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Present Situation and Outlook of Enterprise Green Innovation Research based on Bibliometrics

-- Bibliometric Analysis based on CSSCI (from 1998 to 2023) Data

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Abstract. This paper uses bibliometric analysis and knowledge graph analysis to standardize and compare the relevant paper published in CSSCI (including CSSCI extended edition) database from 1998 to 2023, and comprehensively and systematically analyzes the basic picture of research related to enterprise green innovation. The relevant research in this field shows a prosperous trend with high enthusiasm for research, more research papers and rich research topics. In the future, academia can further study green innovation of enterprises from aspects such as strengthening theoreticality, broadening research horizons, improving research methods and promoting interdisciplinary research.

Keywords: Enterprise Green Innovation; CSSCI Data; Bibliometrics.

1. Introduction

With the continuous advancement of industrialization and rapid economic development, countries all over the world are generally facing problems such as resource shortage and ecological environment destruction. Enterprises are an important part of economic life, so the research on green innovation of enterprises is an important link to coordinate the relationship between ecological environment and economic development. Enterprise green innovation refers to a series of creative activities that can not only meet the value needs of consumers and enterprises, but also reduce environmental pollution and damage to achieve sustainable development goals. Correspondingly, academia has also conducted a series of studies on green innovation. Since 1998, domestic academic circles have fully studied the theoretical basis, influencing factors and action mechanism of enterprise green innovation, forming a series of research results. Combing these achievements, summarizing the research characteristics and contents of each stage, and grasping the overall research form play an important reference role in judging the actual progress of academia's research on enterprise green innovation and building future research paths.

2. Data Sources and Research Methods

2.1. Data Sources

To grasp the research status of enterprise green innovation and ensure the comprehensiveness and authority of data, this paper selects CSSCI (including CSSCI extended edition) database for retrieval with enterprise green innovation as the subject. The deadline for retrieval is September 30, 2023, and a total of 1,072 relevant papers are retrieved. To improve the accuracy and authority of papers, non-research papers such as empty authors and conference reviews and papers unrelated to the topic are manually excluded. 1070 valid papers were refined as the sample papers for this study, with an effective recording rate of 99.81%.

2.2. Research Methods

This study mainly uses bibliometric research methods to study the overall situation, research hotspots and frontier progress of enterprise green innovation research, and specifically adopts word frequency analysis, clustering analysis and time evolution analysis. Word frequency analysis is mainly used to

count and analyze the number of important words. This paper extracts important fields such as year, author, and keyword from sample papers according to word frequency analysis, to realize the analysis of research development trend and hot spot in this field; Clustering analysis is a multivariate statistical analysis method that divides the research objects into relatively homogeneous groups, and clustering analysis of sample paper is conducive to grasping hot research issues in the research field. Time evolutionary analysis is a method that describes the historical span of the research objects and reflects their rise, prosperity, and decline processes. The application of time evolutionary analysis is conducive to analyzing the development trend and frontier progress in the research field.

To better summarize the external characteristics of enterprise green innovation research and sort out its development context, this paper uses Python software for word frequency analysis and time evolution analysis, CiteSpace software for word co-occurrence analysis, and visualization software VOS viewer for knowledge graph analysis.

3. Quantitative Analysis of Enterprise Green Innovation Research Paper

3.1. Analysis of Sample Paper Characteristics Based on Bibliometrics

(1) Number of papers and highly cited papers

Based on the sample paper searched by China National Knowledge Infrastructure (CNKI), this paper counts the temporal distribution of green innovation paper of enterprises (as shown in Figure 1). It can be seen from the figure that after the Ministry of Environmental Protection issued the Guidelines for Environmental Information Disclosure of Listed Companies in 2010, the green innovation research of enterprises has entered the initial stage, and the number of papers has increased rapidly, from 9 papers in 2010 to 39 papers in 2017. On January 1, 2018, the first turning point occurred. After the implementation of the Law of the People's Republic of China on Environmental Protection Tax, research on green innovation by enterprises entered a rapid growth stage, increasing from 57 papers in 2018 to 235 papers in 2022.

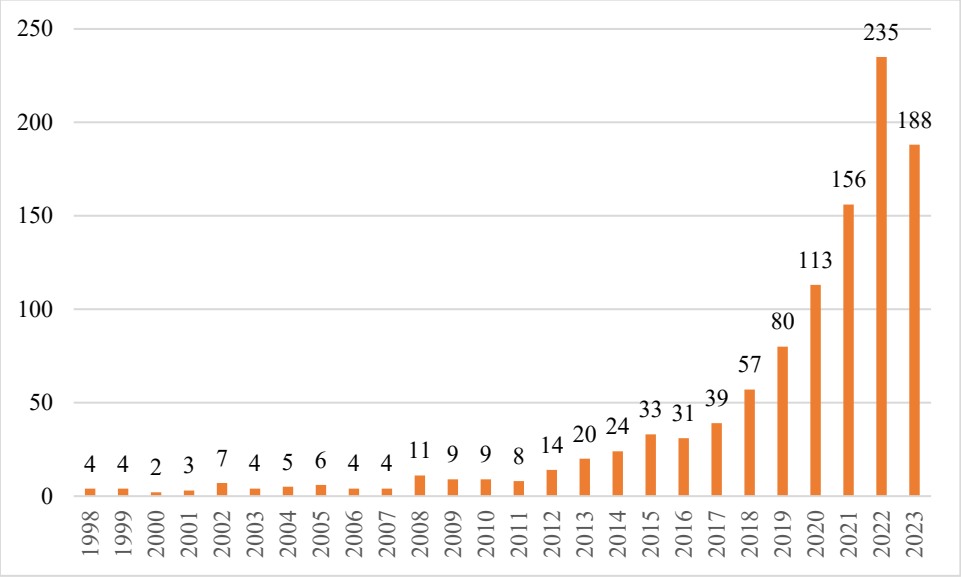

Figure 1. Annual Distribution of Research Paper on Enterprise Green Innovation

Highly cited papers are indicators proposed by Clarivate Analytics (US) in 2001 to measure the influence of a discipline or research field. In this paper, the top 1% of cited papers in enterprise green innovation research paper are defined as highly cited papers, with a total of 10 papers (see Table 1). According to Table 1, the highly cited papers in this research field have the following four characteristics: First, they are all cited more than 471 times. Specifically, Qi Shaozhou et al. of Wuhan University published the paper, Can the Environmental Rights and Interests Trading Market Induce Green Innovation? —Evidence Based on Green Patent Data of Listed Companies in China was cited

the most frequently, 969 times. Second, the highly cited paper is mainly concentrated in colleges and universities.

Table 1. Highly Cited Paper on Green Innovation Research of Enterprises (Top 1% in Citation Frequency)

No.	Author(s) (Affiliate)	Title	Source Journal	Year	Citation Frequency
1	Qi Shaozhou; Lin Shen; Cui Jingbo (Wuhan University; Hubei University of Economics)	Can the Environmental Rights and Interests Trading Market Induce Green Innovation? — Evidence Based on Green Patent Data of Listed Companies in China	Economic Research	2018	969
2	Li Qingyuan; Xiao Zehua (Wuhan University)	Heterogeneous Environmental Regulatory Tools and Enterprise Green Innovation Incentives--Evidence from Green Patents of Listed Enterprises	Economic Research	2020	721
3	Wang Xin; Wang Ying (Shandong University)	Research on Green Credit Policy Enhancing Green Innovation	Management World	2021	536
4	Xu Jia; Cui Jingbo (Central China Normal University; Duke Kunshan University)	Green Technology Innovation in Low-carbon Cities and Enterprises	China Industrial Economics	2020	480
5	Tao Feng; Zhao Jinyu; Zhou Hao (Jinan University)	Does Environmental Regulation Achieve "Incremental Quality Improvement" of Green Technological Innovation--Evidence from the Target Responsibility System for Environmental Protection Goals	China Industrial Economics	2021	376
6	Zhang Jiangxue; Zhu Lei (Beijing Normal University)	Research on Technological Innovation Efficiency of Industrial Enterprises in Various Regions of China Based on Green Growth	The Journal of Quantitative & Technical Economics	2012	376
7	Wang Hui; Wang Shuqiao; Miao Zhuang; Li Xiaocong (Huaiyin Institute of Technology; River Sea University Business College; Taizhou University)	The Heterogeneous Threshold Effect of R&D Investment on Green Innovation Efficiency--An Empirical Study Based on China's High-tech Industries	Science Research Management	2016	359
8	Li Yina;Ye Fei (South China University of Technology)	The Relationship among Institutional Pressure, Green Innovation and Enterprise Performance--Based on the Perspective of New Institutionalism Theory and Ecological Modernization Theory	Studies in Science of Science	2011	311
9	Luo Liangwen; Liang Shengrong (Zhongnan University of Economics and Law)	Green Technological Innovation Efficiency and Factor Decomposition of Regional Industrial Enterprises in China	Chinese Journal of Population, Resources and Environment	2016	294
10	Wang Fengzheng; Jiang Tao; Guo Xiaochuan (University of Inner Mongolia)	Government Quality, Environmental Regulation and Enterprise Green Technology Innovation	Science Research Management	2018	292

Third, the highly cited paper mainly focuses on exploring and analyzing the motive and efficiency of enterprise green innovation from the perspective of the relationship between environmental equity trading market, environmental regulatory pressure and green credit policy and enterprise green innovation. Fourth, in terms of highly cited papers from journals publishing, economic journals published the most papers, which is 5 papers, the number of highly cited papers from management journals is 4, and the number of highly cited papers from natural resources and environment is 1. Fifth, in terms of publication time, the highly cited papers on green innovation of enterprises were concentrated in 2016 to 2021, including 2 papers in 2016, 2018, 2020 and 2021.

(2) Core authors and research institutions

The top 10 authors of green innovation research papers published by enterprises and their work units are shown in Table 2. Data show that colleges and universities are the main force in green innovation research of enterprises. It can be seen from Table 3 that Harbin Engineering University has achieved fruitful research results and ranks first among the issuing institutions. Different regions also show differences in the number of research on green innovation of enterprises. In general, Harbin is higher than other regions in China. Among the top 10 publishers, 26.19% are from Beijing; one of the top 10 authors is from Beijing.

Table 2. Authors of Enterprise Green Innovation Research

No.	Author	Number of Papers Issued	Work unit
1	Bi Kexin	19	Harbin Engineering University
2	Yang Chaojun	16	Kunming University of Science and Technology
3	Xiao Renqiao	14	Anhui University of Finance and Economics
4	Wang Xu	14	Shandong University of Finance and Economics
5	Li Yingming	12	University of Chinese Academy of Sciences
6	Wang Mingyue	12	Scientific and Technological Strategic Consulting Institute, Chinese Academy of Sciences
7	Qian Li	12	Anhui University of Finance and Economics
8	Tian Hong	10	Jilin University
9	Bi Qian	9	Southwest University
10	Yu Lianchao	8	Lanzhou University

Table 3. Information on Green Innovation Research Issuing Institutions of Enterprises

No.	Issued by	Number of Papers	Location
1	Harbin Engineering University	52	Harbin
2	Kunming University of Science and Technology	42	Kunming
3	Wuhan University	31	Wuhan
4	Zhongnan University of Economics and Law	30	Wuhan
5	Jilin University	26	Jilin
6	Harbin Engineering University	25	Harbin
7	Shandong University	23	Jinan
8	Nanjing University	22	Nanjing
9	Shandong University of Finance and Economics	22	Jinan
10	Tsinghua University	21	Beijing

(3) Distribution of source journals and disciplines

The analysis of the journal source authors, and their affiliated institutions of sample paper is helpful to grasp the distribution of green innovation research forces in enterprises. From the perspective of journal sources, there are 215 types of journals involved in the sample paper, including 19 types with more than 10 publications. According to the discipline classification of journals by Chinese Social Sciences Citation Index (CSSCI), the overall distribution of journal disciplines is shown in Figure 2, and the top 10 journals with the largest number of publications are shown in Table 4.

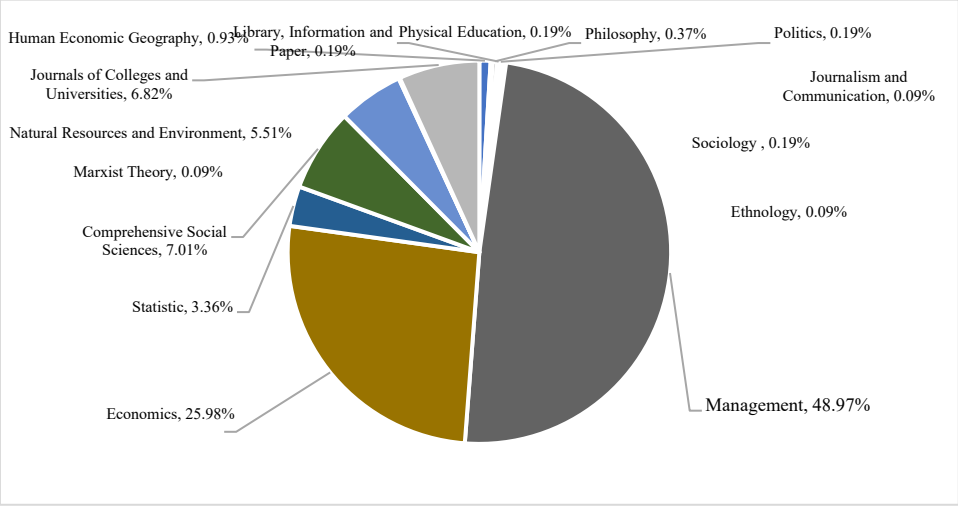

Figure 2. Discipline Distribution of Research Source Journals for Green Innovation of Enterprises

On the one hand, in terms of the overall distribution of journal disciplines, except for highly comprehensive university journals and comprehensive social science journals, management (48.97%), economics (25.98%) and natural resources and environment (5.51%) respectively occupy the top three professional journals. On the other hand, according to the data in Table 4, among the top 10 publications, management accounts for 70%, economics 10%, natural resources and environment 10%, and statistics 10%.

Table 4. Publications of Research Source Journals on Enterprise Green Innovation

No.	Journal Title	Number of Paper	Discipline Distribution
1	Science & Technology Progress and Policy	95	Management
2	Science and Technology Management Research	71	Management
3	Chinese Journal of Population, Resources and Environment	46	Natural Resources and Environment
4	Soft Science	39	Management
5	Science Research Management	34	Management
6	Statistics and Decision	24	Statistics
7	Science of Science and Management of S.&.T.	23	Management
8	R&D Management	22	Management
9	Technical Economy	21	Economics
10	Forum on Science and Technology in China	20	Management

Based on the above data, the research results of enterprise green innovation are distributed in multiple disciplines. This is because green innovation of enterprises involves many research fields such as

corporate social responsibility, energy conservation and emission reduction, energy efficiency and industrial ecology. Enterprises balance the relationship between economic efficiency and environmental protection through environmental management activities such as energy conservation and emission reduction to assume social responsibility and promote sustainable development. Therefore, the research on green innovation of enterprises in academia involves not only management, economics, natural resources, and environment, but also statistics, sociology, and politics. The former is mainly a theoretical study on the influencing factors and efficiency effects of enterprise green innovation; the latter is research on the social value and political impact of enterprise green innovation points through empirical methods.

3.2. Research Hotspot Knowledge Graph and Theme Evolution Context Analysis

(1) Theme evolution context analysis based on burst keywords

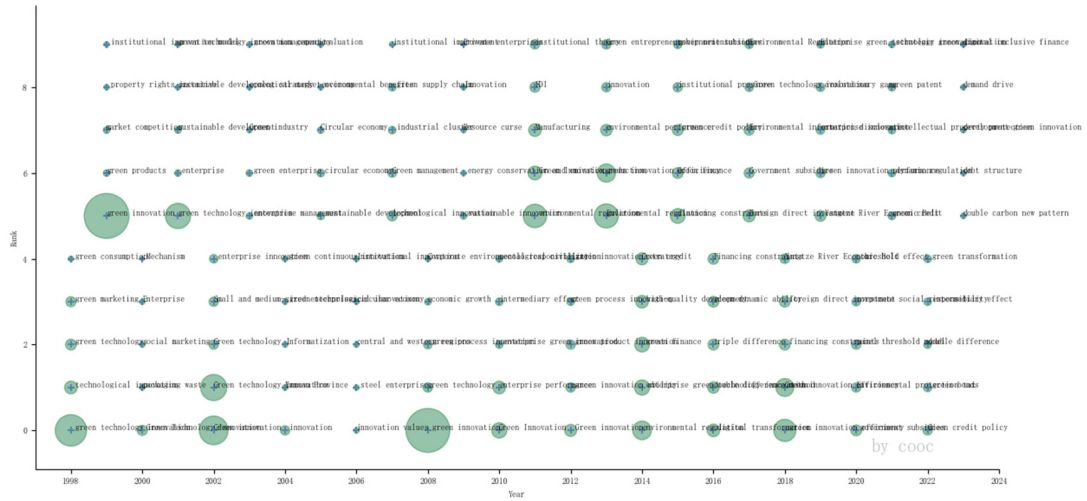

Figure 3. Keyword Evolution Time Zone

Burst keywords are a large number of keywords that burst in a short period of time. We can use burst keywords to analyze the annual research hotspots of enterprise green innovation and sort out the evolution of paper topics. In this paper, the top five burst keywords in the paper in each period are ranked according to their frequency of occurrence as shown in Figure 3. It can be seen from the figure that among the research results on enterprise green innovation, keywords such as enterprise green technology innovation appeared in 1998. Keywords such as green innovation and green products burst in 1999, enterprises' green innovation in 2010, environmental regulation and green innovation capability in 2011, green innovation efficiency in 2013, green finance in 2015, and a new development pattern, high-quality economic development, and a new historical starting point in 2020. Keywords such as corporate social responsibility and environmental protection tax were highlighted in 2021, digital transformation and environmental information disclosure in 2022, and high-energy consumption enterprises and green and low-carbon development in 2023. The research paper is divided into two stages according to the annual publication volume and keyword evolution trend:The first stage is the preliminary exploration stage (from 1998 to 2016). The burst keywords are mainly "green technology innovation", "enterprise green innovation", "green innovation efficiency" and "green finance". Researchers focus on the background and theoretical basis of enterprise green innovation. The second stage is the fast-rising phase (from 2017 to 2023). The burst keywords are mainly "enterprise green technology innovation", "heavy polluting enterprise", "corporate social responsibility" and "green low-carbon development". Researchers have gradually turned their attention to the distinctive topic of how to promote high-quality economic development in China. On March 15, 2021, General Secretary Xi Jinping put forward the basic ideas and main measures to

achieve peak carbon dioxide emissions and carbon neutrality during the 14th Five-Year Plan period, requiring a good relationship between economic and social development and peak carbon dioxide emissions and carbon neutrality, as well as a good relationship between economic development and energy consumption. Compared with 2021, the number of papers published in 2022 increased by 50.64%.

(2) Research hotspot knowledge graph analysis based on co-word matrix

Table 5. Analysis on Research Keyword Frequency and Betweeness Centrality of Enterprise Green Innovation

Keywords	Frequency	Betweeness Centrality	Keywords	Frequency	Betweeness Centrality
Green innovation	362	0.259	Nature of property right	12	0.005
Green technology innovation	169	0.165	Green credit policy	12	0.001
Environmental regulation	112	0.145	Heavy pollution enterprise	12	0.003
Green innovation efficiency	91	0.020	Industrial agglomeration	11	0.003
Enterprise green innovation	49	0.025	Innovation performance	11	0.002
Financing constraints	42	0.024	Institutional pressure	11	0.000
Green finance	27	0.006	Heterogeneity	11	0.010
Corporate performance	23	0.019	Green supply chain	11	0.005
Mediating effect	21	0.011	Difference-in-differences model	10	0.003
Digital transformation	21	0.012	Sustainable development	10	0.003
Green credit	21	0.006	Digital economy	10	0.002
Enterprise green technology innovation	20	0.004	Porter Hypothesis	10	0.002
Threshold effect	20	0.004	Spatial Durbin Model	10	0.010
Government subsidies	19	0.011	Space Spillover Effect	10	0.000
Green product innovation	19	0.004	Green patents	10	0.007
Green innovation performance	19	0.013	Green dynamic capability	10	0.000
Green technologies	19	0.003	Panel Threshold Model	10	0.004
Evolutionary games	18	0.003	Enterprise Life Cycle	9	0.002
High-quality development	18	0.009	Digital finance	9	0.001
Green innovation capability	17	0.002	Environmental protection tax	9	0.001
Industrial enterprises	16	0.006	Economic performance	9	0.006
Environmental performance	16	0.005	Green marketing	9	0.000
Corporate social responsibility	15	0.005	Green transformation	9	0.005
Manufacture	15	0.013	Drivers	9	0.001
Green development	15	0.017	Media attention	8	0.002
Green process innovation	15	0.004	Environmental taxes	8	0.010
Yangtze River Economic Belt	15	0.005	Ecological innovation	8	0.000
Outward Foreign Direct Investment (OFDI)	14	0.001	Organizational redundancy	8	0.001
Difference-in-differences model	13	0.006	Green innovation system	8	0.001

Keywords are the condensation and sublimation of paper content. The frequency of keywords can reflect the frontier hot spots and development trends of enterprise green innovation research, while the co-word matrix identifies the research topic of enterprise green innovation and the relationship between topics by counting the number of occurrences in all papers between every two words. Betweeness centrality reflects the medium status of a certain keyword as a node in the co-occurrence network (see Table 5 for details). This paper utilizes CiteSpace software, combined with routing network (PFNET) algorithm and manual construction method to analyze the co-occurrence of keywords in 1,070 enterprise green innovation papers. For the top 58 keywords that appear more than 8 times, VOS viewer visualization software is used to draw a keyword co-occurrence map as shown in Figure 4. In Figure 4, larger nodes indicate higher frequency of keywords, more node connections indicate higher betweeness centrality of keywords, and thicker node connections indicate higher degree of collinearity of keywords. It can be seen from the figure that the six dimensions with high collinearity are: 1) Green technology innovation, green patents, and green supply chain; 2) Green transformation and environmental performance; 3) Green innovation strategy, green product innovation, and green public welfare innovation; Environmental regulation, industrial agglomeration, and green innovation efficiency; 4) Digital transformation, digital finance, and enterprise green technology innovation; 5) Green innovation, financing constraints, and green credit.

Data research shows that in the process of studying green innovation of enterprises, scholars have the following characteristics: First, pay attention to the mechanism research on green innovation of enterprises; Second, pay attention to the research on the motives and paths of green transformation of polluting enterprises; Third, the research highlights the role of institutional pressure such as environmental regulation and environmental protection tax on green innovation of enterprises; Fourth, the study combines the characteristics of scientific and technological innovation to promote green innovation of enterprises through digital transformation and digital finance.

Figure 4. Keyword Co-occurrence Map of Enterprise Green Innovation

4. Research Conclusion

Based on the method of paper sustainable measurement, this paper uses Python, CiteSpace and VOS viewer software to carry out word frequency statistics, collinearity matrix calculation and knowledge graph drawing. From the aspects of discipline distribution, highly cited papers, core authors, research hotspots, evolution context, etc., it tries to give a full picture of the green innovation research field of enterprises, and sorts out the logical starting point, action mechanism and influencing factors of

enterprise green innovation on this basis. In general, although the research time in this field is short, it advances rapidly, showing a prosperous trend of scholars' enthusiasm for research, more research papers and rich research topics. Research on green innovation of enterprises is an important long-term work. Based on existing research and in combination with the development of productivity and production tools, it is necessary to continuously strengthen theory, broaden research horizons, improve research methods, and promote interdisciplinary research.

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