# FINANCING GREEN INNOVATION STRATEGY: A REVIEW OF CORPORATE GREEN BOND ISSUANCE

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## Abstract

The growing urgency of climate change has intensified interest in green finance, particularly green bonds, as mechanisms for financing environmentally sustainable projects. This study aims to examine the impact of corporate green bond issuance on green innovation outcomes, addressing a notable gap in existing literature regarding sectoral variations in this relationship. Employing a systematic literature review (SLR) approach guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, 32 peer-reviewed studies published between 2010 and 2024 were screened from Scopus, Web of Science (WoS), and Google Scholar. Additionally, bibliometric analysis using VOSviewer and Bibliometrix was conducted to map research trends, co-authorship networks, and keyword co-occurrences. The findings reveal that green bonds exert a positive impact on green innovation, particularly through channels such as research and development (R&D) investment, green patent filings, and resource efficiency improvements (Lin et al., 2022; Wang et al., 2022). However, significant sectoral and regional disparities were identified, with utilities and developed economies dominating issuance while manufacturing remains underexplored. The study concludes that third-party certification and regulatory frameworks are essential to mitigate greenwashing risks. These insights hold relevance for policymakers, investors, and researchers seeking to optimize green bond mechanisms for sustainable development.

**Keywords:** Green Bonds, Green Innovation, Corporate, Systematic Literature Review, Bibliometric Analysis, Sustainable Finance

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## 1. INTRODUCTION

There is a growing urgency to combat climate change. Hence, an increased interest in green finance has been observed over the last decade or so, as the contemporary world aims to transition toward a sustainable economy. The United Nations has come up with an urgent call for action that aims to improve health, reduce poverty, increase education, and spur economic growth (Ahmed et al., 2023).

The problem is that all of this should be accomplished while combating climate change and preserving the ecosystem. This demonstrates the development's heightened relevance. In this regard, the provision of green bonds is mandatory as an instrument for financing environmentally sustainable projects. The International Finance Corporation (IFC) has approved green bonds, with the primary goal of increasing the supply of these bonds in emerging markets (IFC, 2020). They do so by creating and disseminating knowledge regarding the best practices in terms of global public goods. Green bonds basically aim for users to collect capital for projects that promote green innovation and reduce environmental impacts. These bonds collect funds from investors who have a fixed income and use them to support lending by the World Bank for projects that are eligible, which predominantly seek to mitigate climate change or perhaps help those who have been affected by it (World Bank Group, 2025). Therefore, as the market for green bonds is consistently expanding, it is crucial for policymakers, investors, and researchers to gain a comprehensive understanding of their impact on green innovation outcomes. Nevertheless, despite these developments, there is no systematic synthesis of existing literature on this subject that would observe the specific impact of the issuance of green bonds on green innovation at the corporate level, specifically in the various industrial sectors. In this way, the research questions in this study will include two important questions:

*RQ1: What is the association between the issuance of corporate green bonds and green innovation outcomes?*

*RQ2: What is the relationship in various sectors?*

Similarly to how companies are embracing artificial intelligence (AI) and digital solutions to drive customer satisfaction and corporate strategy, firms are also adopting green finance solutions to enable corporate strategy to meet the goal of environmental objectives. Effective technology implementation presupposes strategic enablers and institutional support, and the same applies to the green bond implementation and green innovation in companies. This paper is based on the resource-based view (RBV) of the firm that suggests the availability of green financing in the form of bond issuance gives firms the resources that they need to make investments in green innovation resources.

The rest of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes the methodology used. Section 4 presents the results, and Section 5 analyzes them. Section 6 provides a conclusion.

## 2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

According to recent developments in the literature, green bonds encourage technical innovation and increase resource efficiency in addition to funding infrastructure and renewable energy projects. Data from 2007 — the first green bond was issued during this year — to 2021 were examined by Alamgir and Cheng (2023). They discovered that the production of renewable energy is positively impacted by green bonds. Additionally, they cut carbon emissions by almost 0.8 tonnes. These conclusions were further supported by Agarwal and Pathak (2021), who identified green bonds as a key tool for promoting sustainable development. By 2030, they promote their use to reduce CO2 emissions by about 45%. This will assist in keeping the increase in Earth's temperature to 1.5–2 degrees. Green bonds, then, serve as financial tools that enable investors to support the green transition. Over the past 15 years, this market has expanded, reaching a value of US$3.5 trillion in the third quarter of 2023. Remarkably, about US$2 trillion of this is being used to issue green bonds (Organisation for Economic Co-operation and Development [OECD], 2023).

Investment capital is reallocated to research and development (R&D) through corporate green bonds (Dong et al., 2024). In addition to the obvious environmental advantages, financial performance is anticipated to improve with increased green innovation. In this context, Rao et al. (2022) used a difference-in-difference (DiD) model to empirically analyze Chinese A-share listed companies. At the 5% level of significance, they discovered that issuing green bonds enhances a company's green innovation. After adjusting for the fixed effects of industry and year, these results were found. Additionally, bonding is crucial for lowering carbon dioxide emissions (Lian et al., 2023). Better energy use, particularly as seen in renewable energy initiatives, makes this possible. Furthermore, different industries are anticipated to see different effects from green bonds. Eco-friendly bonds may not always be effective in promoting economic growth with greater innovation, according to Bajra and Wagner (2024). The reason for this is that they may have varying effects on various sectors. According to Azhgaliyeva et al. (2022), wealthy countries are more likely to issue green bonds in industries like utilities. However, only Italian business issuers gain from cheaper costs when compared to financial institutions, according to Teti et al. (2022). Likewise, it is anticipated that green bonds will have favorable knock-on effects on neighboring areas. A similar impact was discovered by Panwar et al. (2023). Positive spillover effects from green bonds to renewable energy stocks were discovered by Zhang and Umair (2023). This supports the idea that green bonds have a favorable knock-on effect on related markets and nearby locations. In addition to financial sources, organizational capabilities such as talent management and R&D staff or personnel are also a key driver of the outcomes of the innovation. This raises the idea that the effectiveness of green bonds is not merely determined by the availability of capital, but also theability of firms to mobilize such capital in terms of innovation. Organizational capabilities and strategic position mediate the relationship between the availability of resources and innovation performance. This is in line with our review result that the effectiveness of green bonds differs depending on the firm characteristics and strategic orientation. Implementing new technologies and business strategies requires responsible implementation frameworks, as organizations embrace them, a concept that also applies to the context of green bond markets, where

green markets rely on governance and accountability frameworks to dictate environmental outcomes. Innovation capabilities can be mediators between the available resources and organizational performance, indicating that green bond capital should be accompanied by the capacity of firms to convert the capital into green innovation.

Additionally, a number of studies have examined the role that environmental, social, and governance (ESG) performance plays in the issuance and performance of green bonds. According to Guesmi et al. (2025), issuing green bonds is unquestionably linked to strong ESG scores, but it has nothing to do with lower carbon emissions. According to Wang and Wang (2022), companies with high ESG scores are more focused on governance and environmental issues. As a result, they are more inclined to make investments in green bonds and implement sustainability initiatives. But there's also a chance of greenwashing. Businesses occasionally misuse the money they raise by issuing green bonds in ways that make them appear to be investing in environmentally friendly initiatives (Shi et al., 2023). This type of process is typical of businesses that produce a lot of pollution. They greenwash as a result of growing regulatory demands and higher expenses associated with innovation. Accordingly, bonds like conventional green bonds, currency-dominated green bonds, and municipal bonds are particularly vulnerable to greenwashing (Asl et al., 2024). This is because there isn't a lasting causal link between a sustainable economy and this. Third-party certification is therefore more or less required in this situation. This will increase the market's legitimacy and guarantee that green bonds can fulfil their stated environmental objectives.

A related systematic literature review (SLR) by Liu et al. (2025) similarly examines green finance and corporate innovation linkages using similar search protocols, providing an independent validation and expansion of key findings presented herein. Where applicable, convergence and divergence between these complementary reviews are noted throughout the analysis. However, despite all such advances, the extent to which the issuing of green bonds affects green innovation remains relatively unexplored. This is particularly true given the sectoral differences in their impact that are expected. Therefore, this study aims to fill this gap in existing literature. The aim of the study is to determine the impact of corporate green bond issuance on green finance outcomes. For this purpose, two hypotheses have been curated, which are:

*H1: Corporate green bond issuance entails a positive association with green innovation outcomes at the firm level.*

*H2: Quantitative evidence shows significant sectoral variation in the impact of green bond issuance on green innovation.*

## 3. RESEARCH METHODOLOGY

A rigorous mixed-methods research approach that combines two complementary methodologies, which are SLR and bibliometric analysis, is used in this research. These approaches work at varying levels of analysis but offer inclusive suggestions regarding the greenbond research and influence.

Three complementary databases were employed to cover all the areas effectively:

1) Scopus as a broad interdisciplinary coverage of peer-reviewed literature in finance, business, and sustainability;

2) Web of Science (WoS) as a source of high-quality research with established citation tracking;

3) Google Scholar as a supplementary source of working papers, preprints, and grey literature.

The combination will guarantee the inclusion of peer-reviewed journal articles as well as modern-day research that is not officially published. These databases were chosen due to their prowess in indexing financial and economic studies, as compared to biomedical-oriented databases that do not have much to offer to the corporate literature on green bonds.

### 3.1. Search strategy

A systematic search strategy employed Boolean operators and targeted keywords across three thematic areas — green bonds, corporate finance, and green innovation — searched within titles, abstracts, and author keywords. This approach ensured comprehensive coverage of relevant literature exploring the nexus between corporate green bond issuance and green innovation outcomes while maintaining thematic coherence and precision:

- "green bond" *or* "sustainable bond" *or* "climate bond";
- "corporate finance" *or* "corporate issuance" *or* "corporate bond" *or* "corporate investment";
- "green innovation" *or* "sustainable innovation" *or* "eco-innovation" *or* "environmental innovation".

The timeframe chosen was between 2010 and 2024. This was when the post-financial crisis era was making its mark, when sustainable finance started becoming a norm practice across various parts of the globe, particularly with the advent of ESG models and climate-based investment policies. Only peer-reviewed journal articles, review papers, and conference proceedings were used for analysis, thereby maintaining a scholarly and academic content focus. Only English-language articles were used to maintain uniformity in the analysis, as well as due to English being the dominant language of academic publishing.

### 3.2. Study selection and screening

The initial search yielded 200 articles, which were imported into Zotero for data management. The selection process involved several stages to refine the dataset:

- Duplicate removal: After identifying and removing duplicate entries, the count was reduced to 157 articles.
- Manual filtering: Two books were removed, followed by the exclusion of non-peer-reviewed publications, resulting in 116 peer-reviewed articles.
- Title and abstract screening: Automated screening was conducted, narrowing the count to 69 articles.
- Full-text review: A detailed review of the full text was performed, leading to the final selection of 32 articles that directly addressed the research objectives.

The cleaned data set was imported into Bibliometrix and VOSviewer for performing the bibliometric analysis. They were utilized in order to develop visual maps of co-authorship networks, keyword co-occurrence, and citation relations. This identified intellectual trends, scholarly collaborations, and dominant research themes. By layering bibliometric mapping upon qualitative synthesis of the literature, this research furnishes a broad and deep understanding of academic scholarship in how corporations are applying green bonds to spur innovation toward environmental sustainability.

This has been summarized in the following flowchart, and the data for the process has been summarized in Table 1.

**Figure 1.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart

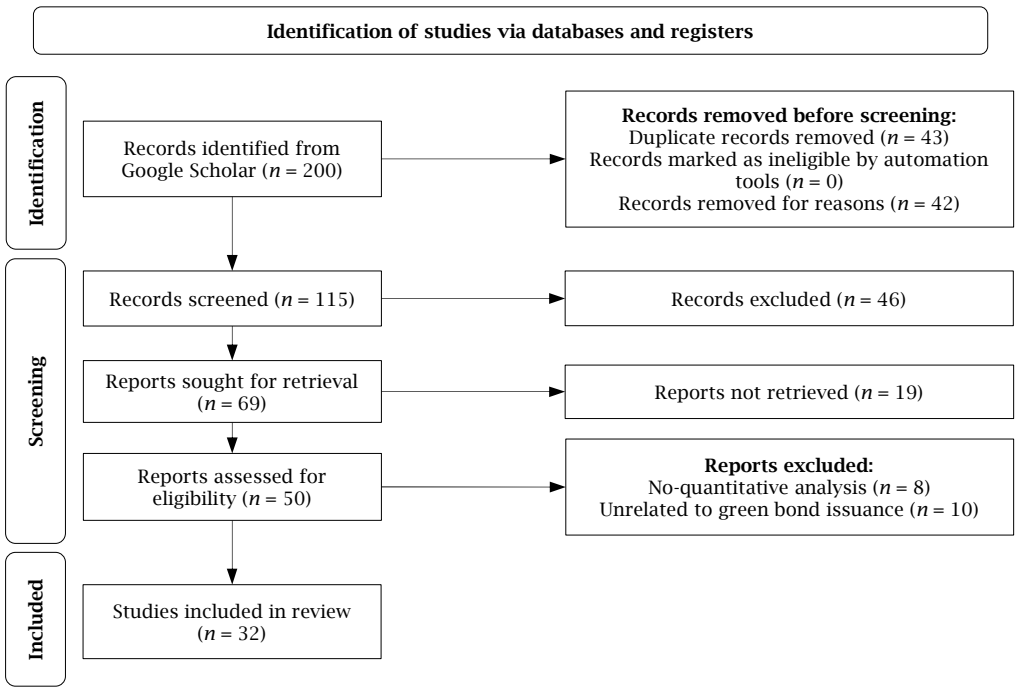



**Table 1.** Screening data summary

| *Phrases searched* | *Number of articles retracted* |
|---|---|
| "Impact of green bond issuance on green innovation outcomes" | 100 |
| "Sectoral difference in the impact of green bond issuance on green finance outcomes" | 100 |
| Total | 200 |
| After removing duplicates | 157 |
| After manually eliminating books | 155 |
| After manually removing non-peer-reviewed articles | 115 |
| Title and abstract screening | 69 |
| Full-text review | 32 |

## 4. RESULTS

### 4.1. Systematic literature review

A sub-total of 32 studies were reviewed under the PRISMA framework for SLR. A thorough analysis of their findings has revealed significant empirical insights into the relationship that exists between the issuance of green bonds and their corresponding impact on green innovation outcomes. This section will capture the recurring themes that have been identified across the studies.

#### *4.1.1. Impact on green innovation and resource efficiency*

According to the majority of research, green bonds are essential for encouraging green innovation. At the same time, they increase resource efficiency. According to Ye and Ehsan (2023), financing green bonds greatly increases resource utilization efficiency. Their findings held for 15 countries in the Asia-Pacific region and were especially applicable to renewable energy initiatives. Wang et al. (2022) found a statistically significant positive correlation between green finance and green innovation over an extended period of time. It should be noted that their results were consistent across 57 developing countries, highlighting the fact that countries with poorer environmental performance tend to be more affected by green money. Furthermore, Chang et al. (2023) looked at the top ten countries that issued green bonds and found a similar, largely favourable correlation between energy efficiency and green bonds. While the impacts were mixed in Canada and China, the results were more noticeable in Spain. Additionally, in the same context, Irfan et al. (2022) emphasised the significance of policy interventions. They discovered that initiatives like green finance

pilot zones greatly boost regional green innovation in China. In this sense, R&D expenditure and the change in industrial structure serve as the main conduits for transfer. Additionally, Lin et al. (2022) provide firm-level evidence that issuance of green bonds boosts green innovation through the channels of R&D investment and green patent filings.

In line with these results, Skordoulis et al. (2022) prove that the strategy of firms is a key mediator of the relationship between green entrepreneurship and competitive advantage and, in particular, between medium and large-sized firms in Greece. This implies that the efficiency of corporate green bond issues is not only related to the availability of capital but also to the strategic positioning of an organization in regard to sustainability. Therefore, effective implementation of green bonds needs resources as well as strategic planning towards innovation. This effect is particularly pronounced across large, non-state-owned enterprises with constrained financing. Moreover, green bonds improve firm performance by 1.65% via green patent output and gains of reputation (Tan et al., 2022). Lastly, Bai et al. (2022) highlight that green finance reduces emissions across low-income regions, most effectively. This indicates that green bonds serve as more impactful drivers of innovation, especially across less-developed markets.

### *4.1.2. ESG performance and greenwashing*

The correlation between the ESG performance and issuing green bonds presents a paradoxical nature: even with the high ESG commitment generally leading to green bond issuance, there are big disparities between the proclaimed environmental commitment and the attained environmental performance. Wang and Wang (2022) found that companies with a more advanced ESG rating are significantly more likely to issue green bonds, and environmental and governance-related considerations have a significant influence on making issuance decisions. The analysis of 1,089 Chinese listed companies in 2016–2020, which they presented in the form of a panel, showed that a one-point rise in ESG scores raised the likelihood of green bond issuance by 0.073%, holding firm size and financial performance constant. Nevertheless, this positive relationship between ESG commitments and the issue of green bonds hides a high degree of heterogeneity: Guesmi et al. (2025) established that whereas the issuance of green bonds is associated with high scores in ESG, it is practically unrelated to the reduction of actual carbon emissions, which may indicate a possible lack of correspondence between reported ESG indicators and real environmental performance. Greenwashing, i.e., the effort to make false environmental statements or to commit green bond proceeds misappropriation, is an issue that is here to stay and is increasing in importance in the market. Baldi and Pandimiglio (2022) made a detailed empirical study of 540 globally issued green and conventional bonds between 2012 and 2020 and reported that the green bond yield is significantly higher in terms of manufacturing companies and multinational issuers, who are considered at risk of greenwashing. Their analysis found that the greenwashing risk, as represented by inconsistencies in the ESG metrics and environmental claim credibility tests, adds bond yields that are, on average, 15–25 basis points over normal credit risk premiums. The manufacturing and multinational corporations are disproportionately high in the risk of greenwashing (coefficient = 0.087, $p < 0.05$), since they not only have higher base environmental effects that put pressure on misleading environmental statements, but also are more sophisticated than other industries to engage in complex greenwashing programs. The greenwashing risk of public green bonds issued by local governments is significantly lower than that of national governments (coefficient = -0.042, $p < 0.05$), indicating that subnational institutions of governance offer greater accountability schemes than national governments.

It is recorded that ESG rating agencies are using different methodologies and data quality criterion which makes it possible for corporations to shop among different rating providers to get the best rating. Asl et al. (2024) reported that the municipal bonds, corporate bonds in carbon-intensive industries, and currency-denominated green bonds are associated with grossly disproportionately high greenwashing risks, and there are indications that specific types of bonds and issuer attributes are correlated with a high likelihood of environmental claim misstatement. These results show that the risk of greenwashing is not haphazardly distributed, but it is concentrated among particular issuers and types of bonds.

Third-party certification schemes are among the essential infrastructure in terms of fighting greenwashing by enforcing third-party accountability and standardized verification measures. By exploring the role of third-party certification in green bond environmental efficacy, Yeow and Ng (2021) revealed that green bonds do not produce positive environmental performance in terms of corporate environmental performance (coefficient = 0.156, $p < 0.05$), yet they produced no difference in uncertified green bonds. The criticality of this finding is as follows: it proves that green bond instruments alone cannot help produce environmental gains; but instead, certification systems that establish external responsibility are needed to assure environmental deliverables. The most commonly-known certification standard, and the only one known to many, is the Climate Bonds Initiative (CBI), which was founded in 2011 on the basis that certified bonds must fund a project that satisfies a set of climate impact standards, which are checked by means of independent assessment. The standards of the International Organization for Standardization (ISO) standard No. 14064 are designed and established by the ISO to provide some guidelines on how to quantify and verify the emission reduction of greenhouse gases. In 2023, the European Union (EU) introduced a regulatory standard of green bond issuance, the Green Bond Standard (EUGBS), establishing a regulatory framework in the jurisdiction of the EU, requiring third-party oversight, and stipulating that issuers must report in-depth environmental impact measures.

Kenyon et al. (2022) emphasize that transparency in carbon emissions reporting is a core to obtaining true results of sustainable finance, and it is a direct way to eliminate risks of greenwashing. Their model states that with the introduction of carbon accounting standards, where companies measure and publish the total value-chain carbon emissions (Scope 1, 2, and 3 emissions), there will be systemic accountability, and greenwashing will be significantly harder and more costly. When the environmental impact metrics are based on physical and verifiable carbon accounting, but not on the subjective emission intensity ratings, the arena of misleading claims will be considerably reduced. Nevertheless, it is still not done: most corporations (voluntarily) have yet to adopt comprehensive carbon accounting (including Scope 3 value-chain emissions), and less than 20% of businesses in the world issue full Scope 3 disclosures.

### *4.1.3. Sectoral and regional disparities*

Empirical literature shows that the effectiveness of green bonds varies widely both in the sectoral and geographic contexts, which denies the premise that the effects are homogenous. Although most of the reviewed literature focuses on utilities and the energy industry, recent facts point to major differences in industrial landscapes that should be explored further. This distribution of green bond issuance by developed countries and utility sectors is shown to cause underrepresentation of key differences between the geographic and sectoral concentrations of the response of different economic structures to green finance (Azhgaliyeva et al., 2022). The authors used multilevel models that cover 41 economies in eight sectors between 2010 and 2021 and concluded that macroeconomic shocks, in particular fluctuation in crude oil prices, have different impacts on the probability of issuing green bonds across sectors, with utilities having a considerably larger market share than other sectors.

Although manufacturing is both highly carbon-intensive and has enormous potential in terms of innovation, the industry is largely overlooked in the research on green bonds. Although the energy and utility industries lead in the volume of issuances and scholarly interest, manufacturing companies have distinctive obstacles and prospects in the green bond markets that have not been fully exploited. This gap in the sector is notable in that manufacturing contributes to about 30% of the worldwide carbon emissions, but less than 15% of the studies reviewed in this literature. The relative lack of studies regarding the manufacturing of green bonds might be due to the number of years during which the sector adopted conventional financing and resistance by manufacturers towards signing environmentally-specific targets that must be publicly verified. Large, non-state-owned firms with limited access to financing were found by Lin et al. (2022) to have particular access to green bond emission through improved R&D investment channels, which implies that capital-intensive industries such as manufacturing could gain disproportionately through such instruments.

Regional inequalities do not just end at the dichotomous developed-developing countries, but there are also significant sub-national spatial structures. Huang et al. (2022) presented evidence of the spatial spillovers in Chinese provinces and proved that the green finance policy enhances local innovation, as well as affects the neighbouring regions favourably due to such mechanisms as the technological diffusion of innovations, knowledge spillover, and pattern of capital flows. In their study, they determined the optimal intensity of environmental regulation to be moderate (a threshold value of 0.935) to maximize positive effects using spatial Durbin models without controlling for time-varying covariates on 30 Chinese provinces, 2009–2017, and found that there is an inverted-U relationship between regulatory stringency and the effectiveness of green bonds. This spatial analysis was extended by Tang and Zhou (2023), who discovered that green finance has improved local and regional development of renewable energy across China, but COVID-19 shocks reversed the diffusion patterns, making the impacts concentrated instead of diffused. Interestingly, they found that geographical limits to spillover effects and the effect of geographical proximity, institutional coordination, and policy harmonization are critical factors in the effectiveness of green bonds, as shown by the fact that green finance influence decays beyond a radius of about 700 kilometers.

Research on the developed economy has identified different tendencies that represent the maturity of the institutions and the depth of the financial market. The quantile-on-quantile regression analyses conducted by Chang et al. (2023) to estimate the asymmetric relationship between green bonds and energy efficiency additionally revealed the experiment of predominantly positive effects of green bonds in Spain, mixed effects in Canada, and unexpectedly negative effects in China, Germany, and Japan among the top ten countries in the issuance of green bonds. Such an uneven heterogeneity indicates that the performance of green bonds is highly context-specific to aspects such as the structure of the energy system in place, the current penetration of renewable energy, the industrial structure, and other policies. Teti et al. (2022) discovered in Italy alone that the cost benefits of corporate green bond issuers are 35 to 40 basis points lower than conventional bonds in primary markets, which is significantly greater than in secondary markets, indicating that the preference of investors to green instruments may be information-based and sensitive to market-microstructure.

The situation with emerging and developing economies is unique in that it has unique dynamics that should be analyzed separately. Prajapati et al. (2021) conducted a survey research on 125 retail investors in India, and found that financial incentives, ESG awareness, and credit ratings play a significant role in making a green bond investment decision. Their conclusions indicate that tax relief and specialized financial education might serve the purpose of growing green bond markets among individual investors of the emerging economies,

a process that has not yet been studied in the developed markets dominated by institutional investors. The differences in the regional bond pricing and environmental effects among the continents prove the idea that not all the effectiveness of the green bonds is transferable. Taghizadeh-Hesary et al. (2021) examined 1,174 bond observations between 2017 and 2020 in Asia-Pacific, Europe, and North America and observed that Asia-Pacific green bonds have higher returns, but also more risk and heterogeneity than others, and returns are significantly lower when the issuing firm is a banking institution than when it is a corporation.

This sectoral distinction within the financial sector is generated by the fact that corporate and financial institution issuers generate a significant sectoral dissimilarity. Fatica et al. (2021) established that corporate and supranational issuers are enjoying substantial greenium (price premiums) in comparison to financial institutions that issue green bonds, which do not enjoy similar pricing benefits. But the arrangers as banks that issue green bonds, later cut down lending to carbon-intensive industries, indicating that the indirect environmental benefits are obtained through changed patterns of capital allocations and not the direct improvement of environmental performance of firms. This difference has fundamental impacts on the explanation of the green bond transmission, and it points to the fact that the effectiveness of green bonds cannot be measured only based on issuer returns but also based on the impact of systemic reallocation of capital.

#### *4.1.4. Green bonds as financial instruments and hedging tools*

Finally, several studies assessed the financial performance and risk-hedging potential of green bonds. Tiwari et al. (2022), for instance, found that green bonds can be significantly impacted by carbon markets and renewable energy equities. Additionally, their minimal connectivity portfolios offer superior risk mitigation. Furthermore, Naeem et al. (2021) showed that green bonds have the ability to hedge commodity markets over the long term. While precious metals showed minimal connections with returns on green bonds, they were analyzed across industrial metals and natural gas. Yeow and Ng (2021) discovered that green bonds have no discernible effect on corporate performance in addition to financial performance. However, this is not applicable when they are certified by third parties, as in this case, weak governance remains a barrier to realizing the full potential of green bonds. Moreover, Yang et al. (2021) found that green finance, alongside financial technology (FinTech) innovation, promotes high-quality economic development. This enhances efficiency and structural transitions. Nenavath (2022) shows that green finance policies and FinTech reduce emissions collectively. This, in turn, drives green investment behavior. Moreover, fuzzy analytic hierarchy process models are used to identify green bonds as the most effective instrument in boosting energy efficiency and green economic recovery, particularly in emerging Asian economies (Zhao et al., 2022). Finally, Lin et al. (2022) caution that geopolitical and inflationary pressures may moderate green finance impacts. They emphasized the importance of a stable policy environment to ensure the effectiveness of bonds.

### 4.2. Bibliometric analysis

#### *4.2.1. Keyword co-occurrence network analysis*

In order to better consolidate the understanding of trend research at the confluence of green bonds, green innovation, and their corresponding financial and environmental themes, an extended keyword co-occurrence analysis was performed. Data were collected from two of the largest academic databases — WoS and Scopus — to ensure sufficient coverage of high-quality, peer-reviewed articles.

The 2,985 distinct words were found in the combined sources. To focus on the most influential words in the field, a threshold of five uses per keyword was applied. As a result, 107 words cleared the inclusion threshold and were selected for network visualization.

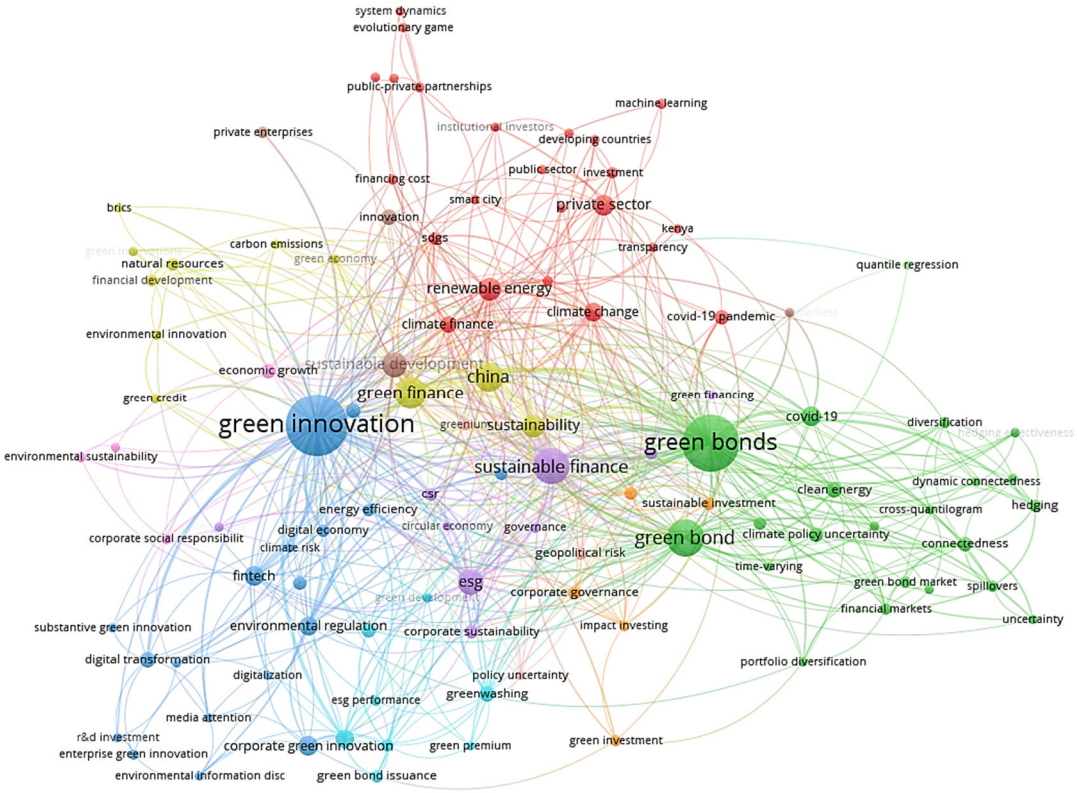
**Table 2.** Keywords co-occurrences

| *Keyword* | *Occurences* | *Total link strength* |
|---|---|---|
| Green bonds | 184 | 235 |
| Green innovation | 217 | 221 |
| Sustainable finance | 75 | 143 |
| Green bond | 79 | 113 |
| Green finance | 59 | 100 |
| ESG | 38 | 83 |
| Sustainable development | 37 | 69 |
| Sustainability | 31 | 57 |
| Renewable energy | 30 | 56 |
| China | 48 | 53 |
| Climate finance | 17 | 49 |
| Climate change | 21 | 40 |
| FinTech | 22 | 39 |
| COVID-19 | 24 | 35 |
| Financing constraints | 21 | 35 |
| Environmental regulation | 20 | 33 |
| Greenwashing | 15 | 32 |
| SDGs | 10 | 28 |
| Connevtedness | 12 | 27 |

*Note: SDGs — Sustainable Development Goals.*

With VOSviewer, a keyword-specified co-occurrence map was created. The map (see Figure 2) shows the frequency with which words appear together in the same papers and maps the structure and thematic clusters of the research landscape. The nodes are words, and their size is proportional to frequency. The lines between nodes show the degree of their co-occurrence, and thematic clusters are colored by the algorithm of the software.

**Figure 2.** Keyword co-occurrences network




*Source: Authors' elaboration.*

### *4.2.2. Findings and thematic clusters*

#### *Blue cluster: Green innovation and technological transformation*

Its biggest and most dominant cluster is centered around the term "green innovation", signifying its importance in the literature. Close synonyms include:

- corporate green innovation;
- environmental regulation;
- digital transformation;
- R&D investment;
- FinTech;
- ESG performance.

The cluster suggests a unified focus on how firms embed green innovation through digitalization, policy requirements, and corporate strategies. It demonstrates a blend of environmental sustainability and technology-driven innovation in firms' operations.

#### *Green cluster: Green bonds and financial risk*

This cluster is focused on "green bonds" and contains terms such as:

- hedging, connectedness, portfolio diversification;
- financial markets, uncertainty, spillovers;
- clean energy, quantile regression.

These terms indicate the financial aspects of green bonds, highlighting their function in managing market risk, facilitating energy transitions, and impacting asset allocation strategies in times of uncertainty — like the COVID-19 pandemic, also prominently referred to prominently.

#### *Red cluster: Climate change and renewable energy*

This cluster emphasizes policy-oriented and macro-level sustainability issues. Core terms are:

- climate change;
- renewable energy;
- private sector;
- public-private partnerships;
- developing countries, SDGs.

Having governance-related terms (e.g., transparency, institutional investors) indicates increased research interest in stakeholders' and partnerships' roles in climate mitigation financing through green finance mechanisms.

#### *Light purple cluster: Sustainable finance and governance*

In the cluster mentioned, the following keywords are prominently found:

- sustainable finance;
- CSR (corporate social responsibility);
- circular economy;
- governance.

#### *Yellow cluster: Environmental and economic development*

Similarly, in another cluster, we can see coherence around the following keywords:

- natural resources;
- environmental innovation;
- green credit;
- economic growth;
- financial development.

This extended co-occurrence map presents a rich and multifaceted picture of the scholarly environment around green bonds and innovation. The richness of the clusters indicates the interdisciplinary character of the field, ranging from finance, environmental science, corporate strategy, and policy. The strong presence of green innovation, green bonds, and climate change reflects the important anchors in the studies, while the unfolding themes of digital transformation, corporate sustainability, and risk management indicate new areas to be explored.

This examination not only charts the existing organization of scholarly work but also provides useful direction for researchers seeking to detect gaps, contribute to the known, or link fragmented subfields.

### *4.2.3. Co-authorship network*

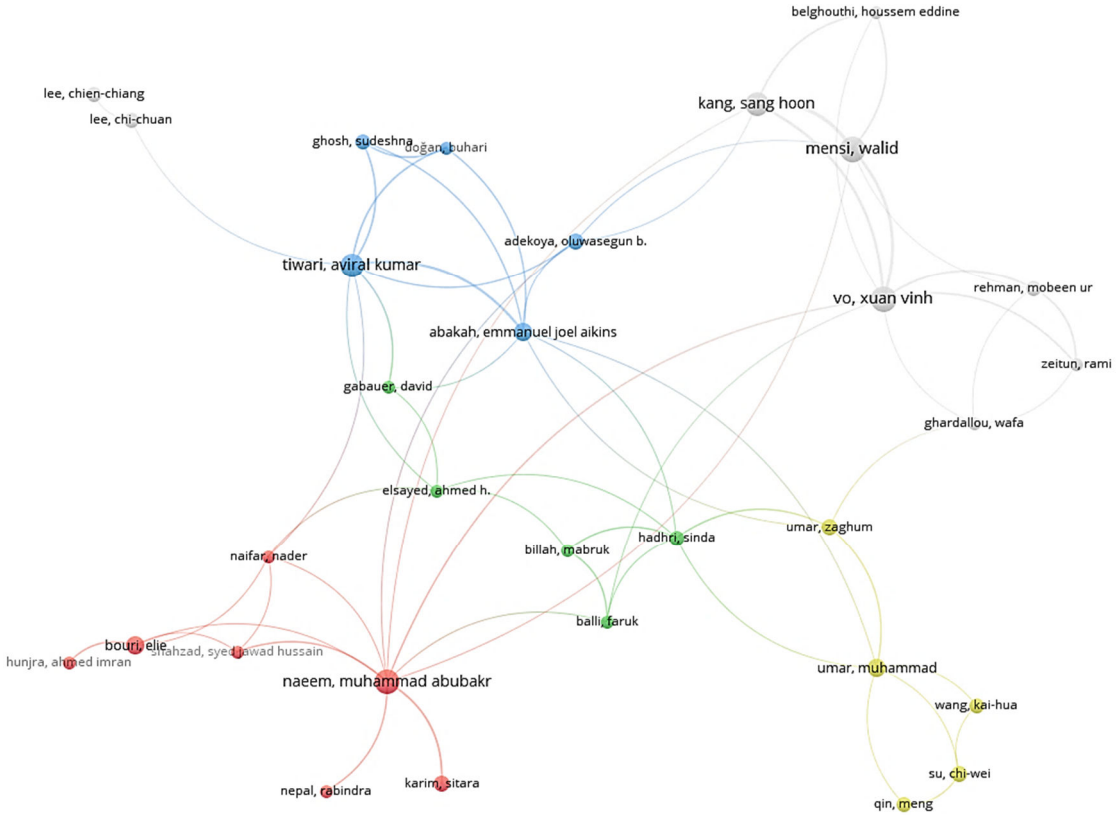
Table 3 and Figure 3 lay out the co-authorship ties among researchers who have authored papers related to green innovation and green bonds. This network was constructed based on Scopus and WoS data and examined co-authorship patterns to discern how researchers are collaborating in this research area.

**Table 3.** Author productivity and collaboration strength

| *Author* | *Documents* | *Total link strength* |
|---|---|---|
| Xuan Vinh Vo | 12 | 25 |
| Walid Mensi | 12 | 23 |
| Sang Hoon Kang | 10 | 21 |
| Aviral Kumar Tiwari | 10 | 18 |
| Muhammad Abubakr Naeem | 11 | 15 |
| Emmanuel Joel Aikins Abakah | 6 | 14 |
| Pengfei Ge | 4 | 11 |
| Chuxiong Tang | 4 | 11 |
| Rui Zhu | 4 | 11 |
| Shivam Azad | 6 | 9 |
| Yichao Liu | 3 | 9 |
| Mobeen Ur Rehman | 4 | 9 |
| Buhari Doğan | 3 | 8 |
| Sudeshna Ghosh | 4 | 8 |
| Sinda Hadhri | 4 | 8 |
| Houssem Eddine Belghouthi | 3 | 7 |
| Muhammad Umar | 6 | 7 |
| Rami Zeitun | 3 | 7 |
| Oluwasegun B. Adekoya | 5 | 6 |

This co-authorship analysis identifies 88 notable green finance and sustainability authors who have authored at least three publications. Vo Xuan Vinh, Mensi Walid, and Kang Sang Hoon stand out not only with the number of publications they have but also with large collaboration teams, as indicated by their high total link strength scores.

**Figure 3**. Co-authorship network graph




### *4.2.4. Selection criteria*

Of the total 3,226 authors found in the dataset, those with a minimum of three published documents were selected for this analysis. This narrowed the selection down to 88 authors, all of whom were plotted in the co-authorship network. The target was to exhibit the most productive and networked contributors in the subject matter.

- Each circle (node) stands for an author, and its radius corresponds to the number of publications the author has.

• Solid lines between the nodes indicate co-authored papers, representing collaborative relationships.

• Colors cluster authors by how often they collaborate, which in many cases can represent overlapping research topics, institutions, or regional emphasis areas.

Muhammad Abubakr Naeem is a notable individual within one of the largest clusters (marked red). The fact that he co-authors frequently with researchers such as Elie Bouri, Nader Naifar, and Syed Jawad Hussain Shahzad indicates a close-knit research group dedicated to finance and sustainability.

Another extremely cooperative cluster (in blue) is headed by Aviral Kumar Tiwari, who frequently co-authors with scholars such as Sudeshna Ghosh and Oluwasegun B. Adekoya. This cluster must be indicative of a very active academic collaboration in economic or financial modeling.

Other prominent co-authors are Xuan Vinh Vo, Walid Mensi, and Ahmed H. Elsayed, each being the center of their respective cooperative groups, indicating different but equally active research networks.

1. *Collaboration trends.* The map indicates high levels of interconnectedness; researchers in this field often collaborate between various institutions and perhaps even countries. This is necessary in a field as multidisciplinary as green finance, where issues cut across economics, sustainability, policy, and innovation.

2. *Geographic and thematic spread.* The clusters can also provide suggestions of geographical trends. Names such as Su Chi-Wei and Kai-Hua Wang in the yellow cluster could be representative of researchers located in East Asia, while red and green clusters would signify groups from Europe or the Middle East. Such patterns of collaboration indicate that green finance is a global issue being tackled through global collaborations.

This co-authorship analysis not only helps us see who is most active in this research space but also shows how knowledge in green bond issuance and innovation is being built through joint efforts. It highlights opportunities for future collaborations and offers insights into the structure of the research community in this growing field.

## 5. DISCUSSION

The results of this SLR and bibliometric analysis suggest a subtle picture of the connection between the corporate green bonds issuance and the green innovation outcomes. The synthesis of empirical evidence from 32 rigorously screened studies shows that green bonds are designed as multifaceted tools that go beyond the traditional debt financing to mobilize technological innovation, lead to increased efficiency in the use of resources, and change the sector towards sustainability. In this discussion, the findings are presented in the framework of the developed hypotheses (*H1* and *H2*), the emergent role of digital technologies is discussed, and the theoretical and practical implications of these findings for the stakeholders.

This is in the overwhelming support of *H1*, which assumed a positive relationship between the issuance of corporate green bonds and the results of green innovation at the firm level. Various empirical studies prove that companies that have a source of access to green bond capital observe a significant improvement regarding the number of green patents, expenditures on R&D, and innovation output (Lin et al., 2022; Rao et al., 2022). The non-parametric DiD design of Rao et al. (2022) on Chinese A-Share listed companies established an improvement of 3.2% in green patent applications over three years after the issuance of green bonds with the firm and time fixed effects. This observation implies that green bonds are a plausible commitment device that sends managerial signals to investors and allows companies to access innovation-driven capital, which would not otherwise be accessible through other conventional financing sources. The mechanism is efficient in the following pathways: green bond goes directly into R&D projects, increases firm legitimacy in sustainable market economies, including reputational incentives in making long-term investments in innovation.

It is also greatly supported by *H2* of the existence of significant sectoral differences in the effects of green bonds. The review found a high level of heterogeneity in the results among the industrial sectors and geographical regions. Although the energy industries and utilities are the leading categories of issuers and the most published in literature, manufacturing, a major (around 30) source of global carbon emission, is grossly underrepresented in both green bond issuance (nearly 15% of reviewed studies) and literature on innovation outcomes. Such sectoral imbalance is not only a difference in the level of their financing needs, but also underlying differences in their ability to innovate, level of exposure to regulation, and their market positioning. There are cost benefits that are different between financial institutions that issue green bonds and corporate issuers; Fatica et al. (2021) reported that corporate and supranational issuers receive significant greenium pricing premiums, but financial institutions receive little pricing advantage. The implications of this difference are far-reaching in relation to transmission mechanisms because green bonds appear to work by reallocating capital systemically, but not because they improve the environmental performance of issuing firms.

The *H2* is equally supported by geographic differences. Chang et al. (2023) found that the relationships between green bonds and energy efficiency are asymmetric in the top ten bond-issuing countries across the globe, with a relatively large number of positive effects in Spain and a relatively large number of negative effects in China, Germany, and Japan to the contrary. These results highlight the fact that the effectiveness of green bonds is relative and is based on the current energy infrastructure, renewable energy penetration figures, industrial form, and supportive policies. The spatial analysis conducted by Huang et al. (2022) showed the inverted-U association between the stringency of environmental regulation and green bond effectiveness, and an optimal regulatory strength of 0.935, implying that weak and strong regulation lead to a decrease in the results of innovation. Tang and Zhou (2023) also reported that the COVID-19 shocks reversed the patterns of spatial diffusion, concentrating the effects instead of diffusing them, and found that a critical distance of some 700 kilometres in which spillover effects fade away critically dictated success.

One of the key conflicts that has been revealed in the reviewed literature is the lack of connection between the ESG commitment and environmental performance. Whereas Wang and Wang (2022) determined that companies with high ESG ratings are more likely to issue green bonds (an increase in the level of one ESG score by one point increases the likelihood of issuing a green bond by 0.073%), Guesmi et al. (2025) reported that high ESG scores are practically uncorrelated with the actual carbon emissions reductions. This paradox shows that the framework of ESG is multi-dimensional in the sense that its governance and social aspects can be used to make issuance decisions without regard to environmental performance undertakings.

The greenwashing phenomenon needs a specific mention based on the implications in the market. Baldi and Pandimiglio (2022) put those greenwashing risk premiums at 1525 basis points to the yield on a green bond of a manufacturing and multinational corporation, which is huge risk compensation. The authors found that disproportionality in greenwashing concentrations exists with regard to carbon-intensive sectors, multinational corporations, city bonds, and currencies, which suggests that risk is not distributed haphazardly but is instead concentrated in a select few issuers. The third-party certification becomes an essential component of the infrastructure: Yeow and Ng (2021) revealed that certified green bonds generate favorable corporate environmental performance gains (coefficient = 0.156, $p < 0.05$), but uncertified bonds do not produce any significant difference between them in comparison with the conventional bonds. The discovery confirms the need for external verification mechanisms that are independent, where the CBI and new forms of regulation, like the EUGBS, offer standardized verification processes.

## 6. CONCLUSION

This SLR is a systematic review of the literature, which synthesized 32 rigorously vetted studies using PRISMA protocol guidelines, and was further supported by bibliometric analysis, setting the ground that corporate green bond issuance is a relevant mechanism in green innovation promotion and enhancing sustainable finance goals. The two research hypotheses are supported by the empirical evidence. First, green bonds show a strong positive correlation with the firm-level green innovation outcomes, which are measured in terms of higher green patent filing, resource efficiency R&D investment, and enhanced green patent filing. The mechanisms of impact are capital provision, signaling effect, and reputational incentive, which are believed to bring corporate strategic direction into innovation. Second, this relationship is highly sectoral and regionally heterogeneous, nullifying the assumptions of the homogeneity of effectiveness. The benefits enjoyed by utilities and developed-economy companies are stronger, and manufacturing industries, even though carbon-intensive and potentially the most innovative, are continuously under-investigated and underserved by green bond markets. Additional evidence of policy-specificity includes geographic spillover effects, which depend on the spatial proximity (optimal at around 700 kilometers), as well as the complement to the policy.

The study found a serious paradox in the study: high ESG performance is highly related to the likelihood of green bonds but weakly related to the reduction of carbon emissions in reality. This lack of connection highlights the dangers of greenwashing, especially when some of the carbon-intensive industries and the multinational enterprises are subjected to yield premiums on the order of 1525 basis points. Sourced third-party certification mechanisms become crucial infrastructure in bringing green bond issuance to a statistically significant performance in the environmental domain, with certified bonds exhibiting statistically significant improvement of environmental performance that was not observable in their uncertified counterparts.

To policymakers, the results indicate that the efficacy of green bonds would be complemented by regulatory schemes with respect to balancing the environmental stringency and economic viability. The observed inverted-U type of relationship between regulatory intensity and innovation outcome points to the fact that the best policy design would not be based on maximization of constraints but calibration. It is here that subnational policy coordination is important, as is evidenced by spatial spillover effects and cross-border institutional harmonization necessities.

This review has a number of limitations. To start with, English language publication bias can shut out related non-English articles, especially in developing economies. Second, coverage in peer-reviewed publications does not include developing grey literature, preprints, and preliminary research. Third, the 2010–2024 timeframe will cover the mature green bond market period, but it will not cover concept development. Fourth, reviewed studies are geographically concentrated — mostly in China and developed economies — which is a limitation in terms of representativeness concerning dynamics in developing economies.

Sixty-five percent of studies reviewed used correlational and not causal identification strategies, enabling limited certainty of the evidence about mechanism specificity. The heavy emphasis on utilities and energy industries results in a gap in sectoral knowledge in areas such as manufacturing, agriculture, and transportation, which integrate high carbon intensity and have high potential to innovate.

Future studies should focus on: 1) causal identification strategies — DiD, regression discontinuity design, natural experiments — to address the endogeneity constraint; 2) geographic growth (Africa, Latin America and underrepresented developing economies) to overcome the geographic constraint; 3) sectoral diversification beyond utilities into manufacturing, transportation, and agriculture; 4) retail investor incentives and financial literacy impacts on the participation in the green bonds; 5) tracking of the long-term environmental and innovation impacts of green bonds.

Market integrity and market access can be enhanced using the substantial potential presented through the integration of emergent digital tools such as blockchain to enhance transparency, AI to enhance ESG validation, FinTech to democratize the market, and real-time monitoring to measure impacts. Nonetheless, the barriers associated with adoption, such as the disjointedness of regulatory frameworks, lack of technical standards, cybersecurity risks, and capacity-related issues in developing economies, would need a concerted stakeholder effort.

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