



Article

A Bibliometric Analysis of Green Bonds and Sustainable Green Energy: Evidence from the Last Fifteen Years (2007–2022)

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Abstract: Organizations are shifting their focus towards utilizing green energy in the business process to enhance environmental sustainability. Similar to other business roles, the managerial team in the financial sector has also engaged in environment-friendly operations. A green bond is a new financial approach integrating the protection of the ecosystem into economic profits. This paper analyzes green bonds' intellectual structure, publication, and networking. The bibliometric statistics utilized in the green bonds emerged from the Scopus database. The research examines published works from the most resourceful nations, institutions of higher learning, scholars, and high-profile publications on green bonds. Additionally, the study maps bibliographic coupling and co-citation to visualize the knowledge network.

Keywords: environmental finance; sustainable development; green bonds; green innovations; green energy; systematic review; bibliometric analysis



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1. Introduction

Rapid and uncontrolled eco-unfriendly human activities have contributed to climate change and other negative implications on the ecosystem. The critical issue of our time is discovering how to ensure a prosperous economy without adverse impacts on the ecological systems. Recently, countries and non-governmental agencies global have made great efforts to invest in environment-friendly business processes [1]. However, insufficient funding necessary to mitigate the incumbent climate change has slowed the process [2].

A green bond is a mechanism that combines finance and business with an environmentally friendly attitude from stakeholders, including investors, manufacturers, consumers, and financial institutions [3,4]. In contrast to the old financial measures, green bond emphasizes the benefits of the natural environment and pays more attention to environmental protection when climate change is a problem for mankind, and the concerned countries' parties are required to maintain sustainable development for a healthy and environmentally friendly economy [5]. In line with this, the Paris Agreement at the global level endorsed the idea of drastic reduction in global emissions to mitigate the climate risk [6].

The efforts of the World Bank to mitigate the climate changes in the developing and recently developed countries could present a double increment in the current USD 100 billion fund annually [7]. Thus, diverse funding foundations to curb the adverse effects of climate change are essential. Current financial methods have been invented to facilitate the growing demand to invest in eco-friendly energy sources. Approximately 60% of green

bond annual market growth and increased funding for global environment protection projects have been recorded [8–11].

A green bond maintains debt security that the bank issues to raise capital that can effectively support the climatic change and other environmental programs [12]. Labelled green bonds are officially advertised as ‘green’. Those issuing the bonds indicate the categories of schemes they are targeting and regularly print the bond progress to the investors. The unlabeled green bonds have no official green tags even though they are offered by either the wind or solar energy industries. Green bond sponsors developments are associated with clean energy and reduced levels of carbon transport [13–15]. Up to two-thirds of emerging green bonds were issued by non-multilateral development banks in 2014 [11,16–18]. It attracted many investors such as executive asset teams, pension-funding firms, religious groups, and non-profit organizations.

Since conventional investors viewed environmental projects as extremely risky and non-profitable [19], green bonds did not capture much interest among many investors during the 2008 financial crisis [20]. On the contrary, green bond issuing has met exponential growth after the crisis due to the improved creation of awareness and increased knowledge among the conventional investors regarding the merits of green investments [21], plus underlying negative implications of the changes in climate on monetary assets [22–27].

The research focuses on two critical objectives of analyzing the in-depth structure of green bonds that revolve around the publication figures, several citations, co-citations, and bibliographical connections. Secondly, the research issues a suggestion on the future research factors and other critical agenda concerning the green bonds.

The targets mentioned above fit in given phases, with the phase that analyzes publications and relevant citations ranging between 2007 and 2022. In addition, the worldwide view evaluates the states with some necessary codes of documentation and sources of references. The paper list also includes top active universities and other relevant institutions. Additionally, it recognizes the leading journals and lists of the most celebrated writers according to the publication and citation information. Moreover, evaluate how the research relates to the states and the writers based on the bibliometric coupling and co-citation evaluations. Lastly, the study suggests future potential research themes for the green bond according to the presented data.

The key contributions of this research entail the presentation of a basic summary of the critical geographical localities, institutional profiles, journals, writers, the most cited publications and the general goals for the research revolving around the green bonds. In addition, it stands a chance of playing a role in location determinations that could further enable universities to conduct their research efficiently. Furthermore, the analysis allows policymakers to acknowledge the top-performing states in green bonds, improve the understanding of the ecosystem, and guide their development efforts and further research. More significantly, it recommends a research plan recognizing the opportunities and challenges that call for future analysis and investigations.

2. Literature Review

A green bond serves as security for a debt incurred in supporting a sustainable ecosystem through climate change mitigation. Such bonds can be issued by financial agencies, sovereigns, corporates, or municipalities. Whenever a bond is labelled “green”, proceeds for specific projects must be established. The World Bank became the first institution to issue a green bond, raising funds from fixed-income investors to support lending for eligible climate-focused projects in 2007 [8]. In fact, however, the green bond had received earlier attention from researchers since 2007. Eventually, more banks and other money-lending institutions and financial corporations embraced green bonds in 2013, and three years later, USD 81 billion green bonds had been published [28]. This move amounted for green bonds worth USD 166 billion [29,30].

The more developed technique on green bond reported by ref. [31] highlights the issue of volatility of the green bond, and this is considered the first empirical study on the

volatility of market; it found there was more volatility in the label green bond segment when spillover effects were taken into account, as opposed to conventional bond markets. Thus, the contribution of this work to the initial growth of the market hence laid a following step for future studies. Since then, a number of researchers have taken into account the market volatility and have investigated this issue seriously, where market volatility can contribute to this body of knowledge by assuming the green bond as a risk alleviating tool [32–39]. It is being noted that the focus of the existing literature on green bond market and the benefits to investors through the diversification of portfolio gives an opportunity to investors to consider a proper strategy for trading with a better understanding of this green bond [40–46].

More attention is being given by researchers to the perceived behavior of the stock market towards eco-friendly tools. The other facets of the previous studies regarded stock market reactions to green bond publication and achieved the distribution of positive feedbacks from the market, strongly justifying that the market responds positively towards issuance with a signing quality of issuers for their environmental commitments, which further enhanced the issuance quality of green bond [47–53]. The fact that the majority of the previous studies completed from the demand side of green bond was well-observed, whereas only partial studies have examined green bond market from the supply-side perspective [54–59].

Due to the fast-growing attention in green bond return as compared to conventional bonds, major aspects of the literature have focused on the “Green-bond” and the difference in yield between green and conventional bond [60–65], where robust evidence on the “Greenium” exists regarding the lower yield on green bond against conventional bond [66–72]. In the view of green bond and its impact on environmental performance, the previous studies shed light on the activities of ESG which determined the favorable benefits [73–78]. Instability was witnessed by global financial markets due to the pandemic; the most recent studies were focused on the green bond and its behavior with other forms of markets. It is likely noted that the green bond is termed a better investment avenue for investors during pandemic times with their increased return and demand due to its financial and non-financial benefits [79].

Close monitoring of and regular reporting on the progress of the green bond projects are conducted to avoid information asymmetry between the concerned parties. More than 50% of the bonds are certified through an external party to obtain a different view [80]. Either an organization directed towards making profit or social purposes qualify for the coverage. Those who play in the market and other concerned companies must define the “green label”. Several financial institutions developed the principles concerning the bonds, which are updated annually to enhance efficacy [81]. The principles entail voluntary guidelines to regulate the binding standards by market participants to steer market growth [82]. All the monitoring operations occur in separate accounts. Unlike non-green bonds, the cost of allocating green bonds is relatively high. For instance, the price of a second opinion on bond issuance ranges from 0.3 to 0.6 bps for each USD 500 million question concerning the nature of exertion involved [83]. The cost of certification of the problem, which entails determining procedures to select projects, management proceeds, issuing frequency, and regular reporting, is approximately 0.1 bps. Ref. [84]’s measurement results on bond performance indicated that the average SRI fund outperformed the predictable slots by 1.3%.

Ref. [85] investigated the influence of societal and organizational performance on corporate and corporate social performance on the corporate bond number, spaces and ratings. They discovered that high ratings and low margins characterize excellent corporate social performance. Ref. [86] claim that organizations with an outstanding social performance reputation have favorable risk profiles. The nature of the argument on performance depends on the issuers. Ref. [87] points out that lenders price unfriendly environmental operations such as effluent of harmful waste and emission of toxic gases when it comes to issuers. From an issuer’s point of view, ref. [88] argued that research findings could

elucidate that all bond components do not need to spread. Thus, organizational social performance remains missing in the empirical asset pricing puzzle.

3. Methodology

The Scopus database, a global social reference source, was used to scan for academic publications on green bonds. A timeless search on “Green Bonds” in the article was conducted. The oldest paper was dated 2007, and 319 pieces were retrieved. The bibliometric approach enables the researchers to evaluate the data. It is a library containing scientific data and other quantitative techniques for research content. This strategy helps identify and assess the overall trend of a particular topic, such as a journal, area of study, or country [89].

The bibliometric analysis is used in literary studies to determine the relevance of the concepts and the subject. It also acknowledges the contributions of different journals, learning institutions and other states. VOS viewer and RStudio are vital in the analysis and evaluation processes [31,32] The duo generates understandable results such as tables and graphics, differentiating them from other software applications [76]. In addition, the two pieces of software are used in the presentations and preparations of co-citations and bibliographic coupling. Bibliographic coupling is the connection between the two work references where they reference the third work in the bibliographies. Co-citation, on the other hand, revolves around the involved frequency in which two papers are cited together by another document. This move implies that two articles share a subject.

4. Results

4.1. The Current State of Publishing

From the Scopus database, it was evident that there have been 319 publications on green bonds since 2007. Structure-based analysis (Table 1) showed that there had been a significant increase in the frequency of the publications over the three consecutive years, and the year 2021 remains the most productive, with 133 papers. The remarkable increase in publications indicated intensive integration of research on green bonds.

Table 1. The current state of publishing.

Year	Number of Articles
2007	1
2010	1
2011	1
2012	3
2014	4
2015	1
2016	9
2017	12
2018	32
2019	38
2020	77
2021	133
2022	7

Green bonds have become an important tool to address the impacts of climate change and related challenges. The reasons behind the growth of green bonds publication is that growth of green bonds in the capital markets has been explosive and is increasingly attracting attention from investors. Increasing investment in green bonds during the last few years has led to green bonds becoming an important tool to address the impacts of climate change and related challenges.

4.2. Highly Productive Regions and Nations in Green Bonds Research

Most countries are at the forefront of contributing to the green bond studies. This part of the research analyzes the most active states from 2007 to 2022. The table portrays the results that capture the top ten countries that have published green bond studies.

China tops the productive countries with 111 publications, and its academics focus is the highest on the green bonds amidst another research. The USA comes second with 84 papers, while the UK follows with 49 related articles. Other Asian nations such as Japan and India are among the best performing countries with 22 and 29 pieces, respectively. The main reason that those countries had the highest number of publications is that they have the highest capital markets size around the world and are considered developed countries, thus having a higher impact on climate changes. On the other hand, there are high rules on eligibility for green bond status in China and it became a leader in the green bond initiative.

A bibliometric coupling (BC) has its ground in understanding the involved networking within the countries publishing the green bonds. Bibliographic pairing takes place when two documents widely quote a report. It occurs when a paper from two states reference happens when a third report is commonly cited in two copies. That is when an article from two states references the third document while highlighting the related subject matter.

Figure 1 depicts the bibliometric findings' finding, and each circle stands for a country, with the size representing its contribution. The dots represent the level of assistance. Table 2 displays China as the most productive nation and the country with the most substantial bibliometric ties to other nations. USA and UK follow in series.

The interesting question is how the authors from various states work together globally. A co-authorship evaluation with the heads of the states portrays the connections, and Figure 1 depicts the co-authorship pattern of the performing nations.

Figure 2 portrays the connection of the co-authorship regardless of skin color. For example, the USA tops the list, implying that other nations must comply and work together with the top country.

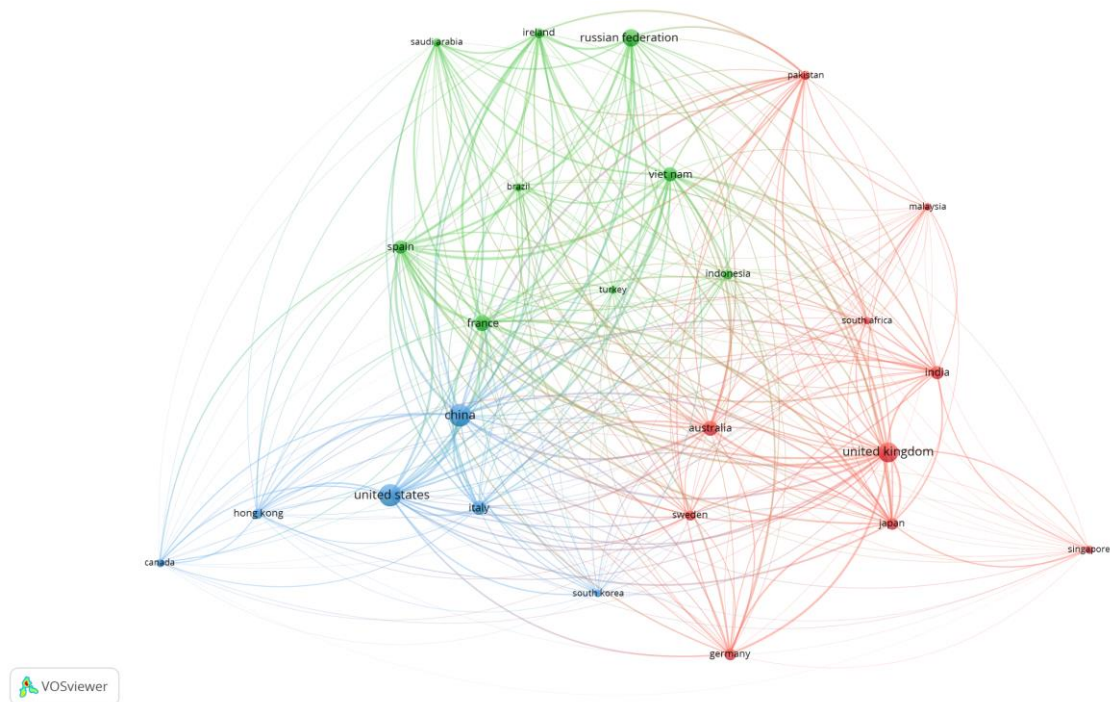


Figure 1. Bibliometric coupling of countries.

Table 2. The most productive countries.

No	Country	Number of Paper
1	China	111
2	USA	84
3	UK	49
4	Australia	40
5	India	29
6	Italy	29
7	France	28
8	Spain	23
9	Japan	22
10	Germany	19

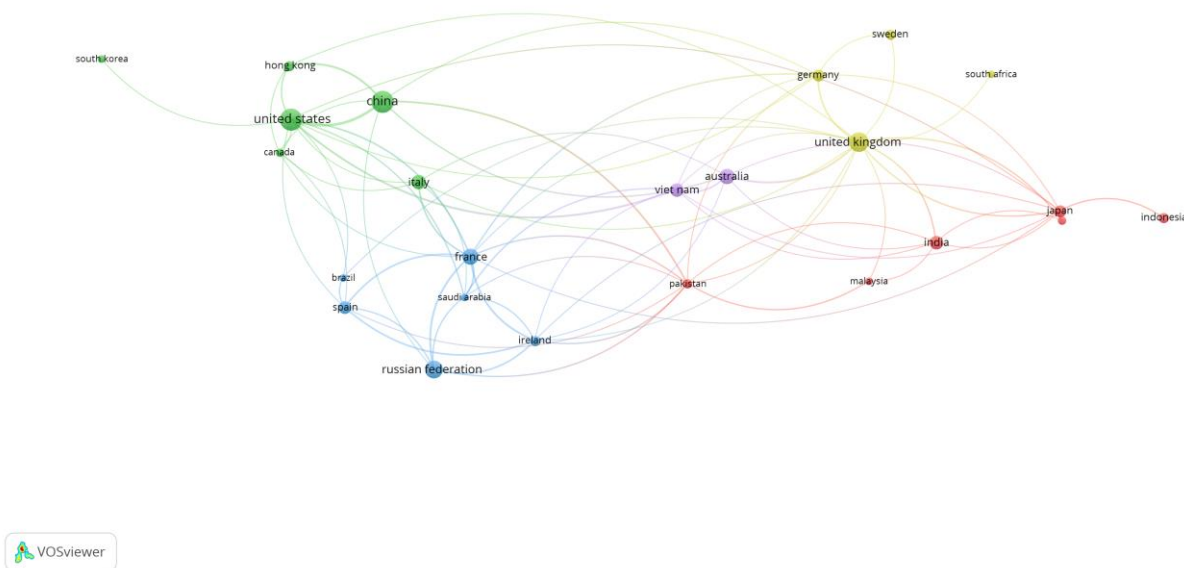


Figure 2. Co-authorship among countries.

4.3. Universities and Learning Institutes with the Most Significant Number of Publications

Table 3 portrays the results of the University of Bologna, which is located in Italy; unfortunately, the most significant university does not belong to the first five countries with the most publication—rather, it belongs to the country which ranked in sixth place. It shows that it has 13 publications, marking it as the most effective university. Griffith University Queensland is ranked 2nd, with ten articles. Financial University Under the Government of The Russian Federation, Kyushu, Economics Ho Chi Minh City, Science and Technology Beijing universities are ranked 3rd with eight papers. In case of a tie, the authors position them according to article citation numbers.

Table 3. The most productive universities.

Affiliations	Articles
University of Bologna	13
Griffith University Queensland	10
Financial University Under the Government of The Russian Federation	8
Kyushu University	8
University of Economics Ho Chi Minh City	8
University of Science and Technology Beijing	8
Peking University Shenzhen Graduate School	7
Universities Indonesia	7

Table 3. *Cont.*

Affiliations	Articles
Federation University Australia	6
Jinan University	6
London School of Economics and Political Science	6
Southwestern University of Finance and Economics	6
University College London	6
China University of Mining and Technology	5
Esch-Sur-Alzette	5
Massey University	5
National University of Singapore	5
Stockholm Environment Institute	5
University of Auckland	5

4.4. Top Journals in Terms of Productivity

The best-performing journals publish increased research on green bonds compared to others. Table 4 shows the journals publishing four publications and above regarding the analysis of green bonds. The Journal of Sustainable Finance and Investment has 16 papers making it the top journal; then, the Finance Research Letters, with 12 publications since 2007. Finally, the Journal of Business Strategy and The Environment, with four pieces. Screening of sources concludes that the publications were performed in high prestige and specialist journals in finance and environmental science, for example, Journal of Sustainable Finance and Investment, by the publisher is Taylor and Francis online indexed in Web of Science and Scopus first quarter.

Table 4. Top journals that publish green bonds research.

No	Sources	Articles
1	Journal of Sustainable Finance and Investment	16
2	Finance Research Letters	12
3	Journal of Cleaner Production	12
4	Sustainability (Switzerland)	12
5	Ion Conference Series: Earth and Environmental Science	11
6	Energy Economics	8
7	E3s Web of Conferences	7
8	Energy Policy	7
9	World Economy and International Relations	6
10	Business Strategy and The Environment	4

The co-citation evaluation of the leading journals is a critical factor in the bibliometrics. Co-citation takes place when a third party jointly cites two documents. Figure 3 displays the energy policy as having the robust strongest co-citation of all then, followed by the sustainability journal. It occurs when two articles appear in the citations of a third document. The paper proves that the journal presented in Table 4 has similar literature and hence robust co-citations.

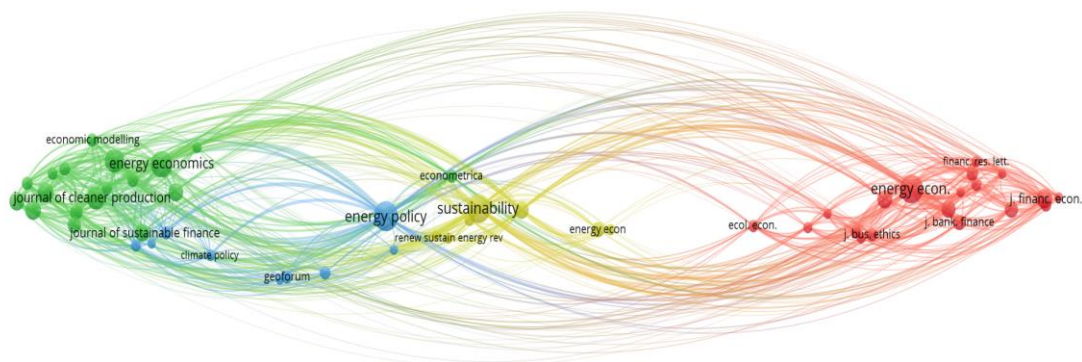


Figure 3. Co-citation of the top journals.

4.5. The Most Prolific Authors in Green Bonds

Table 5 contains the results of the most frequent publishers on green bonds. It shows Naeem MA with six papers, and Agliardi E., Managi S., Pham I., and Siswantoro D., each with five publications. As the most productive publisher, Naeem M.A.’s research interests are in financial markets and renewable energy.

Table 5. The most productive authors.

No	Author	Documents	Citations
1	Naeem M.A.	6	43
2	Agliardi E.	5	27
3	Managi S.	5	93
4	Pham I.	5	78
5	Siswantoro D.	5	7
6	Agliardi R.	4	27
7	Fu j.	4	3
8	Keeley A.R.	4	92
9	Ng A.W.	4	47
10	Shahzad S.J.H.	4	24

4.6. The Most-Cited Publication

Referencing is a critical factor in evaluating the works of other authors and journals. Therefore, the most-cited publication was listed, relying on the statistics within the Scopus database. The method section had earlier indicated that the search on the term green bonds in the journal articles, keywords and texts is the first step. This strategy provides a series of strategic publications with green bonds and related terms mentioned within the title. Table 6 displays a series of publications with over 40 citations.

Table 6. The most-cited publication.

Authors	Title	Year	Source Title	Total Citations
Zerbib Od	The effect of pro-environmental preferences on bond prices: Evidence from green bonds	2017	Journal of Banking and Finance	118
Reboredo Jc	Green Bond and Financial Markets: Co-Movement, Diversification and Price Spillover Effects	2017	Energy economics	81
Tang Dy	Do shareholders benefit from green bonds?	2018	Journal of Corporate Finance	65
Hachenberg B	Are green bonds priced differently from conventional bonds?	2018	Journal of Asset Management	61
Gianfrate G	The green advantage: Exploring the convenience of issuing green bonds	2019	Journal of Cleaner Production	59
Febi W	The impact of liquidity risk on the yield spread of green bonds	2018	Finance Research Letters	57
Hanif I	Carbon emissions across the spectrum of renewable and nonrenewable energy use in developing economies of Asia	2019	Renewable Energy	56
Bachelet Mj	The Green Bonds Premium Puzzle: The Role of Issuer Characteristics and Third-Party Verification	2019	Sustainability	54
Pham L	Is it risky to go green? A volatility analysis of the green bond market	2016	Journal of Sustainable Finance & Investment	50
Ng Th	Bond financing for renewable energy in Asia	2016	Energy Policy	49

4.7. Three-Field Plot

A three-field plot analysis was conducted to determine the performance areas in green bonds. This study established a link between authors and their keywords within the green bond research. Figure 4 shows the author’s name appearing on the left, and the country covers the middle, while the right has the keywords applicable in the bonds paper.

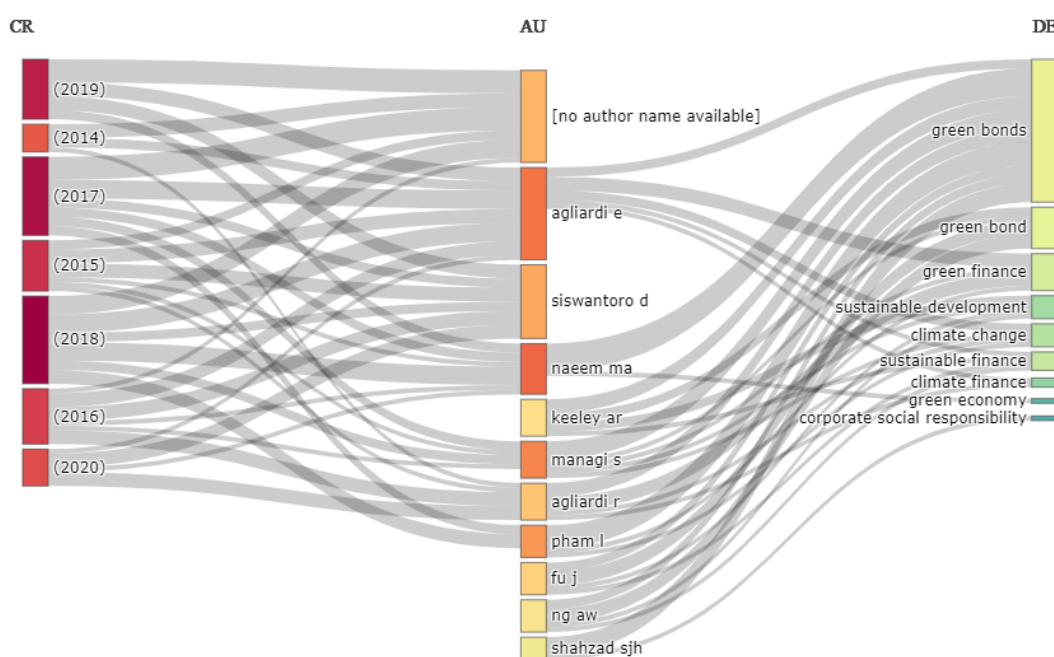


Figure 4. Three-field plot representing authors’ area of research.

4.8. Co-Occurrence of Authors' Keywords

This portion evaluates the content concerning the keywords, which is a valuable tool for locating relevant literature and movements. Note that the keywords researched here were based on the text content of keywords in papers. In addition, the co-occurrence revolves around the frequency that two keywords appear close together. In the study, the researchers utilized keyword analysis to establish trends within the subject of examinations.

As appears in Figure 5, the most keywords used together are related to green bonds and green finance, green bonds and climate change, green bonds and sustainable finance. The results provide scholars with more clearance about the most common keywords searches for future works. Modern researchers may apply keyword evaluations to reveal the present thematic factors in the literature [84]. Indeed, they can easily anticipate the subjects that will obtain more focus in future. However, based on the similarity of the terms, there are high chances of the current trend continuing.

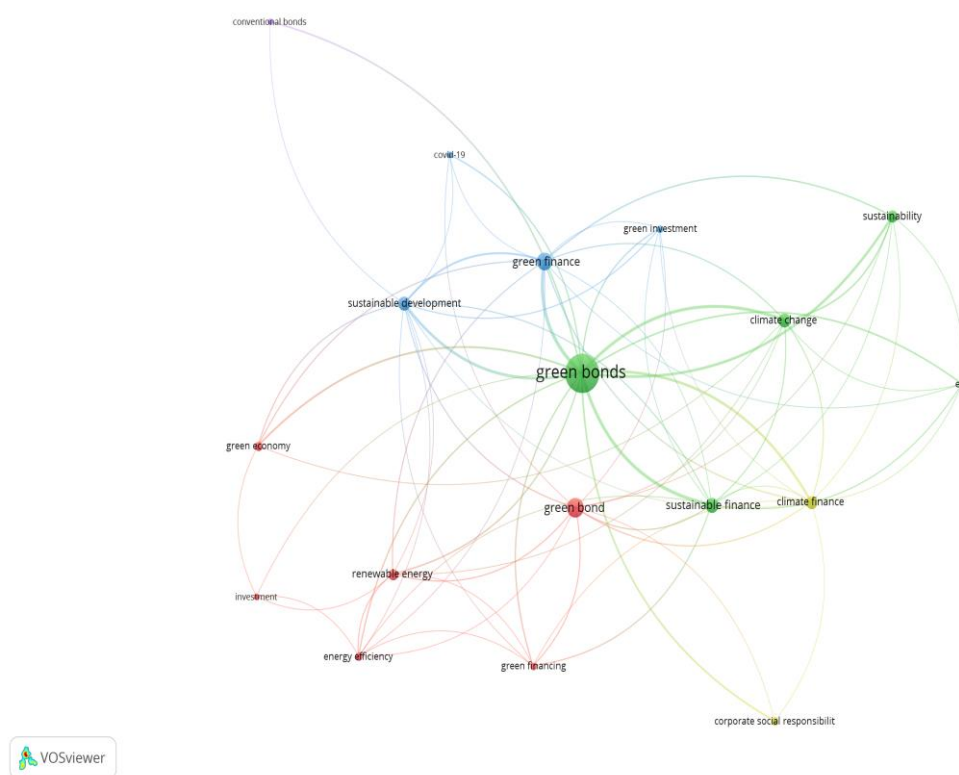


Figure 5. Co-occurrence of authors' keywords.

4.9. The Thematic Map: A Co-Word Analysis

To draw a thematic chart, the researchers used a bibliophagy collection of RStudio with a minor occurrence of 5000 words. Figure 6 illustrates keywords of green bonds. The mapping technique highlights the key factors that the journal addressed. In the proposal by ref. [88], the themes were plotted in four quadrants based on their positions and levels in the X and Y axes. The measure of supremacy shows the importance of green bonds in the entire research. In contrast, density determines the extent of articles' development according to the network's internal strengths.

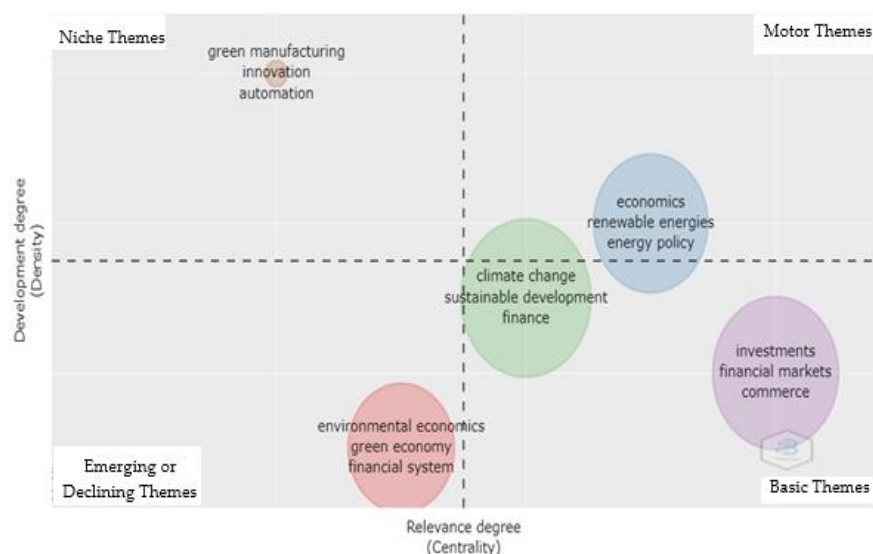


Figure 6. Thematic map of the journal.

4.9.1. Motor Themes

They are adequately developed and constitute the critical outline of the study in the journal. Moreover, these themes share high centrality and density. This quadrant contains economics, renewable energies, and energy policy. Such facts indicate that the journal's most developed research areas are economics and energy policy issues.

4.9.2. Niche Themes

They entail the journal's technically developed and specialized green manufacturing and innovations, as shown in Figure 6.

4.9.3. Peripheral Themes

They involve emerging environmental economics, a green economy, and a financial system based on the third quadrant. The themes usually have low density and declined measures of centrality.

4.9.4. Transversal Themes

Investment and financial market themes are evident in the fourth quadrant. Though poorly developed, they are characterized by low and high density and centrality. The paper established had the bibliometric analysis of green bonds as its primary consideration. This is arguable, and there are opportunities for new research projects that address the weaknesses that this paper finds. The existing environmental challenges bring about a great anxiety in the business environment, whether in the public or private sectors, hence the urge to participate in the regular debates and arguments that focus more on financial viability, profoundly affecting corporate behavior.

All businesses look forward to increasing their monetary limits; therefore, supportable activities within the organizational culture are requirements for their implementation. Therefore, there is a great need to deal with the holistic vision and factors of the green bond to tackle the challenges. The research analyzes critical questions within the context, adopting an objective bibliometric strategy of obtaining findings from different dimensions.

This paper aims at analyzing critical topics within the area of study. The existing gaps serve as opportunities for research by evaluating the contents and trends discussed up to 2022. The research presented the trends. After analyzing the previous findings, it was proven that a research agenda already exists. However, further exploration of new economics, entrepreneurship, and sustainability studies are vital. Green bonds have demonstrated their great value and fast-growing relevance. With the increasing levels

of curiosity in the modern literature and inadequate coverage of critical economics and journals containing financial facts, the study recommends that researchers advance in more than two areas.

Finally, the main objective of this paper was to provide scholars and practitioners with a comprehensive overview of green bonds and sustainable green energy for the period of (2007–2022) by using a common technique, which is the bibliometric analysis. Literature published in journals indexed by the Scopus database was used in order to achieve this objective. Finally, this research contributes to the literature through a field study to grasp the viewpoints of key decision-makers in firms that are involved in financial matters. This study analyzed green bonds' intellectual structure, publication, and networking. In addition, thematic evolution has been found and shows that there are four themes.

5. Limitations

The study has limitations in that the survey concentrated on the bibliometric analysis from the Scopus database. The database has a series of failures that have weakened the universality of the research. Failures are books not widely covered in the Scopus database such as preprint books, Google books and conference proceedings. It also does not cover publications that were published in languages other than English. In addition, the chances are high that the study does not address all journals within the Web of Science indices. Moreover, the study did not extract statistics from other sources, including the science site. In addition, the study conducted a retroactive review between 2007 and 2022 on visual analysis. The complete temporal analysis would have aided in determining how the trends in green bonds literature increased—for example, multi-period analysis to measure the development of green bonds in different periods.

6. Recommendations

Foremost, green bonds are recently emerging trends in the finance realm. This fact calls for an immediate need to dig deeper into the problem concerning finance and financial techniques. In addition, according to conventional finance studies, there should be an urge to analyze green risk management and governance critically. In addition, developed countries represented most countries' issued bonds; thus, there should be further research from these countries as a motivation for other countries which focuses on green bonds to enhance and protect ecological systems around the world. This move will benefit the decision-makers to work on their policy factors and develop a properly designed policy goal. Then, the scholars from developing countries will reflect the knowledge and policies that were formulated by authors and policymakers in their countries. Finally, a significant difference exists between the problems of green bonds and traditional bonds because regulations guide conventional bonds. Hence, the increasing and evolving international economic and political climate will likely increase the challenges. Additionally, a systematic analysis is required for a deep understanding of the available literature. There is also a need to investigate the findings of the bibliometric research and draw comparisons.

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