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Research Article

Mapping the Landscape of Green Innovation Research: A Bibliometric Analysis

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Abstract: Green innovation has become a crucial approach to addressing sustainability challenges within global economic and environmental contexts. This study maps the development of green innovation research through a bibliometric analysis using data from the Scopus database covering the period 2021–2024. Bibliometric techniques were applied with VOSviewer and R Studio to examine publication trends, citation patterns, author collaboration, and keyword networks. The results show a significant growth of publications in the last five years, with major themes focusing on sustainable development, environmental technology, and economic implications of green innovation, while leading contributions come from China. Influential journals in innovation and environmental management are identified as key publication outlets, and keyword analysis reveals the integration of green innovation into sustainability strategies and economic policy discussions. This study contributes to a clearer understanding of the intellectual structure and emerging directions of green innovation research, offering insights for scholars, business practitioners, and policymakers in advancing sustainable innovation practices.

Keywords: Bibliometric Analysis; Economics; Environmental Technology; Green Innovation; Sustainable Development.

1. Introduction

The urgency of addressing environmental degradation, climate change, and sustainable economic growth has led to increasing global attention on the concept of green innovation. Green innovation refers to the development and application of technologies, processes, and practices that minimize environmental impacts while supporting economic competitiveness (Chen et al., 2006). In recent years, it has become a central driver in advancing the global agenda for sustainability, aligning with the objectives of the United Nations Sustainable Development Goals (SDGs) (United Nations, 2015). Businesses, governments, and academic institutions have recognized the importance of green innovation not only in reducing ecological footprints but also in creating long-term economic resilience (Klewitz & Hansen, 2014).

The scholarly interest in green innovation has grown significantly in the past two decades, with a surge in publications focusing on themes such as renewable energy, circular economy, environmental technology, and sustainable business models (Khan et al., 2022). Despite this rapid development, the field remains fragmented, with diverse perspectives and approaches across disciplines. To gain a comprehensive understanding of the intellectual structure and evolving research frontiers, bibliometric analysis offers a systematic method for mapping publication trends, citation networks, and thematic clusters (Donthu et al., 2021).

This study aims to conduct a bibliometric analysis of green innovation research published between 2021 and 2024, based on data retrieved from the Scopus database. Analytical tools including VOSviewer and R Studio are employed to visualize research networks, identify leading authors and institutions, and uncover dominant themes. The findings of this study are significant as they provide insights into the trajectory of green

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innovation research, highlight its integration with sustainable development and economics, and identify opportunities for future exploration. By offering a structured overview of the field, this article contributes to both academic scholarship and practical policymaking in advancing sustainable innovation practices.

2. Literature Review

Green Innovation and Sustainable Development

Green innovation refers to the development and adoption of products, processes, or practices that reduce environmental impact while sustaining or improving organizational performance (Chen et al., 2006). It is considered a crucial driver in achieving the objectives of sustainable development, particularly in balancing ecological protection with economic growth (Klewitz & Hansen, 2014). In the context of business and economics, green innovation enables firms to improve efficiency, comply with environmental regulations, and build competitive advantage through eco-friendly strategies (Albort-Morant et al., 2016).

The significance of green innovation has been widely emphasized in global sustainability discussions, especially in relation to the United Nations Sustainable Development Goals (United Nations, 2015). Research in this field often intersects with renewable energy, circular economy, environmental technology, and corporate responsibility, illustrating its multidisciplinary nature (Khan et al., 2022).

Bibliometric Analysis in Green Innovation Research

Bibliometric analysis is a quantitative method that evaluates the structure and dynamics of scientific literature through citation networks, co-authorship, and keyword co-occurrence mapping (Donthu et al., 2021). This method has been increasingly applied in environmental and sustainability studies to uncover research trends, identify leading authors and journals, and highlight emerging areas of inquiry (Merigó & Yang, 2017). For example, Arfi et al. (2018) conducted a bibliometric analysis of eco-innovation and found that knowledge networks in this field are rapidly expanding and diversifying across industries and disciplines.

In the context of green innovation, bibliometric studies are particularly valuable for synthesizing fragmented literature and providing comprehensive insights into research frontiers (Feng et al., 2020). Tools such as VOSviewer and R Studio enhance this approach by allowing visualization of collaboration networks and thematic clusters, thereby offering a clearer picture of intellectual structures within the field (van Eck & Waltman, 2010).

Hypothesis Development

Although this study is exploratory in nature, prior research suggests several expectations that guide the analysis. First, it is hypothesized that the volume of green innovation publications has significantly increased between 2021 and 2024, reflecting growing global concern with sustainability (Khan et al., 2022). Second, collaborative research networks are expected to be concentrated in developed regions such as Europe, North America, and Asia, given their leadership in environmental technology (Albort-Morant et al., 2016). Third, it is anticipated that sustainable development and environmental technology will emerge as dominant thematic clusters, consistent with previous findings in eco-innovation bibliometric studies (Arfi et al., 2018; Feng et al., 2020).

By framing these hypotheses, the study provides a structured lens through which to interpret bibliometric results and contribute to the understanding of global research trajectories in green innovation.

3. Research Method

An initial search was conducted in the Scopus database, and the evaluation of the retrieved documents was organized into three main phases (Figure 1). Phase 1 involved defining the search criteria to identify relevant records on green innovation and refining the dataset during the data collection process. Phase 2 consisted of exporting the documents into VOSviewer and R Studio for bibliometric analysis, focusing on publications, authors, countries, institutions, journals, and subject areas (data visualization phase). Phase 3 entailed performing a detailed analysis to identify the principal themes, research clusters, and emerging trends in green innovation studies.

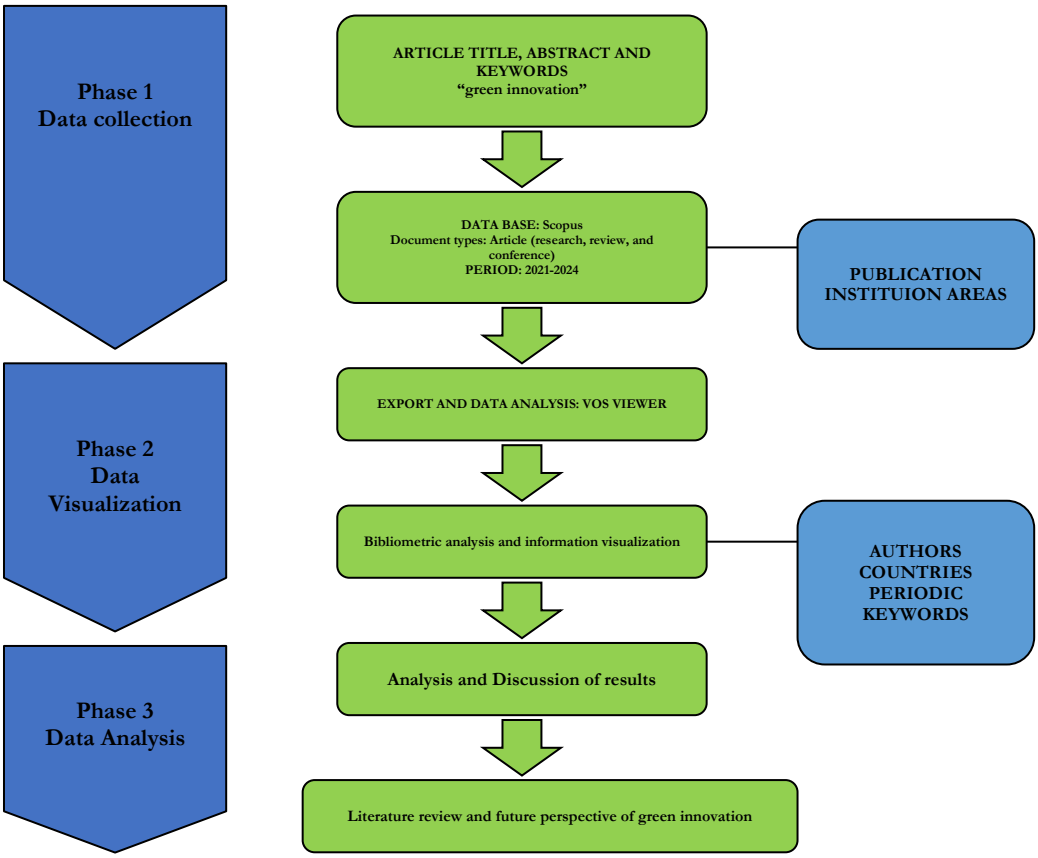

Figure 1. Research methodology phases implemented in this study.

This research employed bibliographic information sourced from the Scopus database within the time span of 2021 to 2024 (Fig. 1). The study adopted a total sampling approach, in which all relevant documents that met the search criteria were included without restriction. The key variables extracted from the database comprised the title of publication, author name, abstract, author-provided keywords, year of publication, publishing journal, document type, and institutional affiliation. To ensure consistency, the data were collected using a single English keyword query: *"green innovation."*

The search results were exported from Scopus in CSV format and subsequently organized with Mendeley Desktop for bibliographic management. Following data collection, a descriptive statistical analysis was carried out to examine annual publication trends, the distribution of publications by journal, and the productivity of authors and institutions. This analysis provided an overview of the evolution and distribution of scholarly work on green innovation during the specified period.

To explore the intellectual structure of the field, the dataset was further processed with VOSviewer version 1.6.19 and R Studio. These tools enabled the construction of bibliometric maps based on keyword co-occurrence, citation relationships, and collaborative networks among authors and countries. The mapping process emphasized the identification of thematic clusters, visualization of research hotspots, and detection of emerging trends in green innovation scholarship. By combining descriptive and network analyses, the methodology facilitated a comprehensive understanding of the development, collaboration patterns, and knowledge frontiers in the domain of green innovation research.

4. Results and Discussion

The dataset provides an overview of green innovation research outputs between 2021 and 2024. It includes records from 510 different sources with a total of 3,032 documents, reflecting a strong annual growth rate of 60.17%. A total of 10,471 authors contributed to these publications, with no single-authored works identified, indicating a highly collaborative research environment. International collaboration is significant, with 31.1% of publications involving co-authors from multiple countries, and the average number of co-authors per paper is 9.53, suggesting a broad pattern of teamwork and knowledge exchange.

Figure 2. Main information overview (using R Studio)

The analysis also reveals 10,841 author-provided keywords and 18,911 references, reflecting the wide thematic diversity and strong engagement with prior studies. The average age of the documents is 1.93 years, which demonstrates the recency of the literature in this field, while the average citation rate of 28.57 per document highlights the high visibility and scholarly impact of green innovation research. Overall, these results provide valuable insights into collaboration patterns, thematic development, and the influence of green innovation studies within the academic community.

The study results should be clearly presented and supported with relevant tables and figures. This section should also discuss the principles and generalizations derived from the findings, along with any exceptions, issues, theoretical and practical implications, and recommendations. All tables and figures must be cantered and numbered appropriately. Table headings should be placed at the top, while figure captions should be positioned below the figures. Any references related to tables and figures should be included beneath them.

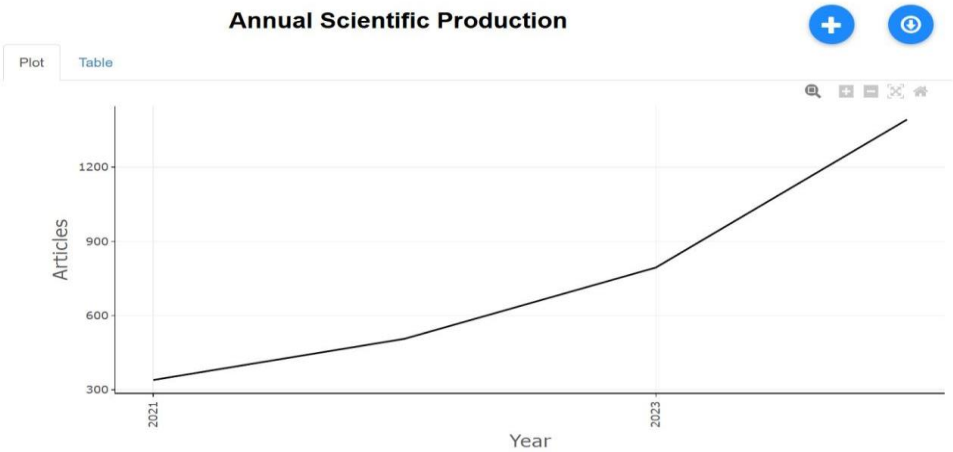

Figure 3. Annual Scientific Production (using R Studio).

The annual scientific production of green innovation research from 2021 to 2024 shows a clear upward trajectory. In 2021, the number of publications was slightly above 300 articles, and it steadily increased in 2022 with more than 500 articles. The growth became more significant in 2023, when publications surpassed 800 articles, before reaching their peak in 2024 with more than 1,200 articles. This pattern indicates a strong and accelerating research interest in green innovation, reflecting its rising importance in the context of sustainability, economics, and environmental technology. The continuous increase over four years also demonstrates that green innovation has transitioned from a niche research topic into a mainstream academic concern, driven by global environmental challenges and policy agendas such as the United Nations Sustainable Development Goals.

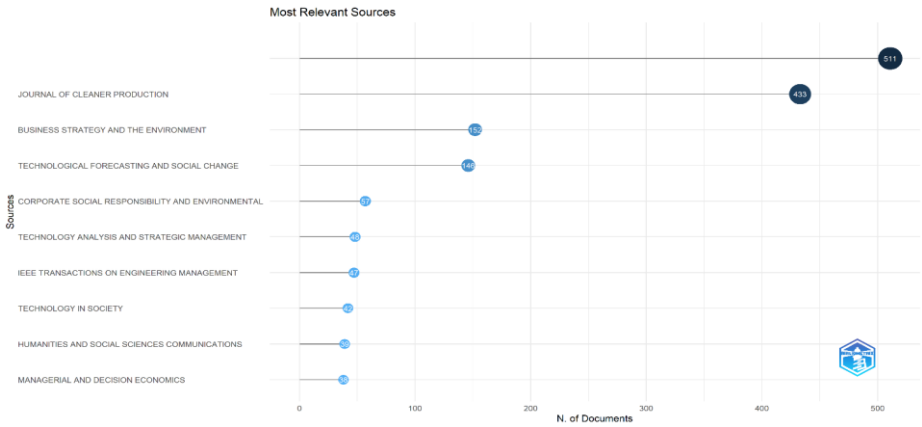

Figure 4. Most Relevant Sources (using R Studio)

The analysis of the most relevant sources demonstrates that research on green innovation is highly concentrated in several leading journals. The Journal of Cleaner Production emerges as the dominant outlet with 511 publications, underscoring its role as the primary platform for studies at the intersection of sustainability, environmental management, and innovation. This is followed by Business Strategy and the Environment with 433 articles, reflecting the growing attention to green innovation within strategic management and corporate policy contexts.

Other notable journals include Technological Forecasting and Social Change (146 publications), which focuses on the forward-looking implications of innovation and sustainability, and Corporate Social Responsibility and Environmental Management (57 publications), emphasizing the role of responsible business practices. Meanwhile, specialized outlets such as Technology Analysis and Strategic Management (48 articles), IEEE Transactions on Engineering Management (47 articles), and Technology in Society (42 articles) highlight the multidisciplinary engagement with green innovation, spanning engineering, policy, and social sciences.

In addition, journals such as Humanities and Social Sciences Communications (39 articles) and Managerial and Decision Economics (38 articles) indicate that green innovation has also penetrated broader discussions in the social sciences and economics. Collectively, these findings reveal that green innovation research is not only concentrated in core sustainability and management journals but is also diffused across a wide range of disciplines, reflecting its broad relevance to environmental, economic, and technological debates.

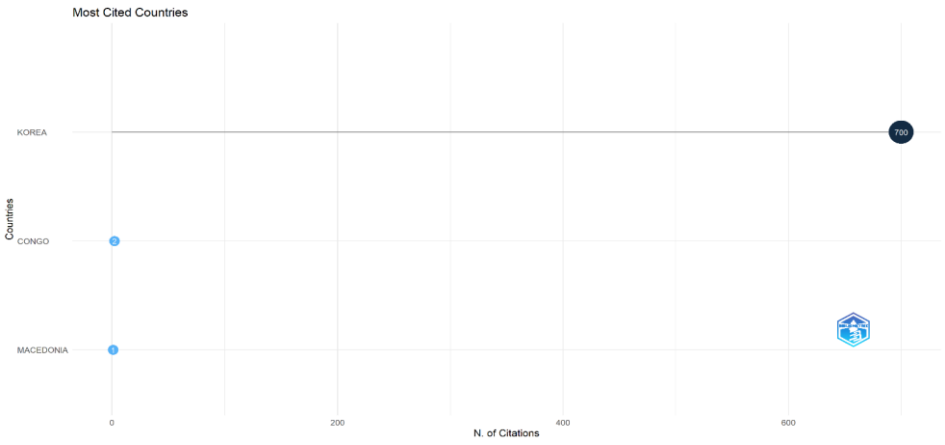

Figure 5. Most Cited Countries (using R Studio).

The analysis of the most cited countries highlights a notable imbalance in the global distribution of scholarly impact within green innovation research. Korea dominates with approximately 700 citations, positioning it as the leading country in terms of academic influence and visibility in this field. This strong performance may reflect Korea's significant investment in sustainable technologies, renewable energy, and green economic policies, which have become focal points in its national innovation agenda.

In contrast, Congo and Macedonia show very limited citation counts, with only 2 and 1 citation, respectively. Their presence, though minimal, indicates that research on green innovation is not restricted to developed economies but has also begun to emerge in less-represented regions. The wide gap between Korea and the other countries demonstrates both the concentration of scholarly influence in certain hubs and the opportunities for expanding green innovation research across different geographic contexts.

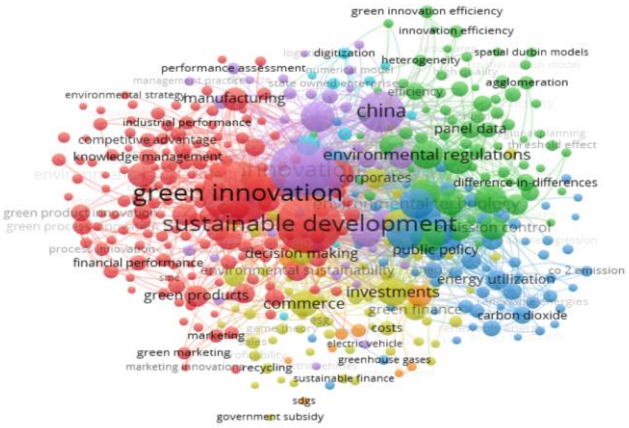

Figure 6. Network Visualization (using Vos Viewer)

The keyword co-occurrence network reveals the intellectual structure of green innovation research, where several clusters represent distinct but interconnected thematic areas. The red cluster is centered around *green innovation* and *sustainable development*, highlighting their role as the core concepts of this research field. Terms such as *green products*, *commerce*, *marketing*, and *financial performance* suggest a strong link between green innovation and business strategies aimed at competitiveness and sustainability.

The green cluster focuses on methodological and regulatory aspects, with keywords such as *environmental regulations*, *panel data*, *corporates*, and *digitization*. This indicates that research in this stream frequently analyzes the role of policies, regulations, and corporate governance in promoting green innovation. The blue cluster emphasizes environmental and technological dimensions, including terms like *energy utilization*, *carbon dioxide*, *emission control*, and *renewable energy*. These keywords reflect the integration of green innovation into efforts to reduce emissions and enhance energy efficiency.

Meanwhile, the yellow cluster is associated with economic and policy perspectives, with terms like *investments*, *public policy*, *sustainable finance*, and *government subsidy*. This highlights the growing interest in financial instruments and policy interventions to foster green innovation. Finally, the purple cluster, which features keywords such as *China*, *industrial performance*, and *knowledge management*, underscores the regional dominance of certain countries as well as the knowledge-sharing mechanisms that support innovation systems.

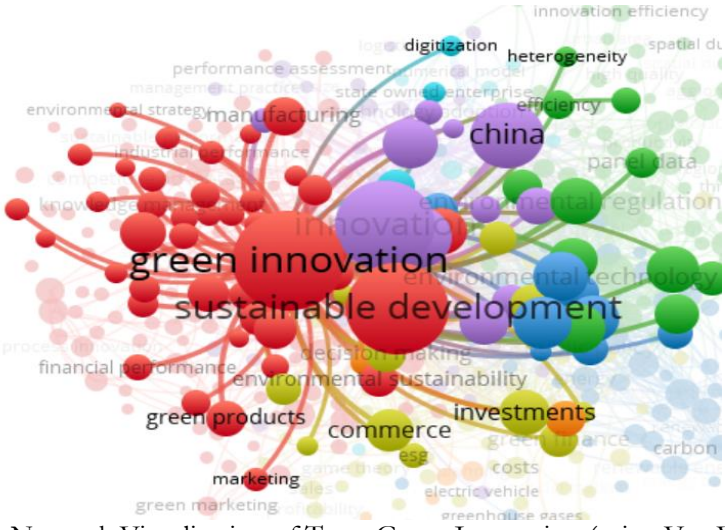

Figure 7. Network Visualization of Term Green Innovation (using Vos Viewer).

The close-up view of the keyword co-occurrence network highlights the central role of "green innovation" and "sustainable development" as the dominant themes in this field. Both appear as the largest nodes, indicating their high frequency and strong interconnections with other research topics. Surrounding these core concepts, the red cluster is closely associated with terms such as *green products*, *manufacturing*, *financial performance*, and *marketing*, showing how green innovation is integrated into industrial practices and business strategies. The yellow cluster reflects economic and policy aspects, with keywords like *investments*, *commerce*, and *environmental sustainability*, suggesting an emphasis on financing and market mechanisms to support sustainable practices. The green cluster connects with *environmental regulations*, *panel data*, and *environmental technology*, highlighting the role of regulatory frameworks and methodological approaches in shaping the research agenda. The purple cluster, including terms like *China*, *digitization*, and *heterogeneity*, underscores the geographical and technological dimensions of green innovation, with China emerging as a highly studied context. Finally, the blue cluster links to *environmental sustainability* and *decision making*, illustrating the integration of governance and policy considerations.

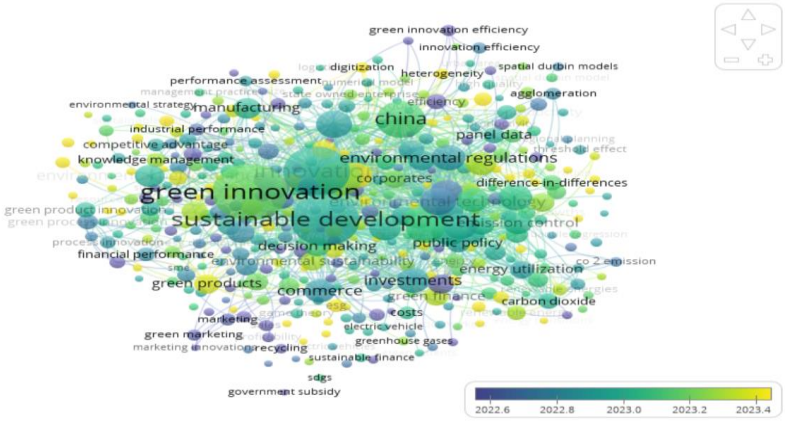

Figure 8. Overlay Visualization of Term Telemedicine (using Vos Viewer)

The overlay visualization of keyword co-occurrence provides insights into the temporal evolution of green innovation research between 2022 and 2023. The largest and most central terms, such as "green innovation" and "sustainable development", remain the dominant focus throughout the period, reflecting their foundational role in the field. The color gradient indicates the progression of research themes over time, where darker shades (blue–purple) represent earlier studies, while lighter shades (yellow–green) reflect more recent contributions.

Earlier research (late 2022) emphasized themes such as *green products*, *manufacturing*, *financial performance*, and *competitive advantage*, pointing to the integration of green innovation into industrial practices and corporate strategy. More recent studies (2023) have shifted attention toward policy and methodological issues, including *environmental regulations*, *public policy*, *panel data*, and *difference-in-differences*, reflecting the growing interest in empirical approaches and regulatory frameworks. Emerging keywords such as *green finance*, *government subsidy*, *carbon dioxide emissions*, and *energy utilization* further illustrate the increasing intersection of environmental technology with economic and policy perspectives.

This temporal visualization suggests that research on green innovation is evolving from a focus on business applications and industrial performance toward broader interdisciplinary themes involving governance, sustainability finance, and environmental regulation. The progression highlights the adaptability of green innovation scholarship in responding to global sustainability challenges and policy agendas.

5. Conclusions

This study provides a comprehensive bibliometric analysis of green innovation research from 2021 to 2024 using the Scopus database, with analytical support from VOSviewer and R Studio. The findings highlight a rapid expansion of scholarly output, with an annual growth rate exceeding 60%, confirming the rising importance of green innovation in addressing global sustainability challenges. The analysis also shows that research in this domain is highly collaborative, with international co-authorship accounting for more than

30% of publications and an average of nearly 10 authors per article, reflecting the interdisciplinary and global nature of the field.

The results further reveal that sustainable development, environmental technology, and economic perspectives dominate the thematic landscape, while policy-oriented concepts such as public policy, green finance, and government subsidy are emerging as new areas of focus. Core publication outlets include the Journal of Cleaner Production and Business Strategy and the Environment, underscoring the central role of sustainability and management journals in disseminating knowledge. In addition, citation patterns show strong geographical concentration, with Korea emerging as a highly influential contributor.

Overall, the study demonstrates that green innovation has evolved into a dynamic and multidisciplinary research area, bridging business, economics, environmental science, and policy. By mapping its intellectual structure and thematic evolution, this research contributes valuable insights for scholars, practitioners, and policymakers seeking to advance sustainable innovation strategies. Future studies may build upon these findings by conducting more focused analyses on specific sectors, regions, or policy interventions to deepen the understanding of green innovation's role in sustainable development.

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