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Geopolitical Risk and Renewable Energy: The Role of Green Bonds

ABSTRACT

Green bonds are financial instruments that enable the analysis of the impacts of geopolitical turbulence on investments in renewable energy. This study aimed to explore the relationship between these factors, considering the geopolitical risk index developed by Caldara and Iacoviello. Through a PRISMA review, four central themes were identified: hedging strategies, asset/portfolio diversification, volatility dynamics/transmission, and the energy transition. Many of the articles addressed more than one theme. However, the most and least frequently addressed topics were asset/portfolio diversification and the energy transition, respectively. The association between geopolitical risk, green bonds, and renewable energy was divided into three categories: risk management, sustainable development, and market positioning. The results of this study are relevant in two respects. First, there is a shortage of research focusing on the theme presented in this article. Second, the present study fills a gap identified in the literature while contributing to a better understanding of the impact of geopolitical risk on an instrument that operates in the context of the energy transition, climate change, and sustainable development.

Keywords: geopolitical risk, green bonds, PRISMA, renewable energy

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INTRODUCTION

There is no consensus in the literature on the definition of geopolitical risk (GPR). However, this study adopts the definition provided by Caldara and Iacoviello (2018a, 2022b). According to the authors, geopolitical risk refers to the risk associated with wars, terrorist acts, and tensions among states that affect the normal course of international relations. The geopolitical events considered include conflicts and acts that generate spillovers beyond a nation's borders. These conflicts are associated with territorial disputes that can involve corporations, rebel groups, political parties, and other actors. Historical and institutional contexts play a key role in the materialisation or escalation of such events, which often affect neighbouring countries and regions and, at times, have global repercussions. Drawing on this definition, Dario Caldara and Matteo Iacoviello developed an index that has been widely adopted in the literature.

The index was constructed based on publications from 11 newspapers: *The Boston Globe*, *The Chicago Tribune*, *The Daily Telegraph*, *The Financial Times*, *The Globe and Mail*, *The Guardian*, *The Los Angeles Times*, *The New York Times*, *The Times*, *The Wall Street Journal*, and *The Washington Post*. The GPR index data are available monthly and daily, with sub-indexes named “geopolitical threat” and “geopolitical act.” Among the available options are historical versions, recent versions, and country-specific versions (Caldara & Iacoviello, 2022). Although the article presenting the index was first published in 2018, databases such as Web of Science and Scopus display only the 2022 version. In both databases, the article has more than 1,000 citations, which demonstrates the strong interest of other researchers.

The interdisciplinary nature of geopolitical risk enables the index to be applied across various fields of knowledge. However, areas related to energy receive considerable attention. A body of literature examines the connection between wars, territorial disputes, and energy commodities. According to Yu et al. (2023), the scarcity of these resources is not the only driving force behind conflicts; their abundance can also play a role. Oil, popularly known as “black gold,” can be highlighted as a driver of wars, strategies, and alliances between countries throughout history (Patidar et al., 2024). Despite the strong relationship between fossil fuels and geopolitical disputes, attention is also given to other types of energy sources. According to Brutsching and Fleig (2018), periods of geopolitical turbulence give alternative energy sources a central role, especially with regard to the investments of oil net-importing countries. Renewable energy sources are among these alternatives.

The International Energy Agency (IEA) defines renewable energy as “all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy, hydro-power, ocean energy, solar energy, and wind energy” (IEA, 2022a). The geopolitics of renewables, often referred to as the geopolitics of the energy transition, provides insight into the positioning of certain countries within a global context characterised by the increasing prominence of renewable energy (Hafner & Tagliapietra, 2020). The age of fossil fuels is coming to an end, not because of the supply or availability of these resources, but because of their impacts on the atmosphere (Blondeel et

al., 2021; Hafner & Tagliapietra, 2020). The rise in Earth's temperature, as well as its implications, was discussed for the first time during the First Earth Summit in 1972 organised by the U.N. (United Nations) (U.N., 2007). Subsequently, the Kyoto Protocol (1997), the Paris Agreement (2015), and the adoption of the Sustainable Development Goals (SDGs) highlighted, at the international level, the relevance of climate and environmental issues.

Regarding the efforts made by governments, institutions, and other actors to combat climate change, investment in renewable energy has become one of the main tools. The Green Deal launched by the European Union (EU) in 2019 is an example illustrating the scale of efforts focusing on climate issues. The initiative aims to allocate around 1 trillion euros in sustainable finance for decarbonisation and the promotion of renewable energy production and adoption (EU, 2025). Initiatives focusing on the energy transition have also been observed in Japan through the GX (Green Transformation) strategy (Climate Bonds Initiative [CBI], 2025). Regardless of the specific plan, it is apparent that among the most widely implemented financial mechanisms are regulated carbon markets and green bonds (GB).

Green bonds (GB) are debt instruments used to finance or refinance new or existing sustainable projects. These bonds adhere to the guidelines of the Green Bond Principles (GBP), established by the International Capital Market Association (ICMA, 2025), which include objectives such as climate change mitigation, conservation of natural resources, and the prevention and control of pollution, among others. The first green bond was issued in 2007 by the European Investment Bank (EIB), followed by the World Bank, whose issuance was finalised in November 2008 (Cheong & Choi, 2020). Since then, the green bond market has grown rapidly and, in 2024, reached an issuance amount of around half a trillion dollars for the fourth consecutive year (CBI, 2025). These instruments affect the three dimensions of sustainability. However, the energy sector receives the most attention compared with other sectors (CBI, 2024).

The relationship between geopolitics and the energy sector has been explored in the literature mostly in contexts marked by geopolitical turbulence. Aishwarya and Muthumeenakshi (2024) conducted a bibliometric analysis and a PRISMA systematic review to identify research trends concerning geopolitical risk, finance, and relevant macroeconomic variables. The results indicated a concentration of the literature on the spillovers and volatility generated by GPR in oil markets, stock markets, renewable energy, bitcoin, and commodities. The predominance in the literature on GPR of topics related to oil has also been identified by Tamilselvan et al. (2024). The authors broaden Caldara and Iacoviello's definition to include events such as trade wars, man-made disasters, and conflicts between regional organisations, among others. Their bibliometric analysis indicated that the relationship between GPR and energy (oil and gas) is the most frequently studied topic.

Yu et al. (2023) conducted a bibliometric analysis of the governance of natural resources and geopolitical risk. The authors identified that prior to 2015, the literature focused on the relationship between natural resources and geopolitical risk. After 2015, attention shifted to the relationship between geopolitical risk and the governance of natural resources. The number of studies related to geopolitical risk has increased, not only with regard to the governance of these resources but also in areas connected to Sustainable Development (SD) (Wang et al., 2024). Wang et al. (2024) identified

a growing interest in this theme after 2019. In this strand of literature, some of the prominent topics include business development, food security, the energy sector, and global supply chains (GSC).

The relationship between geopolitics and GSC is also considered by Pandey and Kumar (2025), except that the focus is on the Indian energy transition. Given that renewable energy production requires specific inputs, the relationship between geopolitical turmoil and supply chain disruptions is highly relevant for countries that import these materials. Rare earths, copper, lithium, cobalt, and nickel have gained prominence because of their importance in green energy production, but their supply and processing are geographically concentrated (IEA, 2022b). Geopolitical turbulence has the potential to endanger and hinder the shift from a fossil-fuel-intensive system to a material-intensive one by disrupting global supply chains. Focusing on the impact of the energy transition, Vakulchuk et al. (2020) reviewed the literature on geopolitics and renewable energy. The authors identified five main themes. Among them are critical materials, cybersecurity, and the potential winners and losers of the energy transition.

Fossil-fuel-rich countries such as Russia, Venezuela, Saudi Arabia, and Iran are often depicted as losers in the energy transition. The worldwide adoption of renewable energy will likely promote a shift in global power dynamics, since these dynamics have long been influenced by dependence on and national control of fossil fuels (Hafner & Tagliapietra, 2020). A potential scenario in which countries have their oil, gas, or coal reserves stranded would have a direct economic impact and, consequently, lead to a geopolitical reshuffle. This reshuffle could be associated with a reduction in dependence on fossil fuels and an intensified search for critical materials (Wang et al., 2023). Countries such as Iceland and the Democratic Republic of Congo are perceived as winners given their territorial endowment of critical materials (Hafner & Tagliapietra, 2020; Vakulchuk et al., 2020). Regarding China and India, two major players in the global economy, there is no consensus on the position they occupy in this dynamic. However, some authors perceive them as winners given that they are not rich in fossil fuels and are rapidly adopting renewable energy (Hafner & Tagliapietra, 2020; Hassan et al., 2024). The same line of interpretation is observed in analyses of some EU countries (Hafner & Tagliapietra, 2020; Hassan et al., 2024; Makarov & Smolovic, 2026).

Geopolitical exposure to conflicts, access to alternative energy sources, as well as the historical and institutional context of a nation are of utmost relevance, as they are connected to a country's ability to foster renewable energy investment. Regulatory policies, the commitment to raising environmental awareness, improvements in infrastructure, and standardisation are among the factors that can promote green investment (Deschryver & Mariz, 2020). These measures often reflect a solid institutional framework, an advantage that nations frequently drawn into military conflicts and economies that are still developing may lack (Lisbinski & Burnquist, 2024; Rizvi & Véganzonès-Varoudakis, 2023).

However, the abundance of natural resources is perceived as a form of leverage. Brazil is one of the nations that does not display a robust institutional framework but has low geopolitical exposure to conflicts and wide access to alternative sources of energy. For these reasons, there is no consensus on the position that Brazil occupies as either a winner or a loser in the energy transition. Despite its

institutional fragility and fossil fuel reserves, the country has significant biofuel production and one of the cleanest energy matrices in the world (Hafner & Tagliapietra, 2020; Vega et al., 2024).

The intersection between GPR, renewable energy, and green finance encompasses all the aspects mentioned above, as it acknowledges geographical, cultural, and institutional characteristics. Understanding how these variables interact contributes to the advancement of humanitarian causes without neglecting the intrinsic attributes of the geopolitical landscape.

Despite the existence of bibliometric studies and systematic reviews on geopolitics, geopolitical risk, and their influence on renewable energy, studies focusing on the role of green bonds were not found. Most of the literature analyses the influence of geopolitics on renewable energy from a broader perspective without accounting for specific mediating mechanisms. Therefore, the present article fills a gap identified in the literature while contributing to the understanding of the impact of geopolitical risk on a financial mechanism that influences the energy transition, climate change, and sustainable development.

The objective of this article is to explore the relationship between geopolitical risk (GPR) and renewable energy while considering the role of green bonds, specifically the manner in which these factors are related and influence each other. To attain these objectives, a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) systematic literature review was conducted. The present article follows the PRISMA version employed by Pandey and Kumar (2025).

METHODS

Applying PRISMA in Systematic Literature Reviews

Literature reviews constitute the foundation on which academic research is built. However, exploring existing knowledge on a specific topic can be complex given the acceleration of scientific production. This factor may influence the quality and scope of reviews (Snyder, 2019). Many research articles include sections of bibliographic review that seek to support their discussions. Nevertheless, when applied as a methodology, reviews can assume different formats.

A systematic review is a research method that critically identifies and presents data from previous research on a specific topic (Liberatti et al., 2009). It is more meticulous than a simple theoretical background because it follows protocol-based eligibility criteria (Sharif et al., 2019). Systematic reviews can take different forms, but this study adopts the PRISMA format. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) is a set of guidelines created to improve the reporting of systematic reviews (PRISMA, 2020). It was originally designed for the healthcare field but has also been applied in other areas of knowledge.

Pahlevan-Sharif et al. (2019) applied PRISMA to explore systematic reviews in the tourism and hospitality literature. López et al. (2025) employed the PRISMA format in a content analysis focusing on the influence of geopolitics on supply chain disruptions. Aishwarya and Muthumeenakshi (2024)

conducted a bibliometric analysis and a PRISMA systematic review to identify research trends related to geopolitical risk in finance. Finally, Pandey and Kumar (2025) applied PRISMA to explore the literature concerning the risks associated with the gradual coal down-phase in India.

Among the studies mentioned, there are qualitative reviews (Pandey & Kumar, 2025) and mixed-approach reviews that employed automation tools to assess the quality of the studies (López et al., 2025). The reviews that did not use such tools were rigorous in selecting databases, relying on their indexing standards to ensure data quality.

Search Protocol for Systematic Review

The searches were conducted between April 15 and June 4 in Scopus (Elsevier) and Web of Science (WOS). Initially, different keyword combinations were tested. The final combination included the following terms: (“geopolitical risk” OR “geopolitical threat” OR “geopolitical act” OR “GPR index”) AND (“renewable energy” OR “clean energy” OR “energy transition” OR “energy security”) AND (“green bonds” OR “green finance”). The term “GPR index” refers to the geopolitical risk index, and its inclusion relates to this article’s objective of analysing works that utilised the index constructed by Caldara and Iacoviello.

After the keyword search, all works citing the index were selected. This approach ensured that studies adopting the authors’ definition of GPR were considered. Subsequently, the data concerning the authors, title, and abstract of each article were added to an Excel sheet for the application of the eligibility criteria.

Eligibility Criteria for Study Selection

The process of gathering and selecting the studies followed the criteria below:

1. Publication period: Works not published between 2018 and 2025 were excluded. This criterion reflects the fact that the first version of the index was published in 2018. Although the databases only include the 2022 version, this period was considered based on the assumption that some indexed articles could contain the first version of the index.
2. Publication type: Only research articles were considered. Therefore, book chapters and review articles were excluded.
3. Language: Only articles published in English were considered.
4. Usage of the GPR index: There are other GPR indices in the literature. However, this review adopts the definition proposed by Caldara and Iacoviello. Consequently, studies that did not use the authors’ index were excluded.

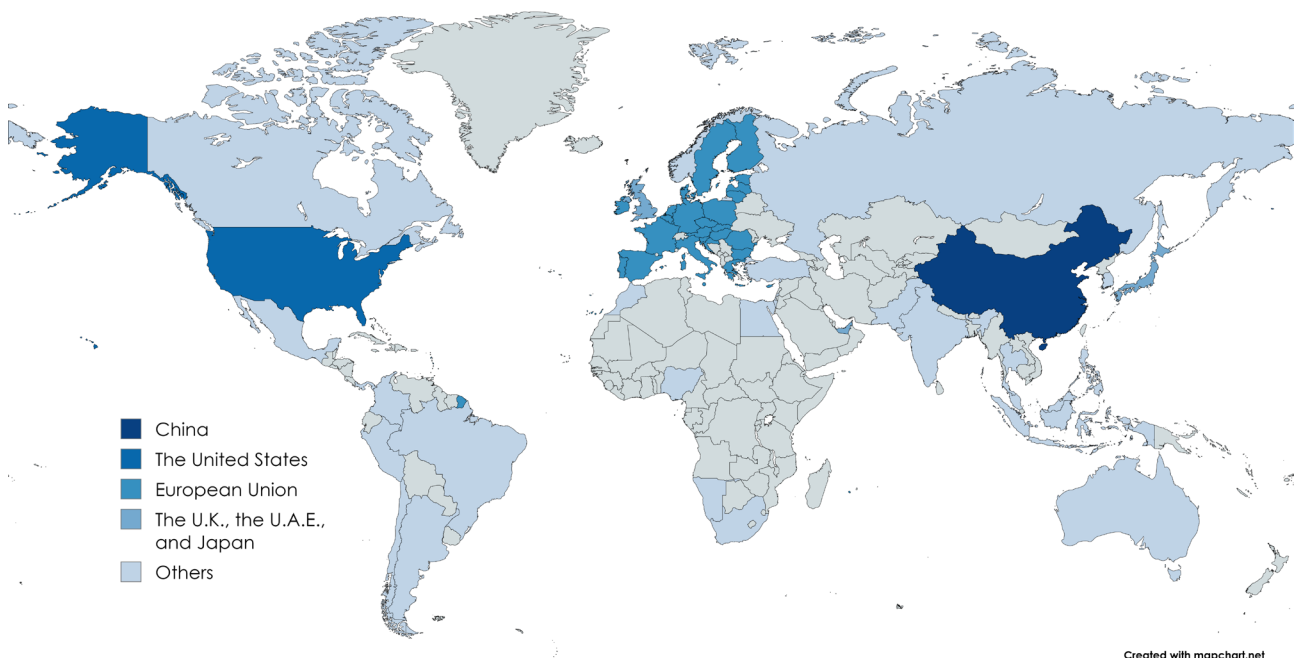
During the evaluation phase, the titles and abstracts were analysed to identify which works incorporated the three variables relevant to this review. Works that did not consider renewable energy, green bonds,

and Caldara and Iacoviello's GPR index were excluded. The remaining articles were included in the systematic review. Finally, categories were created to organise the relationships identified between green bonds, GPR, and renewable energy. The criteria used in the categorisation were the main themes discussed in each article.

RESULTS

Forty-eight articles were included in the analysis. Some of the articles focused on specific countries, while others analysed broader regions. The geographical focus of the studies is displayed in Figure 1.

Figure 1. Geographical Distribution of the Studies Included in the Systematic Review

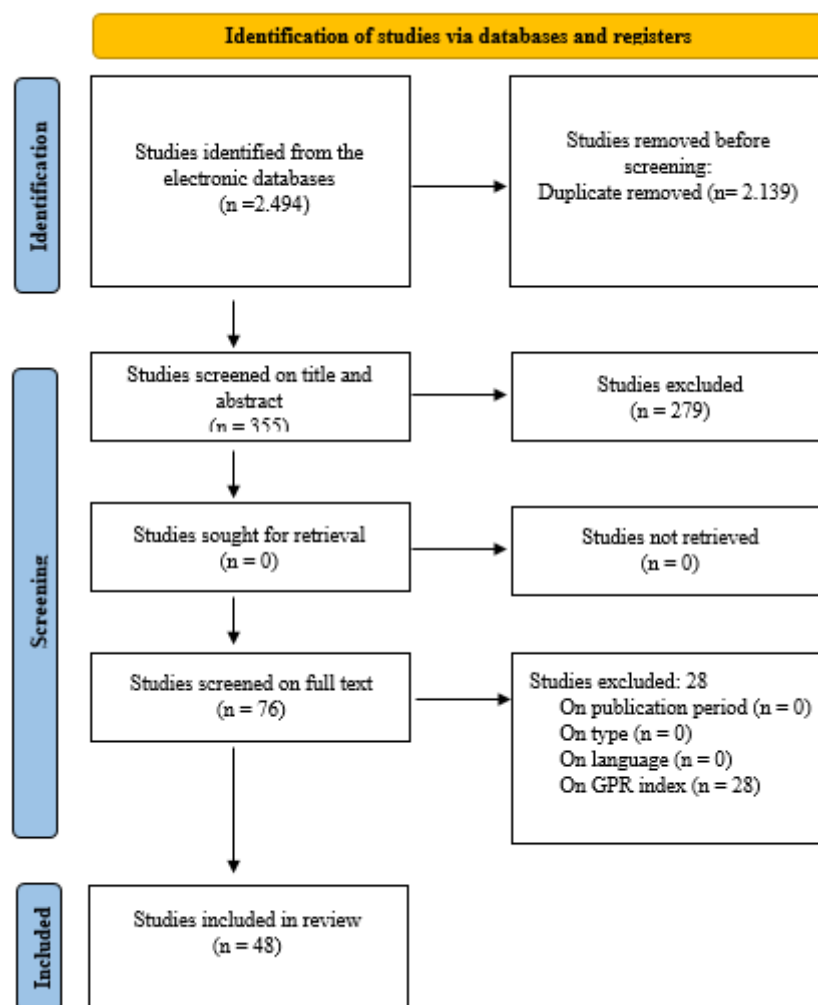


Source: Elaborated by the authors

China, the U.S., and the EU represent the three most frequently analysed locations, in that order. The U.K., the U.A.E., and Japan were also examined in several studies. The category “Others” refers to studies that used a broad global sample, including countries such as Australia, Canada, Russia, Brazil, India, and South Africa, among others. All of the studies employed quantitative methods, as they used the geopolitical risk index in their analyses. Although the first version of the index was released in 2018, all the works that met the selection criteria were published between 2021 and 2025. Figure 2 presents the results corresponding to the identification, screening, and inclusion phases.

The core themes approached by the articles were identified, even though many studies included more than one theme. Table 1 and Figure 3 present the categories referring to the identified themes.

Figure 2. Results of Search and Screening Process (in PRISMA format)



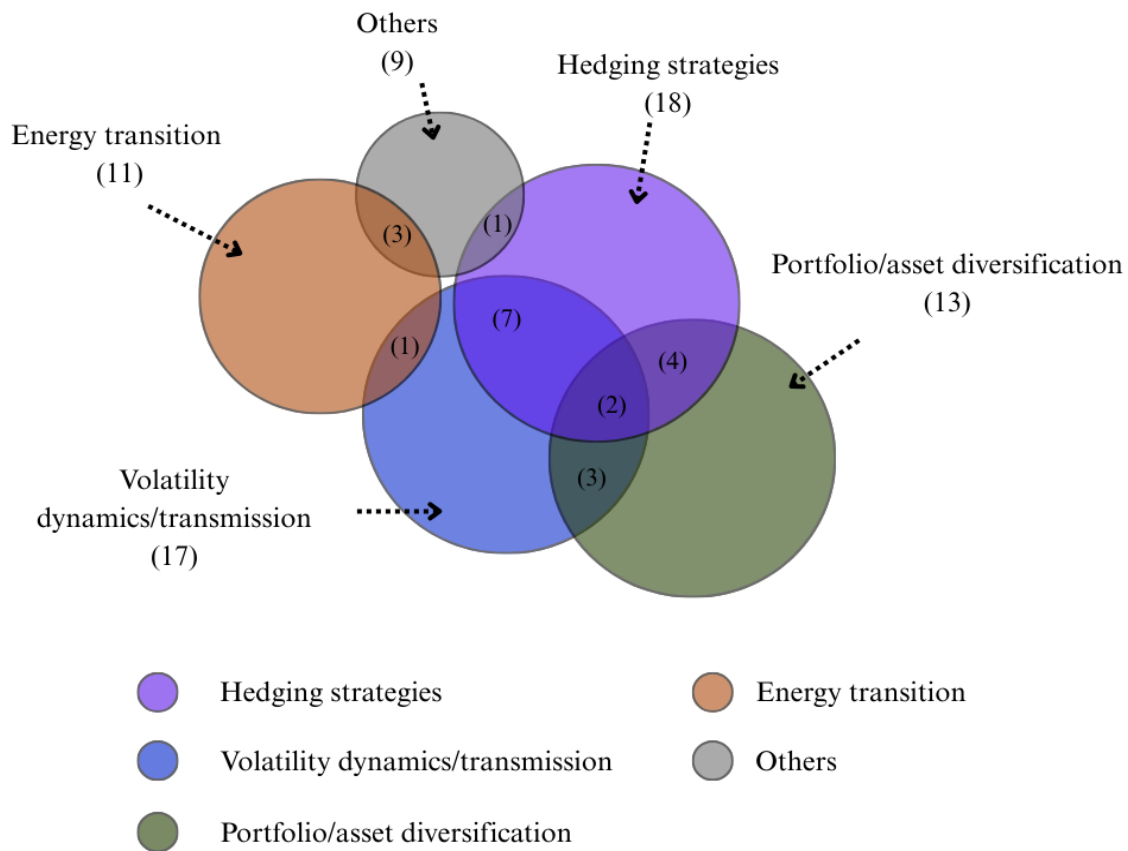
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Table 1. Identified Themes

Core themes	n° of articles
Hedging strategies	18
Volatility dynamics/transmission	17
Asset/portfolio diversification	13
Energy transition	11
Others	9

Core themes	Hedging strategies	Volatility dynamics/transmission	Asset/portfolio diversification	Energy Transition	Others
Hedging strategies	18	7	4	0	1
Volatility dynamics/transmission	7	17	3	1	0
Asset/portfolio diversification	4	3	13	0	0
Energy transition	0	1	0	11	3
Others	1	0	0	3	9

Figure 3. Identified Themes



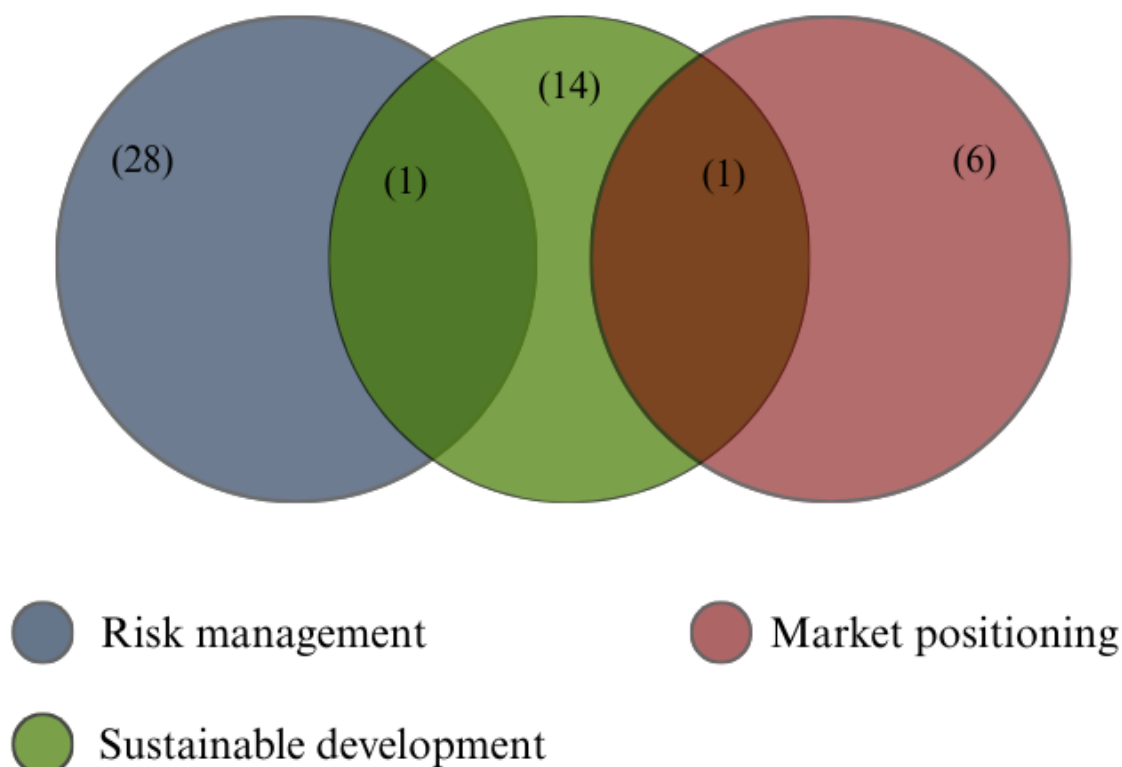
Source: Elaborated by the authors

The most recurrent theme was “hedging strategy,” while the least recurrent was “energy transition.” Themes that were not frequently discussed were grouped under the category “Others.” This category includes topics such as climate change, the environment, and capital flows. Most of the studies did not include a theoretical framework, although some articles presented well-established theories to introduce and discuss the themes. This article aims to comprehend the relationship between geopolitical risk, green bonds, and renewable energy. Consequently, the study focuses on identifying how the literature combines these three factors. Table 2 and Figure 4 present the identified relationships.

Table 2. Identified Relationships

Identified categories	n° of articles
Risk management	28
Sustainable development	14
Market positioning	6

Figure 4. Identified Relationships



Source: Elaborated by the authors

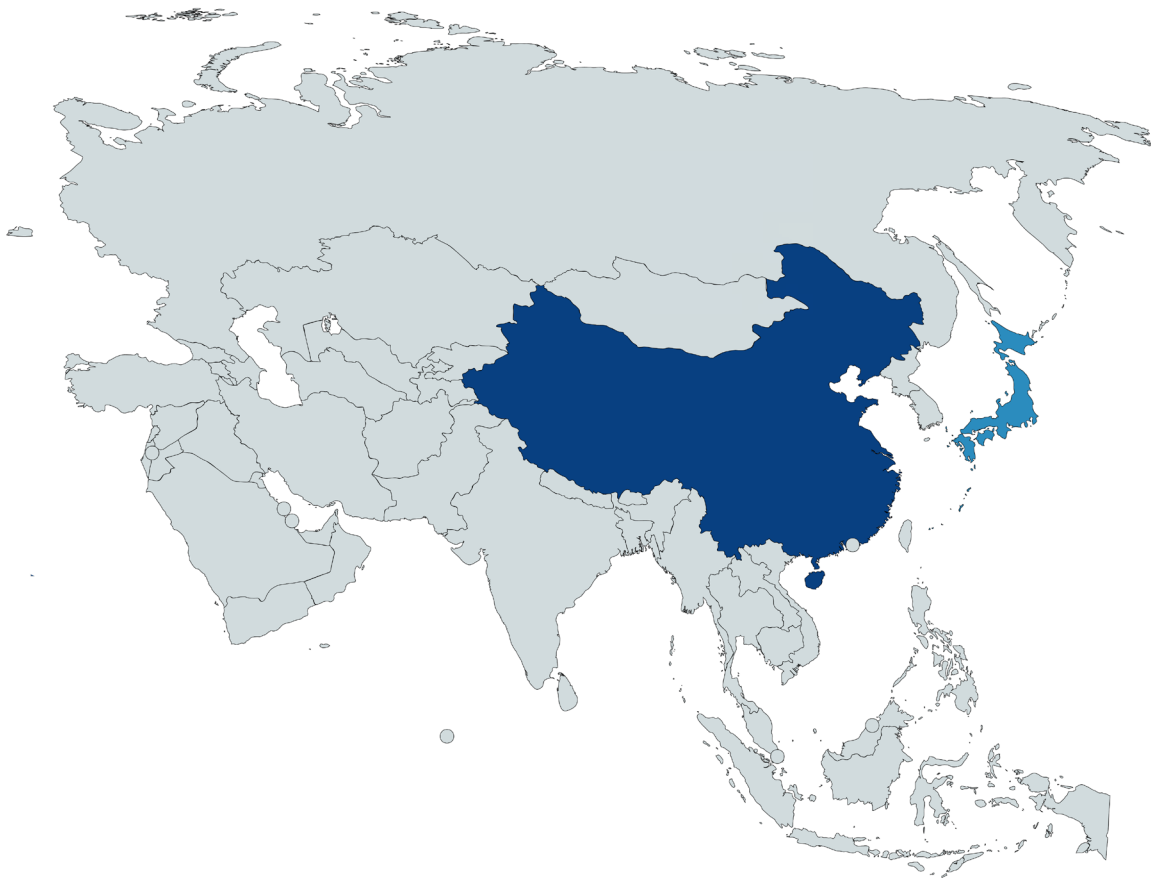
The results revealed three types of relationships: “market positioning,” “risk management,” and “sustainable development.” In some cases, these relationships were examined simultaneously within the same analysis. The frequency of each identified relationship is presented in Table 2.

The three relationships illustrate how geopolitical risk, green bonds, and renewable energy interact. In some relationships, all elements are associated, whereas in others only two of the variables appear to be connected. “Market positioning” is a relationship that does not associate all three variables. Nevertheless, the connection between geopolitical risk, green bonds, and renewable energy is present in the “risk management” and “sustainable development” relationships.

There are different versions of the GPR index. The database developed by Caldara and Iacoviello contains both global and country-specific versions of the index. Most articles utilised the global version; however, some studies employed country-specific indices to evaluate Asian countries. Figure 5 shows the country-level use of the GPR index.

China was the most frequently analysed nation, followed by Japan. Many studies had a specific geographical focus, as shown in Figure 1. However, the majority employed the global version of the GPR index in their analyses. The data extracted from the review are presented in Appendix A.

Figure 5. Country-Specific GPR Indices Used in the Literature



Source: Elaborated by the authors

Market Positioning

The market positioning of companies focuses on corporate investments and ESG conduct. Several articles applied signalling theory, rooted in neoclassical thought, as the basis for their analysis. This theory is based on the existence of information asymmetry and was initially developed considering only two parties. Differences in the level of information enable only one party involved in a transaction to be fully aware of certain factors. The informed party must decide which signals to send, and the receiving party must interpret them (Connely et al., 2011). Market signalling aims to influence agents' perceptions regarding the quality or reputation of an organisation (Wang et al., 2025).

Therefore, investing in sustainable finance can be perceived as a strategy used by organisations to signal their concern for climate issues to stakeholders, contributing to the formation of reputational capital (Wang et al., 2025). Certain articles argued that companies use signals to communicate their commitment to sustainability through Corporate Social Responsibility (CSR), ESG conduct, or green bond investment (Fiorillo et al., 2024; Lian & Hou, 2024; Mertzanis & Tebourbi, 2025; Mohammed et al., 2024).

This literature primarily focused on the primary green bond market. Costs, prices, and bond yields were the main aspects examined. Benefits such as the “greenium,” referring to the issuance of green bonds at a negative premium, are explored by Fiorillo et al. (2024), Lian and Hou (2024), and Mertzanis (2025). This advantage allows companies to issue bonds at a higher price and consequently a lower yield. These conditions are made possible by investors’ willingness to accept lower yields in exchange for funding projects with a higher purpose, namely sustainability. This cost advantage is observed in the primary market when compared with conventional bonds. Results are heterogeneous for the secondary market; when positive, the margin is narrow (Fiorillo et al., 2024; Lian & Hou, 2024).

Beyond greenium, the influence of foreign direct investment, monetary policy, digital transformation, and climate change on green bond issuance has also been examined (Christnacht & Mertzanis, 2025; Guesmi et al., 2025; Mertzanis et al., 2025).

Geopolitical risk was presented in the studies as a factor that could either promote or discourage green bond issuance. However, most studies identified positive impacts of GPR on the issuance of these bonds. Mertzanis and Tebourbi (2024) concluded that both geopolitical acts and threats are positively correlated with green bond issuance, although the effect is neither immediate nor linear. Positive results regarding the influence of geopolitical risk on GB issuance were also reported by Christnacht and Mertzanis (2025), Houcine and Mertzanis (2025), Fiorillo et al. (2024), and Lian and Hou (2024). None of the studies detected negative impacts of GPR on GB issuance. Mertzanis et al. (2025) did not identify a significant influence of geopolitical risk on green bond issuance; however, their focus was on the impact of digital transformation on GB issuance rather than the direct relationship between GPR and GB.

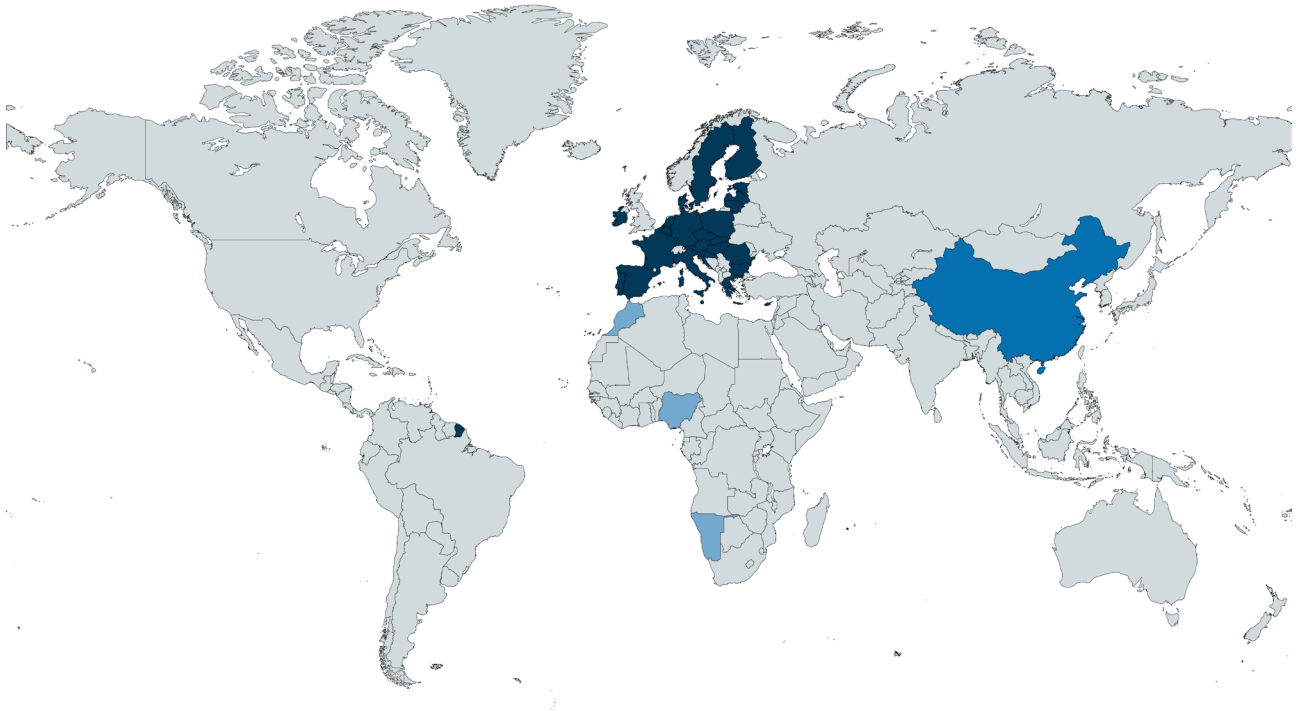
The influence of green bonds on renewable energy investment was not addressed unequivocally. These studies primarily emphasised the effect of geopolitics on the primary green finance market. Although the association between geopolitical risk, green bonds, and renewable energy is not fully explored, it is possible to highlight the relationships observed among two of the variables. The results indicate that the impact of geopolitical risk on green bonds is predominantly positive, especially regarding their issuance.

It is worth noting that, except for Lian and Hou (2024), who focused solely on China, studies on GB issuance employed globally representative samples. Advanced economies accounted for the largest green bond issuance (Mertzanis, 2023; Mertzanis & Tebourbi, 2025; Mertzanis & Houcine, 2025). The only emerging economy among the leaders in global issuance was China. EU members were also among the top issuers, while African countries were at the lower end of the issuance spectrum (Mertzanis, 2023; Mertzanis & Tebourbi, 2025). Figure 6 illustrates the global distribution of green bond issuance.

The difference in green bond issuance between advanced and emerging economies is strongly associated with the more established sustainable markets in developed countries. Developed nations possess the institutional mechanisms that enable green finance to expand, whereas many developing

countries struggle to implement incentives such as policies, regulations, and fiscal measures, which are considered key to the growth of the green bond market (Mertzanis & Tebourbi, 2025).

Figure 6. Regional Distribution of Global Green Bond Issuance



Source: Elaborated by the authors

Risk Management

The literature analysed volatility dynamics, spillovers, and the resilience of certain assets, particularly sustainable finance. This category focuses on the relationship between green bond investment and renewable energy. Several studies examined interactions among traditional energy indices, clean energy, and green bonds under extreme market and geopolitical conditions (Bajra et al., 2025; Deng et al., 2023; Gao & Liu, 2024; Ha, 2024; Lee et al., 2021; Lorente, 2023; Zheng et al., 2025).

Signalling theory is also referenced in this group of studies, although many analyses are grounded in modern portfolio theory (MPT). MPT focuses on maximising expected returns while mitigating risk, considering investor profiles and addressing aspects such as asset allocation (Elton & Gruber, 1997). The theory emphasises that it is insufficient to observe how a single asset responds to systematic risk; instead, one must consider how it correlates with other assets in the portfolio. Diversifying across asset classes can generate significant benefits, allowing investors to achieve the same expected return at a lower risk level compared with non-diversified portfolios (Elton & Gruber, 1997).

While MPT primarily addresses diversification, other risk mitigation strategies also draw on its principles. Several studies examined hedge and safe-haven assets, demonstrating how including

specific assets can increase portfolio resilience in adverse scenarios. The integration of different asset classes creates opportunities for the strategic use of sustainable finance, a pattern observed in the analysed literature.

These studies investigated the hedging and safe-haven properties of assets. Regarding hedging mechanisms, the connection between fossil fuels and geopolitical events was used to explore the role of green bonds. Hedging properties can be attractive to investors, encouraging renewable energy investment. Analyses of asset resilience during bullish or bearish market states or prior to geopolitical events address both risk management and renewable energy investment (Bouri et al., 2024; Dong et al., 2023; Lorente et al., 2023; Mohammed et al., 2025; Sohag et al., 2022).

Safe-haven assets, in contrast, exhibit resilience specifically during periods of extreme market uncertainty (Xia et al., 2024). The potential for green bonds to serve as safe havens under geopolitical risk was explored by Ahmed et al. (2024), Xia et al. (2024), and Aloui et al. (2025). Important characteristics for identifying hedging and safe-haven properties include volatility transmission and the relationship with geopolitical risk. This analysis is based on observing a collection of assets and their interactions before geopolitical acts and threats.

The Ukraine war and the COVID-19 pandemic are presented as scenarios of high geopolitical risk and economic uncertainty. While the pandemic was not originally considered in Caldara and Iacoviello's definition, many authors used both periods to analyse volatility transmission dynamics between green and conventional assets (Deng et al., 2023; Ha, 2023; Liu et al., 2024; Zhou et al., 2025). Green bonds acted as volatility receivers during periods of high GPR, which can be beneficial for renewable energy investment, considering the volatility of fossil fuels (Deng et al., 2023). Conversely, in comparison to other assets, this role could be disadvantageous, discouraging investment in green bonds (Zheng et al., 2025). Geopolitical risk was introduced as either a driver of spillovers and interconnectedness (Jin, 2025; Li et al., 2025; Lucey & Ren, 2023; Zhou et al., 2025) or as a volatility, risk, or shock transmitter/receiver (Deng et al., 2023; Gao & Liu, 2024; Ha, 2023; Liu et al., 2024). Most studies used S&P Global indices to represent the markets, enhancing the international relevance of the findings, though generalisation still depends on sample coverage.

Despite heterogeneous results, the relationship between green bonds, renewable energy, and geopolitical risk was identified. In some contexts, the relationship was positive, though this effect was not consistent across all analyses.

Sustainable Development

Several theoretical frameworks inform literature in this category, including business cycle theories, the energy ladder theory, Schumpeterian perspectives on innovation, corporate social responsibility theory, Pigouvian tax theory, central bank theory, game theory, stakeholder theory, and Douglas North's institutional perspective (Chishti et al., 2024; Christnacht & Mertzanis, 2025; Mertzanis, 2024; Mertzanis et al., 2025). This literature strand emphasises the energy transition beyond corporate

and financial market dynamics, considering the role of government planning, policy characteristics, and institutions such as central banks (Chishti et al., 2024; Mertzanis, 2023; Mertzanis, 2024). Nevertheless, corporate interactions and financial markets remain part of the analysis (Lin et al., 2023; Wang et al., 2023; Zhao et al., 2024).

Regarding the influence of green bonds on the energy transition, results are heterogeneous. Some studies examined the relationship between GB and renewable energy under geopolitical risk conditions. Chishti et al. (2024) considered the impact of sustainable finance, the Paris Agreement, the Belt and Road Initiative, and GPR on energy transition, detecting a negative effect of geopolitical risk on green bonds and the energy transition. Similarly, Zhao et al. (2024) found that geopolitical threats negatively affected renewable energy through green bonds.

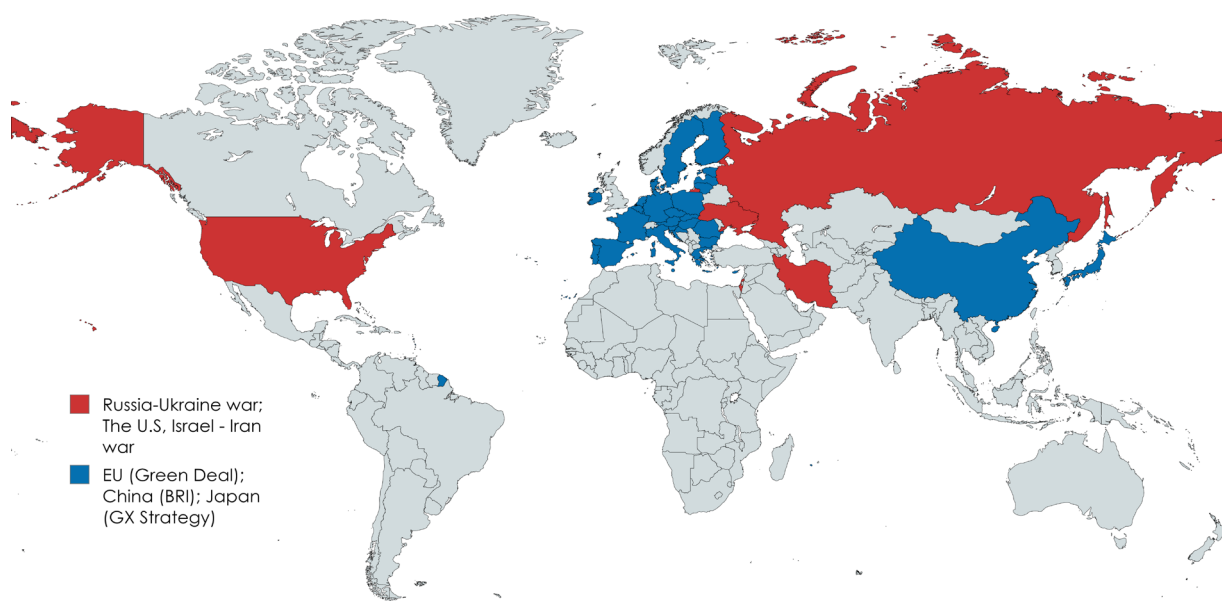
Mertzanis (2024, 2025) explored implementation, policy diversification, and green bond issuance, highlighting the influence of GB on business cycles (Chishti et al., 2024). Wang et al. (2023) reported heterogeneous effects of green bonds on geopolitical risk: while promoting energy security, they simultaneously stimulated conflicts over resources needed for renewable energy technologies.

Despite large country samples, efforts towards national sustainable development were geographically concentrated. China (BRI), Japan (GX strategy, net-zero roadmap, 2030 Basic Energy Plan), and EU members (Green Deal) were among the most active nations (Chishti et al., 2024; Taghizadeh-Hesary et al., 2023). Higher policy diversification and social tolerance were associated with positive impacts on GB issuance, consistent across most analysed countries (Mertzanis, 2023; Mertzanis & Houcine, 2025).

These studies highlight the influence of cultural, institutional, and regulatory factors on fostering sustainable finance and development. Such factors can facilitate or hinder government efforts, while geopolitical exposure and historical involvement in military conflicts often shape institutional environments. Volatile regions tend to have weaker institutions, slowing renewable energy adoption, whereas stable political environments provide a more conducive setting for implementing policies and tools for sustainable development (Mertzanis et al., 2025). Figure 7 links current geopolitical hotspots with major energy transition initiatives.

Geopolitical turbulence can either discourage or stimulate renewable energy investment. However, the nature of the conflict and the characteristics of the countries involved play a crucial role (Wang et al., 2023). Some articles considered both geopolitical risk and green bonds in their analyses without evaluating the relationship between them directly, focusing instead on other factors (Lin et al., 2023; Taghizadeh-Hesary et al., 2023). For example, Taghizadeh-Hesary et al. (2023) explored renewable energy development in Japan, using both geopolitical risk and green bonds as explanatory variables, without examining their interaction. The relationship between renewable energy, geopolitical risk, and green bonds produced heterogeneous results. In the evaluated articles, the context, the variables considered, and the GPR subindices—along with their behaviour—strongly influenced the outcomes.

Figure 7. Key Geopolitical Regions and Major Energy Transition Initiatives



Source: Elaborated by the authors

CONCLUSIONS

The influence of geopolitical issues on markets has been increasing. The construction of the geopolitical risk index by Caldara and Iacoviello (2022), alongside recent events such as the war in Ukraine and geopolitical tensions involving Iran, underscores the magnitude of this influence. Geopolitics affects financial markets, which in turn generate repercussions for the economy and the environment. Green bonds serve as one mechanism through which this process occurs. Since these financial instruments are particularly relevant for the energy sector, they can be perceived as a nexus connecting the impacts of conflicts and geopolitical turbulence with renewable energy investment. This study aims to explore the literature linking these three factors, using the geopolitical risk index developed by Caldara and Iacoviello.

The systematic review identified four core themes: hedging strategies, asset/portfolio diversification, volatility dynamics/transmission, and energy transition. Several articles addressed more than one theme. The most and least discussed topics were asset/portfolio diversification and energy transition, respectively. The association between geopolitical risk, green bonds, and renewable energy was divided into three categories, each representing how the factors are connected in the literature: “market positioning,” “risk management,” and “sustainable development.” Some articles spanned more than one category.

The analysed studies showed a geographical concentration in developed economies, with China as the only emerging economy consistently evaluated. The “sustainable development” literature highlighted the efforts of Japan, China, and EU members, focusing on government planning and policies

targeting energy transition and climate issues. Studies in the “market positioning” category included a broader country sample, highlighting differences in green bond issuance between developed and emerging economies. These findings underscore the predominance of nations from the global North over the global South, reflecting disparities in social and institutional frameworks that affect the maturity and performance of green markets.

The “risk management” category did not have an explicit geographical focus, as it examined market interactions and asset resilience/performance. Most studies relied on S&P Global indices to represent world market dynamics, typically using the global GPR index. In contrast, the only country-specific indices identified were for China and Japan, with analyses incorporating the geopolitical characteristics of these economies. Factors such as location, neighbouring countries, and exposure are crucial to understanding how a nation responds to different conflict stages, such as geopolitical threats or acts. Nonetheless, most studies relied on the global GPR index, limiting the analysis to responses to global geopolitical risks while considering only institutional, cultural, social, and economic characteristics of the sampled nations.

This study contributes to the literature by exploring the association between geopolitical risk, green bonds, and renewable energy. The results indicate a heterogeneous effect of GPR on green bonds and renewable energy, often depending on the conflict stage (threat or act) or the risk level (low, medium, high). Country-specific index characteristics were also influential. While Caldara and Iacoviello defined geopolitical risk in terms of wars and conflicts with cross-border spillovers, some studies broadened this definition to include events such as the COVID-19 pandemic, recognising their indirect geopolitical implications.

The study has limitations. The adoption of a specific GPR definition and index excludes other perspectives and factors that can influence financial markets, green bonds, and renewable energy, such as trade tariffs. The analysis period is also a limitation. Although the index has been widely used since 2018, the relationship between GPR and green bonds is not yet fully understood. Broader GPR definitions or comparisons across authors could allow for longer study periods and more comprehensive analyses.

Several directions for future research are suggested. The relationship between geopolitical risk, green bonds, and renewable energy was identified within the categories of “risk management” and “sustainable development.” However, this relationship was not evident in the “market positioning” category, obscuring the association between renewable energy and the other two factors—a clear gap in the literature. Future studies could examine how green bonds are employed to promote sustainability in this context. It is also noteworthy that green bonds (GBs) are used in sectors beyond energy. Additionally, future research should consider all three variables with a broader definition of geopolitical risk, addressing the limitations associated with using a single index and excluding studies that did not adopt Caldara and Iacoviello’s framework.

REFERENCES

- Ahmed, F., Islam, M., & Abbas, S. (2025). Assessing the impact of Russian–Ukrainian geopolitical risks on global green finance: a quantile dependency analysis. *Environmental Economics and Policy Studies*, 13, 615–641. <https://doi.org/10.1007/s10018-024-00395-3>
- Aiswarya, S., & Muthumeenakshi, M. (2024). Exploratory bibliometric analysis on geopolitical risk. *International Research Journal of Multidisciplinary Scope*, 5(4), 1180–1197. <http://dx.doi.org/10.47857/irjms.2024.v05i04.01652>
- Alnafrah, I. (2024). ESG practices mitigating geopolitical risks: Implications for sustainable environmental management. *Journal of Environmental Management*, 358, 120923. <https://doi.org/10.1016/j.jenvman.2024.120923>
- Aloui, C., Mejri, S., Hamida H., & Yildirim. (2025). Green bonds and clean energy stocks: Safe havens against global uncertainties? A wavelet quantile-based examination. *North American Journal of Economics and Finance*, 76, 102310. <https://doi.org/10.1016/j.najef.2024.102310>
- Bajra, U., Aliu, F., & Prenaj, V. (2025). Connectivity of green financial assets under geopolitical risks and market-implied volatility. *Finance Research Letters*, 76, 107037. <https://doi.org/10.1016/j.frl.2025.107037>
- Będowska-Sójka, B., Demir, E., & Zaremba, A. (2022). Hedging geopolitical risks with different asset classes: A Focus on the Russian invasion of Ukraine. *Finance Research Letters*, 50, 103192. <https://doi.org/10.1016/j.frl.2022.103192>
- Blondeel, M., Bradshaw, M. J., Bridge, G., & Kuzemko, C. (2021). The geopolitics of energy system transformation: A review. *Geography Compass*, 15, e12580. <https://doi.org/10.1111/gec3.12580>
- Bouri, E., Gök, R., Gemici, E., & Kara E. (2024). Do geopolitical risk, economic policy uncertainty, and oil implied volatility drive assets across quantiles and time-horizons? *Quarterly Review of Economics and Finance*, 93, 137–154. <https://doi.org/10.1016/j.qref.2023.12.004>
- Brutschin, E., & Fleig, A. (2018). Geopolitically induced investments in biofuels. *Energy Economics*, 74, 721–732. <https://doi.org/10.1016/j.eneco.2018.06.013>
- Caldara, D., & Iacoviello, M. (2018). Measuring geopolitical risk. *International Finance Discussion Paper*, 1222, 1–66. <https://doi.org/10.17016/IFDP.2018.1222r>
- Caldara, D., & Iacoviello, M. (2022). Measuring Geopolitical Risk. *American Economic Review*, 112(4), 1194–1225. <https://doi.org/10.1257/aer.20191823>
- Climate Bonds Initiative. (2025). *Data*, 2024. <https://www.climatebonds.net/datainsights/market-data/insights-from-climate-bonds-data>
- Cheong, C., & Choi, J. (2020). Green bonds: a survey. *Journal of Derivatives and Quantitative Studies*, 28(4), 175–189. <https://doi.org/10.1108/JDQS-09-2020-0024>

- Chishti, M., Sharif A., Xu Q., & Sharma G. (2024). Toward sustainable development: Revealing the dynamic impacts of the belt and road initiative on energy transition. *Sustainable Development*. <https://doi.org/10.1002/sd.3069>
- Chishti, M., Dogan, E., & Binsaeed, R. (2024). Can artificial intelligence and green finance affect economic cycles?. *Technological Forecasting and Social Change*, 209. <https://doi.org/10.1016/j.techfore.2024.123740>
- Christnacht, L., & Mertzanis, C. (2025). Foreign direct investment, technology transfer and the global issuance of green bonds. *Energy Economics*, v. 143. <https://doi.org/10.1016/j.eneco.2025.108246>
- Connely, B. Certo S., Ireland R., & Reutzel C. (2010). Signaling Theory: A Review and Assessment. *Journal of Management*, 37(1), 39–67. <https://doi.org/10.1177/0149206310388419>
- Deng, Y., Fang G., Zhang J., & Ma H. (2023). Dynamic connectedness among oil, food commodity, and renewable energy markets: Novel perspective from quantile dependence and deep learning. *Journal of the Knowledge Economy*. <https://doi.org/10.1007/s13132-023-01485-5>.
- Deschryver, P., & Mariz, F. (2020). What future for the green bond market? How can Policymakers, companies, and investors unlock the potential of the green bond market? *Risk and Financial Management*, 13(61). <https://doi.org/10.3390/jrfm13030061>
- Dong, X., Xiong Y., Nie S., & Yoon S. (2023). Can bonds hedge stock market risks? Green bonds vs conventional bonds. *Finance Research Letters*, 52, 103367. <https://doi.org/10.1016/j.frl.2022.103367>.
- Elton, E., & Gruber, M. (1997). Modern portfolio theory, 1950 to date. *Journal of Banking & Finance*, 21, 1743–1759. [https://doi.org/10.1016/S0378-4266\(97\)00048-4](https://doi.org/10.1016/S0378-4266(97)00048-4).
- Fiorillo, P., Meles A., Salerno D., & Verdoliva V. (2024). Geopolitical turmoil and investor green preference: Evidence from the corporate bond market. *Journal of International Money and Finance*, 149, 103218. <https://doi.org/10.1016/j.jimonfin.2024.103218>
- Gao, Y., & Liu, X. (2024). Time and frequency spillovers and drivers between rare earth and energy, metals, green, and agricultural markets. *North American Journal of Economics and Finance*, 72, 102128. <https://doi.org/10.1016/j.najef.2024.102128>
- Guesmi, K., Makrychoriti, P., & Pyrgiotakis, E. (2025). Climate change exposure and green bonds issuance. *Journal of International Money and Finance*, 152, 103281. <https://doi.org/10.1016/j.jimonfin.2025.103281>
- Ha, L. (2023). An application of QVAR dynamic connectedness between geopolitical risk and renewable energy volatility during the COVID-19 pandemic and Russia–Ukraine conflicts. *Journal of Environmental Management*, 342, 118290. <https://doi.org/10.1016/j.jenvman.2023.118290>
- Ha, L. (2024). A wavelet analysis of dynamic connectedness between geopolitical risk and renewable energy volatility during the COVID-19 pandemic and Ukraine–Russia conflicts. *Environmental Science and Pollution Research*, 31(12), 17994–18009. <https://doi.org/10.1007/s11356-023-26033-1>
- Hafner, M., & Tagliapietra, S. (2020). *The geopolitics of the global energy transition*. Springer Open.

- Hasan, Q., et al. (2024). The renewable energy role in the global energy transformations. *Renewable Energy Focus*, 48, 100545. <https://doi.org/10.1016/j.ref.2024.100545>
- Hasan, M., Hassan M., Rashid M., Akter T., & Rafia H. (2024). The resilience of ethical assets against different uncertainty shocks. *Heliyon*, 10(24), e40980. <https://doi.org/10.1016/j.heliyon.2024.e40980>
- Helmi, M., Elsayed, A., & Khalfaoui, R. (2024). The impact of geopolitical risk on sustainable markets: A quantile-time-frequency analysis. *Finance Research Letters*, 64, 105380. <https://doi.org/10.1016/j.frl.2024.105380>
- International Capital Market Association. (2025). *Green Bond Principles*. <https://www.icmagroup.org/>.
- International Energy Agency. (2022a). *Renewable Energy*. <https://www.iea.org/>.
- International Energy Agency (2022b). The role of critical minerals in clean energy transitions. *World Energy Outlook Special Report*. <https://www.iea.org/>.
- Jin, X. (2025). Extreme risk connectedness and its determinants between carbon, green finance and energy markets. *Asia-Pacific Financial Markets*. <https://doi.org/10.1007/s10690-025-09536-4>
- Jin, Y., Liu, S., Sun, Y., & Fang J. (2024). Energy transition and housing market bubbles: Evidence from prefecture cities in China. *Energy Economics*, 133, 107485. <https://doi.org/10.1016/j.eneco.2024.107485>
- Kojić, M., Mitić, P., Schlüter, S., & Rakić S. (2024). Complex non-linear relationship between conventional and green bonds: Insights amidst COVID-19 and the RU–UA conflict. *Journal of Behavioral and Experimental Finance*, 43, 100966. <https://doi.org/10.1016/j.jbef.2024.100966>
- Lee, C., Lee, C., & Li, Y. (2021). Oil price shocks, geopolitical risks, and green bond market dynamics. *North American Journal of Economics and Finance*, 55, 101309. <https://doi.org/10.1016/j.najef.2020.101309>
- Lian, J., & Hou, X. (2024). Navigating geopolitical risks: deciphering the greenium and market dynamics of green bonds in China. *Sustainability*, 16(15), 6354. <https://doi.org/10.3390/su16156354>.
- Liberati, A., Altman, D., Tetzlaff J., Mulrow, C., Gøtzsche, P., Loannidis, P., Clarke, M., Devereaux, P., Kleijnen, M., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PlosMed*. <https://doi.org/10.1371/journal.pmed.1000100>
- Li, H., Li, H., Luo, F., & Guo., L. (2025). Navigating extreme risk spillovers: Building a synergistic network of rare earths, green bonds, and clean energy markets in China. *Energy Economics*, 147, 108562. <https://doi.org/10.1016/j.eneco.2025.108562>
- Lin, Z., Alvarez-Otero, S., Belgacem, S., & Fu, Q. (2023). Role of sustainable finance, geopolitical risk and economic growth in renewable energy investment: Empirical evidence from China. *Geological Journal*, 58(9), 3339–3347. <https://doi.org/10.1002/gj.4654>

- Lisbinski, F. C., & Burnquist, H. L. (2026). Institutions and financial development: Comparative analysis of developed and developing economies. *Economía*, 25(2), 347–376. <https://doi.org/10.1108/ECON-11-2023-0201>
- Liu, T., Zhang, Y., Zhang, W., Hamori, S. (2024). Quantile connectedness of uncertainty indices, carbon emissions, energy, and green assets: Insights from Extreme Market Conditions. *Energies*, 17(22). <https://doi.org/10.3390/en17225806>
- López, C., Morales-Contreras, C., Langella, I., & Alonso-Monge, J. (2025). Modeling supply chain disruptions due to geopolitical reasons: A systematic literature review. *Transportation Research Part E: Logistics and Transportation Review*, 202, 104290. <https://doi.org/10.1016/j.tre.2025.104290>
- Lorente, D., Mohammed, K., Cifuentes-Faura, F., & Shahzad, U. (2023). Dynamic connectedness among climate change index, green financial assets and renewable energy markets: Novel evidence from sustainable development perspective. *Renewable Energy*, 204, 94–105. <https://doi.org/10.1016/j.renene.2022.12.085>
- Lucey, B., & Ren, B. (2023). Time-varying tail risk connectedness among sustainability-related products and fossil energy investments. *Energy Economics*, 126, 106812. <https://doi.org/10.1016/j.eneco.2023.106812>
- Mertzanis, C. (2023). Energy policy diversity and green bond issuance around the world. *Energy Economics*, 128, 107116. <https://doi.org/10.1016/j.eneco.2023.107116>
- Mertzanis, C. (2024). Central bank policies and green bond issuance on a global scale. *Energy Economics*, 133, 107541. <https://doi.org/10.1016/j.eneco.2024.107541>
- Mertzanis, C., Marashdeh, H., Kampouris, I., & Atayah, O. (2025). Managing environmental finance in the digital era: Evidence from green bonds. *Journal of Environmental Management*, 373, 123434. <https://doi.org/10.1016/j.jenvman.2024.123434>
- Mertzanis, C., & Houcine, A. (2025). Social tolerance, environmental responsibility and green bond market growth. *Journal of Environmental Management*, 381, 125263. <https://doi.org/10.1016/j.jenvman.2025.125263>
- Mertzanis, C., & Tebourbi, I. (2025). Geopolitical risk and global green bond market growth. *European Financial Management*, 31(1), 26–71. <https://doi.org/10.1111/eufm.12484>
- Mnif, E., Zghidi, N., & Jarboui, A. (2025). Evaluating the effectiveness of green bonds and clean cryptocurrencies as hedging tools in volatile financial environments. *Management of Environmental Quality*. <https://doi.org/10.1108/MEQ-07-2024-0300>
- Mohammed, K., Bouri, E., Hunjra, A., Tedeschi, M., & Yan, Y. (2025). The heterogeneous reaction of green and conventional bonds to exogenous shocks and the hedging implications. *Journal of Environmental Management*, 364, 121423. <https://doi.org/10.1016/j.jenvman.2024.121423>
- Pahlevan S., Mura, P., & Wijesinghe, S. (2019). Systematic reviews in Asia: Introducing the “PRISMA” protocol to tourism and hospitality scholars. *Perspectives on Asian Tourism*. 184, 13–33.

- Pandey, J., & Kumar, A. (2025). Navigating India's energy transition: A systematic literature review of risks in the coal phase-down process. *Renewable and Sustainable Energy Reviews*, 210, 115260. <https://doi.org/10.1016/j.rser.2024.115260>
- Patidar, A. K., Jain, P., Dhasmana, P., & Choudhury, T. (2024). Impact of global events on crude oil economy: a comprehensive review of the geopolitics of energy and economic polarization. *GeoJournal*, 89(2). <https://doi.org/10.1007/s10708-024-11054-1>
- Preferred Reporting Items for Systematic Reviews and Meta-Analysis. (2020). *PRISMA statement*. PRISMA. <https://www.prisma-statement.org/>
- Rizvi, S. M. A., & Véganzonès-Varoudakis, M. (2023). Institutional determinants of internal conflicts in fragile developing countries. *Journal of Policy Modeling*, 45, 910–934. <https://doi.org/10.1016/j.jpolmod.2023.06.004>
- Sheenan, L. (2023). Green bonds, conventional bonds and geopolitical risk. *Finance Research Letters*, 58, 104587. <https://doi.org/10.1016/j.frl.2023.104587>
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333–339. <https://doi.org/10.1016/j.jbusres.2019.07.039>
- Sohag, K., Hammoudeh, S., Elsayed, A. H., Mariev, O., & Safonova, Y. (2022). Do geopolitical events transmit opportunity or threat to green markets? Decomposed measures of geopolitical risks. *Energy Economics*, 111, 106068. <https://doi.org/10.1016/j.eneco.2022.106068>
- Soltani, H., Taleb, J., Hamadou F. B., & Boujelbène-Abbeset (2024). Using machine learning to forecast clean energy, commodities, green bonds and ESG index prices: How important is financial stress? *EuroMed Journal of Business*. <https://doi.org/10.1108/EMJB-12-2023-0341>
- Taghizadeh-Hesary, F., Phoumin, H., & Rasoulinezhad, E. (2023). Assessment of role of green bond in renewable energy resource development in Japan. *Resources Policy*. <https://doi.org/10.1016/j.resourpol.2022.103272>
- Tamilselvan, M., Halder, A., & Kannadhasan, M. (2024). Exploring the ingredients, mixtures, and inclinations of geopolitical risk. *International Review of Economics and Finance*, 90, 187–206. <https://doi.org/10.1016/j.iref.2023.11.009>
- United Nations. (2007). *From Stockholm to Kyoto: A brief history of climate change*. United Nations. <https://www.un.org/en/chronicle/article/stockholm-kyoto-brief-historyclimate-change>
- Urom, C., Ndubuisi, G., & Guesmi, K. (2024). Global macroeconomic factors and the connectedness among NFTs and (un)conventional assets. *Research in International Business and Finance*, 71, 102429. <https://doi.org/10.1016/j.ribaf.2024.102429>
- Vakulchuk, R., Overland, I., & Scholten, D. (2020). Renewable energy and geopolitics: A review. *Renewable and Sustainable Energy Reviews*.

- Vega, L. P., Bautista, K. T., Campos, H., Daza, S., & Vargas, G. (2024). Biofuel production in Latin America: A review for Argentina, Brazil, Mexico, Chile, Costa Rica and Colombia. *Energy Reports*, 11, 28–38. <https://doi.org/10.1016/j.egy.2023.10.060>
- Wang, A., Ding, S., & Cui, T. (2025). Green bond market stability and Russia–Ukraine conflict: The role of green inclusive finance. *Research in International Business and Finance*, 74, 102734. <https://doi.org/10.1016/j.ribaf.2024.102734>
- Wang, D., Davies, G., & Lam, W. (2025). Market signalling by microenterprises when building reputational capital. *International Entrepreneurship and Management Journal*, 21(98). D<https://doi.org/10.1007/s11365-025-01128-y>
- Wang, K. H., Wen, C., Liu, H., & Liu, L. (2023). Promotion or hindrance? Exploring the bidirectional causality between geopolitical risk and green bonds from an energy perspective. *Resources Policy*, 85, 103966. <https://doi.org/10.1016/j.resourpol.2023.103966>
- Xia, Y., Chen, Y., He, L., Shi, Z., Ji, X., & Cai, R. (2024). Can green bonds hedge against geopolitical risk? A cross-market connectedness analysis with portfolio implications. *Technological and Economic Development of Economy*, 31(1), 92–130. <https://doi.org/10.3846/tede.2024.22088>
- Yu, J., Wang, S., & Yang, W. (2023). Natural resources governance and geopolitical risks: A literature review and bibliometric analysis. *Resources Policy*, 86, 104299. <https://doi.org/10.1016/j.resourpol.2023.104299>
- Zhang, D., Chen, X, Y., Lau, C, K, M., & Cai, Y. (2023). The causal relationship between green finance and geopolitical risk: Implications for environmental management. *Journal of Environmental Management*, 327, 116949. <https://doi.org/10.1016/j.jenvman.2022.116949>
- Zhang, Q., Wei, R., & Fan, S. (2025). New energy mineral price shocks and volatility responses in green securities markets: Structural effects and dynamic spillovers. *Applied Energy*, 382, <https://doi.org/10.1016/j.apenergy.2024.125230>
- Zhao, D., E-ali, M, S., Chaudhry, M, O., Ayub, B., Waqas, M., & Ullah, I. (2024). Modeling the Nexus between geopolitical risk, oil price volatility and renewable energy investment: evidence from Chinese listed firms. *Renewable Energy*, 225, 120309. <https://doi.org/10.1016/j.renene.2024.120309>
- Zheng, H., Wang, S., & Zhang, T. (2025). Dynamic risk spillovers between green bonds and energy markets: New evidence from the GARCH-MIDAS-D-Copula-CoVaR approach considering uncertainties. *Renewable Energy*, 239, 122129. <https://doi.org/10.1016/j.renene.2024.122129>
- Zhou, Y., Xie, C., Wang, G., Zhu, Y. (2025). The role of uncertainty in return spillovers among digital, green, and traditional financial assets: New insights from the shock of unprecedented events. *International Review of Financial Analysis* 103, 104225. <https://doi.org/10.1016/j.irfa.2025.104225>

APPENDIX A

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORETICAL FRAMEWORK
Chishti et al., 2024	Toward sustainable development: Revealing the dynamic impacts of the belt and road initiative on energy transition	Geopolitical risk negatively impacts green bonds and, consequently, the energy transition.	Pigouvian theory (Pigouvian tax) The energy ladder theory
Deng et al., 2023	Dynamic Connectedness Among Oil, Food Commodity, and Renewable Energy Markets: Novel Perspective from Quantile Dependence and Deep Learning	Geopolitical risk and green bonds are net volatility receivers before and after the beginning of the Russia-Ukraine war, being considered potential „buffers”. The renewable energy investment was stimulated by the elevated oil's volatility in the period. However, the RE investment was represented by a clear energy index. Green bonds were volatile throughout the entire analysis.	
Ha, 2024	A wavelet analysis of dynamic connectedness between geopolitical risk and renewable energy volatility during the COVID19 pandemic and UkraineRussia conflicts	Geopolitical risk negatively impacts renewable and green energy. The relationship between GPR and green bonds is negative.	
Mnif et al., 2025	Evaluating the effectiveness of green bonds and clean cryptocurrencies as hedging tools in volatile financial environments	Green bonds demonstrated potential to be hedging tools before geopolitical risk.	Portfolio theory Market efficiency hypothesis
Liu et al., 2024	Quantile Connectedness of Uncertainty Indices, Carbon Emissions, Energy, and Green Assets: Insights from Extreme Market Conditions	Geopolitical risk transmits volatility to green bonds but it is not the main source of impact.	
Soltani et al., 2024	Using machine learning to forecast clean energy, commodities, green bonds and ESG index prices: How important is financial stress?	Geopolitical risk negatively influences the price of green bonds.	
Hasan et al., 2024	The resilience of ethical assets against different uncertainty shocks	Green bonds have the potential to be hedging instruments before geopolitical risk.	
Aloui et al., 2025	Green bonds and clean energy stocks: Safe havens against global uncertainties? A wavelet quantile-based examination	Green bonds have the potential to be safe haven assets before geopolitical risk only in the medium/short run. In the long run, this potential decreases.	
Bajra et al., 2025	Connectivity of green financial assets under geopolitical risks and market-implied volatility	Green bonds are highly sensitive to geopolitical risk.	
Helmi et al., 2024	The impact of geopolitical risk on sustainable markets: A quantile-time-frequency analysis	The impact of GPR in green bonds is negative in the short run, but positive in the long run.	

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORATICAL FRAMEWORK
Zhang et al., 2023	The causal relationship between green finance and geopolitical risk: Implications for environmental management	Geopolitical risk impacts volatility and return of green bonds.	
Alnafrah, 2024	ESG practices mitigating geopolitical risks: Implications for sustainable environmental management	Companies that invest in green bonds are less exposed to geopolitical risk than companies that do not.	Framework „Quintuple Helix model” Financial Resilience Theory
Zheng et al., 2025	Dynamic risk spillovers between green bonds and energy markets: New evidence from the GARCH-MIDAS-D-Copula-CoVaR approach considering uncertainties	Green markets transmit volatility and make green bond less attractive during periods of high geopolitical risk. When considering the traditional market, this effect does not occur.	
Urom et al., 2024	Global macroeconomic factors and the connectedness among NFTs and (un)conventional assets	Green bonds are predominantly volatility recipients during extreme geopolitical and economic market conditions.	
Lorente et al., 2023	Dynamic connectedness among climate change index, green financial assets and renewable energy markets: Novel evidence from sustainable development perspective	Green bonds are negatively associated with geopolitical risk. Except for the COVID-19 period, they can hedge against GPR, especially, during the Ukraine war.	
Sohag et al., 2022	Do geopolitical events transmit opportunity or threat to green markets? Decomposed measures of geopolitical risks	The impact of GPR in green bonds is positive in scenarios of low/medium intensity. In these periods, green bonds become interesting hedging options. During high GPR scenarios (geopolitical act), the association is negative and the hedging potential weakens.	
Lin et al., 2023	Role of sustainable finance, geopolitical risk and economic growth in renewable energy investment: Empirical evidence from China	GPR negatively impacts renewable energy investment. Sustainable finance (GB) positively impact renewable energy investment.	
Lee et al., 2021	Oil price shocks, geopolitical risks, and green bond market dynamics	Geopolitical risk impacts green bonds, especially during bearish (lower quantile) markets.	Behavioral Theory (market reaction hypothesis)
Zhao et al., 2024	Modeling the Nexus between geopolitical risk, oil price volatility and renewable energy investment; evidence from Chinese listed firms	Through green bonds, geopolitical threat harms renewable energy investment in certain periods (COVID-19) and stimulate in others.	

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORETICAL FRMAEWORK
Wang et al., 2023	Promotion or hindrance? Exploring the bidirectional causality between geopolitical risk and green bonds from an energy perspective	Scenarios characterized by higher geopolitical risk harm the investment in green bonds. Lower geopolitical risk scenarios have a positive effect on GB. The effect of green bonds on geopolitical risk is heterogeneous (discourages conflict by promoting energy security, but stimulates the search for materials essential to RE production, ultimately leading to disputes).	
Taghizadeh-Hesary et al., 2023	Assessment of role of green bond in renewable energy resource development in Japan	Green bonds impact the consumption of wind, solar and hydro energy positively, stimulating the investment in these renewable sources. GPR impacts these sources negatively. Green bonds and GPR are used as explanatory variables and their relationship is not evaluated in the article.	
Dong et al., 2023	Can bonds hedge stock market risks? Green bonds vs conventional bonds	Green bonds are good hedging options during „normal” periods. During high GPR periods, both GB and traditional bonds are considered good hedging options.	Signalling Theory
Wang et al., 2025	Green bond market stability and Russia Ukraine conflict: The role of green inclusive finance	Only the short run was evaluated. Both markets were negatively affected by the conflict. However, in comparison with the inclusive GB market, the traditional green bond market was more affected. The inclusive GB market presented greater resilience.	
Christnacht & Mertzanis, 2025	Foreign direct investment, technology transfer and the global issuance of green bonds	Geopolitical risk was depicted as a control variable in the relationship between foreign direct investment and GB issuance. The results indicate that GPR positively impacts the issuance of green bonds.	Institutional Theory OLI framework Resource-Based Theory Corporate Social Responsibility Theory
Mertzanis et al., 2025	Managing environmental finance in the digital era: Evidence from green bonds	Geopolitical risk is an additional control variable in the analysis of the relationship between digital transformation and green bond issuance. The most influential variables were stable political conditions, lower enforcement costs, and the FinTechs market growth. The political conditions, despite referring to domestic and external (terrorism) matters, were represented by another variable. The GPR impact was not significant when compared to the mentioned variables. Therefore, geopolitical risk did not influence the relationship between digital transformation and green bond issuance.	Innovation Diffusion Theory Institutional Theory Stakeholder Theory Strategic Management Theory Game Theory

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORETICAL FRAMEWORK
Ahmed et al., 2024	Assessing the impact of Russian–Ukrainian geopolitical risks on global green finance: a quantile dependency analysis	In the short run, the Russian geopolitical risk exhibited a positive relationship with green bonds during the bullish market and a negative relationship during the bearish market. There is no dependency between the variables in the medium term, and in the long term, the dependency is slightly negative and presents a downward trend. Regarding the quantile dependence, the same results were obtained for Ukraine. In the short run, the Ukrainian geopolitical risk presented a strong relationship with green bonds during bullish states and a strong negative relationship during bearish states. In the long run, both Russian and Ukrainian geopolitical risk presented a weak relationship with green bonds, highlighting their safe haven potential during periods of geopolitical turbulence.	
Bouri et al., 2024	Do geopolitical risk, economic policy uncertainty, and oil implied volatility drive assets across quantiles and time-horizons?	In the short run, green bonds are good hedging options due to their immunity to geopolitical risk. In the medium and long term, their immunity wakens, negatively impacting their performance as safe haven assets during periods of financial stress. Geopolitical risk was not the main influence for green bonds. The most influential factors were oil volatility (OVX) and economic and policy uncertainty (EPU), respectively.	
Mertzanis, 2024	Central bank policies and green bond issuance on a global scale	Geopolitical risk was an additional control variable in the relationship between central bank policies and their impact in green bond issuance. The GPR effect was not evaluated. The central bank policy that was beneficial to green bond issuance was the use of systemic risk tools. The impact from higher monitoring and enforcement intensity was negative.	Central Bank Theory Game Theory
Guesmi et al., 2025	Climate change exposure and green bonds issuance	Geopolitical risk was an additional control variable in the analysis. The GPR influence was not highlighted in the article. According to the results, firms that are exposed to climate change exhibit a propensity to issue green bonds. This relationship is mainly motivated by the desire of firms to protect themselves against regulatory and physical risks instead of capitalizing on new climate-related opportunities.	
Fiorillo et al., 2024	Geopolitical turmoil and investor green preference: Evidence from the corporate bond market	GPR (act) was the greatest influence in greenium (negative risk premium) in the secondary market for green bonds, surpassing geopolitical threat among initial issuances and the ones considered high risk. Geopolitical risk influences investors to give preference to green bonds certified by a third party over bonds that have not been certified.	Signalling Theory

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORETICAL FRAMEWORK
Mertzanis, 2023	Energy policy diversity and green bond issuance around the world	Geopolitical risk is an additional control variable in the analysis, moderating the relationship between energy policy diversification and green bond issuance. Therefore, the results indicate that, in average, countries with diversified energy policies tend to higher levels of green bond issuance. However, changes in policies targetting environmental issues do not have an immediate response due to the amount of time it takes for investors to be aware of the changes.	Game Theory
Mertzanis & Houcine, 2025	Social tolerance, environmental responsibility and green bond Market growth	Geopolitical risk is an additional control variable in the analysis. The impact of GPR is highlighted, as well as the impact of other variables. The results indicate that high geopolitical risk positively impacts green bond issuance.	Social Capital Theory Human Capital Theory Institutional Theory Stakeholder Theory CSR Theory Innovation Diffusion Theory Game Theory
Kojić et al., 2024	Complex non-linear relationship between conventional and green bonds: Insights amidst COVID-19 and the RU–UA conflict	Conventional bonds presented higher sensitivity to geopolitical risk when compared with green bonds. However, both markets showed resilience to GPR. The results indicate that there is not a great difference when it comes to performance, meaning that the type of bond is defined by the personal preference of the investor.	
Sheenan, 2023	Green bonds, conventional bonds and geopolitical risk	Green bonds presented higher sensitivity to geopolitical risk than conventional bonds in both regimes, especially during high volatility conditions.	
Lian & Hou, 2024	Navigating Geopolitical Risks: Deciphering the Greenium and Market Dynamics of Green Bonds in China	The analysis considered the recent geopolitical risk index, China's GPR, the historical GPR index, and geopolitical acts and threats. Accroding to the findings, geopolitical risk increases green bond prices promoting a cost advantage (greenium) over conventional bonds. This pattern was observed in all indices, but geopolitical act had the greatest impact. In the financial sector (secondary market), the results were the same. However, green bonds did not perform as well as they did in the primary market, with advantages falling below the sector average.	Signalling Theory

AUTHORS	TITLE	IDENTIFIED FACTORS	THEORETICAL FRAMEWORK
Chishti et al., 2024	Can artificial intelligence and green finance affect economic cycles?	The geopolitical risk index represented economic cycles and green bonds represented green finance in the analysis. According to the results, the impact of green bonds in economic cycles is heterogeneous in the short run. In the long run, the impact is predominantly positive. These findings highlight the ability of green finance to decrease economic cycles in the long run. This pattern was observed in the context of the COVID-19 pandemic and the Ukraine war.	Economic Cycles Theory Schumpeterian Theory Endogenous Growth Theory
Zhang et al, 2025	New energy mineral price shocks and volatility responses in green securities markets: Structural effects and dynamic spillovers	In order to represent green finance in China, the article used a green bond index and a green stock index. The results revealed a significant impact of geopolitical risk in green finance, with green bonds displaying higher sensitivity than green stocks, especially during the COVID-19 pandemic. The justification could be associated with the negative effect the pandemic had on supply chain, impacting sustainable projects.	
Li et al., 2025	Navigating extreme risk spillovers: Building a synergistic network of rare earths, green bonds, and clean energy markets in China	Green bonds received volatility from other markets during the entire analysis. The data indicated the presence of contagion, evidencing a strong connection between them. Geopolitical risk strengthened this pattern, mainly during high GPR periods. Among the conduction factors included in the analysis, GPR was the most influential factor in the volatility spillovers between markets during low quantile periods.	Natural Resources Price Theory Capital Asset Pricing Model (CAPM) Hedging Theory Modern Portfolio Theory
Lucey & Ren, 2023	Time-varying tail risk connectedness among sustainability-related products and fossil energy investments	The article evaluated the spillovers between green indices, energies in the future market, and energy stocks. Geopolitical risk was introduced in the analysis as a conducting factor. The results indicated that GPR did not have a significant impact in the relationship between green bonds and the other variables. Green bonds transmitted and received low levels of volatility, receiving risk during most of the analyzed period.	
Jin et al., 2024	Energy transition and housing market bubbles: Evidence from prefecture cities in China	Geopolitical risk was included in the analysis as an additional control variable and green bonds as interaction variables to moderate the relationship between the energy transition and the housing market bubbles. During high and low GPR scenarios, the energy transition negatively impacted the Chinese provinces housing market bubbles. Even with the inclusion of green bonds, the negative effect remained. The relationship between geopolitical risk and green bonds was not explored.	Singalling Theory Portfolio Theory Production Factor Substitution Theory

AUTHORS	TITLE	IDENTIFIED FACTORS	
Mohammed et al., 2024	The heterogeneous reaction of green and conventional bonds to exogenous shocks and the hedging implications	The article considered the indices of geopolitical risk and act. According to the results, green bonds are efficient hedges against geopolitical risk and act, and periods of financial stress. Green bonds performed better than conventional bonds, especially corporate bonds.	Signalling Theory
Ha, 2023	An application of QVAR dynamic connectedness between geopolitical risk and renewable energy volatility during the COVID-19 pandemic and Russia-Ukraine conflicts	In the short run, geopolitical risk is a shock recipient. In the long run, GPR becomes a transmitter. Green bonds were shock recipients in both terms. After the beginning of the Ukraine war, GPR became one of the main shock transmitter to green bonds, in comparison with other risk indices.	Cobb-Douglas Production Model
Zhou et al., 2025	The role of uncertainty in return spillovers among digital, green, and traditional financial assets: New insights from the shock of unprecedented events	Green bonds were shock recipients during most of the analysis period. Still, they influenced other assets. The COVID-19 pandemic amplified the return spillovers between green and digital assets. Geopolitical risk was one the main factors influencing total spillovers during extreme market conditions.	Extreme Value Theory (EVT)
Mertzanis & Tebourbi, 2025	Geopolitical risk and global green bond market growth	The analysis considered geopolitical threats and acts. Both were positively correlated with green bond issuance, even though geopolitical threats had a greater impact. The results indicated that high geopolitical risk stimulates green bond investment. However, changes in geopolitical conditions did not have an immediate or linear effect in green bond issuance.	Signalling Theory Game Theory
Będowska-Sójka et al, 2022	Hedging Geopolitical Risks with Different Asset Classes: A Focus on the Russian Invasion of Ukraine	High geopolitical risk, characterized by the beginning of the conflict, impacted markets differently. Green bonds are among the assets that presented greater resilience to the changes in GPR, displaying hedging potential against military conflicts.	
Xia et al., 2024	Can Green Bonds Hedge Against Geopolitical Risk? A Cross-Market Connectedness Analysis With Portfolio Implications	The analysis used the general geopolitical risk index and the country indices for China and Japan. The results indicate that GPR impacts green bonds returns in the EU, USA, and Japan makets, but not in the Chinese market. The spillovers between green bonds and GPR were limited in China, but intense in the other regions during high geopolitical risk periods. Additionally, only green bonds in China and Japan presented hedging properties, despite being weak. In the Chinese market, the analysis detected hedging properties and potential safe haven assets.	Real Option Theory Modern Portfolio Theory
Jin, 2025	Extreme Risk Connectedness and its Determinants Between Carbon, Green Finance and Energy Markets	Green bonds were used to represent green finance. The results indicated a connectivity between carbon, green finance, and energy markets. However, geopolitical risk did not influence this connection.	

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Gao & Liu, 2024	Time and frequency spillovers and drivers between rare earth and energy, metals, green, and agricultural markets	Green bonds were risk recipients in the analysis. Geopolitical risk harmed the spillover dynamics between the evaluated markets, which could indicate that GPR weakens the connection between them in certain periods.	Signalling Theory Financial Accelerator Theory Rational Expectation Theory (J. Muth) Portfolio Theory

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