}_{i,b,t} + \sigma_i + \eta_t + \varepsilon_{i,b,t} \quad (2)$$

where $\vec{Z}_{i,b,t}$ refers to the Recent GPR index (gpr), recent geopolitical threats index (gprrt), recent geopolitical acts index (gprra), Historical GPR index (gprh), historical geopolitical threats index (gprrht), historical geopolitical acts index (gprrha), China-specific Recent

GPR index (chn), and China-specific Historical GPR index (chnh). In the table presentation below, all variable names such as $Green_{i,b,t} \times \vec{Z}_{i,b,t}$ are represented as Ggpr, Ggprh, etc., respectively.

4. Empirical Results

4.1. Descriptive Statistics

The table below presents summary statistics for all bonds used in this study, including both green and conventional bonds. The average yield spread of the aggregate bond is 0.917, and the standard deviation is 0.575. Green bonds constitute 28.8% of the total, with 70.14% of these receiving third-party certification. The overall sample features high credit ratings (average above AAA), with an average remaining maturity of 32.52 months. The issuers have an average age of 19.8 years, and the average issuance size per bond is CNY 1.86 billion. The average monthly issuance proportion is 6.2%, with a monthly turnover rate of 0.6%. The CSI 300 Index Average Monthly Return is 4.4%, and the average coupon rate is 3.77% (Table 2).

Table 2. Descriptive statistical analysis.

Variables	N	Mean	Median	St. Dev	Min	Max
Ysprd1	37,480	0.917	0.875	0.575	−0.617	3.396
Green	37,480	0.288	0.000	0.453	0.000	1.000
certified	37,480	0.202	0.000	0.401	0.000	1.000
Rating2	37,480	4.931	5.000	0.885	1.000	6.000
Lmaturity	37,480	3.482	3.516	0.658	1.438	5.178
LnFage	37,480	5.470	5.595	0.414	3.989	6.157
BondSize	37,480	2.924	2.996	0.959	0.693	5.598
IssueSize	37,480	0.062	0.037	0.076	0.000	0.399
Turnover	37,480	0.006	0.000	0.018	0.000	0.128
MIR	37,480	0.044	0.029	0.268	−0.453	0.930
Coupon	37,480	3.771	3.680	0.678	2.370	5.900

This table presents summary statistics for green and conventional bonds, issuers, and measures of liquidity and volatility. The sample includes all unique issuers and covers the period from Q2 2018 to Q3 2021.

4.2. Green Bond Financing Costs

4.2.1. VIF Test

To avoid potential multicollinearity, this study first tested the overall regression model using the Variance Inflation Factor (VIF). The results, as shown in the Table 3, indicate a maximum VIF of 2.87 and an average VIF of 1.67, both well below the threshold of 10. Thus, the model does not exhibit multicollinearity in the conventional sense.

Table 3. Variance inflation factor (VIF) test results.

Variable	VIF	1/VIF
BondSize	1.43	0.699697
LnFage	1.30	0.769709
Green	2.87	0.347951
Turnover	1.10	0.906271
IssueSize	1.09	0.920146
Treasury	1.65	0.607670
MIR	1.01	0.987742
certified	2.84	0.352075
Lmaturity	1.77	0.563975
Rating2	1.68	0.595770
Mean VIF	1.67	

4.2.2. Green Bond Premium

As noted in Section 2, green bond pricing remains unresolved. Yet, bond market price movements have traditionally been seen as sensitive leading indicators of financial markets [67,68]. Therefore, to reliably analyze the relationship between geopolitical risk and green bond prices, addressing green bond pricing is essential.

This study used the two-stage estimation method by Kripfganz and Schwarz [19], which resolves the bias and inconsistency in coefficients of time-invariant variables that traditional methods face when the strong orthogonality assumption is violated. This approach enables more thorough experimental results under stricter conditions, enhancing deeper discussions.

The regression outcomes for the baseline model equation (1) using the specified estimation method are displayed in Table 4. Column 1 includes only basic bond characteristics as control variables, column 2 additionally controls for bond liquidity and volatility, column 3 incorporates issuer characteristics, and column 4 accounts for macroeconomic features. All model specifications control for individual effects and time effects.

Table 4. Analysis of green bond premium.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1
Green	−0.123 *** (−6.168)	−0.126 *** (−6.285)	−0.101 *** (−5.030)	−0.103 *** (−5.112)
Lmaturity	0.039 *** (5.242)	0.037 *** (4.944)	0.039 *** (5.159)	0.074 *** (4.710)
Rating2	−0.396 *** (−70.198)	−0.394 *** (−68.681)	−0.374 *** (−59.232)	−0.374 *** (−59.247)
MIR		−0.029 (−0.651)	−0.034 (−0.760)	−0.063 (−1.370)
Turnover		0.346 * (1.795)	0.230 (1.184)	0.213 (1.094)
IssueSize			−0.383 *** (−5.225)	−0.380 *** (−5.180)
LnFage			−0.135 *** (−9.753)	−0.135 *** (−9.784)
Treasury				−0.086 ** (−2.544)
BondSize	−0.002 (−0.271)	−0.001 (−0.201)	0.007 (1.163)	0.007 (1.161)
certified	−0.026 (−1.073)	−0.031 (−1.259)	−0.038 (−1.559)	−0.040 * (−1.658)
_cons	0.070 * (1.867)	0.065 * (1.740)	0.098 *** (2.618)	0.097 *** (2.587)
FEs	Y	Y	Y	Y
N	10,139	10,116	10,116	10,116

T statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

The findings reveal that including additional control variables has only a negligible impact on the premium for issuing green bonds, thus underscoring the robustness of the baseline regression. The results show that the green bond premium, progressively incorporating different control variables, ranges between 10 and 12 basis points. Credit Rating (Rating2) is a comprehensive indicator encompassing multidimensional information such as market, issuer, and bond data. In the table below, it can be seen that the higher the bond rating, the lower the yield spread. This is consistent with the conclusions of previous research and reflects that the bond rating is an effective risk indicator for the fixed-income securities market. In this model, the indicator representing bond liquidity, monthly turnover (Turnover), has an insignificant effect on the spread, while the monthly issuance amount (IssueSize) has a significant negative effect on the spread, with an impact

value of approximately -0.383 . As a proxy indicator for the amount of information released by the issuer to the market, the age of the firm (LnFage) has a significant negative effect on the spread. The higher the yield of treasury bonds (Treasury), representing the macro environment of the capital market, the lower the yield spread. The main results of these control variables are consistent with traditional expectations.

A fundamental measure of green bond pricing returns is the yield spread at issuance. Hence, these results suggest that green bonds achieve a pricing benefit of approximately 10–12 basis points over conventional bonds, offering issuers a significant pricing advantage. This indicates that green bonds have a pricing edge over matched conventional bonds. Furthermore, from the perspective of market investors, there is a positive willingness to bear the costs for environmentally friendly products, providing regulators with viable solutions to foster the growth of the green market, promote healthy market interactions, and address substantial funding gaps in sustainable transitions.

The results concluded from Table 4 display that green bonds have an issuance cost advantage compared to conventional bonds, which supports H_{1b} .

4.3. Geopolitical Risk and Green Bond Financing Costs

Having laid the foundation for assessing green bond financing costs, this section is dedicated to exploring the correlations between the prices of geopolitical risks and the pricing of green bonds. This study first examines the relationship between Recent GPR and the financing costs of green bonds, followed by an analysis of Historical GPR's impact on these costs. Finally, this study conducts a focused study on the financial sector to gain deeper insights into the opportunities and risks associated with its green transition.

4.3.1. Recent GPR and Green Bond Financing Costs

Table 5 reports empirical results on the impact of Recent GPR on green bond pricing, showing that geopolitical risk fluctuations significantly modulate the green bond premium. Column 2 illustrates that an increase in global geopolitical risks reduces the relative price of green bonds by 0.2 bps. The results from columns 3–4 indicate that the GPR threats index and GPR acts index decrease green bond prices by 0.1 bps and 0.2 bps, respectively, with the acts index having a slightly greater effect. Column 5 reveals that the China GPR index significantly affects Chinese green bond pricing, reducing costs by as much as 16.7 bps for issuers.

Table 5. Recent GPR and green bond financing costs.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
Green	−0.103 *** (−5.112)	0.030 (0.833)	0.055 (1.483)	0.011 (0.354)	0.034 (1.000)
gpr		0.026 *** (40.149)			
Ggpr		−0.002 *** (−9.949)			
gprt			0.019 *** (40.153)		
Ggprt			−0.001 *** (−9.952)		
gpra				0.041 *** (33.652)	
Ggpra				−0.002 *** (−9.787)	
chn					3.093 *** (35.623)
Gchn					−0.167 *** (−9.683)

Table 5. Cont.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
Treasury	−0.086 ** (−2.544)	−0.094 *** (−2.778)	−0.093 *** (−2.747)	−0.097 *** (−2.863)	−0.091 *** (−2.694)
IssueSize	−0.380 *** (−5.180)	−0.351 *** (−4.812)	−0.352 *** (−4.823)	−0.350 *** (−4.787)	−0.357 *** (−4.895)
LnFage	−0.135 *** (−9.784)	−0.119 *** (−8.630)	−0.119 *** (−8.624)	−0.120 *** (−8.706)	−0.120 *** (−8.655)
MIR	−0.063 (−1.370)	0.991 *** (19.431)	1.094 *** (20.998)	1.154 *** (18.599)	0.152 *** (3.043)
Turnover	0.213 (1.094)	0.495 ** (2.532)	0.495 ** (2.530)	0.482 ** (2.464)	0.492 ** (2.516)
Lmaturity	0.074 *** (4.710)	0.072 *** (4.633)	0.072 *** (4.597)	0.074 *** (4.738)	0.071 *** (4.557)
Rating2	−0.374 *** (−59.247)	−0.389 *** (−60.230)	−0.389 *** (−60.234)	−0.389 *** (−60.204)	−0.389 *** (−60.155)
BondSize	0.007 (1.161)	0.003 (0.270)	0.002 (0.190)	0.007 (0.719)	0.001 (0.107)
certified	−0.040 * (−1.658)	0.124 *** (3.031)	0.086 ** (2.069)	0.084 ** (2.313)	0.111 *** (2.864)
_cons	0.097 *** (2.587)	0.243 *** (3.863)	0.233 *** (3.622)	0.181 *** (3.239)	0.252 *** (4.213)
FEs	Y	Y	Y	Y	Y
N	10,116	10,116	10,116	10,116	10,116

T statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

4.3.2. Historical GPR and Green Bond Financing Costs

Table 6 presents the empirical results of Historical GPR's effect on green bond pricing, indicating that fluctuations in historical geopolitical risks significantly modulate the green bond premium, consistent with the effects observed from Recent GPR. As shown in column 2, an increase in global historical geopolitical risks decreases the relative price of green bonds by 0.2 bps, identical to the impact of the Recent GPR index. Columns 3–4 demonstrate that the Historical GPR threats index reduces green bond prices by 0.1 bps and the GPR acts index by 0.3 bps, with the acts index showing a slightly greater impact and more so than the Recent GPR acts index. Column 5 reveals that the China Historical GPR index has a significant effect on Chinese green bond pricing, reducing financing costs by up to 17.4 bps, which surpasses the 16.7 bps impact of the Recent China GPR index, offering substantial cost advantages to issuers.

Table 6. Historical GPR and green bond financing costs.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
Green	−0.103 *** (−5.112)	0.034 (0.933)	0.037 (0.912)	0.015 (0.475)	0.028 (0.628)
gprh		0.034 *** (40.090)			
Ggprh		−0.002 *** (−9.700)			
gprht			0.022 *** (40.067)		
Ggprht			−0.001 *** (−9.621)		
gprha				0.052 *** (40.177)	
Ggprha				−0.003 ***	

Table 6. Cont.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
				(−9.612)	
chnh					2.527 *** (33.041)
Gchnh					−0.174 *** (−8.812)
Treasury	−0.086 ** (−2.544)	−0.093 *** (−2.751)	−0.091 *** (−2.704)	−0.097 *** (−2.877)	−0.090 *** (−2.680)
IssueSize	−0.380 *** (−5.180)	−0.354 *** (−4.845)	−0.355 *** (−4.866)	−0.352 *** (−4.820)	−0.360 *** (−4.925)
LnFage	−0.135 *** (−9.784)	−0.119 *** (−8.635)	−0.119 *** (−8.627)	−0.121 *** (−8.740)	−0.121 *** (−8.776)
MIR	−0.063 (−1.370)	0.916 *** (18.203)	1.069 *** (20.608)	1.281 *** (23.574)	0.986 *** (15.052)
Turnover	0.213 (1.094)	0.500 ** (2.554)	0.499 ** (2.550)	0.479 ** (2.451)	0.474 ** (2.419)
Lmaturity	0.074 *** (4.710)	0.072 *** (4.633)	0.072 *** (4.589)	0.075 *** (4.766)	0.072 *** (4.616)
Rating2	−0.374 *** (−59.247)	−0.389 *** (−60.161)	−0.389 *** (−60.145)	−0.388 *** (−60.159)	−0.387 *** (−59.963)
BondSize	0.007 (1.161)	0.002 (0.155)	−0.000 (−0.015)	0.004 (0.476)	−0.003 (−0.259)
certified	−0.040 * (−1.658)	0.122 *** (3.010)	0.153 *** (3.334)	0.096 *** (2.646)	0.184 *** (3.612)
_cons	0.097 *** (2.587)	0.255 *** (4.067)	0.291 *** (4.115)	0.210 *** (3.735)	0.340 *** (4.339)
FEs	Y	Y	Y	Y	Y
N	10,116	10,116	10,116	10,116	10,116

T statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

In sum, by Tables 5 and 6, the results show that the geopolitical risks increase the prices of green bonds, thereby promoting a green premium, which corroborates the H_2 .

4.3.3. For Finance Industry

Table 7 presents empirical results on the impact of Recent GPR on green bond pricing. Overall, fluctuations in global geopolitical risks significantly modulate the green bond premium, consistent with previous findings. A notable distinction, as shown in the first column, is that in the financial sector, green bonds do not command a premium. This phenomenon is also related to the unique characteristics of the financial sector. In the financial industry, the issuance of green bonds predominantly serves to support local green development through green credit mechanisms. Financial institutions do not directly manage green financing projects. Consequently, this indirect involvement in green financing does not enable financial firms to achieve the cost-saving incentives that are typically available to companies that directly participate in the management of green bond projects.

Furthermore, within this sector, overall GPR, GPR threats, and GPR acts each reduce the financing costs of green bonds by only 0.1 bps, with the effects of the threats and acts indices being identical, diverging slightly from the larger impact observed in the full sample. The final column indicates that an increase in China's geopolitical risks significantly reduces the relative financing costs of green bonds by 8.8 bps, a reduction lower than the market average.

Table 8 details the empirical effects of Historical GPR on green bond pricing, showing that fluctuations in global historical geopolitical risks significantly modulate the green bond premium, in line with previous findings. In the financial sector, Historical GPR and Historical GPR threats each reduce the financing costs of green bonds by only 0.1 bps, while

the Historical GPR acts index reduces them by 0.2 bps, consistent with the full sample results. The final column reveals that an increase in China's historical geopolitical risks significantly lowers the relative financing costs of green bonds by 10 bps, slightly more than the 8.8 bps decrease seen with Recent China GPR, yet still below the market average.

Table 7. Recent GPR and green bond financing costs (finance industry).

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
Green	−0.080 (−1.299)	0.042 (0.431)	0.017 (0.171)	0.032 (0.368)	0.021 (0.226)
gpr		0.020 *** (17.088)			
Ggpr		−0.001 *** (−3.391)			
gprt			0.014 *** (17.068)		
Ggprt			−0.001 *** (−3.296)		
gpra				0.032 *** (16.150)	
Ggpra				−0.001 *** (−3.621)	
chn					2.336 *** (16.449)
Gchn					−0.088 *** (−3.045)
Treasury	−0.123 *** (−2.929)	−0.126 *** (−3.021)	−0.125 *** (−2.990)	−0.130 *** (−3.113)	−0.124 *** (−2.959)
IssueSize	−0.005 (−0.049)	0.017 (0.155)	0.016 (0.146)	0.019 (0.171)	0.010 (0.091)
LnFage	−0.090 *** (−3.414)	−0.084 *** (−3.165)	−0.083 *** (−3.156)	−0.085 *** (−3.202)	−0.084 *** (−3.159)
MIR	−0.078 (−1.320)	0.734 *** (9.626)	0.810 *** (10.323)	0.832 *** (9.432)	0.087 (1.344)
Turnover	2.331 *** (7.566)	2.363 *** (7.679)	2.365 *** (7.681)	2.356 *** (7.659)	2.361 *** (7.669)
Lmaturity	0.036 * (1.845)	0.031 (1.555)	0.030 (1.539)	0.032 (1.623)	0.030 (1.547)
Rating2	−0.248 *** (−27.005)	−0.259 *** (−26.635)	−0.259 *** (−26.599)	−0.260 *** (−26.788)	−0.259 *** (−26.464)
BondSize	−0.074 *** (−8.188)	−0.063 *** (−4.708)	−0.062 *** (−4.605)	−0.064 *** (−5.314)	−0.064 *** (−5.065)
certified	−0.033 (−0.527)	0.044 (0.449)	0.054 (0.542)	0.012 (0.141)	0.053 (0.565)
_cons	−0.051 (−1.049)	0.066 (1.480)	0.100 ** (2.278)	0.108 ** (2.199)	0.155 *** (3.291)
FEs	Y	Y	Y	Y	Y
N	3892	3892	3892	3892	3892

T statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

In conclusion, as seen in Tables 7 and 8, the results indicate that the impact of such exogenous shocks (GPR and GPRH) exhibit industry-specific characteristics in the financial sector, which add to the H_3 .

Table 8. Historical GPR and green bond financing costs (finance industry).

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1	(5) Ysprd1
Green	−0.080 (−1.299)	0.038 (0.399)	0.050 (0.473)	0.031 (0.348)	0.053 (0.454)
gprh		0.026 *** (17.094)			
Ggprh		−0.001 *** (−3.422)			
gprht			0.017 *** (17.070)		
Ggprht			−0.001 *** (−3.333)		
gprha				0.039 *** (17.142)	
Ggprha				−0.002 *** (−3.557)	
chnh					1.899 *** (15.768)
Gchnh					−0.100 *** (−2.885)
Treasury	−0.123 *** (−2.929)	−0.126 *** (−3.017)	−0.124 *** (−2.969)	−0.132 *** (−3.153)	−0.125 *** (−2.983)
IssueSize	−0.005 (−0.049)	0.014 (0.123)	0.012 (0.109)	0.016 (0.148)	0.004 (0.040)
LnFage	−0.090 *** (−3.414)	−0.084 *** (−3.160)	−0.083 *** (−3.144)	−0.085 *** (−3.226)	−0.085 *** (−3.201)
MIR	−0.078 (−1.320)	0.678 *** (9.070)	0.792 *** (10.166)	0.958 *** (11.526)	0.734 *** (8.007)
Turnover	2.331 *** (7.566)	2.366 *** (7.687)	2.368 *** (7.691)	2.357 *** (7.661)	2.359 *** (7.660)
Lmaturity	0.036 * (1.845)	0.030 (1.549)	0.030 (1.518)	0.033 * (1.669)	0.031 (1.598)
Rating2	−0.248 *** (−27.005)	−0.260 *** (−26.604)	−0.260 *** (−26.567)	−0.260 *** (−26.765)	−0.258 *** (−26.437)
BondSize	−0.074 *** (−8.188)	−0.063 *** (−4.750)	−0.062 *** (−4.234)	−0.064 *** (−5.242)	−0.062 *** (−3.924)
certified	−0.033 (−0.527)	0.052 (0.526)	0.065 (0.592)	0.030 (0.334)	0.081 (0.668)
_cons	−0.051 (−1.049)	0.069 (1.601)	0.260 *** (4.347)	−0.038 (−0.760)	0.241 *** (4.163)
FEs	Y	Y	Y	Y	Y
N	3892	3892	3892	3892	3892

T statistics in parentheses, * $p < 0.1$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

4.4. Robustness Tests

4.4.1. Switching the Regression Method to LSDV

To enhance the reliability of the results, this study employs the traditional Least Square Dummy Variable (LSDV) method for regression. Recognized as equivalent to the Fixed Effects Model [69], LSDV excels by allowing for the estimation of individual heterogeneity. This study leverages this advantage by including year-month and issuer dummy variables, which control for time and individual effects. Additionally, this study uses issuer-specific cluster-robust standard errors to accommodate moderate correlations among observations within the same entity.

The Table 9 shows that using the LSDV method yields conclusions consistent with the baseline regression. In the primary market, green bonds exhibit a significant green premium of approximately 10 basis points.

Table 9. Green bond pricing analysis—LSDV estimation.

	(1) Ysprd1	(2) Ysprd1	(3) Ysprd1	(4) Ysprd1
Green	−0.103 *** (−5.259)	−0.108 *** (−5.494)	−0.090 *** (−5.599)	−0.091 *** (−5.611)
Lmaturity	0.010 (0.286)	0.005 (0.151)	0.008 (0.218)	0.041 (1.008)
Rating2	−0.302 *** (−11.941)	−0.299 *** (−11.963)	−0.288 *** (−10.418)	−0.288 *** (−10.415)
BondSize	−0.030 (−1.128)	−0.027 (−1.038)	−0.019 (−0.731)	−0.020 (−0.739)
certified	0.003 (0.034)	−0.000 (−0.003)	−0.009 (−0.090)	−0.009 (−0.087)
MIR		3.554 *** (2.725)	3.252 ** (2.467)	4.174 *** (2.969)
Turnover		0.854 * (1.895)	0.691 (1.409)	0.673 (1.372)
IssueSize			−0.188 (−1.387)	−0.186 (−1.365)
LnFage			−0.098 (−1.585)	−0.098 (−1.592)
Treasury				−0.081 * (−1.931)
_cons	2.585 *** (12.336)	2.349 *** (13.029)	2.856 *** (8.696)	2.946 *** (9.018)
FEs	Y	Y	Y	Y
N	10,139	10,116	10,116	10,116
adj. R ²	0.399	0.399	0.402	0.402
F	10.983	10.745	10.475	10.450

T statistics in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects. Moreover, bond-level clustering robust standard errors are employed so that it will allow for moderate correlation between observations of the same bond.

4.4.2. Dependent Variable Substitution

In the primary market, substituting the credit spread with the yield to maturity as the dependent variable maintains robust conclusions (to save space, further regression using the LSDV method is not presented here, but the conclusions remain robust. Please contact the author if needed) (Table 10).

Table 10. Dependent variable substitution.

	(1) YTM	(2) YTM	(3) YTM	(4) YTM
Green	−0.226 *** (−7.300)	−0.210 *** (−6.765)	−0.208 *** (−6.701)	−0.213 *** (−6.752)
Lmaturity	0.048 *** (4.378)	0.067 *** (6.077)	0.058 *** (5.312)	0.137 *** (5.995)
Rating2	−0.265 *** (−31.868)	−0.283 *** (−33.907)	−0.292 *** (−31.679)	−0.292 *** (−31.698)
MIR		−0.136 ** (−2.080)	−0.144 ** (−2.214)	−0.210 *** (−3.123)
Turnover		−3.855 *** (−13.706)	−3.581 *** (−12.645)	−3.620 *** (−12.786)
IssueSize			−1.219 *** (−11.413)	−1.212 *** (−11.349)
LnFage			−0.049 ** (−2.414)	−0.049 ** (−2.460)
Treasury				−0.194 ***

Table 10. Cont.

	(1) YTM	(2) YTM	(3) YTM	(4) YTM
BondSize	0.030 *** (3.139)	0.021 ** (2.236)	0.021 ** (2.186)	(−3.924) 0.021 ** (2.162)
certified	0.020 (0.551)	0.021 (0.562)	0.037 (0.979)	0.031 (0.816)
_cons	−0.115 ** (−1.992)	−0.072 (−1.237)	−0.049 (−0.843)	−0.051 (−0.869)
FEs	Y	Y	Y	Y
N	10,139	10,116	10,116	10,116

T statistics in parentheses, ** $p < 0.05$, *** $p < 0.01$. The FEs include year-month fixed effects and individual issuer effects.

4.4.3. Propensity Score-Matching Method for Green Bonds

This study established stringent criteria for sample selection, ensuring bonds issued by the same entity had closely matched characteristics. All regressions rigorously controlled for time and issuer effects and incorporated extensive control variables into the baseline model to mitigate endogeneity issues arising from reverse causality and omitted variables. Building on this framework, this study opted for a two-stage panel regression approach, offering greater robustness than the GMM method. Despite these measures, attention must still be given to potential endogeneity bias.

This study employs observational data, not derived from a natural random experiment, potentially leading to self-selection bias due to issuers' decisions on whether to issue green bonds, which could cause inconsistent estimates. To address these issues, the PSM method was implemented. This approach reduces the sample size, allowing for a more rigorous comparison of pricing differences between green and conventional bonds under stricter matching criteria.

Table 11, columns (1) to (8), presents eight matching methods used to validate primary market pricing of green bonds: one-to-one nearest neighbor, one-to-four nearest neighbor, caliper, radius, kernel, local linear regression, spline, and Mahalanobis matching.

Table 11. PSM method for green bonds.

	(1) NN = 1	(2) NN = 4	(3) Cal(0.01)	(4) Radius	(5) Kernel	(6) LLR	(7) Spline	(8) Maha
ATT	−0.111	−0.136	−0.134	−0.118	−0.061	−0.095	−0.138	−0.089
T-stat	−3.19	−4.88	−4.83	−4.72	−3.47	−3.71	0.000(P)	−4.04
S.E.	0.035	0.028	0.028	0.025	0.024	0.035	0.022	0.022
On support	9063	9059	9055	9055	9059	9059	9062	9078
Off support	15	19	23	23	19	19	16	0

Collectively, the Average Treatment Effect on the Treated (ATT) aligns with prior findings regarding both the magnitude and significance, further reinforcing the robustness of the benchmark results regardless of the empirical methods applied.

5. Conclusions

This study examines the relationship between geopolitical risks and green bond premiums based on the daily transaction data from the Chinese bond market between May 2018 and August 2021, along with the global geopolitical risk index, the China geopolitical risk index, the geopolitical threats index, and the geopolitical acts index. The results show that (1) Green bonds have an issuance cost advantage compared to conventional bonds, which supports H_{1b} . Specifically, green bonds achieve a green premium of approximately 10–12 basis points over conventional bonds in the primary bond market of China, offering

issuers a significant pricing advantage, which indicates that green bonds have a pricing edge over conventional bonds; (2) Geopolitical risks increase the prices of green bonds, thereby promoting a green premium, which corroborates H_2 . Details are as follows. First, Recent GPR and Historical GPR both increase the price of green bonds by 0.2 basis points. The sub-index GPR threats similarly increase by 0.1 basis points. A slight difference is observed in the price impact of the sub-index GPR acts: Recent GPR acts increase by 0.2 bps, while Historical GPR acts increase by 0.3 bps, indicating a marginally greater effect of Historical GPR acts. Second, the China GPR index has the most significant impact on increasing the price of Chinese green bonds. Specifically, the Recent China GPR index and the Historical China GPR index result in substantial cost savings of 16.7 basis points and 17.4 bps, respectively, representing considerable savings for issuers. (3) The impact of such exogenous shocks exhibits industry-specific characteristics in the financial sector, which add to the H_3 : first, green bonds in the financial sector do not exhibit issuance premiums, likely due to the indirect involvement of financial institutions in green projects. Second, both Recent and Historical GPR contribute to a green premium of 0.1 bps, which is lower than the industry-wide average of 0.2 bps. The impact of their sub-index, GPR threats, aligns with the industry average. However, the effects of GPR acts differ slightly: Recent GPR acts reduce the cost by 0.1 bps, and Historical GPR acts reduce it by 0.2 bps, both 0.1 bps below the industry average. Third, the China GPR index continues to have the most significant impact on increasing the price of Chinese green bonds. The Recent China GPR index and Historical China GPR index result in substantial cost savings of 8.8 bps and 10 bps, respectively. Although these figures are lower than the industry average, they still represent significant savings for issuers, indicating a strong market willingness to share the costs of sustainable transition.

Based on the above results, the following policy recommendations are proposed:

First, the findings indicate that green bonds in China's primary market achieve a green premium of approximately 10–12 basis points, offering issuers a significant pricing advantage. Therefore, policymakers should implement measures such as tax incentives, subsidies, and streamlined issuance procedures to further reduce the issuance costs of green bonds and enhance market attractiveness. Additionally, market promotion should be strengthened to raise awareness among potential issuers and investors about the pricing benefits and the positive environmental and social impacts of green bonds, thereby expanding market participation.

Second, given that both recent and historical geopolitical risk indices reduce green bond financing costs by 0.2 basis points, policymakers should encourage financial institutions and enterprises to develop and utilize risk-management tools to mitigate geopolitical risks and stabilize financing costs. Furthermore, international cooperation should be intensified to improve coordination in addressing geopolitical risks, particularly through policy dialogue and information sharing with major economies, to mitigate the adverse effects of geopolitical tensions on the green bond market.

Third, the results show that the China GPR index significantly impacts the reduction in financing costs for Chinese green bonds. Therefore, targeted support policies should be introduced, such as the establishment of special green funds and the provision of low-interest loans, to alleviate the adverse effects of geopolitical risks on green project financing. Moreover, regional green financial cooperation should be promoted, especially under the framework of the 'Belt and Road Initiative,' to share the costs of sustainable transition and jointly address geopolitical risks.

Additionally, this study found that green bonds in the financial sector do not exhibit issuance premiums, likely due to the indirect involvement of financial institutions in green projects. Hence, policymakers should encourage financial institutions to increase direct investment and management of green projects to enhance their proactivity and influence in green finance. Simultaneously, financial institutions should devise effective risk-diversification strategies to mitigate the impact of geopolitical risks on their investment portfolios.

Through the empirical analysis of geopolitical risk indices and green bond premiums, it is evident that geopolitical risks not only affect the financing costs of green bonds but also reveal the market's strong commitment to sustainable development. Policymakers should use these findings to formulate and adjust policies that promote the development of the green bond market, enhancing the stability and sustainability of financial markets. Investors and issuers should actively address geopolitical risks and leverage the advantages of the green bond market to achieve lower financing costs and greater environmental benefits.

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