RELATIONSHIP BETWEEN GREEN BONDS AND OTHER FINANCIAL ASSETS: A BIBLIOMETRIC ANALYSIS

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Abstract - Green bonds have evolved in line with the aspirations of the economy. Green bonds, an initiative of economies to innovate and sustainably transform their financial systems, have drawn the attention of academics and policymakers due to the growing global concern for environmental protection, climate change mitigation, and adaptation. The purpose of this study is to investigate the development and scholarly evolution of the Green Bond idea through bibliometric analysis. A survey of academic literature from 2016 to 2024 (May) was conducted using the Scopus database. Intellectual structure and bibliographic analysis of the selected articles were conducted using R-Packages software and WebInterface Biblioshiny. The journals used in this study are Scopus-indexed journals, which are searched using the keywords green bond, cointegration, transmission, and spillover. The results showed that the theme of green bonds is exciting to research because it has increased yearly. France became the most researched country and produced 24 frequencies of articles. The most productive country with the most citations is China, which has 663 citations. Previous studies have found a spillover transmission from the financial asset market to the green bond market. This suggests that volatility in financial markets will spill over and affect the green bond market. This research can be used as an investment decision-making strategy, especially in building an investment portfolio.

Keywords: Bibliometrix; Green Bond; Green Finance; Scopus; Spillover.

1. INTRODUCTION

1.1 Research Background

Climate change is an undeniable reality and a significant concern that occupies an important position on the global agenda (Uckun-Ozkan, 2024). Lin & Zhu, (2019) stated that climate change will consume nearly 10% of the global economic value by 2050. In addition, it is worth noting that climate risks are increasingly becoming a significant financial issue (Uckun-Ozkan, 2024). According to financial specialists, global economic growth will decline by 80% if global warming is not addressed and temperatures rise quickly. Conversely, if the global temperature is reduced by less than 2° Celsius, global economic growth will decrease by about 4% (Nurvita et al., 2023). Thus, the primary focus of the Paris Agreement is on adaptation and mitigation strategies for climate change (Urekeshova et al., 2023). Carbon pricing, green energy, and green bond issuance are a few strategies that can lower carbon emissions (Ahmad et al., 2022).

Green bonds are an essential funding source and a diversified investment option for investors and companies concerned about the environment (Liu & Song, 2020). Green bonds have the advantage of having enormous development potential through investments in clean and renewable energy and the environment (Ren et al., 2022). Green Bond is an investment that has goals in line with the Sustainable Development Goals (SDG) and meets the requirements of Sustainable and Responsible Investing (SRI) (Nurvita et al., 2023). Green bonds are issued with the aim of funding projects related to environmental preservation, anticipating global climate change, and developing renewable energy (Pham & Huynh, 2020).

The first environmental bond was issued in 2007 by the European Investment Bank (EIB), known as the Climate Awareness Bond (European Investment Bank, 2022). The purpose of the issue was to raise funds for renewable energy, and the bond was valued at EUR 600 million (European Investment Bank, 2022). In 2008, the World Bank, through the International Bank for Reconstruction and Development (IBRD), issued a green bond for the first time with an issuance value of around USD 440 million (Nurvita et al., 2023). The world banking foundations that also issued Green Bonds were The African Development Bank (AfDB) in 2013, The International Finance Corporation (IFC) in 2010, the Asian Development Bank (ADB), the European Bank for Reconstruction and Development (EBRD), and Nordic Investment Bank (NIB) (World Bank, 2015).

Companies that issue green bonds are companies whose commitment to environmental preservation can be seen in the improvement in environmental performance and financial performance of the issuing company (Flammer, 2021). Currently, green bonds are traded on world exchanges such as Europe, China, Singapore, the United States, and South America, and in the last four years have been traded on the Shenzen, Bombay, and Indonesian exchanges (Nurvita et al., 2023). In addition to multilateral financial foundations and governments, companies also issue green bonds (Flammer, 2021). In order to promote green transformation and ensure the overall expansion of the bond market, the present strategic focus is on encouraging genuine firms to increase their energy-saving capabilities and green production awareness through the issuance of green bonds. Assuring the expansion of the bond market overall (Cheng & Wu, 2024).

A long-term substitute for bank loans and equity funding is green bonds (Wei et al., 2023). Companies raise specialized funds to finance projects that have environmental and climate benefits. Another research subject is the relationship between the green bond market and other financial markets. Understanding the reciprocal movements between green bonds and asset prices is essential for investors, especially for managing investment portfolios and asset diversification (Nurvita et al., 2023). The market for green bonds has been gradually growing, indicating that investors are becoming more and more drawn to these bonds (Wei et al., 2023). This research is supported by Wei et al., (2023) which shows a strong correlation between the green bond market, the treasury market, and corporate bonds. There has been a rise in both the green bond market's liquidity and the information flow between it and other financial markets. During times of economic instability, there has been a significant increase in the connectivity between green bonds and other markets, particularly the spillover risk from the stock market (Wei et al., 2023). This research is also supported by (Nurvita et al., 2023), stating that green bonds can be used as an alternative in diversifying portfolio instruments. There is spillover transmission from the financial asset market to the green bond market (Deng et al., 2022). This suggests that volatility in financial markets will spill over and affect the green bond market (Nurvita et al., 2023).

According to earlier studies, there is a transmission of spillover between the markets for green bonds and financial assets. For instance, the research by Wei et al., (2023) demonstrates

heightened connectivity between green bonds and stock markets during times of economic instability. In contrast, the study by Deng et al. (2022) emphasizes the connection between volatility in fossil energy markets and green financial markets. By concentrating on bibliometric analysis that takes into account publishing trends, citation patterns, and theme links in the literature about green bonds, this study broadens that understanding. In contrast to earlier research, this study maps scholarly advances in the green bond theme using a bibliometric analysis approach. Furthermore, this study's primary goal is to investigate the intellectual links among earlier research, which has not yet been a big focus of other investigations. In addition, unlike other studies, this one offers a long-term trend analysis from 2016 to 2024 that considers publication dynamics, citations, and thematic connections.

Our research is motivated by the pressing need to use cutting-edge financial tools to help efforts to mitigate climate change and promote sustainable development. Green bonds are one clever way to collect money for green projects and draw in investors concerned about sustainability. Even though green bonds have much potential, more research is still needed to understand how they interact with other financial markets fully. This disparity makes it necessary to learn more about how volatility in other financial markets might impact and be impacted by green bonds. Furthermore, the value of bibliometric analysis in spotting significant themes, trends, and patterns in the literature on green bonds serves as another driving force behind this study. To maximize the advantages of green bonds, this research gives investors, practitioners, and policymakers strategic insights and a summary of the academic development in this area. Additionally, it is anticipated that the findings of this study will provide the foundation for future investigations aimed at enhancing global financial sustainability utilizing tools like green bonds.

This research aims to develop the cutting-edge topic of green bonds with a primary focus on the relationship between green bonds and other financial assets and other determinants. For portfolio managers and investors, the higher the diversification of investment instruments, the closer the achievement of investment strategy objectives. Therefore, it is essential to understand the market connectivity between countries and the co-movement, cointegration, spillover, and contagion between markets and financial assets. The research phase reviews previous studies using spillover, spillover transmission, volatility transmission, and proximity. The findings will inform future research.

1.2. Related Theory

Businesses are better informed about their capabilities than investors are. This research is based on Signal Theory, developed by Spence (1973). This theory explains how companies can signal to the market about their quality through observable actions. In the context of green bonds, the issuance of green bonds is considered as a signal of the company's environmental credibility to investors. Transaction costs are incurred to find organizations with desirable features because of this information asymmetry (Flammer, 2021). Consequently, businesses have a stake in lessening this knowledge asymmetry by communicating this information through "signals" or by acting in a way that is seen as credible. According to signal theory, a signal is considered credible if enterprises with less desirable traits find it difficult to reproduce (Flammer, 2021). Signal theory provides an interpretation of the issue of corporate green bonds. It is common for investors to need more knowledge to assess a company's environmental mitigation (Flammer, 2021). In the eyes of investors, this makes it necessary to discern (credibly) between environmentally conscious businesses and those that are not. Companies can demonstrate their environmental commitment by issuing green bonds. For the reasons listed below, this signal is credible (Flammer, 2021). Initially, through the issuance of green bonds,

businesses pledge to finance numerous eco-friendly initiatives. Second, to ensure that the money raised is indeed utilized to finance the green initiatives specified in the bond prospectus, green bonds are frequently certified by an impartial third party (Flammer, 2021). It costs issuers money to comply with green bond standards, including the Climate Bonds Initiative's Climate Bond Standard, because it takes a lot of managerial work and resources. Furthermore, violating certification requirements (also known as "green default") is expensive. Green bond issuance is a reliable way for a business to demonstrate its environmental commitment. Various anecdotal reports frequently note the signaling role of corporate green bonds (Flammer, 2021).

2. RESEARCH METHODOLOGY

The data used in this study are articles published in Scopus-indexed reputable journals. The data were downloaded from the Scopus Elsevier database using green bond, cointegration, transmission, and spillover. This method was used to compile a systematic literature review (SLR). Data analysis and visualization in this study used bibliometric analysis using R-Packages software and Biblioshiny WebInterface. A systematic literature review is conducted to formulate a research question using a systematic method to identify, select, and critically appraise relevant research (Nurvita et al., 2023). Using structured analytical review schemes and explicit algorithms, systematic literature reviews enable high-quality searching and critical assessment of existing literature (Zhou et al., 2024). This study has five stages: determining keywords relevant to the research topic, searching for data according to keywords, selecting articles, data validation, and data analysis.
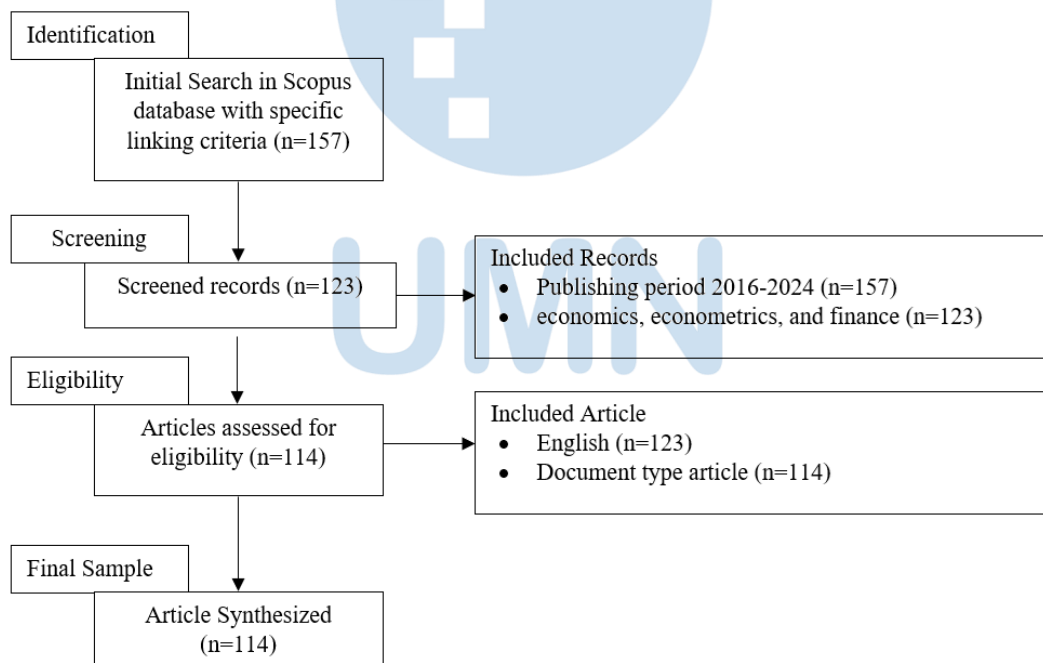
Figure 1. Research Sample Selection Strategy
Source: Created by Athor (2024)

The first step in determining the literature related to green bonds is to download it through Elsevier's Scopus database. The selected published articles are English language articles published in Scopus-indexed journals. The journal publishing period is from 2016 to 2024. The article search used the keywords green bond, Volatility, Transmission, and Spillover. Then, the

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criteria were narrowed down to only use research articles and subjects, including economics, econometrics, and finance, resulting in 114 articles. Then, the data obtained from the search results were selected and validated using diagrams and tables to make it easier to analyze. Some aspects that will be analyzed in this study are the leading journals, the growth rate of publications per year, the type of publication, the most productive authors, the quantity of publications by author origin, and the author's country.

3. RESULT AND DISCUSSION

According to (Gafoor et al., 2024) the bibliometric analysis can be categorized into five significant heads: Total Scientific Literature Production, Journal Level, Author Level, Document Level, and Thematic Level. The entirety of the literature created according to nation, affiliation, and research sponsoring organization makes up the scientific research. Lastly, the association between green bonds and other financial assets is determined by this study using a variety of science mapping bibliometric tools, including Thematic Map, Thematic Evolution Map, Co-word analysis, and Co-itation analysis. As a result, statistics on publication trends, pertinent sources, subject areas, author data, and thematic data organization are presented in the section that follows.

3.1 Main Information

The publications used in this study are publications from 2016 to 2024. The author limits using only one type of document, namely articles. Based on the search results on the Scopus Database by the selected keywords, namely green bond, cointegration, transmission, and spillover, 114 article documents were obtained. Table 1 shows key information about the data used in this study, including the time span, number of documents, and annual growth rate. In the development data of scientific publications on green bonds, the growth rate per year is 50.98%, the average year of publication is 1.36, the average citation per year per document is 35.07, and the reference is 5353. Regarding data on the development of authors worldwide, there are 281 authors from a total of 114 documents obtained, nine documents written by a single author, and an international author collaboration index of 48.25%. An overview of the applicability of green bond research in an expanding body of literature is given in this material.

Table 1. Main Information

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2016:2024
Sources (Journals, Books, etc)	47
Documents	114
Annual Growth Rate %	50.98
Document Average Age	1.39
Average citations per doc	35.07
References	5353
DOCUMENT CONTENTS	
Keywords Plus (ID)	336
Author's Keywords (DE)	323
AUTHORS	
Authors	281
Authors of single-authored docs	8
AUTHORS COLLABORATION	
Single-authored docs	9

Description	Results
Co-Authors per Doc	3.4
International co-authorships %	48.25
DOCUMENT TYPES	
article	114

Source: R-Packages dan WebInterface Biblioshiny
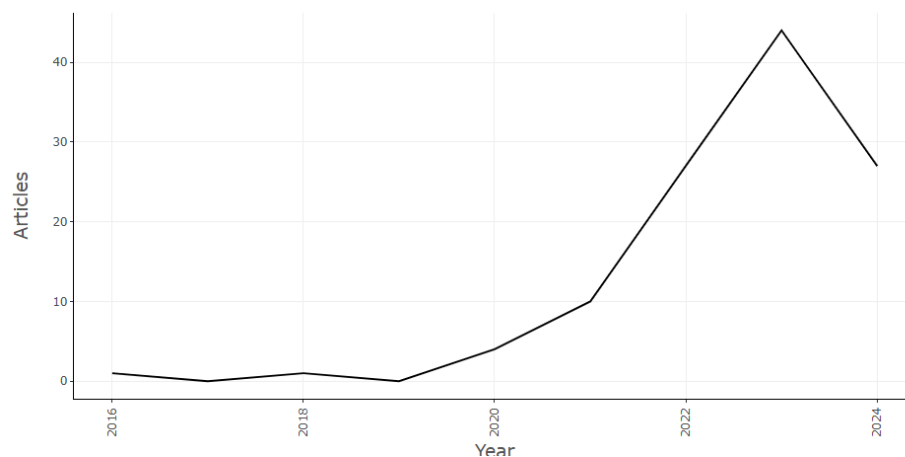
3.2 Publication Trend and Sources

Table 2 shows the publication trend from year to year. The results of the publication trend analysis from 2016 to 2024 show fluctuations each year. Scientific publications related to green bond topics from 2020 to 2024 continue to increase every year. The highest increase was in 2022, by 73%, with 27 articles. The decrease in articles from 2024 to May can be explained by the lack of data for that year.

Table 2. Publication Trend

Year	Articles
2016	1
2017	0
2018	1
2019	0
2020	4
2021	10
2022	27
2023	44
2024	27

Source: R-Packages dan WebInterface Biblioshiny

Figure 2 also explains the development of publication trends, which illustrates that the trend of publications on green bonds and other financial assets fluctuates yearly.

Figure 2. Publication Trend
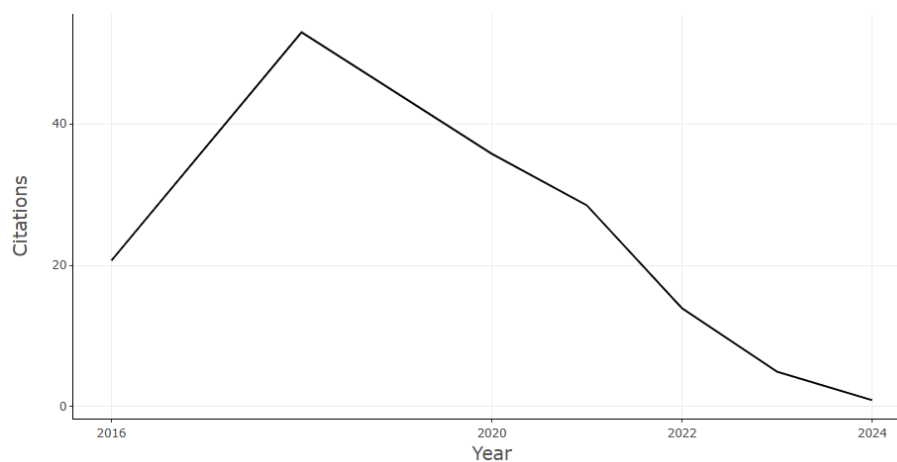*Source: R-Packages dan WebInterface Biblioshiny*

In line with the publication trend, the citation trend also fluctuates yearly. The highest citation trend in 2018 was 53%. However, there was a decrease in the citation trend from 2020 to 2023 until it reached the lowest figure of 4.93%. However, the situation has declined in

subsequent years, indicating the need for further research to maintain the relevance of this topic. As shown in Table 3 and Figure 3, as follows:

Table 3. Citation Trend

| Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2016	186.00	1	20.67	9
2018	371.00	1	53.00	7
2020	179.00	4	35.80	5
2021	114.00	10	28.50	4
2022	41.74	27	13.91	3
2023	9.86	44	4.93	2
2024	0.89	27	0.89	1

Source: R-Packages dan WebInterface Biblioshiny

Figure 3. Citation Trend
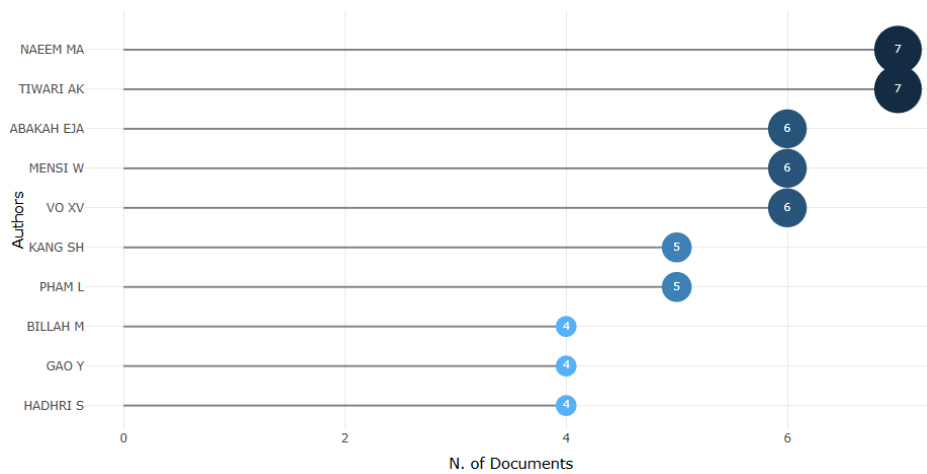*Source: R-Packages dan WebInterface Biblioshiny*

3.3 Most Productive and Relevant Authors

Bibliometric analysis is also used to find the most productive author data. Figure 4 describes the most productive authors by searching using selected keywords. The results show no author whose number of works is dominant. They only have 4-7 scientific publications on green bonds and other financial assets. The blue dots indicate the number of publications, and if the circle size is more significant, it means that more publications are published, and the solid blue circle indicates the more significant number of citations. In this analysis of the most productive authors, the author took a sample of the top 10 authors, Naaem MA and Tiwari AK, who have produced seven publications.
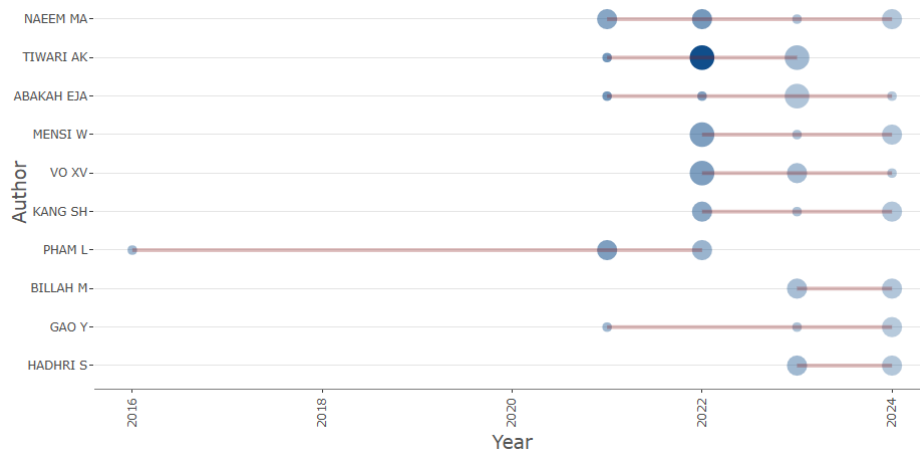
Figure 4. Most Productive Authors
Source: R-Packages dan WebInterface Biblioshiny

The analysis of relevant authors provides a more precise and more detailed picture. Figure 5 explains that Naeem MA and Tiwari AK are the most productive authors, with seven scientific publications. Abakah Eja, Mensi W, and Vo XV have six scientific publications. Kang SH and Pham L have five scientific publications. Billah M, Gao Y, and Hadri S have four scientific publications.

Figure 5. Most Relevant Authors
Source: R-Packages dan WebInterface Biblioshiny

3.4 Most Relevant Affiliations and Most Influential Publications

Based on the analysis results, the most affiliated is the University of Economics Ho Chi Minh City with 16 publications, then Central South University with 12 publications. China University of Mining and Technology follows this with ten publications. The rest of the publications range from 6-9, as shown in Figure 6.
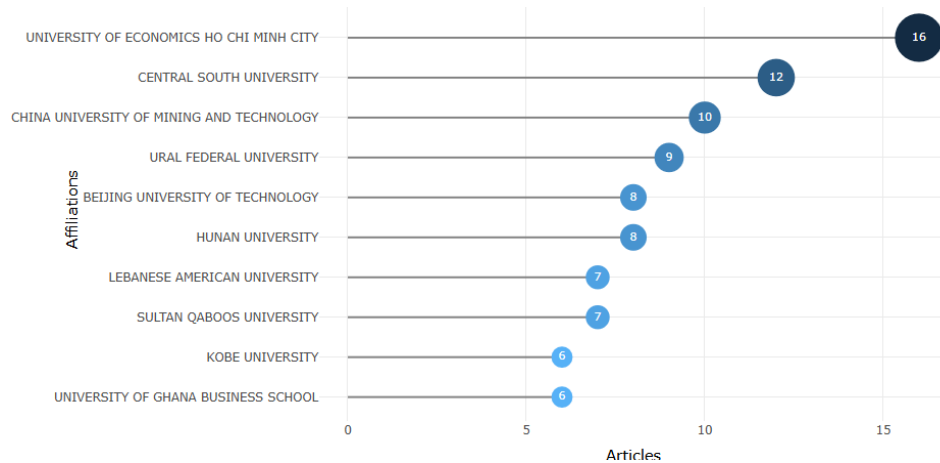
Figure 6. Most Relevant Affiliates
Source: R-Packages dan WebInterface Biblioshiny

The search results in Figure 7 explain that the most influential publication, "Network Connectedness of Green Bonds and Asset Classes" by Juan C. Reboredoa, Andrea Ugolinib, and Fernando Antonio Lucena Aiube, published in 2020, was cited 371 times. The study results state a strong relationship between green bonds and government and corporate bonds in the short and long term, both in the EU and the US, where green bonds receive considerable spillover effects from government and corporate bond prices and transmit negligible effects. Green bonds have weak relationships with corporate bonds, stocks, and high-yielding energy assets on different time scales (Reboredo et al., 2020). also affect how green bond investors should structure their portfolios, choose how to hedge, and direct financial resources toward businesses that support a decarbonizing economy.
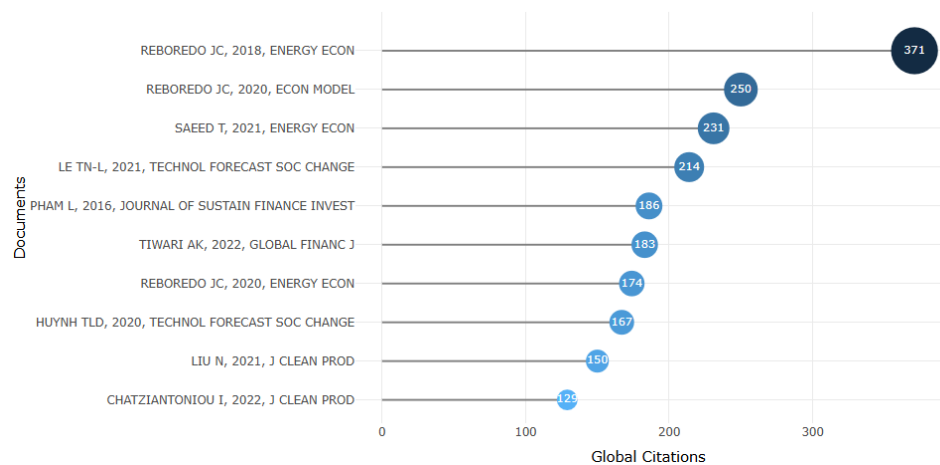
Figure 7. Most Influential Publications
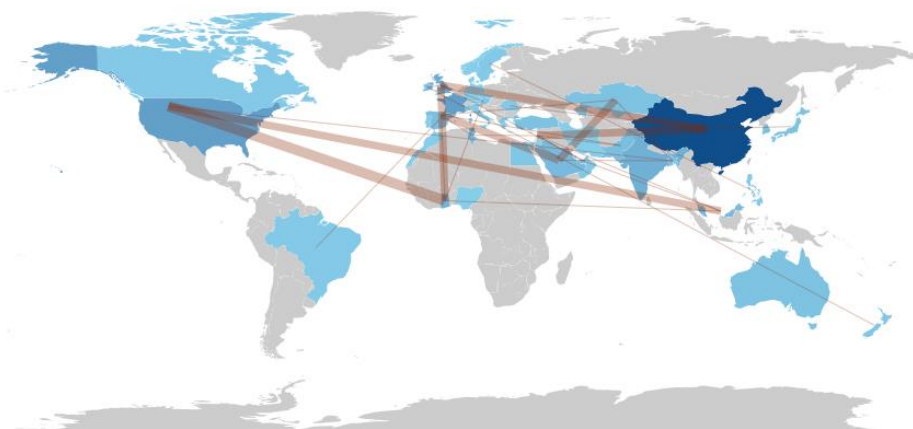*Source: R-Packages dan WebInterface Biblioshiny*

3.5 Most Productive Countries and Most Cited

As can be seen in Figure 8 and Table 4, research using bibliometric analysis indicates that France is the most productive author, with 24 publications; China is second with 14 articles, and the USA is third with 13 articles.

Table 4. Country Scientific Production

Regional	Frequency
France	24
China	14
USA	13
Lebanon	12
Ghana	11
India	11
Tunisia	10
United Kingdom	9
Ireland	7
United Arab Emirates	5
Saudi Arabia	4
Bangladesh	3
Philippines	3
Spain	2
Austria	2
Ireland	2
Australia	1
Canada	1
Greece	1
Sweden	1

Source: R-Packages dan WebInterface Biblioshiny

Figure 8. Country Scientific Production
Source: R-Packages dan WebInterface Biblioshiny

Figure 9 provides more information on the citation count. It shows that China is the most productive nation with 663 citations, followed by the USA (498 citations), Spain (485 citations), Australia (247 citations), and India (237 citations).
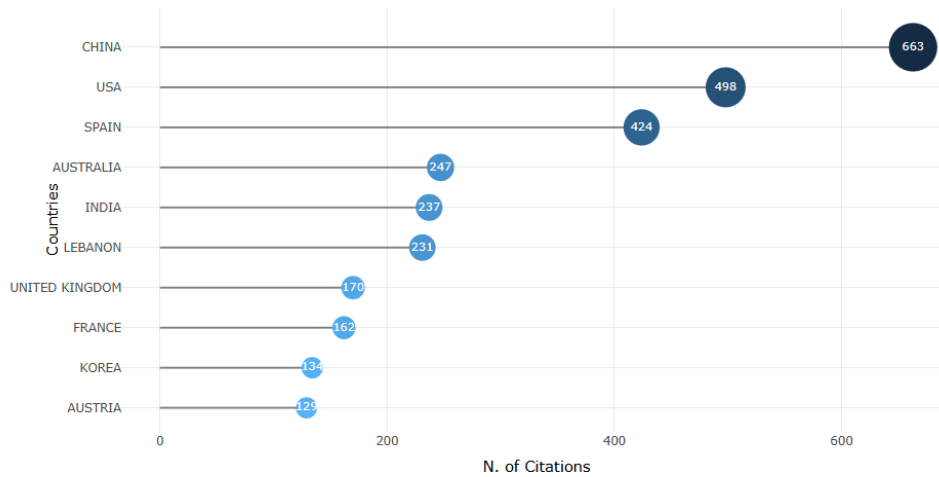
Figure 9. Most Cited Countries
Source: R-Packages dan WebInterface Biblioshiny

3.6 Trending Publication Topics

The thematic map shows a connection between several themes, namely the green bond financial market, energy market, bond market, and spillover effect. A thematic map is one of the most critical analyses, in which the thematic map is divided into four quadrants based on density and centrality. The upper right quadrant shows themes that should be further developed and studied due to high density and centrality. At the same time, the upper left quadrant is a rare and specific theme but highly developed with a high density and low centrality. Furthermore, the themes in the lower right quadrant are fundamental, with low density and high centrality, and those in the lower left quadrant have a downward trend. So, in future research, it is necessary to conduct research related to the relationship between these themes.
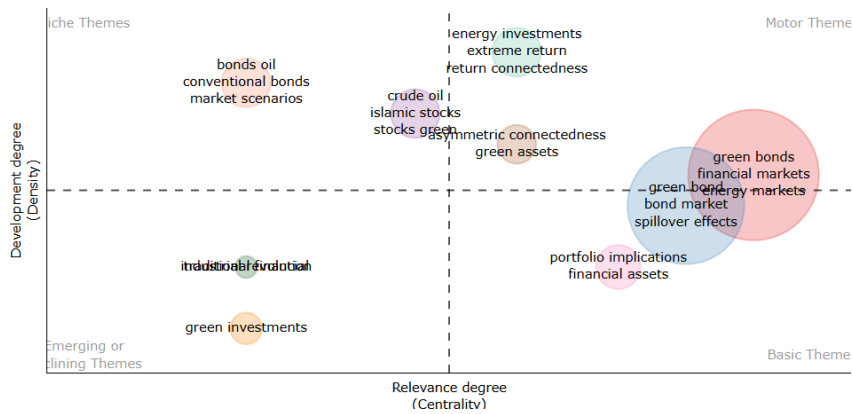
Figure 10. Thematic Map
Source: R-Packages dan WebInterface Biblioshiny

Figure 11. Co-ocuration Network
Source: R-Packages dan WebInterface Biblioshiny

Meanwhile, Figure 12, based on thematic evolution, shows a shift in thematic trends in 2024. Themes on green bonds, energy markets, dynamic connectedness, green finance, bond markets, and spillovers become interesting in 2024.

Source: R-Packages dan WebInterface Biblioshiny
Figure 12. Thematic Evolution

Figure 13, based on WordCloud, shows the top 50 themes based on keywords in research on green bonds and other financial assets. The size of each word illustrates the number of frequently published topics. The larger the size of the word, the more it is used as a trend topic in research, such as the words green bond, financial market, bond market, and green finance.

Figure 13. WordCloud
Source: R-Packages dan WebInterface Biblioshiny

While Figure 14 is based on trend topics, in 2024, bond markets and spillover effects are the trend topics studied. Moreover, in 2021, green bonds, green bonds, and bond markets are trend topics in great demand. Between 2022, the training topics are related to financial markets, energy markets, and the COVID-19 pandemic.

Figure 14. Trend Topic
Source: R-Packages dan WebInterface Biblioshiny

3.7 Trend Keywords

Figure 15 and Figure 16 show the search trend based on titles. Titles that are widely used are the word green bonds as much as 39 (15%), the word green bond as much as 37 (10%), the word financial market as much as 14 (5%), the word bond market as much as 12 (5%), and the energy market as much as 8 (3%).
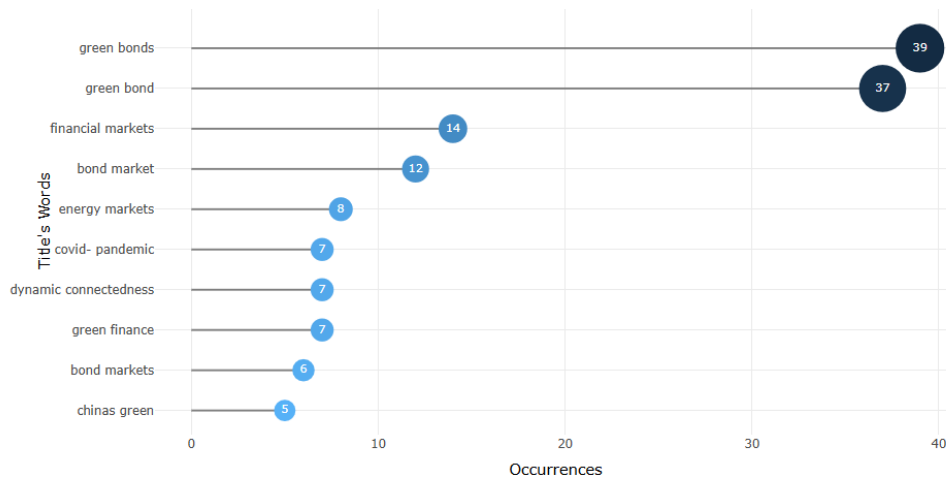
Figure 15. Most Relevant Word
Source: R-Packages dan WebInterface Biblioshiny

Figure 16. Tree Map
Source: R-Packages dan WebInterface Biblioshiny

3.7 Discussion

This study emphasizes that green bonds serve not only as an environmental financing instrument but also as an investment alternative that can be integrated with traditional asset portfolios. This analysis aligns with previous studies Deng et al., (2022) and Wei et al., (2023), showing increased connectivity between green bonds and other financial markets during economic instability. The findings indicate a strong correlation between green bonds and other financial markets, including corporate bonds and the stock market. This result aligns with a prior study by Deng et al., (2022) that demonstrated a transfer of spillover from the energy market to the green bond market. In keeping with the findings of Wei et al., (2023), this study also discovered that market connections tended to rise during economic uncertainty. Furthermore, according to bibliometrics, China had the most citations (663), whereas France was the most frequently examined (24 publications). These results show how crucial these nations are to developing the green bond literature.

This study also includes an analysis of the results in light of contemporary research. For instance, Zhou et al., (2024) demonstrated that financial digitization can hasten the adoption of green bonds in international investment portfolios, while Uckun-Ozkan, (2024) emphasized the significance of the impact of market uncertainty on green bond returns. The significance and importance of the research are made more evident by relating the results of this study to those investigations.

4. CONCLUSION AND LIMITATION

4.1 Conclusion

Green bonds are financial assets that promise a steady income. Green bonds have maturities, coupon rates, and ratings like conventional bonds. The difference is that the funds obtained from green bonds are only used to fund projects with green qualifications. Therefore, academic studies in green bonds have experienced an upward trend from 2020 onwards, and a sharp increase has been observed from 2022. Several countries highlight green bonds as a research topic, led by France with 24 frequencies of articles; second place comes from China with 14 frequencies, and third place comes from the USA with 13 frequencies. Regarding journal publications, the most affiliated is the University of Economics Ho Chi Minh City with 16 publications, then Central South University with 12.

Moreover, the most productive country with the most citations is China, with 663 citations. The publication "Network Connectedness of Green Bonds and Asset Classes" by Juan C. Reboredoa, Andrea Ugolinib, and Fernando Antonio Lucena Aiube, published in 2020, became the most influential and has been cited 371 times. There is a connection between several themes: the green bond financial market, the energy market, the bond market, and spillover effects. The bond market and spillover effects will be the trend topics studied in 2024. In 2021, green bonds, green bonds, and bond markets will be trend topics in great demand. Between 2022, the training topics are related to financial markets, energy markets, and the COVID-19 pandemic.

The results show that green bonds are closely related to other financial assets, such as government and corporate bonds. The practical implications include improving portfolio diversification and risk management for investors. The findings are also relevant for policymakers who want to encourage sustainable investment through green financial instruments. This study makes a novel contribution to the academic literature by mapping the development of green bond research themes through a bibliometric approach. In addition, the findings on spillover transmission add to the understanding of the dynamics of the relationship between green bond markets and traditional financial assets.

4.2. Limitation

This research still has many shortcomings due to limitations in data processing based on the selection of keywords that have yet to be systematically planned in their selection. For future researchers, themes regarding green bonds, energy markets, dynamic connectedness, green finance, bond markets, and spillovers are interesting to research.

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