

Article

Green Innovation in Business: A Comprehensive Bibliometric Analysis of Trends, Contributors, and Future Directions

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Abstract: Evolving from an ethical consideration to a strategic imperative, green innovation (GI) compels businesses to continually enhance their processes to achieve sustainable growth. Based on bibliometric analysis of 594 Web of Science (WOS)-sourced articles from 2000 to 2023 using VOSviewer-1.6.20 and Bibliometrix-4.3.0, this study sheds light on the existing trends of green innovation, its contributors, and potential future directions in today's business landscape. Our findings unveil significant insights from GI literature; an upward growth trajectory in publications; limited collaboration among researchers and institutions (notable collaborative networks among countries include China, Spain, and the United Kingdom); and trending GI terms and themes include green intellectual capital, GI efficiency, green product innovation, green absorptive capacity, green knowledge acquisition, big data, etc. These insights serve as a comprehensive guide for practitioners and scholars navigating the study of GI within the business and management sphere.

Keywords: bibliometric analysis; business; green innovation; management



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1. Introduction

In recent years, global environmental degradation has received special attention from scholars, firms, and policymakers [1–3]. Acknowledging its significance, businesses started emphasizing both financial rewards as well as their contributions to society and the environment in particular [4]. To address growing environmental concerns endangering sustainability in today's dynamic landscape, businesses have devoted substantial attention towards adopting green innovation (GI). Multiple notions have been used in extant literature regarding innovations minimizing environmental impact, making it theoretically elusive [5]. Prominent terms include “environmental innovation; sustainable innovation; eco-friendly innovation; low-carbon innovation; eco-innovation; clean technology innovation; or green innovation”. For instance, [6] defined GI “as hardware or software innovation that is related to green products or processes, including the innovation in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs, or corporate environmental management”. Similarly, where “sustainable innovation” stresses that any new creation must improve three aspects of sustainable development, i.e., social, environmental, and economic, “eco-innovation” “is the creation or implementation of new, or significantly improved, goods and services, processes, marketing methods,

organizational structures, and institutional arrangements that—with or without intent—lead to environmental improvements compared to relevant alternatives” [7]. Though all such notions have definite commonalities, they slightly differ in descriptive precision on various aspects such as impulse, level, phase, environmental impact, or innovation object [8]. However, all cited terminologies agreed to have a negative impact on environmental degradation [2]. Encapsulating eco-friendly practices and technologies, GI has become a pivotal element in business management strategies, significantly impacting operations, sustainability, and financial performance. Considering stakeholder demands and institutional environmental pressures, the connection between environmental sustainability and corporate financial performance (CEP) gains prominence [9,10] and is viewed as essential for commercial success [10]. Businesses integrate GI to innovate their products, processes, and strategies, aligning them with environmental conservation goals [11]. This integration facilitates a paradigm shift in conventional business approaches, fostering a focus on environmental impact alongside profit generation. Moreover, management studies further delve into the strategic implementation of GI, exploring how organizations adopt and embed eco-efficient practices, considering managerial decisions’ ecological repercussions [12]. It acts as a strategic catalyst to help businesses to achieve their great goals of primarily achieving sustainable competitive advantage, leading to enhanced organizational performance [13], along with pollution prevention, energy saving [14], waste disposal, and environmental management performance [15]. Effective management of GI involves not just technological advancements but also strategic planning, resource allocation, and organizational restructuring to accommodate eco-friendly initiatives [16]. Businesses that embrace GI often justify shifts in consumer preferences, wherein eco-friendly products and activities become more appealing, influencing purchasing decisions [16]. GI, while primarily focused on environmental benefits, has also demonstrated a profound impact on financial outcomes, showcasing a symbiotic relationship between eco-conscious practices and economic success [11]. For instance, innovations geared towards minimizing waste, reducing energy consumption, and optimizing resource utilization often lead to cost savings, bolstering profitability [12]. These savings not only stem from operational efficiencies but also result from the development of new, marketable green products that cater to an increasingly environmentally conscious consumer base [17]. Furthermore, GI contributes to risk mitigation and enhanced reputation management. Businesses proactively employing eco-friendly policies often avoid potential regulatory fines, legal entanglements, and market backlash associated with environmental non-compliance [18]. This proactive approach, termed as ‘Environmental Strategy’ (ES), has been associated with better Environmental Performance (EP) and subsequently, improved financial results [19].

The relationship between GTI and CFP occupies an important position within the research community [20–22]. However, challenges persist in quantifying the direct financial benefits of GI due to various factors such as initial investment costs, longer payback periods, and the intangible nature of some eco-friendly initiatives. Nevertheless, empirical evidence consistently indicates that businesses integrating GI into their core strategies tend to experience competitive advantages and improved financial resilience over time.

Recent years have witnessed an emerging interest in GI in both practice as well as in academic circles [23]. Numerous systematic and bibliometric reviews have explored diverse topics related to innovation, including GI, low carbon technology, eco-innovation, and sustainable business models [24–36]. For instance, a bibliometric analysis was conducted from WOS-indexed articles on GI for a time frame from 1970 to 2015 [37]. Similarly, a descriptive and content analysis was performed on GI through a systematic literature review, without bibliometric content [5,34]. Although a plethora of studies on GI aiding concept extension, trends, and its relationship with organizational performance-related variables are available, there remains untapped potential in the rapidly evolving field of business and management. Our study aims to provide a comprehensive overview of GI within this domain, focusing on several central research questions as follows:

- Are the relevant publications gradually increasing?

- Who are the most efficient contributors in this dimension?
- Which journals, countries, and institutions are significantly participating in this field?
- What current research topics are trending in GI research?
- How have the research trends changed over time?

Our exploration extends beyond specific topics to offer a comprehensive understanding of GI's role in business and management studies. Gathering data from 594 articles spanning from 2000 to the present, our bibliometric analysis, conducted using R language, delves into the contribution of GI within this domain, providing a systematic and scientific review.

This remainder study follows the following structure: Section 2 involves detailed research methodology to conduct bibliometric analysis. Section 3 presents the study's data results, which include publication output, number of publications, most influential authors, country-wise global research productivity, impactful journal distribution, highly cited publications, authors' thematic map and network analysis of authors' keywords, authors' co-citation analysis, and journal citation analysis. Lastly, results' discussion, implications, and future directions are presented in Sections 4 and 5 respectively.

2. Materials and Methods

2.1. Bibliometric Analysis

Several methods can be used for conducting a literature review. These methods help researchers identify limitations and guide the selection of future research topics. Bibliometric analysis is a statistical method that provides an extensive overview of literature contributions in a specific field, offering insights into current and future research topics [38]. This method is effective for stimulating a large number of publications by linking articles, citations, authors' productivity, and emerging keyword trends. Visual demonstrations through network mapping also help identify research gaps in existing literature [39–42]. Since bibliometric analysis efficiently handles large amounts of data over time and provides significant results to justify its theoretical and numerical contributions, it is a convenient method for literature review studies [38,43].

In this study, we employ bibliometric analysis to explore the concept of Green Innovation (GI) within the field of business and management research. We use VOSviewer 1.6.20 and Biblioshiny, part of the bibliometrix 4.3.0 package in R [44], as our primary tools for analysis [45,46]. These software tools, being free and user-friendly, offer an extensive and comprehensive literature set for analysis and scientific mapping [38,40]. VOSviewer, developed by [47], is a significant instrument widely used for constructing and visualizing networks in bibliometric analysis. It provides valuable insights into research trends by designing network mappings [47].

Bibliometric analysis operates in two primary modes. Firstly, performance analysis evaluates the productivity and impact of publications using various bibliometric factors, including the number of publications, citations, annual citations for highly cited publications, influential authors, nations, and journals [48]. Secondly, scientific mapping analysis assimilates distinct elements like citation analysis, co-citation analysis, bibliographic coupling, and clustering. These tools contribute to revealing the knowledge structure within specific research areas or journals [40,49].

2.2. Bibliographic Data Search Selection

In this study, bibliometric analysis serves as an efficient approach for extracting insights into highly cited publications and various trends in published articles, citations, journals, and publishers. We leveraged the Web of Science (WoS), a prominent database known for its stringent protocols ensuring the inclusion of high-quality articles, to assemble a corpus of pertinent articles on Green Innovation (GI) and related concepts. Terms such as "green", "environmental", "eco", "sustainable", "renewable", and "low-carbon" often interchangeably describe innovations with reduced negative environmental impacts [33,50–53]. However, these terms may carry nuanced differences based on context and emphasis. To

comprehensively grasp the concept of GI within the business and management field, it was imperative to encompass all these different terminologies associated with environmentally friendly innovations, as seen in prior literature reviews [54]. Consequently, we initiated a document search using a refined search string (“GI” OR “environmental innovation” OR “sustainable innovation” OR “eco innovation” OR “renewable energy innovation” OR “low-carbon innovation” OR “climate-friendly innovation” OR “clean technology innovation”). This search generated a total of 3045 results.

2.3. Inclusion and Exclusion Criteria

In compiling data for the bibliometric study, two pivotal criteria guided the process: “inclusion” and “exclusion”. The search strategy was confined to a specific timeframe, extending up to December 2023. Documents were filtered using the “Topic” category within the Web of Science (WoS) database. Specifically, the selected documents pertained to the research subjects of “Business” and “Management” and were written in English. Among document types, only “articles” were considered. Ultimately, the dataset used for analysis comprised 594 entries.

3. Results

3.1. Publications Output

The primary data retrieved from the Web of Science (WoS) database is summarized in Figure 1. It encompasses 594 documents sourced from 150 distinct sources spanning the period from 2000 to 2023. Throughout this duration, the annual publication growth rate stands at 20.72%, with an average of 52.87 citations per document. These documents yielded 1649 author keywords and 1159 keyword plus. A total of 1513 authors contributed to this research area. On average, there were 3.11 co-authors per article, with international co-authorship averaging 18.52%. Details are summarized in Figure 1.

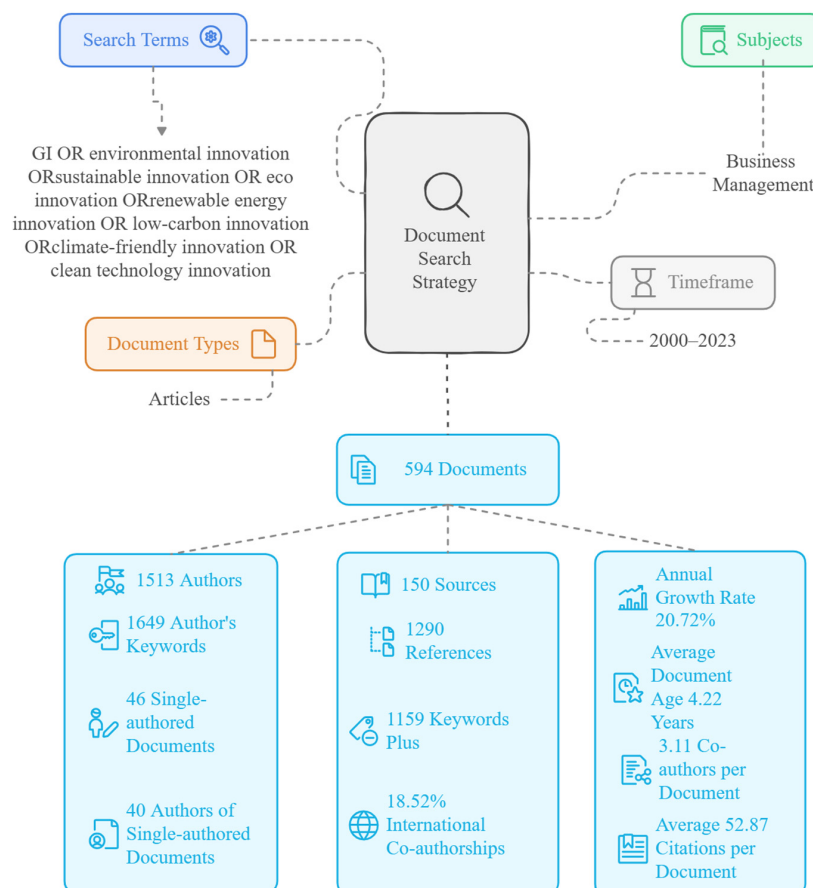


Figure 1. Comprehensive document search strategy for green innovation research (2000–2023).

3.2. Number of Publications

The earliest documented paper on innovation within business and management research, titled “Suppliers and environmental innovation: the automotive paint process”, authored by Charlette A. Geffen and Sandra Rothenberg, was indexed in the Web of Science (WoS) database in 2000 and published in the *International Journal of Operations & Production Management* [55]. Post-2010, a gradual increase in document output is noted, reaching a significant peak of 72 documents in 2021 and further escalating to 152 in 2023. Concurrently, the mean total citations (TC) exhibit variability, with notable peaks in 2010 and 2013, before stabilizing around 8–15 from 2015 to 2022. The data suggest a sharp rise in document production in recent years, indicating a growing interest or expansion in the field. However, the mean TC does not exhibit a consistent upward trend, suggesting that while more documents are being produced, citation impact per document remains variable. This could imply either a broadening of research topics or varying levels of influence among the published works. Figure 2 illustrates the temporal trends in the mean total citations (TC) per year and the number of documents published from 2000 to 2023.

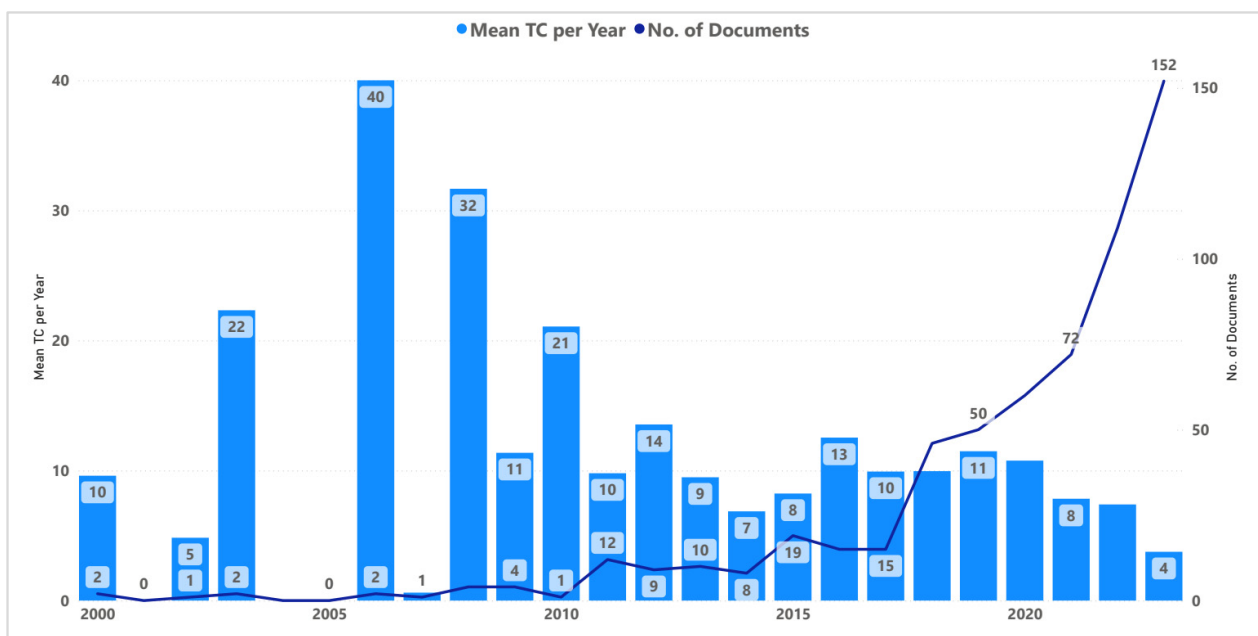


Figure 2. Temporal trends in mean total citations and document publications (2000–2023).

3.3. Most Influential Authors

A total of 1513 authors actively contribute to research in green innovation (GI) and related areas within the field of business and management, with 40 individuals having single-authored documents. Table 1 highlights the top 20 most prolific authors in this research domain, focusing on authorship roles and citation impact. These authors have each contributed between 4 and 18 articles. Notably, LIAO ZJ leads with 18 publications, demonstrating a dominant role in research with 88.9% as first author and 61.1% as corresponding author. This indicates substantial contributions to both the research and communication processes. LIAO ZJ also maintains a high h-index of 11, supported by 494 citations, reflecting both productivity and impact.

In terms of citation impact, SINGH SK is remarkable, amassing 1267 citations from only four articles, suggesting a significant influence in their research domain. Despite a first authorship rate of 50%, SINGH SK is the corresponding author for all their publications, highlighting their pivotal role in research dissemination. WANG Y, with seven articles, shows an interesting case of low first authorship (14.3%) but a high citation count (343), implying participation in highly impactful studies. FENG TW and CHANG CP present

high corresponding authorship percentages (66.7% and 80.0%, respectively), underscoring their roles in managing research outputs. Meanwhile, REN SG, with 80.0% as first author and zero corresponding authorship, emphasizes a focus on research contribution rather than manuscript submission.

Authors such as ALI A and REHMAN SU, despite moderate first authorship percentages, have accrued fewer total citations (13 and 805, respectively), indicating lesser recognition in the academic community. The fractionalized article counts reveal a balanced distribution of credit among co-authors, with values ranging from 0.98 to 2.00, reflecting varying degrees of collaboration.

Table 1. Publication and impact metrics of selected top 20 prolific authors: an analysis of authorship roles and citation impact.

Authors	Articles	% As First Author	% As Corresponding Author	Articles Fractionalized	H-Index	Total Citations
LIAO ZJ	18	88.9%	61.1%	9.83	11	494
WANG Y	7	14.3%	28.6%	1.83	6	343
ALI A	6	50.0%	16.7%	1.62	2	13
FENG TW	6	0.0%	66.7%	1.57	5	331
CHANG CP	5	0.0%	80.0%	1.45	4	105
REN SG	5	80.0%	0.0%	1.23	5	498
WANG JR	5	40.0%	100.0%	1.75	5	152
ADOMAKO S	4	25.0%	50.0%	1.50	4	120
CUI RX	4	75.0%	25.0%	1.42	4	93
DAI J	4	25.0%	100.0%	1.03	3	209
DE MARCHI V	4	75.0%	50.0%	2.00	4	925
JOHL SK	4	0.0%	75.0%	1.67	4	157
LI DY	4	75.0%	75.0%	1.07	4	396
LONG SY	4	25.0%	50.0%	1.75	4	79
PAN X	4	50.0%	50.0%	1.42	3	72
QU Y	4	25.0%	100.0%	1.03	3	300
REHMAN SU	4	25.0%	25.0%	0.98	4	805
SCARPELLINI S	4	75.0%	50.0%	1.17	4	175
SINGH SK	4	50.0%	100.0%	1.15	4	1267
TRIGUERO A	4	75.0%	25.0%	1.33	4	210

3.4. Global Research Productivity by Country

The global distribution of research productivity based on citations and publication metrics across various countries was explored. China emerges as the foremost contributor with 10,802 citations and 312 publications, of which 225 are as the corresponding country, highlighting its significant role in academic research. European nations, such as the United Kingdom, Spain, and Italy, also demonstrate robust research outputs, evidenced by high citation counts and substantial numbers of publications, primarily as corresponding countries. The United States, although with fewer total publications (32), maintains a strong presence with 2016 citations. Other notable contributors include Brazil and Indonesia in terms of publications and citations within their respective regions. Oceania, represented by Australia and New Zealand, shows a focus on publications as corresponding countries, as evidenced by Australia's ten publications all being as the corresponding country. The data underscores the varied academic contributions across continents, with Asia and Europe leading in both citations and publication numbers, reflecting their critical roles in advancing global research efforts. The details are presented in Figure 3.

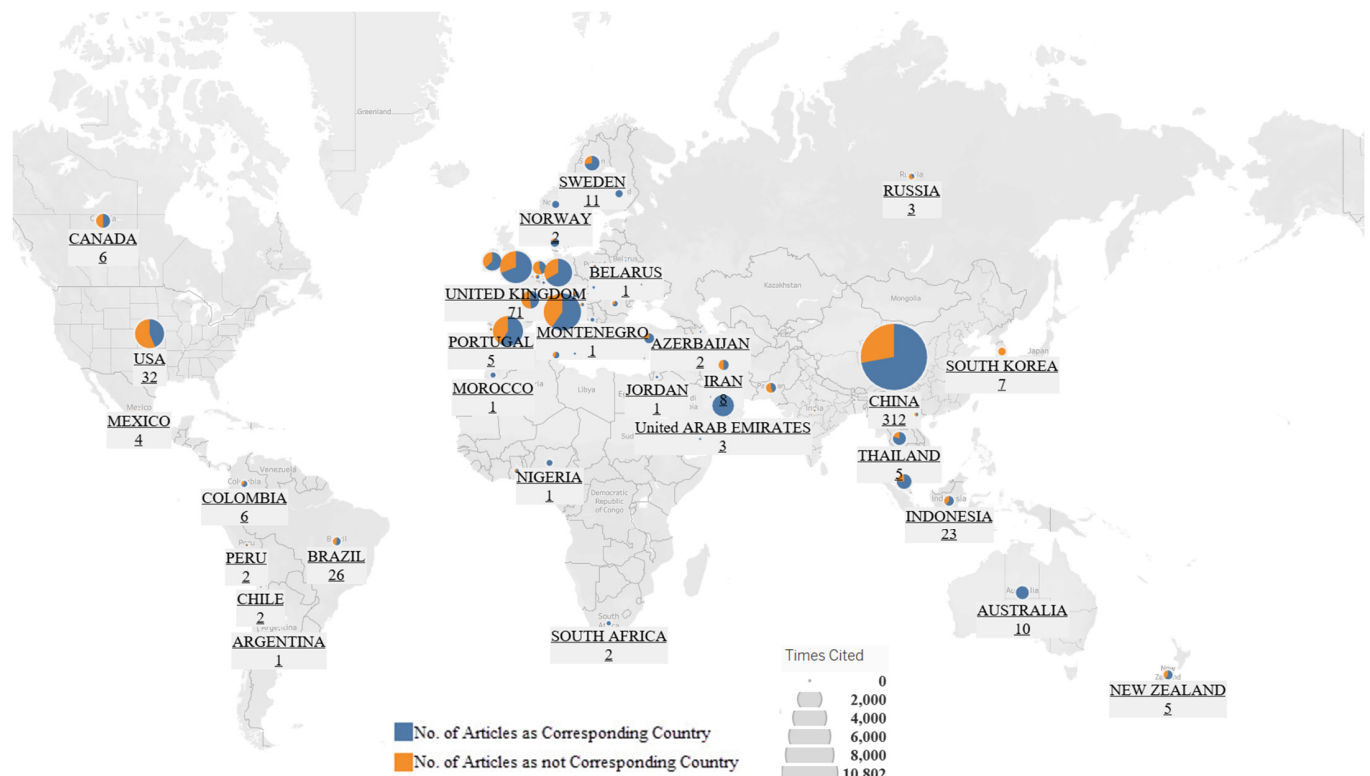


Figure 3. Global research productivity by country: citations and publication distribution.

3.5. Distribution by Impactful Journals

The journal “Business Strategy and the Environment” emerges as the most prolific, featuring 101 articles with a total of 5868 citations. Following closely is “Technological Forecasting and Social Change” with 67 publications and 5321 citations, succeeded by “Corporate Social Responsibility and Environmental Management” with 35 publications and 1161 citations. “Research Policy” and “Journal of Business Ethics” trail closely with 15 publications and 3413 citations, and 11 publications and 3349 citations, respectively. Notably, “Journal of Business Ethics” was the pioneer in publishing articles on green innovation (GI) and related topics in the field of business and management research, starting from 2006. Details are summarized in Table 2.

Table 2. Analysis of green innovation in business journals: performance metrics and trends.

Journals	TC	NP	FPY	TC/NP	H-Index	G-Index	M-Index
<i>Business Strategy and the Environment</i>	5868	101	2011	1.72	46	75	3.538
<i>Technological Forecasting and Social Change</i>	5321	67	2009	1.26	35	67	2.333
<i>Corporate Social Responsibility and Environmental Management</i>	1161	35	2018	3.01	18	34	3
<i>Research Policy</i>	3413	15	2008	0.44	12	15	0.75
<i>Journal Of Business Ethics</i>	3349	11	2006	0.33	11	11	0.611
<i>Journal Of Business Research</i>	663	16	2016	2.41	10	16	1.25
<i>Technology Analysis and Strategic Management</i>	318	15	2012	4.72	10	15	0.833
<i>European Journal of Innovation Management</i>	354	11	2019	3.11	9	11	1.8
<i>Industry And Innovation</i>	464	11	2011	2.37	8	11	0.615
<i>Journal Of Innovation & Knowledge</i>	283	13	2019	4.59	8	13	1.6

3.6. Analysis of Highly Cited Publications

Table 3 outlines the top 10 most-cited papers in the field of green innovation (GI) and related studies in business and management from 2000 to 2023. These top 10 articles

collectively garnered 7057 citations, representing 22.5% of the total citations, underscoring the significance of the study of GI in the field. The most highly cited paper, “The Influence of GI Performance on Corporate Advantage in Taiwan”, authored by Yu-Shan Chen, Shyh-Bao Lai, and Chao-Tung Wen, published in the *Journal of Business Ethics* in 2006, holds the highest citation count of 1103 and has maintained the highest citation rate per year until 2023. This influential article established a positive link between green product and process innovation performances and corporate competitive advantage, emphasizing the importance for businesses to invest in green product and process innovation by recognizing the value and position of GI [6].

Table 3. Analysis of the top 10 papers about green innovation in business: performance metrics.

Title	Authors	Year	Journal	Total Citations	TC per Year Reference	Reference
The Influence of Green Innovation Performance on Corporate Advantage in Taiwan	Yu-Shan Chen, Shyh-Bao Lai, and Chao-Tung Wen	2006	<i>Journal of Business Ethics</i>	1103	61.28	[6]
Determinants of environmental innovation new evidence from German panel data sources	Jens Horbach	2008	<i>Research Policy</i>	958	59.88	[56]
Determinants of environmental innovation in US manufacturing industries	Smita B Brunnermeier and Mark A Cohen	2003	<i>Journal of Environment Economics and Management</i>	898	42.76	[57]
The Driver of Green Innovation and Green Image Green Core Competence	Yu-Shan Chen	2008	<i>Journal of Business Ethics</i>	787	49.19	[12]
Environmental innovation and R&D cooperation: Empirical evidence from Spanish manufacturing firms	Valentina De Marchi	2012	<i>Research Policy</i>	750	62.5	[10]
Green innovation and environmental performance: The role of green transformational leadership and green human resource management	Sanjay Kumar Singh, Manlio Del Giudice, Roberto Chierici, and Domenico Graziano	2020	<i>Technological Forecasting and Social Change</i>	631	157.75	[58]
Green innovation in technology and innovation management an exploratory literature review	Tim Schiederig, Frank Tietze, and Cornelius Herstatt	2012	<i>R&D Management</i>	530	44.17	[52]
The Influence of Corporate Environmental Ethics on Competitive Advantage: The Mediation Role of Green Innovation	Ching-Hsun Chang	2011	<i>Journal of Business Ethics</i>	520	40	[59]
Green innovation and organizational performance: The influence of big data and the moderating role of management commitment and HR practices	Abdul-Nasser El-Kassar and Sanjay Kumar Singh	2019	<i>Technological Forecasting and Social Change</i>	463	92.6	[15]
Eco-innovation and new product development: understanding the influences on market performance	Devashish Pujari	2006	<i>Technovation</i>	417	23.17	[60]

Another influential work, “Determinants of Environmental Innovation: New Evidence from German Panel Data Sources” by Jens Horbach, published in Research Policy in 2008, has amassed 958 citations until 2023. This study delves into environmental innovations using German databases, highlighting the significant influence of technological advancements through R&D, environmental regulations, management tools, and organizational changes on environmental innovation, aligning with the Porter hypothesis [56].

The publications of these articles in highly reputable journals encourage researchers to contribute to these esteemed platforms, driving further research in this area and shaping future research agendas.

3.7. Thematic Map of Authors' Keywords

The thematic map in Figure 4 illustrates significant research areas identified through author keywords, categorizing them into four quadrants based on development status and relevance.

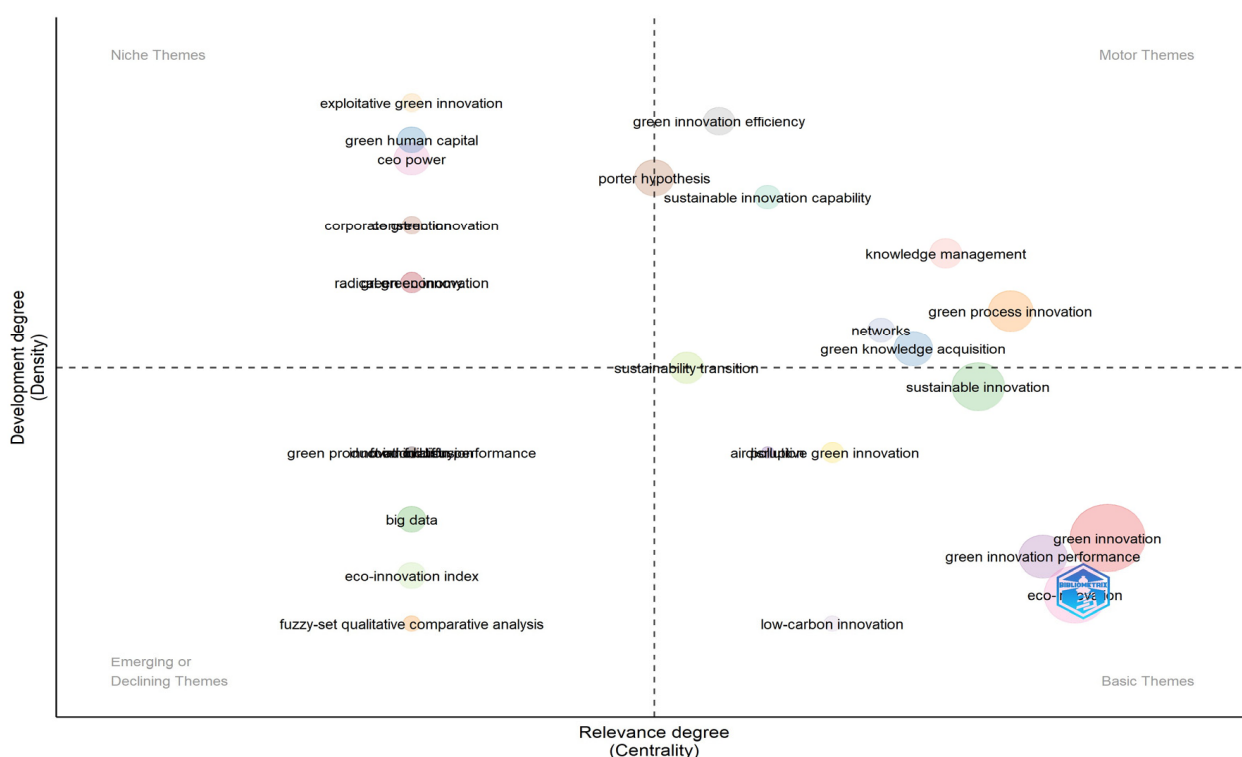


Figure 4. Thematic map of research areas in green innovation.

Emerging Themes (bottom left): This quadrant includes areas with low development and relevance, suggesting potential for further exploration. Notable topics such as green product innovation performance, innovation diffusion, the eco-innovation index, and big data warrant additional research to enhance their understanding and application.

Fundamental Themes (bottom right): These themes are critical yet underdeveloped, requiring more comprehensive network development. Key areas such as green innovation (GI), GI performance, low-carbon innovation, and eco-innovation need increased scholarly attention to bolster foundational knowledge.

Niche Themes (upper left): Specialized but peripheral, these themes are well-developed within their contexts. Topics like green human capital, radical and disruptive GI, CEO power in innovation, and corporate GI offer valuable insights and should be explored further to enrich niche knowledge.

Motor Themes (upper right): Characterized by high development and centrality, these themes are pivotal in advancing research. Keywords such as GI efficiency, knowledge management, sustainable innovation, and the Porter hypothesis are crucial focal points,

driving forward the field of green innovation. This thematic breakdown highlights varying levels of development and importance, serving as a guide for future research directions in green innovation.

3.8. Network Analysis of Authors' Keywords

The analysis of author keywords spanning 594 publications from 2000 to 2023 is crucial for discerning research patterns and trends. Out of approximately 1648 keywords derived from these articles, only 59 keywords met the threshold of at least 5 occurrences each. Employing VOSviewer with a focus on keywords meeting this criterion revealed a network map showcasing the most prevalent keywords in the study of green innovations (GIs) or related innovations within business and management research (Figure 5). This network map displays keyword clusters, with node size representing the frequency of keyword occurrence and the interconnecting lines indicating associations between keywords. Additionally, cluster colors denote the strength of relationships among these keywords. Overall, the analysis delineates six major clusters of keywords, offering insights into the interconnectedness and prevalence of specific themes within this research domain.

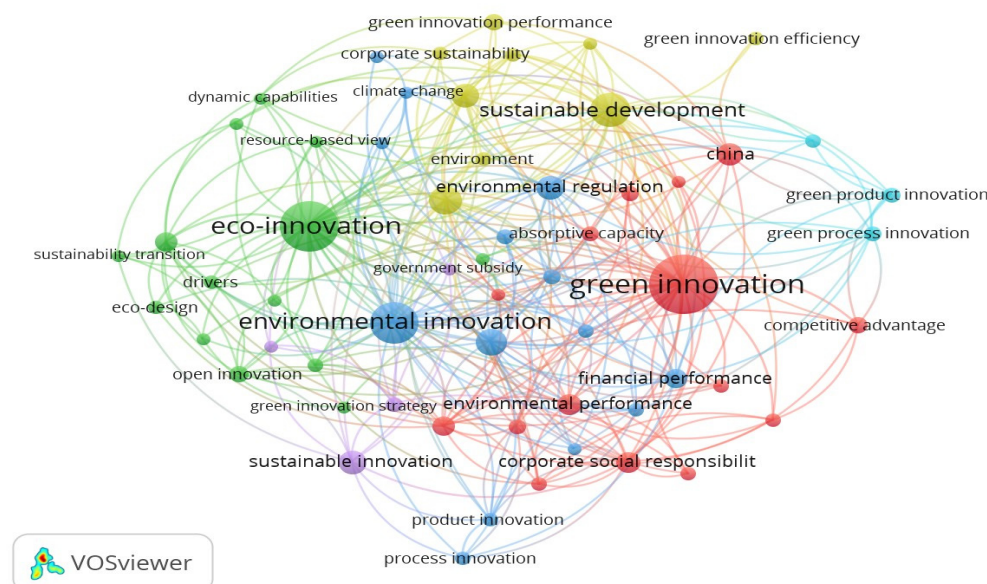


Figure 5. Authors' keywords co-occurrence network visualization.

The clusters identified through the author keyword analysis reveal crucial thematic concentrations within GI research in business and management. The first cluster, labeled 'Sustainable Innovation Ecosystems' (red), delves into multifaceted aspects such as absorptive capacity [61,62], corporate social responsibility [63], and stakeholder pressure [64], painting a comprehensive picture of factors influencing sustainable innovation. The 'Circular Automotive Innovation Ecosystems' cluster (green) highlights transitions toward sustainability within the automotive industry, exploring areas like circular economy [65] and dynamic capabilities [66]. 'Eco-Innovation Framework' (blue) encompasses policy influences [67], financial constraints [68], and technological advancements in environmental innovation [69]. The 'Integrated Green Sustainability Nexus' (yellow) explores the intersection of corporate sustainability [70], green innovation efficiency, and sustainable development [71]. 'Sustainable Performance Support' (purple) delves into government subsidies [72] and market-oriented approaches for supporting sustainable innovation [73]. Lastly, 'Green Innovation Capabilities' (beige) emphasizes crucial capabilities necessary for effective green innovation strategies and product/process development [74,75]. Notably, the presence of country-specific keywords like China and Spain reflects focal areas within the broader landscape of green innovation research.

3.9. Co-Citation Analysis of Authors

The impact of an author's contribution to the study of green innovation (GI) or related innovation in the business and management field is reflected in the co-citation analysis of authors. In Figure 6, the network map illustrates the co-citations among authors based on VOSviewer analysis, indicating 87 authors meeting the threshold, each with a minimum of one article and at least 50 citations. The map portrays three distinct clusters. The first cluster (green) comprises 49 authors, with the central figure being 'Horbach, J', whose cluster garners 372 citations, connected by 86 links with a total link strength of 7299. The second cluster (red) encompasses 36 authors, centered around 'Chen, YS', accumulating 445 citations, linked through 86 connections with a total link strength of 6874. The third cluster (blue) consists of only two authors, with the core being 'Teece, DJ', contributing 132 citations and supported by 86 connections, totaling 2277 link strength.

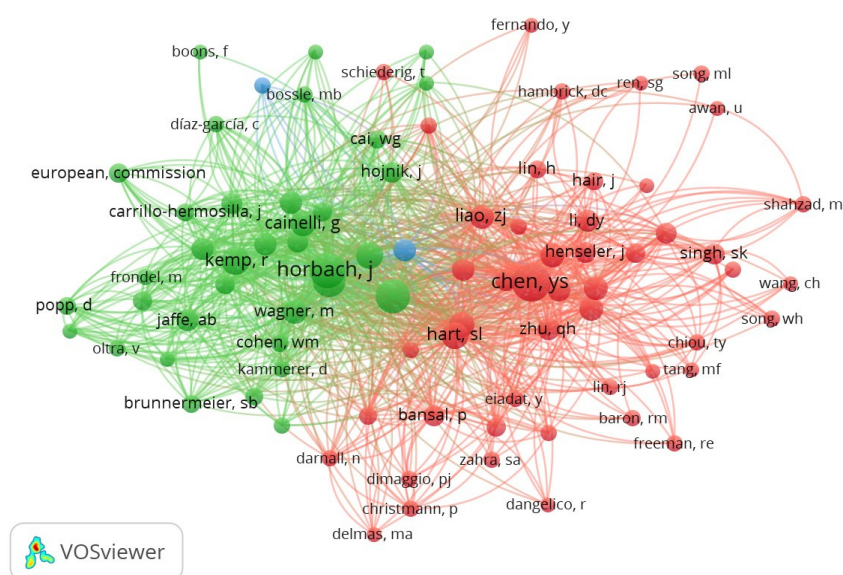


Figure 6. Visualization of authors' co-citations network visualization.

This network map serves as an illustration highlighting the most impactful authors engaged in the study of GI or related innovation within the business and management field.

3.10. Citation Analysis of Journals

Figure 7 illustrates the citation sources crucial for analyzing the most significant and dynamic contributors to the research on green innovation (GI) or related innovations in the business and management field. Using VOSviewer analysis, 14 sources meeting the threshold criteria of 10 documents and 50 citations out of a total of 150 sources were identified. The resulting network map unveils four distinct clusters. The first cluster (red) revolves around 'Business Strategy and the Environment', boasting 112 publications and 5868 citations, interconnected by 13 links with a total link strength of 673. The second cluster (green) is centralized on 'Technological Forecasting and Social Change', encompassing 67 publications and 5321 citations, connected by 13 links with a total link strength of 431. The third cluster (blue) is led by 'Technology Analysis & Strategic Management', with 15 publications and 318 citations, linked by 12 connections amounting to 95 link strength. Lastly, the fourth cluster (yellow) is dominated by 'Technovation', contributing 10 publications and 657 citations, connected by 12 links with a total link strength of 87. This network map provides an insightful overview of the most impactful publication sources within the realm of GI or related innovations in business and management research.

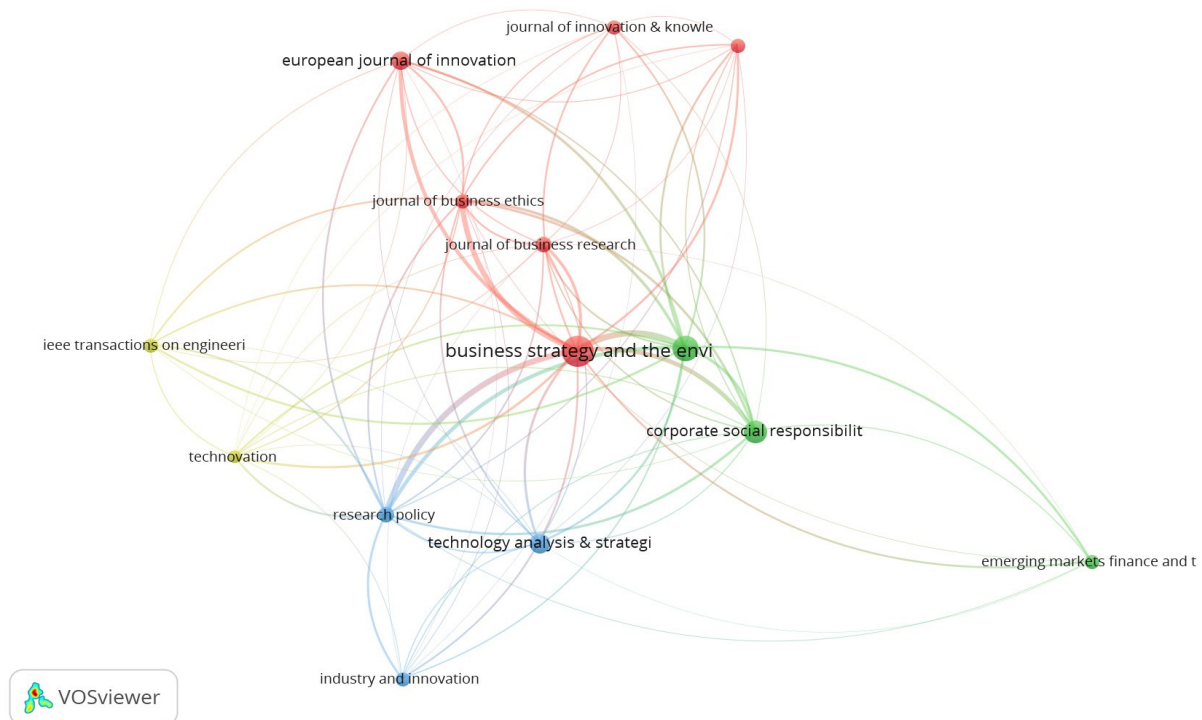


Figure 7. Network mapping of most impactful citation sources.

4. Discussion

The bibliometric analysis conducted in this study reveals significant trends and patterns in the research on green innovation (GI) within the business and management domain. Responding to the study's questions regarding relevant publication trends, the most efficient contributors, journals, institutions, and countries, our findings indicate an upward trend in GI-relevant publications from developing countries. It signifies GI as a growing global concern in scholars and businesses from both developed and developing nations, thus recognizing the importance of sustainable practices in business [48]. Notably, China emerges as the most influential and productive country in this field, accounting for the findings that indicate that the upward trend in publications from developing countries signifies a growing global concern for GI, with scholars from both developed and developing nations increasingly recognizing the importance of sustainable practices in business. However, despite the high productivity observed in institutions such as Zhejiang SciTech University and Xian Jiaotong University, collaboration among authors from different countries remains limited. This suggests considerable room for enhanced collaboration across diverse fields and geographical regions, which could lead to more comprehensive insights and innovative solutions in the field of GI.

Notably, China emerges as the most influential and productive country in this field, accounting for approximately 38.72% of the total publications. This prominence can be attributed to the active engagement of Chinese companies in sustainable development strategies [76], positioning them as pivotal players in the global landscape of GI. Following China, Spain, the United Kingdom, and Italy also demonstrate robust contributions, highlighting a diverse geographical participation in GI research. The highest productivity was observed in institutions such as Zhejiang Sci-Tech University and Xian Jiaotong University. However, collaboration among authors from different countries remains limited. One of the main reasons behind low collaboration is the stringent environmental policies across countries, which may hamper the cross-country research avenues [77]. Also, co-patenting tends to be less if countries are at different levels of technological development.

Moreover, the citation analysis also reveals that China not only leads in the number of publications but also in citation impact, with a total of 10,951 citations and an average

article citation of 47.61%. This reflects the significant societal contributions of research conducted in China, further solidifying its role as a leader in GI research. A similar trend of green innovation and green finance research output was also observed in a study in the field of finance [78]. The analysis of citation sources reveals that “Business Strategy and the Environment” stands out as the most influential journal in this field, boasting a significant number of publications and citations. This underscores the journal’s critical role as a premier platform for disseminating research on green innovation (GI) and related innovations. Additionally, the presence of other notable journals, such as “Technological Forecasting and Social Change” and “Technology Analysis & Strategic Management”, further emphasizes the diverse avenues through which GI research is being explored. A study by [79] identified a different set of top five core journals for publishing papers in this field, including “Environmental Science and Pollution Research”, “Renewable Energy”, “Frontiers in Environmental Science”, and “Sustainability”. This indicates that a growing number of journals are emerging as vital avenues for research on GI, reflecting the expanding interest and evolving landscape of this important area of study. The analysis of highly cited publications reveals that seminal works have significantly shaped the discourse on GI. For instance, the influential paper by [80] established a critical link between green innovation performance and corporate competitive advantage, reinforcing the necessity for businesses to invest in sustainable practices. Top-cited articles analysis also showed that researchers investigated both GI consequences as well as antecedent sides across different contextual settings, making it a matter of global concern.

Responding to emerging themes in GI, our study reveals that the most emerging current themes having high relevance and low density include green product innovation performance, eco-innovation, and big data or innovation diffusion. Despite having high relevance, such themes are underdeveloped. Similarly, themes such as green innovation, green performance, and low-carbon innovation are at the lowest density level.

Finally, research on GI over the years revealed a slightly stable trend with little upward variation till 2016 and took up substantially from 2019 onwards with a sharp jump in 2021. One possible reason is the positive association between COVID-19 and green innovations [81,82]. Where literature has some mixed results regarding the impact of COVID on green innovation or sustainable innovation [83], dominant literature advocates the relationship. The findings collectively highlight the expanding interest, key contributors, global participation, influential journals, and emerging research directions within the realm of GI, emphasizing its significance in striving for sustainable development.

5. Conclusions and Future Directions

The bibliometric analysis conducted on the evolution of research in green innovation (GI) within the field of business and management reveals several significant findings. A total of 594 documents were sourced from the Web of Science database, covering the period from 2000 to 2023. The annual publication growth rate stands at 20.72%, with an average of 52.87 citations per document, culminating in a total of 27,650 references. The analysis identified 1649 author keywords and 1159 indexed keywords, with 1513 authors contributing to this research area. Notably, the most prolific author, Zhongju Liao from Zhejiang Sci-Tech University, has published 18 articles, accumulating 494 citations. The data indicates a notable surge in publications post-2011, particularly since 2018, highlighting a growing scholarly interest in GI, with 152 papers published in 2023 alone.

The analysis further illustrates the interconnectedness among authors, keywords, and affiliations through a three-field plot, revealing that 16 authors are associated with 17 affiliations in the domain of GI. The visualization underscores a substantial volume of research in GI, environmental innovation, and eco-innovation, with a significant concentration of work originating from China. Despite the high productivity observed in institutions such as Zhejiang Sci-Tech University and Xian Jiaotong University, collaboration among authors from different countries remains limited, indicating considerable room for increased collaboration across diverse fields and geographical regions.

The bibliometric review also acknowledges several limitations, including the potential impact of database selection on the quantity of relevant articles and the exclusion of literature from other disciplines that could provide valuable insights. Future research directions should focus on expanding database inclusion, exploring interdisciplinary approaches, and conducting meta-analyses to enhance the understanding of GI in business and management.

Also, while the results indicate a positive trend in research output, they also underscore the need for increased collaboration and interdisciplinary approaches to fully harness the potential of GI in promoting sustainable development. Future research directions should focus on fostering international partnerships and exploring interdisciplinary approaches to enrich the understanding of GI's role in business and management studies. Further, in response to the identified emerging themes, future researchers may explore the impact of low-density themes on GI antecedents and outcome variables such as business financial performance, firms' competitive advantage, or stringent environmental policies across countries. Such foundational studies not only guide current research but also pave the way for future inquiries into the mechanisms through which GI can enhance organizational performance.

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