MAPPING THE PATH TO SUSTAINABILITY: A GREEN FINANCE ROADMAP AND BIBLIOMETRIC INSIGHTS

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Abstract

Aim: This paper seeks to provide a comprehensive analysis of past, present, and future trends in green finance. As countries face increasing public pressure to tackle climate change, green finance serves as the bridge between investors seeking more secure funding options and society's demands for solutions to reduce the risks caused by climate change. **Methodology:** A bibliometric analysis was conducted to gain in-depth insights into the trends in green finance, while also identifying essential researchers, relevant keywords, and future trends. **Results:** Researchers have shown a growing interest in green finance, especially since 2018. The most active regions in green finance—East Asia, Europe, and North America—already benefit from strong environmental regulations and developed financial markets. **Originality / value:** The results shed light on the field of green finance and its future trends. Moreover, they highlight the issues faced by entrepreneurs and the general public, considering the increasingly powerful effects of climate change. **Practical Implications:** Green finance is gaining prominence as the bridge between investors' needs for less risky investments and society's demands for climate-conscious capital formation and investments. **Social Implications:** Green finance plays an important role in establishing more private–public partnerships, which lead to enhanced sustainability standards and long-term and stable economic growth.

Keywords: green finance, bibliometric analysis, sustainable investing, climate change, roadmap
JEL: G11, Q01, Q56, C80

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TRAZANDO EL CAMINO HACIA LA SOSTENIBILIDAD: HOJA DE RUTA DE LAS FINANZAS VERDES Y PERSPECTIVAS BIBLIOMÉTRICAS

Resumen

Objetivo: ofrecer una visión global de las tendencias pasadas, presentes y futuras en el ámbito de las finanzas verdes. A medida que los países se enfrentan a presiones cada vez mayores de la opinión pública para hacer frente al cambio climático, las finanzas verdes sirven de puente entre los inversores que buscan opciones de financiación más seguras y las demandas de la sociedad de soluciones para reducir los riesgos causados por los cambios en el clima. **Metodología**: se realizó un análisis bibliométrico para conocer en profundidad las tendencias de las finanzas verdes y, al mismo tiempo, identificar a los investigadores importantes, las palabras clave relevantes y las tendencias futuras. **Resultados:** el interés de los investigadores en las finanzas verdes se ha incrementado, especialmente a partir del año 2018. Las regiones más interesadas en las finanzas verdes son Asia Oriental, Europa y América del Norte, que ya se benefician de fuertes regulaciones ambientales y mercados financieros desarrollados. **Originalidad / valor:** los resultados de este trabajo arrojan luz sobre el campo de las finanzas verdes y las tendencias futuras a las que se enfrentará. Además, también pone de relieve los problemas a los que se enfrentan los empresarios y el público, teniendo en cuenta los efectos cada vez más potentes del cambio climático. **Implicancias prácticas**: las finanzas verdes, como tema cada vez más importante, sirven de puente entre las necesidades de los inversores de proyectos menos arriesgadas y las demandas de la sociedad de formación de capital e inversiones con conciencia climática. **Implicancias sociales**: las finanzas verdes desempeñan un papel importante en el establecimiento de más asociaciones público-privadas que conduzcan a normas de sostenibilidad más estrictas y a un crecimiento económico duradero y estable.

Palabras clave: finanzas verdes, análisis bibliométrico, inversión sostenible, cambio climático, hoja de ruta

1. INTRODUCTION

This study aims to examine the academic literature on green finance through a bibliometric analysis to identify the main thematic trends, research networks, and conceptual developments in the field between 2015 and 2023. In addition, it explores how the literature contextualises green finance within a paradoxical framework. At the same time, it analyses how the evolution of the concept of green finance is reflected in scientific publications, identifying the main themes, emerging trends, and existing gaps in sustainable green finance. The study also considers how green finance policies can contribute to achieving sustainability objectives, considering the importance of integrating sustainability objectives into financial digitalisation and digital transformation policies to support sustainable green finance.

Thus, to guide this bibliometric analysis, we focus on the following research questions:

1. What are the main emerging trends and themes in green finance research identified through the bibliometric analysis of publications from 2015 to 2023, and how do these trends reflect the evolution of climate change concerns and environmental regulation globally?

2. How is the network of collaboration between researchers and institutions in the field of green finance structured, and who are the key actors and research hubs influencing the direction and impact?
3. To what extent does the bibliometric analysis of green finance publications reveal an integration of digital transformation concepts and tools, and what potential synergies and research opportunities arise from combining these two areas?

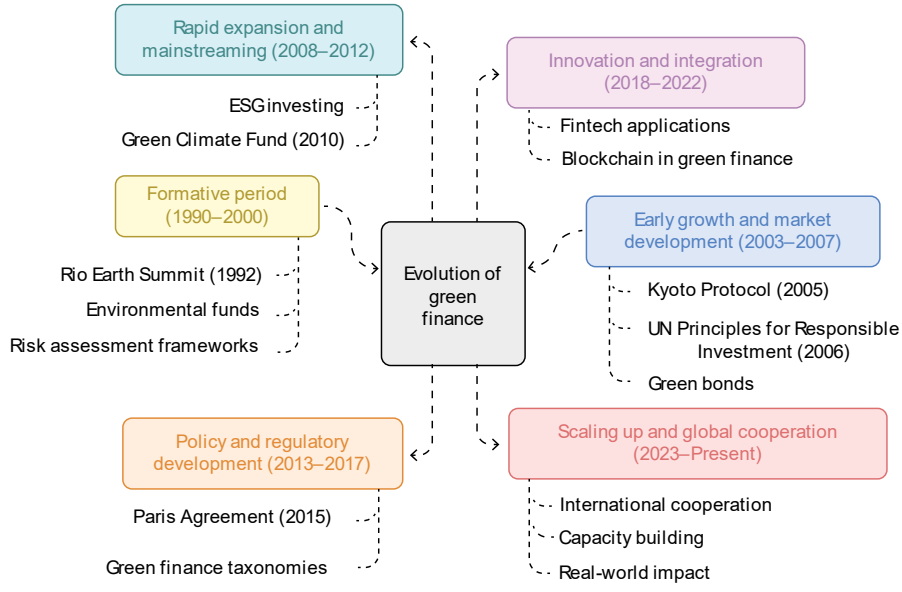
The current body of literature highlights the ever-increasing role of green finance in reaching sustainable development goals across the European Union (EU) member states. Therefore, the bibliometric analysis offers a comprehensive tool for identifying changes in green finance research. This approach is supported by Ozili (2022), who offers a global review of green finance literature and underscores the importance of bibliometric methods in clarifying the field's evolution and fragmentation.

The growing emphasis on sustainability is not only a response to global environmental degradation but also a shift in economic thinking—from short-term growth to long-term resilience (Pan et al., 2020; Volz, 2018; Zhang et al., 2019). Notably, the 1992 Rio Earth Summit and the Kyoto Protocol laid the foundation for financial instruments tailored to environmental outcomes, including carbon markets and green bonds (Chang et al., 2020; Newell et al., 2014). These initiatives have helped formalise the role of finance in addressing environmental externalities.

Figure 1 presents the key milestones and initiatives in the evolution of green finance.

Figure 1

Evolution of Green Finance: Key Milestones and Initiatives



Green finance represents a dynamic and increasingly critical dimension of sustainable economic development. It connects financial markets with environmental sustainability objectives, fostering investments that support green technologies, renewable energy, and low-carbon infrastructure. The urgency of addressing climate change, together with international commitments such as the Paris Agreement and the United Nations (UN) Sustainable Development Goals (SDGs), has accelerated the relevance of green finance in both academic research and policy planning (Daoulhadj & Hussin, 2023; Ma & Chang, 2023). Moreover, Liu and Wu (2023) highlight the growing integration of green finance into sustainability reporting and the environmental, social, and governance (ESG) performance frameworks, thereby strengthening its influence on regulatory practices and investment behaviour.

Between 2008 and 2024, green finance has transitioned from a niche concept to a cornerstone of economic policy. Crises such as the 2008 global financial collapse and the COVID-19 pandemic catalysed transformations in how capital is deployed, giving rise to ESG standards and green climate funds (Berensmann & Lindenberg, 2016; Kotsantonis et al., 2016). Increasing attention from academia and the private sector has further legitimised this paradigm shift (Ivanova et al., 2021; Scheel et al., 2020). Nevertheless, the field still lacks a consolidated analytical synthesis of these developments. Furthermore, the success of green finance depends on institutional alignment with innovation and policy tools, especially in emerging economies (Chen et al., 2024).

The 2008 global financial crisis had a profound impact on the financial markets worldwide, but it catalysed changes in investment practices (Geels, 2013). Prior to the crisis, in 2006, the UN published the Principles for Responsible Investment, which focused on ESG—an integral component of green finance—thereby increasing its visibility on the financial landscape (Berensmann & Lindenberg, 2016; Kotsantonis et al., 2016). Moreover, the Green Climate Fund and the Paris Agreement—which came into force in 2010 and 2015, respectively—jump-started national green finance strategies within the EU (Berensmann & Lindenberg, 2016). Furthermore, the development of green finance taxonomies before 2020 facilitated the standardisation of definitions and measurements (Ehlers et al., 2022).

A significant milestone occurred in 2018, with the emergence of technological developments and innovative financial instruments (Nassiry, 2019). Dorfleitner and Braun (2019) stated that advancements in blockchain and fintech have enhanced the efficiency and accessibility of green finance. Additionally, green finance faces a growing need for integration with global frameworks and regulations (Puschmann et al., 2020). The surge of interest in green finance from institutions and academia observed in 2018 can be attributed to macroeconomic factors, overconsumption of limited natural resources, and heightened public awareness of global climate challenges (Bautista-Puig et al., 2021; Paletta et al., 2019; Scheel et al., 2020).

All these events have, therefore, had a significant impact on sustainable development prospects. Consequently, sustainability assessment and improvement have relied on methodologies and performance measures adopted across various fields. Although this quantitative approach facilitates the analysis and improvement of sustainability, it offers a limited perspective on the complex social, environmental, and economic challenges involved (Arena et al., 2009). A diverse range of innovative financial mechanisms has facilitated the implementation of green finance practices, including green loans, green bonds, and sustainability-related finance (Ivanova et al., 2021).

Previous bibliometric efforts, such as that of Yun and Hu (2024), have outlined the evolution of thematic priorities in green finance, revealing how scholarship has diversified both conceptually and geographically over time. While numerous studies examine the evolution and implementation of green finance instruments, a structured bibliometric analysis mapping the intellectual landscape, key contributors, and conceptual trajectories remains underdeveloped (Gao et al., 2021; X. Yu et al., 2021; Zhang et al., 2019). Our study addresses this gap by employing bibliometric techniques to synthesise existing research and propose a roadmap for scholars and policymakers.

Additionally, this paper aims to feature leading global researchers and assess the geographical areas where research is conducted and published. It also focuses on the historical trends and emerging directions in the green finance field. The goal is to create and highlight an analytical roadmap to assist policymakers and researchers alike in understanding and anticipating the future directions of green finance. In this context, Kwilinski et al. (2025) demonstrate that aligning ESG performance metrics with national sustainability frameworks can enhance the policy effectiveness of green finance tools. Furthermore, a growing body of literature explores the barriers and enabling factors for green finance implementation. Hu and Gan (2025) identify institutional readiness, cross-sectoral collaboration, and policy clarity as critical conditions for scaling green finance globally. These findings underscore the timeliness of a structured bibliometric approach to capture both thematic evolution and research gaps.

This research offers an innovative contribution by integrating a roadmap with a comprehensive bibliometric analysis of green finance literature, particularly focusing on the period 2015-2024, which has been marked by significant growth and development in the field. The study highlights key trends, influential authors, regional contributions, and thematic evolutions, thereby highlighting emerging opportunities for future research and structural patterns in the field's development. Moreover, the study is grounded in a theoretical framework drawing from ecological modernisation theory and institutional theory, which provide a lens for interpreting green finance initiatives, particularly regarding the alignment of financial and regulatory systems. These frameworks support the examination of how institutions adapt to environmental challenges and how green innovation is enabled through financial instruments.

The present work is structured into distinct sections. Section 1 provides an introductory discussion establishing the importance of green finance. Section 2 contextualises the study by examining the growing role of green finance in promoting sustainable development goals and synthesising key theoretical perspectives, thus highlighting advancements in understanding green finance. Section 3 describes the methodological design of the bibliometric study. Section 4 outlines the critical findings, frequently utilising tables and figures to illustrate key trends and relationships within the intellectual structure. The final section synthesises the study's conclusions and discussions, drawing the main insights derived from the analysis. This synthesis not only underscores the significance of the findings but also discusses their broader implications for policymakers.

2. LITERATURE REVIEW

Green finance has gained significant momentum over the last decade, and this study aims to explore its evolution through a bibliometric analysis. The goal is to map the existing research landscape, to identify the most influential researchers, entities, and regions, and to assess the impact of green finance across various sectors. The study seeks to provide a comprehensive

overview of how green finance has been integrated into economic and environmental frameworks, while also identifying research gaps and future directions. Green finance contributes to financial stability by diversifying investment portfolios, encouraging long-term investment perspectives, and diminishing financial risks connected to climate change. In addition to fostering financial stability, green finance directly supports environmental sustainability by funding renewable energy and low-carbon infrastructure, encouraging biodiversity preservation and climate adaptation, and promoting sustainable business practices.

Several authors argue that implementing green finance at the international level fosters socioeconomic development without compromising natural resources and the environment. Although the concept of green finance dates back to the 1970s, it only started to gain momentum after the 2000s (Chen, 2013). Nowadays, increasing emphasis is being placed on green finance, especially after the SDGs' approval in 2015 and the Paris Agreement in the same year. Green finance has been described as a bridge connecting finance and the environment (Salazar, 1998, as cited in Gu et al., 2021).

Green finance is increasingly linked to environmental performance, especially through instruments such as green bonds, green loans, and taxonomies (Zhang & Zhao, 2024). Scholars including Liu and Wu (2023) argue that green finance is transformative in encouraging sustainability transitions by enhancing environmental regulation, improving production standards, and catalysing green innovation. Similarly, Zhou et al. (2020) highlight that green finance promotes the coordinated advancement of financial activities, environmental safeguards, and ecological stability. However, its impact on environmental quality is contingent upon the different levels of economic growth.

Dai and Chen (2023) examine the effects of the COVID-19 pandemic on natural resources, emphasising its contribution to environmental degradation, species extinction, and climate change, and argue that green finance can create new opportunities to bolster natural resource management approaches that support ecological, social, and economic sustainability. Likewise, Bei and Wang (2023) highlight the economic recession caused by the COVID-19 pandemic, which resulted in lower natural resource prices due to reduced energy consumption. This, in turn, decreased public and private financial support for renewable energy projects, undermining their competitiveness.

Fu et al. (2023) conducted an exhaustive analysis demonstrating the critical role of green finance in advancing sustainable development and addressing environmental challenges. The aforementioned studies did emphasise its impact on multiple aspects, such as decarbonisation, the way managers assess climate risks, and the ever-increasing emphasis on durable and sustainable investments. Madaleno et al. (2022) further state that the development and promotion of renewable energy have boosted the promotion of green finance. Additionally, green finance has the potential to reduce the risks associated with broader society and with opening a business (Galaz et al., 2015; Scholtens, 2017), improve productivity (Lee & Lee, 2022), and lower CO2 emissions (Wang & Zhang, 2021), contributing to sustainable development. On the other hand, large-scale investments funded through green finance can also have adverse climate effects (Abbas & Sabah, 2024), as evidenced by the increasing trend in both CO2 emissions and green finance in China between 2004 and 2018 (Wang & Ma, 2022).

From a socioeconomic perspective, green finance enables the transition from extractive to regenerative economic models (Tolossa & Gota, 2023; Zhou et al., 2020). In emerging markets, it supports environmental resilience, while in developed economies, it contributes

to decarbonisation and financial diversification. Nonetheless, structural weaknesses persist—ranging from inconsistent definitions and regulatory fragmentation (Bogacheva & Smorodinov, 2017) to weak institutional capacity, underdeveloped green capital markets (Taghizadeh-Hesary & Yoshino, 2020), lack of focused efforts (Clark et al., 2018), and the misuse or underuse of data-driven measures, which exacerbates these challenges (Desalegn & Tangl, 2022). Other studies have explored sociopolitical barriers to green finance implementation, including greenwashing (Du, 2015; Rahman et al., 2015), investor scepticism, and poor alignment between national policy goals and global standards (Udeh et al., 2024). The need for internationally harmonised green investment criteria remains a pressing issue (Deschryver & De Mariz, 2020).

Green finance leads to increased profits alongside achieving climate and environmental objectives. Banks that integrate green practices exhibit stronger profitability (Jain & Sharma, 2023). Coverage ratios for green bonds are higher than those for bank loans, and they offer more substantial internal rates of return, thus making them a preferred choice for financing projects and new investments (Alonso-Conde & Rojo-Suárez, 2020).

Research on green investment and sustainable finance has projected substantial advancements, but some challenges remain. Researchers have identified issues across financial, institutional, operational, and regulatory dimensions. One limitation is the absence of a comprehensive and uniform framework and standards for green finance. At the same time, K. Khan et al. (2022) state the need for policy frameworks that address governmental policies and limited private-sector activities.

Green investments frequently yield lower returns, involve higher risks, and require schedules that are too long for most investors to achieve a reasonable return (Ihar et al., 2022; Nawaz et al., 2021). Falcone and Sica (2019) also point out that inadequate financial institutions cannot securitise projects for funding reasons. Furthermore, there are a few straightforward methods to deal with policy issues associated with screening and choosing eligible initiatives. Sarkar and Singh (2010) note that infrastructure development and long-term financial allocation for renewable energy projects are lacking in underdeveloped nations.

Given its intricacies and complex challenges, climate change mitigation would benefit from larger emphasis on advanced research in green finance. Environmentally oriented frameworks offer the best option for diminishing climate change risks (Zafar et al., 2021).

Despite these challenges, green finance benefits from a growing body of literature encompassing both traditional and emerging areas of study. Ecologically sustainable growth—or "green growth"—has become significant as governments worldwide face multifaceted challenges, including balancing economic strength and job creation while responding to public demand for a greener economy.

Technological innovation, the development of taxonomies, and the promotion of public–private partnerships can help reduce CO2 emissions and improve the economy's overall state by emphasising the need for better, more inclusive financing sourcing. Green fintech has the potential to enhance efficacy, transparency, and data utilisation to lead to long-lasting investments (Delaney, 2021).

Additionally, artificial intelligence (AI) can play a vital role in environmental management, process optimisation, and practices that are deemed sustainable (Trukhachev & Dzhikiya,

2023). Ecologically friendly technologies need new sources of capital for investments, and green finance—through loans, green bonds, and insurance—can provide such funding (Shah et al., 2023).

Lower investment risk through green guarantee schemes positively impacts the environment and makes investments more appealing to both the public and private sectors (Taghizadeh-Hesary & Yoshino, 2019). Additionally, pairing green investments with corporate social responsibility targets further enhances the economic and social benefits of capital investment (Sadiq et al., 2022).

According to S. Khan et al. (2022), public–private partnerships are essential for reducing CO2 emissions, deploying renewable energy, and reaching sustainability targets. Lastly, laws that facilitate the pooling of resources reduce legal risks and promote green finance, which is essential for investors and entrepreneurs to establish climate-conscious enterprises (Sadiq et al., 2022).

3. METHODOLOGY

Given the multifaceted objective of this study—to map thematic, conceptual, and institutional developments in green finance research between 2015 and 2023, while also uncovering its evolving alignment with sustainability—this research adopts a structured bibliometric approach. In doing so, it also seeks to explore how green finance is situated within a paradoxical framework that balances economic growth with ecological responsibility, and to what extent digital transformation tools and policies have been integrated into the discourse. By combining quantitative mapping with qualitative interpretation, the study aims to identify both dominant trends and research gaps, offering a comprehensive overview of the field's evolution and its practical implications for sustainable finance policy design.

This analysis considers productivity metrics, impact indicators, citation counts, and collaborations (Mejía et al., 2021). Therefore, a bibliometric analysis, as a quantitative method, enables researchers to deepen their understanding of a field of study by quantifying and visualising research trends, knowledge structures, and collaborative networks. The timeframe of 2015-2023 was selected to capture the most recent and relevant developments in green finance, reflecting a period of increased global awareness and policy implementation following the Paris Agreement in 2015, leading up to the present state of accelerated digital transformation.

Building on the gaps identified in previous studies (Bhatnagar & Sharma, 2022; Wang et al., 2025; Zhang et al., 2019), this research addresses three critical dimensions: the spatial distribution of green finance scholarship, highlighting underrepresented regions and global imbalances; the thematic undercurrents shaping the field, by detecting neglected subfields and emerging areas; and the evolution of key conceptual anchors over time. While bibliometric analysis offers valuable insights into research trends and structures, it is essential to acknowledge its limitations, including potential biases in publication databases, the exclusion of non-academic sources, and the inability to fully capture the qualitative nuances of research. Despite these limitations, this multilayered analysis provides a comprehensive understanding of the intellectual structure of green finance, directly supports the stated research objectives, and facilitates the advancement of future research agendas aligned with sustainability goals and climate policy challenges.

The bibliometric analysis provides national and global scientific information on the body of knowledge of green finance, as it utilises metrics to assess the quality and quantity of scientific

publications (X. Yu et al., 2021). It allows for the systematic mapping of publication patterns, keyword co-occurrences, co-citation structures, and collaboration networks, offering both a macroscopic and thematic overview of the field. While prior contributions (Criste et al., 2024; Lobonț et al., 2024, 2025) have employed bibliometric tools to map publication trends in this field, these studies have remained largely descriptive, with limited attention to geographical disparities, thematic fragmentation, and the progression of conceptual frameworks.

The analysis considered several key aspects, including influential publications, the most productive journals and countries, authors and collaborations, research domains (Gupta & Dhawan, 2019; Li & Xu, 2021; Valenzuela-Fernández et al., 2018), and changes in relevant keywords related to green finance. Cai and Guo (2021) employed scientometric methods for their quantitative analysis, ensuring data integrity during the data extraction and processing phases.

The data analysis comprised two main components: network extraction and descriptive study. Key data information, document types and contents, as well as author collaborations are among the informative elements and characteristics examined in the descriptive analysis of the bibliographic dataset (Larivière, 2012; Tepe et al., 2022). To reveal the underlying knowledge structure and dynamics of the field, the network extraction component mapped the co-citation and co-authorship networks (Donthu et al., 2021). Furthermore, other methods for mapping networks were employed, including:

a) Co-citation analysis (Small, 1973), which occurs when a third publication cites two other publications. Its general formula is:

$$\text{Bibcocit} = A \times A' \qquad (1)$$

where A represents a reference matrix of the cited documents.

The value of *bab* indicates the number of co-citations between the publications *a* and *b*. Additionally, the Bibcocit matrix is symmetric and can also illustrate relationships and collaborations among researchers.

b) Bibliographic coupling (Kessler, 1963), which occurs when the reference list of one paper contains similar entries that overlap with those of another. Its general formula is:

$$\text{Bibcoupl} = A' \times A \qquad (2)$$

where A′ represents the transpose of the document-cited reference matrix A.

The value of *bab* indicates the number of shared references between publications *a* and *b*. The Bibcoup matrix is symmetric and non-negative, as it can be expressed as the transpose of itself: Bibcoup = Bib'coup.

c) Co-word analysis (Aria & Cuccurullo, 2017), which examines the co-occurrence of keywords or phrases in the literature. The higher the co-occurrence, the stronger the conceptual relationship. The general formula is:

$$\text{Coword} = W \times W' \qquad (3)$$

Where *W* is the document–keyword matrix, and the Coword matrix is symmetric, capturing the co-occurrence of keywords.

d) Co-authorship analysis (Zhao & Strotmann, 2008), which examines patterns of author collaborations. Its general formula is:

$$\text{Coauth} = A \times A' \qquad (4)$$

Where A is the document–author incidence matrix, and the Coauth matrix is symmetric, representing co-authorship relationships.

The intellectual structure, collaboration patterns, and topic progression of the research subject, analysed through the network approaches described above, provide a comprehensive overview of the capabilities of bibliometric analysis. The Web of Science (WoS) Core Collection database, a trustworthy and comprehensive resource for academic research and assessment due to its rigorous indexing procedures, provided the bibliometric data for the study (Takyi-Annan & Zhang, 2023). WoS is considered one of the most significant and popular sources of scientific literature worldwide. This database was selected because it only includes high-quality academic journals. Moreover, the quality of data retrieved from WoS is preferable to that of other databases such as Scopus, where the reference elements are not standardised, or Dimensions, where the search classification algorithm is not efficient. Moreover, exporting WoS data in BibTex format is preferable to other available formats such as Scopus BibTex or Dimensions CSV, which do not allow the export of some metadata. The search strategy utilised the advanced online search engine and incorporated a series of keywords associated with green finance.

The primary keyword was "green finance" (n = 2125). The initial dataset included all records available between 2007 and 2024. However, to ensure relevance and focus on recent developments, the selection was narrowed to the period 2015-2024 (n = 2098). This timeframe is particularly significant due to the adoption of the Paris Agreement and the 2030 Agenda for Sustainable Development in 2015, both of which marked a turning point in the global discourse on green finance. The search and selection process focused exclusively on articles (n = 1953) published in English (n = 1941), reflecting the constraints of the software's operating language. The final bibliometric dataset comprised a total of 1941 research articles that were subjected to rigorous analysis.

Prior to the analysis, the dataset was normalised to enhance data consistency and analytical accuracy. For this purpose, we used the functions available in the Bibliometrix R package and the Biblioshiny graphical interface, which support automated data cleaning and standardisation, including the unification of author names, conversion to lowercase, removal of redundant spaces, and filtering of duplicate records. Additionally, for frequently used or potentially ambiguous terms, we performed manual validation and unification to ensure semantic consistency and the accuracy of the results.

Although complex and involving various stages, scientific mapping has become increasingly accessible with technological advancements. Numerous software tools have been developed for this purpose, among which Bibliometrix—an R package integrated with the Biblioshiny application—is noteworthy. The analysis was conducted in RStudio, a flexible and open-source integrated development environment for R. RStudio was selected over other statistical software due to its seamless integration with bibliometric packages such as Bibliometrix and its support for interactive visualisation tools, making it particularly suitable for handling complex bibliometric workflows and ensuring transparency in the analysis process.

This tool facilitates bibliometric analysis by streamlining the process of visualising and analysing large sets of scientific data, making it easier for researchers to effectively

map academic trends and collaborations. Various studies using Bibliometrix within the Biblioshiny application have focused on key metrics such as the most influential authors, landmark publications, collaboration networks, conceptual structures, and the leading countries regarding productivity and partnerships.

This bibliometric study offers a comprehensive and detailed examination of scholarly literature addressing the impact of green finance and sustainable development over the past decade. It enables the assessment of the evolution of this research domain, the identification of potential avenues for future research, and the establishment of a foundation for more in-depth explorations. The analysis also evaluated national and international collaborations as well as annual author output.

Metrics such as co-citation, bibliographic coupling, keyword co-occurrence, and co-authorship were examined to explore the intellectual and social structure of the field. The analytical framework includes both descriptive statistics and network mapping. Co-word analysis identified conceptual clusters, while bibliographic coupling revealed foundational literature. Co-authorship networks enabled the exploration of international collaboration trends. The results aim to uncover emerging research directions and evaluate the field's maturity.

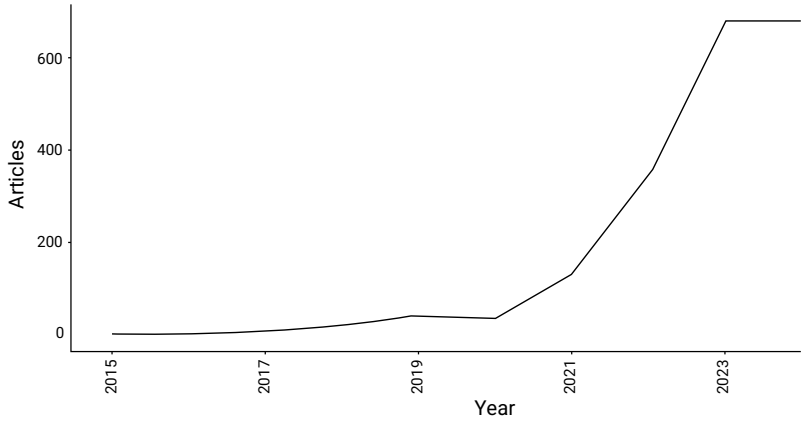
4. RESULTS

Various analyses were conducted using the Bibliometrix R package and the Biblioshiny application, processing 1941 documents from the WoS database to explore the importance and current knowledge about green finance. Visualised through scientific mapping and graphical methods, the results highlight key findings such as significant scientific collaboration networks. The analysis also includes detailed results covering scientific production from 2015 to 2024, including the most relevant and frequently cited sources, influential publications, prolific countries, and productive researchers. The following section presents and discusses these findings using data visualisation tools.

Figure 2 provides a visual representation of the scientific production related to green finance, illustrating the annual growth in academic publications.

Figure 2

Annual Scientific Production of Articles in the Field of Green Finance, 2015-2024



Between 2015 and 2024, the scientific community generated 1937 research papers, with contributions noted in every analysed year. This period reflects a growing interest in green finance, particularly in 2023 and 2024, which recorded the highest outputs with 675 and 680 publications, respectively. This trend highlights the increasing focus on integrating green finance into public policy and entrepreneurial frameworks. The increased number of publications on green finance in the most recent period, 2023 and 2024, reflects the heightened importance given to sustainability factors in global economic and financial processes. International agreements, such as the 2015 Paris Agreement on climate change, and regulatory strategies, including the EU Taxonomy for sustainable activities—which establishes standards for environmental sustainability within the EU—have stimulated the development of green finance instruments, such as green bonds and sustainability linked loans, by setting ambitious targets (including 2025 milestones) for reducing carbon emissions and promoting the transition to sustainable economies.

Green finance has become a focal point in entrepreneurial frameworks, influencing startups, venture capital, and innovation. The record number of publications in 2023 and 2024 underlines its transition from a niche academic interest to a global economic and policy priority, while also reflecting its intersections with fields such as economics, environmental science, and public policy, which have attracted diverse contributions to research. The significant growth observed after 2018 coincides with global policy developments such as the implementation of the European Green Deal and growing emphasis on ESG investing. This upward trend may also reflect increased public and private funding for sustainability-related research, as well as the financial sector's response to climate disclosure frameworks.

An analysis of publication sources was carried out to identify the scientific dissemination channels with the highest visibility in the field of green finance. Table 1 presents the 10 most relevant scientific journals from a total of 394 included in the database, ranked by the number of articles published during the analysed period. These sources reflect the editorial core of the specialised literature and serve as reference points for future research in this field. Together, these 10 journals account for 885 of the 1941 articles, representing almost half of the total sample—an indication of their central role despite the broad scope of the database. *Environmental Science and Pollution Research* is the most prominent, accounting for 10,25 % of all articles, followed closely by *Sustainability* (8,55 %) and *Resources Policy* (6,39 %).

Table 1

Top 10 Leading Journals in Green Finance

Name of the Journal	Number of Articles	Share (%)
Environmental Science and Pollution Research	199	10,25
Sustainability	166	8,55
Resources Policy	124	6,39
Energy Economics	78	4,02
Renewable Energy	75	3,86
Journal of Cleaner Production	65	3,35
Frontiers in Environmental Science	62	3,19

(*continues*)

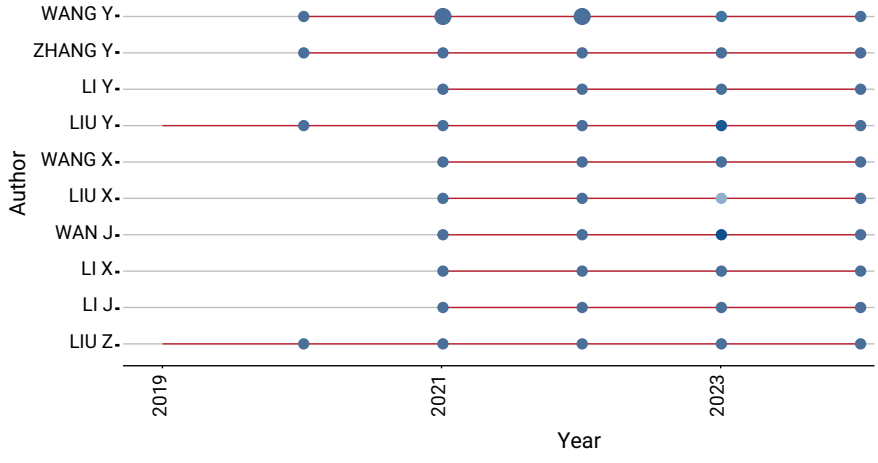
(*continued*)

Name of the Journal	Number of Articles	Share (%)
Finance Research Letters	47	2,42
Heliyon	35	1,80
Journal of Environmental Management	34	1,75
Total Articles	885	45,60

Figure 3 highlights the 10 authors with the highest number of publications in this field.

Figure 3

Production of Top Authors, 2015–2024



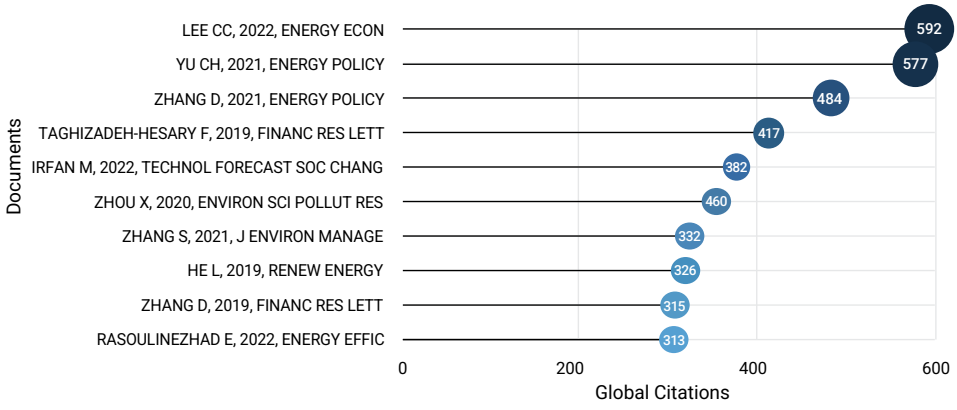
Specifically, the top authors are Liu, Y. (18 documents), Wang, Y. (17 documents), Wang, J. (14 documents), and Zhang, Y. (11 documents). The three most highly cited articles explored diverse facets and dimensions of green finance. Zhang et al. (2021) analysed the green credit policy, which mandates financial institutions to allocate more loans to environmentally friendly enterprises while imposing stricter lending criteria on firms with poor environmental performance. Under this policy, financial institutions must cease all new credit support for projects characterised by high pollution and energy consumption and implement measures to recover previously issued loans to such enterprises, effectively curbing the unchecked growth of "two high" (high energy consumption and high pollution) businesses from a funding perspective. Wang and Wang (2021) explored the role of green finance in ensuring sustainable development, noting that governments and international organisations increasingly leverage financial mechanisms to protect the environment. This entails establishing policy-based environmental protection funds, enacting relevant regulations, and introducing legislation to catalyse the growth of green finance. Traditional patterns of economic development have frequently contributed to an increased ecological burden, whereas green finance facilitates a synergistic relationship between environmental and financial systems, encouraging stakeholders to engage in sustainable practices. Huang et al. (2022) developed a green finance index to assess the relationship between

green finance and green innovation, finding a positive autocorrelation between the two. They noted that financial institutions prioritise the eco-efficiency of borrowers' production or services in the absence of supportive policies. This gap has given rise to the development of green finance, which merges the principles of environmental sustainability with financial mechanisms. As a hybrid concept combining "green" and "finance", green finance represents a market-based approach and a critical tool to promote and support green innovation initiatives. The prominence of Chinese authors reflects academic productivity and strong institutional support in Chinese universities for climate finance research. Many of these authors are affiliated with government-funded institutions, suggesting a top-down influence in prioritising green finance as a national research focus.

The most relevant publications, as indicated by their citation frequencies, are presented in Figure 4.

Figure 4

Authors' Most Significant Publications and Citations, 2015–2024



Given the extensive number of documents and authors, the analysis focused on the 10 most relevant publications, measured by total citations. The findings in Figure 4 reveal that citations are concentrated among these top-cited documents, illustrating their significance in the field. The results indicate that a limited number of works have garnered substantial attention, highlighting the impact of these key publications on the overall discourse in green finance. The highest-ranked article, by Lee and Lee (2022), with 592 citations, examine the relationship between green finance and green total factor productivity (GTFP), addressing a critical area of research as countries aim for greener economies. In the second-ranked article, C.-H. Yu et al. (2021), highlight the essential role of green finance in alleviating the financial barriers to green innovation. The third, Zhang et al. (2021), address critical themes such as public spending, green economic growth, and green finance within the context of the Belt and Road Initiative, offering empirical evidence of the mediating effects of green finance between public spending and green growth.

Table 2 summarises the most cited authors in the green finance literature, ranking them by total citations and reflecting their significant contributions to the theoretical and empirical development of the field.

Table 2

Top 10 Cited Articles in the Green Finance Field

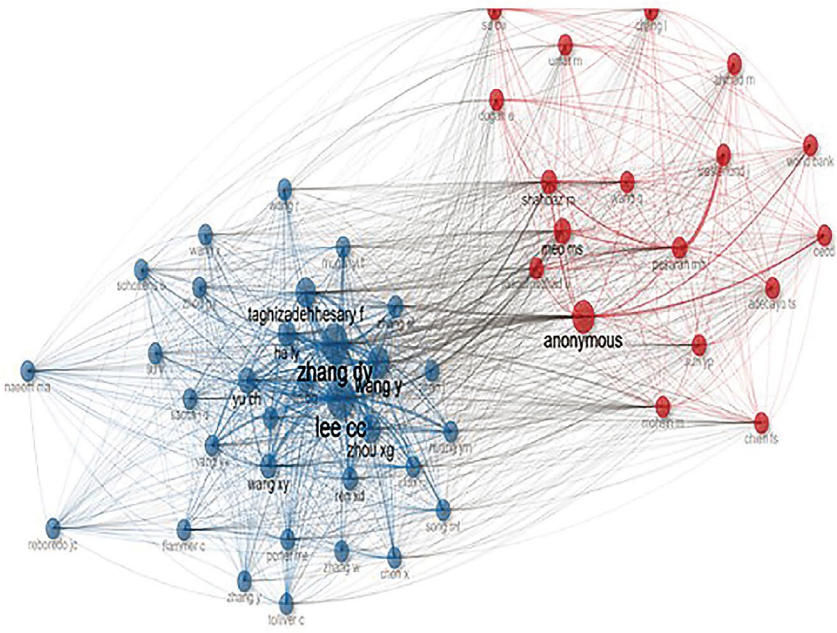
R	Title	Authors	Journal	Year	TC
1	How does green finance affect green total factor productivity? Evidence from China	Lee, C. C., & Lee, C. C.	*Energy Economics*	2022	592
2	Demand for green finance: Resolving financing constraints on green innovation in China	Yu, C. H., Wu, X., Zhang, D., Chen, S., & Zhao, J.	*Energy Policy*	2021	577
3	Public spending and green economic growth in BRI region: Mediating role of green finance	Zhang, D., Mohsin, M., Rasheed, A. K., Chang, Y., & Taghizadeh-Hesary, F.	*Energy Policy*	2021	484
4	The way to induce private participation in green finance and investment	Taghizadeh-Hesary, F., & Yoshino, N.	*Finance Research Letters*	2019	417
5	Influence mechanism between green finance and green innovation: Exploring regional policy intervention effects in China	Irfan, M., Razzaq, A., Sharif, A., & Yang, X.	*Technological Forecasting and Social Change*	2022	382
6	Impact of green finance on economic development and environmental quality: A study based on provincial panel data from China	Zhou, X., Tang, X., & Zhang, R.	*Environmental Science and Pollution Research*	2020	360
7	Fostering green development with green finance: An empirical study on the environmental effect of green credit policy in China	Zhang, S., Wu, Z., Wang, Y., & Hao, Y.	*Journal of Environmental Management*	2021	332
8	Can green financial development promote renewable energy investment efficiency? A consideration of bank credit	He, L., Liu, R., Zhong, Z., Wang, D., & Xia, Y.	*Renewable Energy*	2019	326
9	A bibliometric analysis on green finance: Current status, development, and future directions	Zhang, D., Zhang, Z., & Managi, S.	*Finance Research Letters*	2019	315
10	Role of green finance in improving energy efficiency and renewable energy development	Rasoulinezhad, E., & Taghizadeh-Hesary, F.	*Energy Efficiency*	2022	313

Note. R = Ranking; TC = Total citations.

Figure 5 presents a co-citation analysis of authors, visually demonstrating the intellectual connections and collaborative networks within the field, and identifying influential contributors and thematic clusters.

Figure 5

Co-Citation Analysis of Authors



In Figure 5, the authors' distribution is shown in two clusters. The red cluster features more anonymous authors, alongside prominent figures like Shahbaz, M., Pesaran, M. H., and Meo, M. S., who emphasise macroeconomic impacts and econometric analysis in green finance. The blue cluster centres around Zhang D. Y. and Lee C. C., focusing on environmental sustainability and policy implications. These two main clusters indicate a bifurcation in the green finance literature: one oriented toward macroeconomic modelling and econometrics, and the other toward environmental innovation and ESG policy. This divide suggests that the field is both interdisciplinary and fragmented, possibly requiring theoretical integration to enhance impact.

The most utilised terms in publications can be visualised in Figure 6.

Figure 6

Word Cloud of Significant Terms Used in Publications, 2015–2024

The prominence of terms such as "green finance development", "green finance reform", and "green finance policy" in recent research reflects a strategic focus on using green finance as a lever for both economic and environmental transformation. These terms frame green finance as an evolving, policy-based mechanism that aims to support sustainable development by creating institutional frameworks that support sustainable investments, such as green bonds, green loans, and other climate-focused financial products. "Green finance reform" reflects the financial and policy system adjustments necessary to support green investments through initiatives such as tax incentives for green bonds and subsidies for renewable energy, thereby encouraging the alignment of capital with long-term environmental objectives and promoting green technological innovations essential for the transition to a green economy.

Effective green finance policies combine incentives for compliance with sustainability standards and penalties for non-compliance, thereby incentivising industries to adopt greener and more sustainable practices. Terms such as "innovation in green technology" and "renewable energy development" highlight the essential link between green finance and technology, demonstrating how green investments can support advances in clean energy and eco-innovation. Technologies such as carbon capture and storage, advanced batteries, and low-emission transport are crucial for reducing carbon footprints and achieving net-zero emissions targets. Green finance also attracts venture capital and private investment, stimulating research and development of sustainable solutions and accelerating the transition to a green economy.

Table 3 provides a systematisation of the most frequent keywords extracted from the analysed database, complementing the general view provided by the word cloud.

Table 3

Most-Used Keywords

R	Keywords	OC	R	Keywords	OC
1	Green finance	1168	11	Energy	161
2	China	291	12	Sustainable development	157
3	Impact	288	13	Consumption	150
4	Renewable energy	257	14	Efficiency	138
5	Growth	216	15	Green	137
6	Economic growth	213	16	Emissions	131
7	Performance	203	17	Policy	130
8	Innovation	196	18	Finance	122
9	Investment	193	19	Sustainability	117
10	CO2 emissions	184	20	Green bonds	94

Note. R = Ranking; OC = Occurrence.

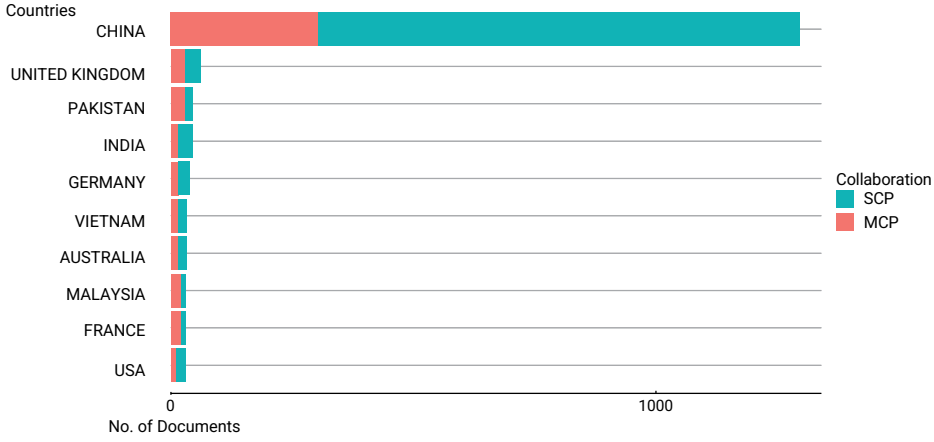
The keyword frequency analysis (Table 3) reveals a conceptually cohesive field centred on "green finance", which dominates all other terms in occurrence. However, this also suggests a risk of thematic saturation, potentially limiting conceptual innovation. The prominence of "China" not only underscores the geopolitical weight of its academic production but also raises questions about the global representativeness of research findings. It also confirms the country's influence on setting the research agenda. Keywords like "impact", "sustainability", and "economic growth" reflect an evolving focus on green finance literature from abstract conceptualisation toward measurable outcomes, directly addressing the study's first research question regarding emerging themes. This progression indicates that researchers are increasingly concerned with assessing the real-world effectiveness of green finance in supporting low-carbon development.

"Innovation" and "investment" emerge as critical channels through which sustainability goals are operationalised, while "efficiency" and "performance" serve as benchmarks for success. These terms show that green finance is considered a strategic mechanism for enabling resilient and inclusive economic growth. Moreover, the high frequency of terms such as "renewable energy", "CO2 emissions", and "green bonds" suggests that the literature focuses heavily on energy-related topics, while social dimensions such as equity or adaptation remain underexplored. This indicates both a strength, in terms of depth within environmental finance, and a gap, which future research could address by integrating interdisciplinary contributions and perspectives from the Global South. The underrepresentation of terms related to digital finance or climate adaptation further reveals gaps aligned with the study's third research question, highlighting potential opportunities for interdisciplinary exploration.

Figure 7 illustrates the collaborative efforts of countries, as well as the most prolific contributors to the core literature on green finance during the study period, 2015–2024.

Figure 7

Scientific Production and Collaboration of Countries



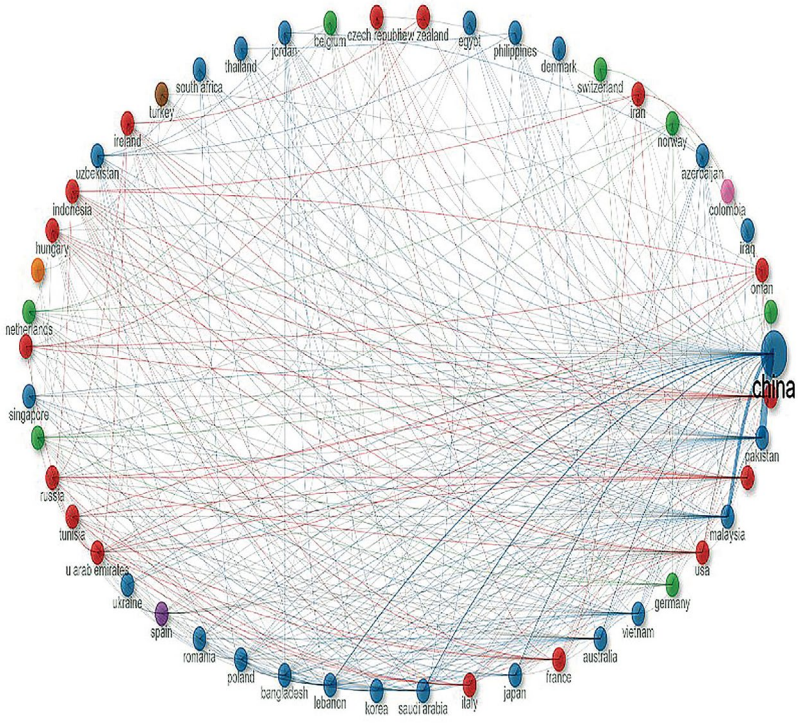
Note. SCP = single country publication; MCP = multiple country publication

Figure 7 shows that China has emerged as the most prolific contributor to green finance research, with 1301 articles published between 2015 and 2024. The EU member states, the United Kingdom, and Asian countries such as Pakistan and India also contribute significantly, although each has published less than 100 articles over the same period. The findings show the publication output of individual countries and indicate the extent of national collaborations (SCP) and international collaborations involving co-authors from multiple countries (MCP). This distribution reflects an increased reliance on international partnerships to advance research, driven by limited domestic resources or a strategic focus on knowledge exchange and cross-border initiatives. China has the highest distinction between SCP and MCP articles, with most being national collaborations. By contrast, for other leading countries, the values between SCP and MCP is relatively balanced. A collaborative network between countries reflects how interconnected and cooperative they are in addressing everyday challenges, encouraging innovation, and facilitating cross-border information and resource sharing. In the EU, the United Kingdom, and other leading regions, balanced SCP and MCP values suggest that green finance research benefits from robust domestic networks and international collaboration, enabling these countries to share insights, methodologies, and findings. This contrast between levels of cooperation is consistent with institutional theory, which suggests that national policy and resource availability influence research output and the structure of collaborative networks.

Figure 8 shows the collaborative network between countries.

Figure 8

Collaborative Network Between Countries



China appears as the largest node, indicating that it plays a prominent role within the network. It likely has the most significant impact or the greatest number of partnerships. The numerous connecting lines in the figure imply extensive international cooperation. China also stands out for its large number of SCPs, indicating a strong focus on domestic collaborations. This suggests a consolidated national effort to advance the field of green finance, with research partnerships mainly involving domestic institutions and researchers. Complementing the figure on scientific production and collaboration among countries, Table 4 summarises the data for the most active countries, highlighting the number of publications and international co-authorship connections, and reflecting the degree of academic engagement and openness to transnational partnerships.

Table 4

Top 10 Countries in Green Finance Research by Number of Publications and National/International Collaborations

Country	Number of Articles	Share (%)	SCP	MCP	International Collaboration (%)
China	1301	67,03	999	302	23,21
United Kingdom	59	3,04	30	29	49,15
Pakistan	43	2,22	13	30	69,77
India	41	2,11	28	13	31,71
Germany	3431	1,75	21	13	38,24
Vietnam	31	1,6	18	13	41,94
Australia	29	1,49	16	13	44,83
Malaysia	29	1,49	9	20	68,97
France	27	1,39	8	19	70,37
USA	24	1,24	12	12	50,00

Note. SCP = National collaborations; MCP = International collaborations involving co-authors from multiple countries.

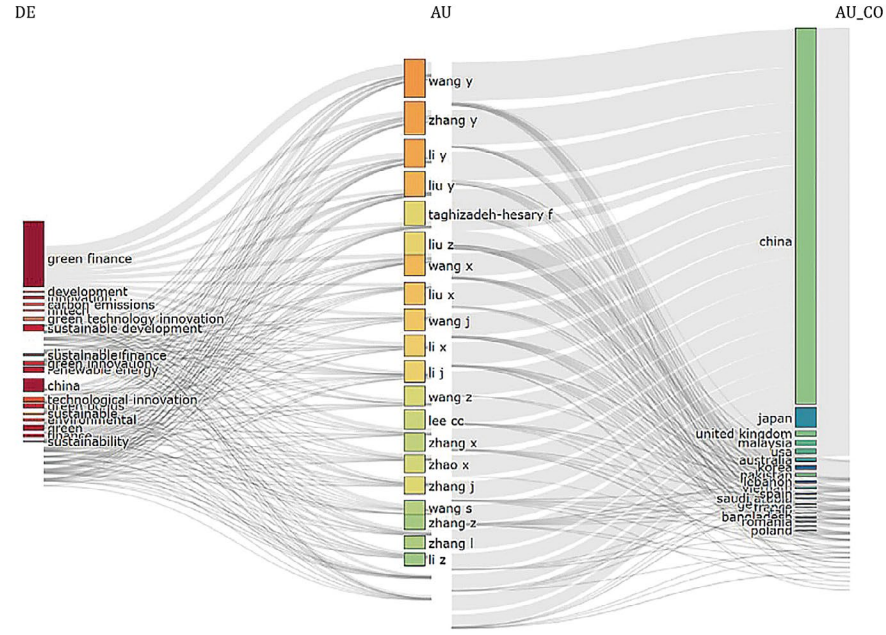
China occupies a dominant position, with 1301 published articles representing 67,03 % of the total analysed articles. Out of these, 999 resulted from SCP and only 302 from MCP, indicating a predominantly domestic research pattern. Although China has the highest absolute number of international collaborations, its relative proportion of international collaborations (21,3 % of total publications) is significantly lower than that of other countries in the ranking. In contrast, countries such as Pakistan, Malaysia, and France are more actively involved in international collaborations, with over 65 % of their research conducted with foreign partners—an externally oriented approach that is often a strategic necessity for resource-constrained countries.

Countries like the United Kingdom, Australia, and the USA maintain a balanced SCP–MCP ratio, reflecting robust domestic research capacity complemented by consistent international engagement. This balanced collaboration pattern may serve as a model for developing nations aiming to scale their scientific presence while remaining globally relevant. The analysis highlights the structural inequalities within global research systems and underscores the importance of fostering inclusive, cross-border partnerships, especially for emerging economies underrepresented in the green finance literature.

Regarding the interrelationship between keywords, authors, and country of co-authors, the results are shown in Figure 9.

Figure 9

Conceptual Structure in Terms of Keywords



Keyword clustering indicates thematic groupings where specific terms are often associated with the same group of authors and countries. For instance, keywords such as "green finance", "development", and "carbon emissions" often appear in publications from China, Japan, the United Kingdom, and the EU, reflecting the global focus on green finance and environmental concerns. The countries of co-authors play a vital role in shaping these interrelationships. Chinese researchers, for example, frequently collaborate on topics related to green development, mirroring China's growing investment in environmental sustainability. This interconnectedness emphasises the global interest in green finance, where both the geographic distribution of co-authors and the frequency of specific keywords highlight the collaborative and interdisciplinary nature of the field.

5. DISCUSSION

This study used bibliometric analysis to answer the research questions concerning the mapping of collaborative structures, the identification of conceptual and thematic trends in green finance research, and the examination of the relationship between sustainability goals and digital transformation in green finance policy design. In addition, it sought to explore how the literature frames green finance within a paradoxical framework and to what extent current research addresses this tension. A final research question considered how green finance literature identifies and reflects critical gaps and limitations in the practical implementation of sustainable finance mechanisms, particularly in terms of geographic disparities, policy inconsistencies, or institutional misalignments. Together, these questions guide a comprehensive bibliometric approach that not only highlights the evolution of scholarly output on green finance but also uncovers opportunities for future research at the intersection of finance, sustainability, and digital transformation.

The surge in publication volume after 2018 coincides with amplified global efforts toward implementing the SDGs and post-Paris Agreement frameworks. This confirms that green finance has shifted from a niche concern to a central policy instrument. The concentration of keywords such as "green finance policy", "renewable energy", "innovation", and "CO2 emissions" suggests that the field is evolving beyond theorisation toward application and measurement. These results are consistent with the ecological modernisation theory, which holds that environmental enhancement and economic growth can coexist through innovation and institutional change. However, there are still gaps: crucial terms like "adaptation," "transition," and "inclusion" are either conspicuously lacking or underrepresented. This reveals a thematic bias aligned with critiques in the literature (Desalegn & Tangl, 2022; Ozili, 2022) regarding green finance's neglect of social equity dimensions.

The national collaboration networks confirm China's dominant role in terms of quantity and centrality. Nonetheless, China's low percentage of international collaboration (23,21 %) indicates a robust domestic research agenda. On the other hand, Malaysia, France, and Pakistan have higher international co-authorship ratios (above 65 %) despite producing fewer publications, which indicates their reliance on external knowledge systems and collaborative funding. These results are consistent with institutional theory, highlighting how national governance and research policies shape knowledge production. Additionally, some fragmentation is evident in grouping author co-citations into two dominant schools: one concentrating on econometrics and growth, and the other on ESG and innovation. This division may hinder interdisciplinary integration, limiting the capacity of the field to address multi-dimensional sustainability challenges.

Although one of the research questions included exploring the integration of digital transformation and green finance, keyword analysis and clustering reveal limited interaction. Terms such as "blockchain", "AI", "fintech", or "digital platforms" are absent from the most-used terms, signalling an underdeveloped research frontier. Despite the promise of these technologies, the lack of theoretical and empirical convergence between digital and green finance undermines the potential for scalable, transparent, and efficient sustainable investments (Nassiry, 2019; Trukhachev & Dzhikiya, 2023).

6. LIMITATIONS AND FUTURE LINES OF RESEARCH

Although the bibliometric analysis provides a structured picture of the evolution and dynamics of green finance research, several limitations should be mentioned to interpret the results correctly.

First, the selection of bibliographical sources was limited to the WoS database—one of the most widely used platforms for bibliometric assessments—but it does not exhaustively cover all relevant publications in the field. Thus, papers indexed exclusively in alternative databases (such as Scopus, Dimensions, or Google Scholar) were excluded, which may affect the overall coverage of the literature. Second, the analysis period (2015-2024) was chosen to reflect recent research trends but excludes earlier contributions that conceptually grounded the field of green finance. Moreover, articles published in most recent years (e.g., 2023-2024) may have low citation counts due to the lagged effect in scientific recognition, which limits comparability with older works. The analysis was also restricted to scientific articles written in English, which introduces a potential linguistic bias by excluding relevant research published in other languages, especially in the context of emerging regions, where local literature may provide valuable insights into the implementation of green finance. Finally, as with any bibliometric analysis, the study relies mainly on quantitative indicators (number of publications,

citations, countries, etc.), without directly capturing the quality or theoretical depth of the contributions. Also, a detailed analysis of the conceptual content of the papers has not been carried out, which limits the ability to assess emerging themes and real research gaps.

7. CONCLUSIONS

This study used bibliometric techniques to provide a comprehensive roadmap of the green finance research landscape between 2015 and 2024, aiming to identify major thematic trends, collaboration networks, and conceptual developments in the field. Beyond capturing intellectual trends, the analysis also identifies emerging directions through which green finance may support sustainable development in a rapidly transforming financial landscape.

The results of the bibliometric analysis reveal a significant increase in the number of studies— including policy decisions and increased researcher interest—in the field of green finance between 2015 and 2024. They provide insights into the evolution and progress of green finance and identify key themes, influential authors, institutions, and geographical regions that have influenced academic research. The main findings highlight that green finance has matured as a research domain, with growing thematic convergence around policy integration, performance metrics, and innovation.

China has played an important role in green finance research, underlining national priorities through its participation in the Paris Agreement and carbon neutrality goals. Although the collaborative network between nations unveiled patterns of international cooperation aimed at addressing collective challenges—such as sustainability and green investments—the co-citation analysis of authors provided valuable insights into the principal contributors within the domain of green finance research and their categorisation into thematic clusters. The co-authorship networks highlight the strong collaborations between researchers in China and Europe, promoting the exchange of concepts and approaches to global environmental challenges and proposing coordinated cross-cutting strategies and policies that require this interconnection. However, the field remains geographically imbalanced, with China dominating output yet showing low international collaboration in terms of the total publications, whereas emerging economies rely more heavily on global networks.

Despite notable progress, several challenges continue to limit the effectiveness of green finance. Significant legislative changes are needed, such as introducing tax incentives and subsidies to encourage private sector participation. Strengthening public–private partnerships could mobilise resources and expertise for green initiatives, while centralising reporting bodies may improve transparency and efficiency. Under these conditions, green finance could become a powerful instrument for promoting a low-carbon economy, propelling international climate action, and accomplishing sustainable development goals.

Although the body of literature is growing, specific areas within green finance remain underexplored. There is a need for more in-depth studies into the long-term impacts of green finance on both global financial stability and environmental sustainability. Future research should also explore the effectiveness of various green finance policies across different national contexts, particularly in developing economies where financial systems may be less robust. Cross-disciplinary collaboration will be crucial in addressing these gaps, as green finance inherently spans multiple domains of expertise.

The conceptual landscape is also marked by a division between econometrics-driven studies and those focused on ESG, governance, and policy mechanisms. This fragmentation

underscores the need for greater theoretical integration, particularly by drawing on ecological modernisation and institutional theory, to explain how national systems, regulatory frameworks, and technological readiness shape green finance trajectories.

Crucially, despite the increasing relevance of digital transformation in the financial sector, the bibliometric evidence reveals a surprising lack of integration between digital tools (e.g., fintech, blockchain, AI) and green finance. This gap represents a limitation of current research and a substantial opportunity for future exploration, particularly in designing scalable, transparent, and impact-oriented green finance mechanisms.

This study reaffirms that ecological modernisation theory and institutional theory remain robust lenses for understanding how policy, governance, and innovation merge in green finance. From a practical perspective, the findings suggest the need for targeted policy measures to foster global collaboration and support the adoption of digital infrastructure in sustainability finance. Addressing these gaps may accelerate the alignment of financial systems with sustainability imperatives while enhancing transparency, accountability, and inclusiveness. By combining bibliometric analysis with theoretical grounding in ecological modernisation and institutional frameworks, this study offers a structured roadmap for understanding the evolution of green finance. It also highlights critical areas for further exploration—such as digital finance integration, institutional alignment, and global disparities—thus providing actionable insights for researchers, policymakers, and financial institutions.

Future research should build on this bibliometric roadmap by employing longitudinal and mixed-method designs, expanding data sources beyond WoS, and incorporating underexplored dimensions such as climate adaptation, behavioural finance, and social inclusion. Governments should implement more robust regulations and guidelines to encourage accountability and transparency in green investments, guaranteeing that money is allocated to initiatives with measurable environmental effects. These are only some of the possible policy ramifications associated with green finance. Policymakers might also provide tax breaks, subsidies, or other financial incentives to encourage private sector involvement in sustainable initiatives. Looking forward, the future of green finance research appears promising. With the global emphasis on sustainability and climate resilience, the demand for financial solutions aligned with environmental goals will only increase. Additionally, the intersection between green finance and digital transformation should be prioritised empirically and theoretically as a key area of innovation and policy relevance in the coming years.

STATEMENTS

Data Availability

The data supporting this study are available from the corresponding author upon reasonable request.

Use of Artificial Intelligence

The authors certify that no artificial intelligence tools were used in the preparation, analysis, or writing of this manuscript.

Conflict of Interest

The authors declare no conflict of interest related to this publication.

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Author Contributions (CRediT)

AD: conceptualization, software, validation, resources, writing, original draft, visualization.

CC: conceptualization, methodology, writing, original draft, data curation.

CB: conceptualization, methodology, validation, writing, original draft.

PMS: formal analysis, investigation, supervision, project administration.

ORL: resources, writing, review & editing, supervision, funding acquisition.

Ethical Approval

Not applicable.

Declaration of Originality

The authors declare that this article is an original work that has not been previously published nor is under consideration elsewhere.

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