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Green Innovation and Environmental Performance: a Bibliometric Review Based on CiteSpace and VOSviewer

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Abstract

The rapid development of the modern economy has caused resource depletion and environmental pollution, drawing increasing attention to sustainability. Green innovation (GI) is widely recognized as a key strategy for improving environmental performance (EP), yet its macro-level mechanisms remain underexplored. To address this gap, this study conducts a bibliometric analysis using data from the Web of Science Core Collection to explore the relationship between GI and EP. From an initial 590 articles, 200 high-quality articles were selected following PRISMA guidelines. CiteSpace and VOSviewer were employed to visualize research networks and thematic evolution. Results show an accelerating publication trend since 2023, with China, Pakistan, and Malaysia leading in output. Key journals include the Journal of Cleaner Production, Sustainability, and Environmental Science and Pollution Research. Four core research areas were identified: EP, financial outcomes, GI, and sustainability. Recent trends reflect a shift from firm-level studies to institutional factors such as policy and green leadership. Findings highlight limited international collaboration, an evolving theoretical focus from resource-based views to external institutional factors, and rising interest in leadership-driven GI strategies. This study provides practical insights for researchers, policymakers, and business leaders, supporting informed decision-making in environmental governance and corporate strategy. However, limitations such as restricted data sources suggest the need for broader future studies.

Keywords: Green Innovation, Environmental Performance, Bibliometrics Analysis, CiteSpace, VOSviewer

Introduction

Since the Industrial Revolution, rapid economic growth has frequently occurred at the expense of resource depletion and environmental degradation (Hanlon, 2020). This has elevated the environmental performance (EP) of corporations, as primary economic agents, into a subject of critical concern (Escrig-Olmedo, Muñoz-Torres, Fernández-Izquierdo, & Rivera-Lirio, 2017). EP reflects a firm's systematic efforts to mitigate its ecological footprint through initiatives such as waste reduction, enhanced energy efficiency, and the implementation of green policies, serving as a key indicator of corporate environmental and social responsibility (Singh, Chen, Del Giudice, & El-Kassar, 2019).

In this context, green innovation (GI) has emerged as an essential strategy for firms to bolster their competitiveness and achieve long-term sustainability amid rising stakeholder pressure for environmental accountability (Albort-Morant, Leal-Rodríguez, & De Marchi, 2018). GI, also termed eco-innovation, encompasses the development of environmentally conscious products, processes, or practices designed to minimize ecological harm (Albort-Morant, Henseler, Leal-Millán, & Cepeda-Carrión, 2017). As a multi-dimensional concept, GI includes green product innovation (GPDI), green process innovation (GPCI) (Albort-Morant et al., 2018), green management innovation (GMI), and green technological innovation (GTI) (Tseng, Huang, & Chiu, 2012). This study adopts these four dimensions as its analytical framework.

Understanding the relationship between GI and EP is crucial, as it provides vital insights for governments and firms in formulating effective environmental strategies (Escrig-Olmedo et al., 2017; Wang, Wang, & Chang, 2022). Although numerous empirical studies have investigated this link, the existing body of work presents a fragmented landscape. Research often concentrates on specific dimensions, such as GPDI and GPCI (Wong, Wong, & Boon-itt, 2020; Wang, Li, Li, & Wang, 2021), or integrates broader concepts like ESG performance (Liang, Cao, Tang, Hu, & Zhang, 2025). Consequently, a comprehensive and systematic overview of the field's intellectual structure, global research patterns, emerging hotspots, and evolutionary trajectory remains absent. This gap in the literature highlights the need for a holistic analysis to map the knowledge domain of GI–EP research.

To address this gap and synthesize the fragmented knowledge, this study employs a bibliometric analysis of research published from 2014 to 2024. The objective is to systematically map the intellectual landscape of the GI-EP field by answering the following questions:

RQ1: What is the productivity distribution of research on the GI-EP relationship in terms of authorship, countries/regions, institutions, and journals over the past decade?
RQ2: What are the research hotspots concerning the GI-EP relationship?
RQ3: What are the current research frontiers regarding the GI-EP relationship?

Methodology and Materials

Research Method

This study employed a bibliometric analysis approach to quantitatively review the literature (Abramo, D'Angelo, & Viel, 2011). Using CiteSpace and VOSviewer, we constructed knowledge maps to visualize research networks and intellectual structures. CiteSpace is effective for analyzing the temporal evolution of knowledge (Chen, 2006), while VOSviewer excels at

creating clear, visually appealing network maps of keywords, authors, and institutions (Van Eck & Waltman, 2010). Together, they provide a comprehensive platform for our analysis.

Data Retrieval and Search Strategies

Data was sourced from the Web of Science Core Collection (WOSCC), specifically the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI). WOSCC was chosen for its high-quality, comprehensive bibliographic data suitable for bibliometric software (Ding, & Yang, 2022).

The search strategy was designed to balance breadth and precision. The final retrieval query is: TS = (("green innovation" OR "environmental innovation" OR "eco-innovation" OR "green product innovation" OR "green process innovation" OR "green managerial innovation" OR "green technological innovation") AND ("environmental performance")). The search, conducted on December 23, 2024, covered the period from December 2014 to November 2024 and yielded 590 articles.

Table 1

Summary of data retrieval and search strategies. (Source: Authors' own work.)

Category	**Specific standard requirements**
Research database	Web of Science Core Collection
Citation indexes	SSCI, SCIE
Searching period	December 1st 2014 to November 30th 2024
Language	English
Searching keywords	TS = (("green innovation" OR "environmental innovation" OR "eco-innovation" OR "green product innovation" OR "green process innovation" OR "green managerial innovation" OR "green technological innovation") AND ("environmental performance"))
Document types	Articles
Data extraction	Export with full records and cited references in plain text format
Sample size	590 (Before manual screening)

Data Screening and Selection

To ensure relevance, a manual screening process was conducted following the PRISMA guidelines, as shown in Figure 1. First, titles and abstracts were reviewed, reducing the sample to 249 articles. Next, a full-text review was performed by two authors based on the inclusion criteria detailed in Table 2, resulting in a final dataset of 200 articles.

Table 2
Inclusion criteria. (Source: Authors' own work.)

Inclusion Criteria
The research themes included in the literature should focus on the nexus between GI (including but not limited to GPDI, GPCI, GMI, or GTI) and EP, explicitly analyzing their relationship, interaction mechanisms, or empirical validation.
The included literature should explore and assess the interaction between GI and EP, covering one or more dimensions such as resource efficiency improvement, carbon emissions reduction, pollution control, sustainable production processes and corporate environmental responsibility, rather than merely discussing innovation or environmental performance in isolation.
The following literature should also be included: studies that explore the drivers, barriers and influencing factors of GI in enhancing EP, including regulatory policies, market forces, corporate strategies, technological capabilities, financial incentives etc.

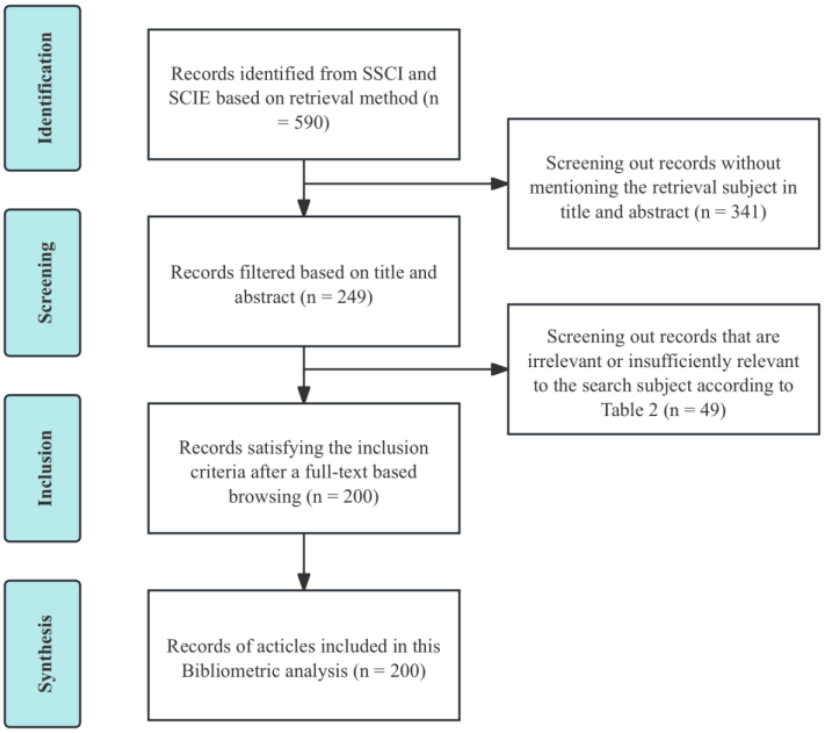

Figure 1. The process of obtaining and screening data based on PRISMA guidelines. (Source: Authors' own work.)
The final dataset of 200 studies was authored by 684 researchers from 413 institutions across 59 countries, published in 64 journals, and cited 11,174 references.

Publication Trends
The number of publications on the GI-EP relationship shows a rapid upward trajectory, as illustrated in Figure 2. From 2015 to 2019, annual output remained in the single digits. A significant growth phase began in 2020, with publications surging past 50 articles per year in 2023 and 2024. This accelerating trend indicates a growing international scholarly focus on the interactions between GI and EP.

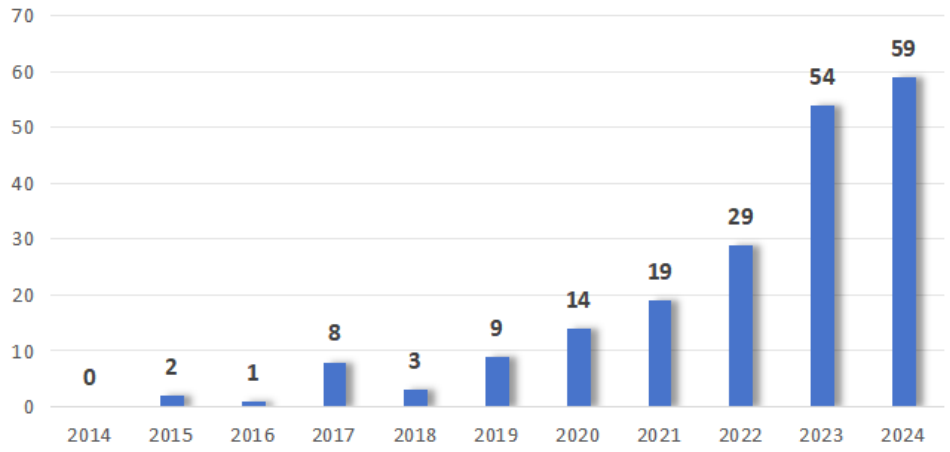

Figure 2. Distribution of publications from 2014 to 2024. (Source: Authors' own work.)

Results and Discussion

Performance Analysis (RQ1)

Leading Authors

Analysis of authorship reveals the core researchers shaping the GI-EP field. Based on Table 3, Abu Bakkar Siddik is the most prolific author with four publications. Wang, Y. has the highest average citations per paper at 146.33. Other authors in the top five by publication volume are Du, Long, and Ali, each with three documents.

Table 3

Most important authors in GI–EP relationship research field. (Source: Authors' own work.)

Rank	Author	Documents	Citations	Average citation per paper
1	Siddik, A.	4	118	29.50
2	Wang, Y.	3	439	146.33
3	Du, J.	3	312	104.00
4	Long, X.	3	312	104.00
5	Ali, S.	3	186	62.00

Leading Countries/Regions and Organizations

Analysis of 200 publications from 59 countries reveals that Asia and Europe are the primary research hubs (Table 4). China is the most influential country, with 127 publications, followed by Pakistan (31) and Malaysia (16). The top ten includes an equal number of developed and developing countries, suggesting widespread scholarly interest.

Table 4
Top 10 countries in the GI–EP relationship research field. (Source: Authors' own work.)

Rank	Country/Region	Documents	Citations	Average citation per paper
1	China	127	5458	42.98
2	Pakistan	31	2090	67.42
3	Malaysia	16	1318	82.38
4	Saudi Arabia	15	986	65.73
5	England	11	1348	122.55
6	Italy	11	1863	169.36
7	USA	11	1123	102.09
8	South Korea	10	788	78.80
9	Spain	10	818	81.80
10	Vietnam	10	487	48.70

The chord diagram in Figure 3 illustrates national publication output and collaborative relationships. It shows that China, Pakistan, and Malaysia account for a significant share of publications. However, the thin connecting lines indicate that international collaboration remains limited, with research predominantly conducted within national or small regional networks. This may be due to differing national research priorities, institutional barriers, or uneven resource distribution (Whetsell & Sidorova, 2024; Cerdeira, Mesquita, & Vieira, 2023; Ćudić, Alešnik, & Hazemali, 2022). To foster stronger collaboration, establishing global research alliances and promoting joint funding initiatives would be beneficial.

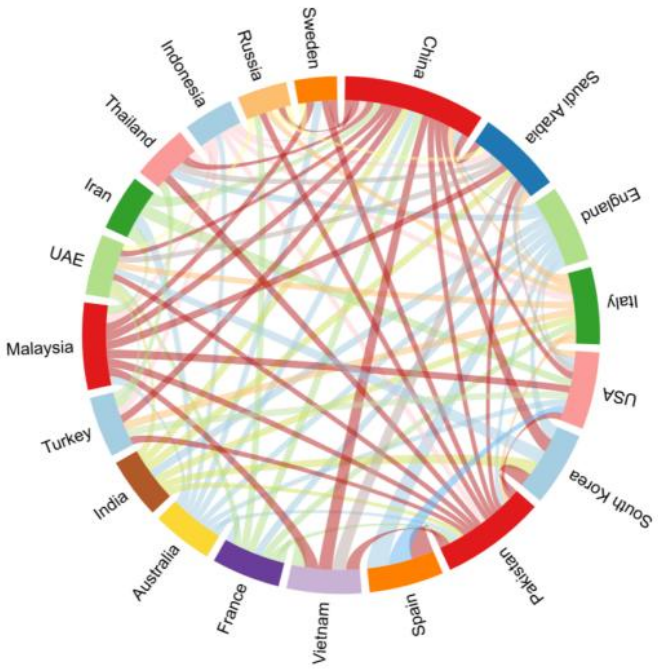

Figure 3. The chord diagram of national collaboration networks. (Source: Authors' own creation using Charticulator.)

At the institutional level, eight of the top ten publishing organizations are located in China, highlighting the country's dominant contribution to research output in this field (Table 5). Jiangsu University ranks first with 13 publications and 964 citations, followed by Ilma University (Pakistan), which achieves the highest average citation per paper (187.50) despite having only six documents. Tianjin University ranks third with six publications and a strong

citation performance (97.00 per paper). Other prominent contributors include Beijing Institute of Technology, Shanghai University, Nanjing University of Aeronautics and Astronautics, Northwestern Polytech University, Tsinghua University, Universiti Sains Malaysia, and Wuhan University, demonstrating a geographically diverse yet China-centered research landscape.

Table 5
Top 10 influential organizations in GI–EP relationship research field. (Source: Authors' own work.)

Rank	Organization	Country	Documents	Citations	Average citation per paper
1	Jiangsu University	China	13	964	74.15
2	Ilma University	Pakistan	6	1125	187.50
3	Tianjin University	China	6	582	97.00
4	Beijing Institute of Technology	China	5	213	42.60
5	Shanghai University	China	5	50	10.00
6	Nanjing University of Aeronautics and Astronautics	China	4	243	60.75
7	Northwestern Polytech University	China	4	400	100.00
8	Tsinghua University	China	4	280	70.00
9	Universiti Sains Malaysia	Malaysia	4	372	93.00
10	Wuhan University	China	4	83	20.75

Leading Journals

The top journals in this field are interdisciplinary, spanning environmental science, sustainability, and management (Table 6). <The Journal of Cleaner Production> ranks first with 29 publications and 3,350 citations, showing the highest overall influence among outlets. <Sustainability> follows with 23 papers and 508 citations, while <Environmental Science and Pollution Research> ranks third with 18 papers and 501 citations. Moreover, <Technological Forecasting and Social Change> stands out for its exceptionally high average citation rate (295.50), indicating the high influence of its publications. These journals reflect the interdisciplinary nature of GI–EP research.

Table 6
Top 10 journals in GI–EP relationship research field. (Source: Authors' own work.)

Rank	Journal	Documents	Citations	Average citation per paper	IF
1	Journal of Cleaner Production	29	3350	115.52	9.8
2	Sustainability	23	508	22.09	8.9
3	Environmental Science and Pollution Research	18	501	27.83	5.8
4	Business Strategy and The Environment	10	500	50.00	12.5
5	Technological Forecasting and Social Change	10	2955	295.50	12.9
6	Journal of Environmental Management	7	236	33.71	8.0
7	Heliyon	6	94	15.67	3.4
8	Environment, Development and Sustainability	5	50	10.00	4.08
9	Sage Open	5	82	16.40	2.0
10	Sustainable Development	5	205	41.00	9.9

Hot Spot Analysis (RQ2)
Keyword co-occurrence analysis using VOSviewer reveals the core research themes and hotspots (Figure 4). As expected, "environmental performance" and "green innovation" are the central nodes. High-frequency keywords form four distinct clusters, each representing a major research stream (Table 7).

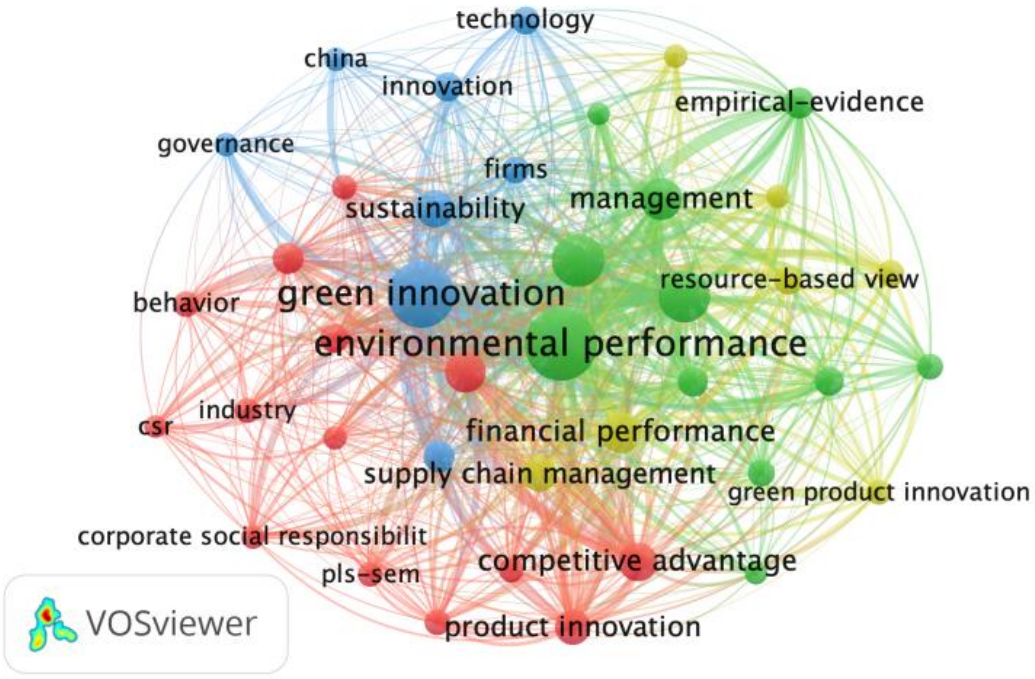

Figure 4. Co–occurrence of keywords. (Source: Authors' own creation using VOSviewer.)

Table 7

Cluster of keywords in GI–EP relationship research field. (Source: Authors' own work.)

Cluster	Color	Keywords
1		firm performance, competitive advantage, product innovation, strategy, advantage, behavior, smes, industry, mediating role, pls–sem, supply chain, companies, corporate social responsibility, csr
2		environmental performance, impact, eco–innovation, management, empirical–evidence, drivers, environmental innovation, determinants, sustainable development, economic performance, model
3		green innovation, sustainability, performance, innovation, technology, firms, china, governance
4		financial performance, supply chain management, resource–based view, business performance, green product innovation, dynamic capabilities, research–and–development

Cluster 1 (Red): Strategic Management and Competitive Advantage. This cluster links GI to overall firm performance (environmental and financial) and competitive advantage. It highlights that GI is not merely a technical initiative but a strategic orientation embedded in performance-driven frameworks. The prevalence of "PLS-SEM" indicates a focus on identifying mediating mechanisms, such as green competitive advantage, that link GI to performance outcomes.

Cluster 2 (Green): Managerial Drivers of Environmental Performance. This cluster focuses on the managerial perspective, exploring the drivers and determinants of GI and EP, such as sustainable supply chain management and environmental regulations. Management is the

key theme, revealing a mechanism where GI serves as a conduit for transforming external pressures and corporate strategies into tangible environmental improvements.

Cluster 3 (Blue): Technology, Governance, and Sustainability in China. This cluster revolves around GI, sustainability, and technology, with a strong focus on Chinese firms. It reflects a technology-oriented governance mechanism where GTI acts as a strategic bridge between sustainability goals and environmental outcomes, aligning with China's national sustainability policies.

Cluster 4 (Yellow): Financial Performance and Resource-Based View (RBV). This cluster emphasizes the financial dimension of performance, grounded in the RBV. It conceptualizes GI as a value-creating asset, exploring how internal capabilities like green product innovation and supply chain management are transformed into financial gains.

Overall, these four clusters depict a multidimensional research landscape, integrating internal firm strategies with external environmental pressures. The coexistence of RBV-driven and policy-driven studies highlights the need to align micro-level practices with macro-level institutional forces to enhance EP. The temporal analysis in Figure 5 further indicates that recent research trends focus on integrating sustainability with strategic management, CSR, governance, and technology.

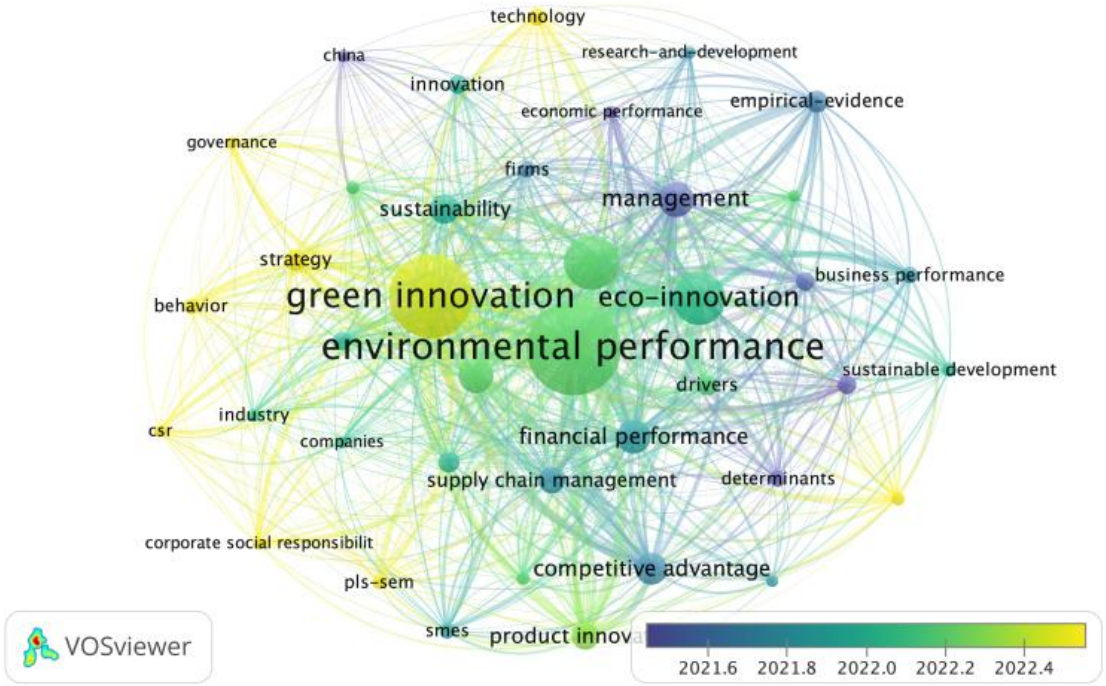

Figure 5. Co–occurrence of keywords across time. (Source: Authors' own creation using VOSviewer.)

Research Frontiers (RQ3)

Keyword burst detection in CiteSpace identifies emerging research frontiers by tracking terms with high-frequency variations over time (Figure 6). The analysis reveals a clear evolutionary trajectory in GI-EP research.

Keywords	Year	Strength	Begin	End	2015 - 2025
environmental innovation	2017	3.3	**2017**	2021	
determinants	2017	2.97	**2017**	2021	
economic performance	2017	2.55	**2017**	2018	
competitiveness	2017	2.03	**2017**	2020	
resource based view	2019	2.21	**2019**	2020	
capability	2019	2.16	**2019**	2022	
financial performance	2017	3.06	**2020**	2021	
policy	2015	2.01	**2021**	2022	
sustainability	2018	1.76	**2021**	2022	
green transformational leadership	2022	2.16	**2022**	2023	

Figure 6. Top 10 keywords with the strongest bursts. (Source: Authors' own creation using CiteSpace.)

From 2017 to 2020, research was dominated by internal, firm-level factors. Burst keywords including "environmental innovation," "determinants," "economic performance," "resource-based view," and "capability" indicate a focus on how internal resources and capabilities drive GI.

After 2021, the focus shifted toward external, institutional-level factors. The emergence of "policy" and "sustainability" as burst keywords reflects a growing recognition of the macro-environment's role in shaping corporate green behavior. This transition from a micro- to a macro-level perspective aligns with the increasing impact of environmental regulations on corporate strategy.

The most recent burst keyword, "green transformational leadership" (2022–2023), signals a new research frontier. This trend reflects a rising interest in how leadership styles, organizational culture, and green HRM facilitate GI and EP. However, research in this area remains in its early stages.

These evolving frontiers suggest several promising research directions. Future studies could explore how leadership styles interact with institutional pressures, the nuanced effects of different policy types (e.g., regulatory vs. incentive-based), and how emerging technologies like AI and Blockchain mediate the financial impacts of GI. This shift also offers insights for policymakers, encouraging a mixed-regulation approach that combines command-and-control policies with market-based incentives to effectively stimulate GI.

Conclusion

Summary of key findings

This bibliometric study analyzed 200 articles from the WOSCC database to map the intellectual landscape of GI-EP research from 2014 to 2024.

Productivity and Collaboration: Research has grown rapidly since 2023, led by scholars like Siddik and Wang, and countries like China, Pakistan, and Malaysia. Key publication outlets

include the Journal of Cleaner Production and Sustainability. While global interest is high, stable international collaborations are limited.

Research Hotspots: Keyword analysis identified four core themes: (1) strategic management for competitive advantage, (2) managerial drivers of EP, (3) technology and governance in China, and (4) RBV on financial performance.

Research Frontiers: The research focus has evolved from internal firm resources (2017-2020) to external institutional factors like policy and sustainability (since 2021). Green transformational leadership is the most recent emerging frontier.

Theoretical and Practical Contributions

The systematic bibliometric mapping of the GI-EP nexus offers three principal theoretical contributions to the literature on innovation and sustainability management. First, this study provides a comprehensive, quantitative mapping of this highly fragmented field over the critical 2014–2024 period, effectively delineating its core intellectual structure, influential actors, and key publication outlets. Second, the analysis formally captures a crucial thematic evolution, highlighting a major theoretical shift from an emphasis on internal firm capabilities (e.g., the RBV) during the earlier years (2017–2020) to a more integrated focus on external institutional factors (policy, governance, and macro-level sustainability) since 2021. Third, by identifying "green transformational leadership" as the most recent emerging research frontier, this work opens a novel avenue for theory, underscoring the necessity of integrating organizational behavior, culture, and C-suite commitment into the GI-EP mechanism.

These findings carry significant implications for practitioners. The shift toward institutional factors highlights that policymakers may adopt a mixed-regulation approach, combining command-and-control mandates with market-based incentives to effectively stimulate corporate GI and align micro-level efforts with broader national environmental goals. For business leaders, the emergence of leadership as a frontier provides direct strategic guidance, emphasizing that investing in green transformational leadership is paramount for proactively managing and improving EP, thereby securing competitive advantage beyond mere regulatory compliance. Furthermore, the limited international collaboration noted in the review suggests that establishing global research alliances is necessary to bridge regional knowledge gaps.

Limitations

This study has several limitations. First, the inclusion of only SCIE and SSCI journal articles from the WOSCC ensures data quality but may introduce publication bias by excluding non-indexed, grey, or non-English literature, potentially underrepresenting research from developing regions. Second, the temporal scope (2014–2024) focuses on recent developments but limits historical depth, omitting earlier foundational studies that could provide a more comprehensive theoretical context. Finally, although bibliometric tools such as CiteSpace and VOSviewer offer objective visualization, the interpretation of clustering and keyword trends remains partly subjective, which may affect the consistency of theme identification and hotspot analysis.

Future Research Directions

Based on the findings and identified limitations of this study, future research could expand data sources by incorporating additional databases such as Scopus and relevant grey literature to construct a more comprehensive global perspective. Moreover, extending the temporal coverage to include foundational studies published prior to 2014 would provide a richer historical context for understanding the evolution of the research domain. In addition, adopting hybrid methodological approaches that integrate qualitative content analysis or machine learning techniques with bibliometric methods could enhance the robustness and reliability of analytical interpretations, thereby yielding deeper insights into the complex interrelationships within this field.

Furthermore, future studies should explore the identified research frontiers, such as the mechanisms of green transformational leadership, the specific effects of different environmental policy types, and the interplay between emerging technologies and the financial outcomes of GI. These directions offer valuable opportunities to advance the understanding of the complex GI-EP nexus.

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