



Evolution and Trend of Green Technology Innovation Research: Visual Analysis Based on CiteSpace

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Abstract

Systematically understanding the global characteristics of green technology innovation research and studying the hotspots and trends of international green technology innovation research can provide beneficial directional references for subsequent scholars' research. Papers on green technology innovation published in the core database of Web of Science from 2007 to 2021 were selected as the research objects. Knowledge map analysis method and CiteSpace software were used for visual analysis, and the trend of published papers, research countries and institutions, authors and keywords of green technology innovation research was summarized. It is found that the research on green technology innovation is on the rise and is the focus of most scholars at present; The publication of papers mainly comes from China, and universities are the main force of research; The research is mainly gathered in technological innovation, environmental regulation and sustainable development, which has very important theoretical value and reference significance for the development of green technology innovation.

Key words: Green technology innovation; Knowledge map; CiteSpace; Trends

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PREFACE

The report of the 19th National Congress of the Communist Party of China proposed to “accelerate the

reform of ecological civilization system and build a beautiful China”, and explicitly requested to “build a market-oriented green technology innovation system”. In order to fully implement the requirements of the 19th National Congress of the Communist Party of China, on January 23, 2019, the Sixth Meeting of the Central Committee for Comprehensively Deepening Reform reviewed and approved the “Guidance on Building a Market-oriented Green Technology Innovation System”, which strengthens the leading role of scientific and technological innovation in green development and embodied the important connotation of the modernization of the harmonious coexistence of man and nature. At present, the realization of development mode has changed from attaching importance to quantity to improving quality, from scale expansion to structural upgrading, and from factor-driven to innovation-driven, which has become a key problem to be solved in promoting high-quality economic development in China. Innovation is the first driving force to lead development, is the strategic support for the construction of a modern economic system. Green technology innovation takes the realization of green development as its core pursuit, pays attention to providing new products, processes and market schemes through innovation, reduces the consumption of natural resources, reduces the damage to ecological environment, and improves the efficiency of resource allocation, which can provide power support and realization path for China to achieve high-quality economic development. It is of great significance to review the international research on green technology innovation in the past 15 years and to explore the hot spots and trends of green technology innovation research.

In this paper, 1080 green technology innovation research literatures collected in the Web of Science database from 2007 to 2021 are taken as data sources, and with the help of CiteSpace visual analysis software, the development trends, hot spots and trends of

green technology innovation in recent 15 years are systematically and intuitively summarized, which can provide beneficial directional thinking for the follow-up scholars' research.

1. DATA SOURCES AND RESEARCH METHODS

1.1 Data Source

The source data comes from the core database of the Web of Science database. This paper searches the theme of "green technology innovation" from 2007 to 2021 (the search time is August 2, 2021), and obtains 2,834 search results. To ensure the accuracy of the search results, the data of non-academic papers such as conference summary, notice, administrative documents and journal guide are excluded, and 1080 valid data are obtained after screening.

1.2 Research Methods

CiteSpace software is simple to operate, accurate and effective in data, (Chen, 2003) and can scientifically identify literature contents and visually process information such as research trends and hot spots. Its functions are mainly reflected in that "co-occurrence map of authors", "co-occurrence map of keywords" and "co-occurrence map of institutions" can be obtained through cooperative analysis, and "co-citation map of authors", "co-citation map of documents" and "co-citation map of periodicals" can be obtained through co-citation analysis. (Chen, 2006, pp.359-377) CiteSpace can not only show the research frontier at different stages in a certain field through time charts, but also show the relationship between research frontier and knowledge base. (Liu, Jin, & Wei, 2021)

This paper mainly uses knowledge map analysis to study the hot spots, evolution and trends of green technology innovation. With the help of CiteSpace software developed by Professor Chen Chaomei of Drexel University, the authors, publishing institutions, keyword clustering maps and keyword highlighting of green technology innovation research from 2007 to 2021 were compared and analyzed quantitatively. Finally, the research contents are summarized accordingly.

2. GREEN TECHNOLOGY INNOVATION RESEARCH DYNAMICS

2.1 Number and Chronological Distribution of Papers Published

A comprehensive analysis of the development of the number of publications and chronological distribution of research sites is important for evaluating the stage of the field and predicting trends and dynamics. (Yin, et al, 2014) Published papers and age distribution are important

indicators to measure the development trend of a certain field. (Tan, Jia, & Xu, 2019) It can be seen from Figure 1 that in the past fifteen years, with the international emphasis on green development and the advocacy of sustainable development, research on green technology innovation has been on the rise. The research on green technology innovation is on the rise, and the number of published articles increases regularly and at a constant speed every year. This shows that green technology innovation has increasingly become the research focus of scholars, and every country pays more and more attention to green technology innovation to promote green development with scientific and technological innovation.

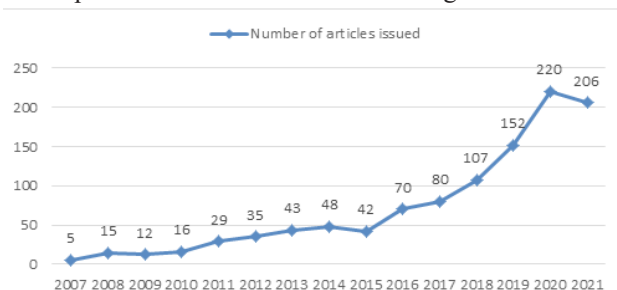


Figure 1 Statistics of green technology innovation issuance from 2007 to 2021

2.2 Distribution of Research Countries and Research Institutions

2.2.1 Study the Distribution of Countries

CiteSpace software was used to study the index of "national cooperative network", and the years from 2007 to 2021 were divided into years. In each time slice, the analysis was carried out according to the principle of "extracting the top 50 and the minimum number of national papers was 3". The research found that the number of countries studied was 48, and the cooperative relationship was 122, as shown in Figure 2. It can be seen from the figure that the research on green technology innovation is centered around China, followed by the United States. The research countries of green technology innovation are characterized by large dispersion and small cooperation.

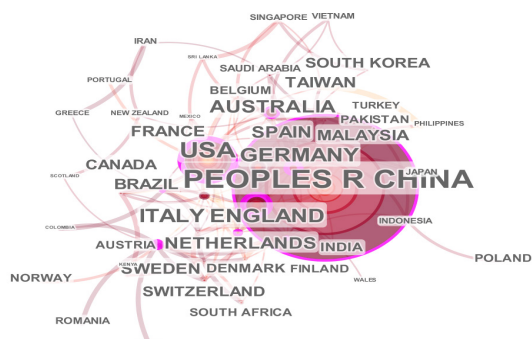


Figure 2 National cooperation map of green technology innovation research from 2007 to 2021

2.2.2 Distribution of Research Institutions

Co-occurrence analysis of institutions can reflect the core institutions and cooperation intensity in this field. (Zhang, Zhou, & Gu, 2021) The analysis of articles published by research institutions is helpful to understand the foreground institutions in the subject field and the current situation of research cooperation among institutions. (Li, et al, 2020) According to the statistics of the Web of Science database, 23 institutions with more than 5 papers have published 193 papers, accounting for 17.87% of the total papers. Among them, Harbin Engn Univ produced the most papers, with 22 articles; Chinese Acad Sci followed closely (16 articles); Jiangsu Univ ranked third (13 articles). The publishing agencies ranked 4 to 10 are Tsinghua Univ, Nanjing Univ Aeronaut & Astronaut, Xiamen Univ, Shanghai Jiao Tong Univ, Dalian Univ Technol, Southeast Univ, Hohai Univ, Sichuan Univ, Nanjing Univ Informat Sci & Technol, and Southwestern Univ Finance & Econ, all of which are from China.

The size of nodes represents the number of posts issued by institutions, and the connection between nodes reflects the density of cooperation between institutions. From Figure 3, it can be seen that 181 research institutions have produced 129 cooperation relationships, with a network density of 0.0079, which indicates that the international cooperation degree of green technology innovation research institutions is not high. It can be seen from the figure that green technology innovation research institutions have the following two characteristics: first, universities are the main force of green technology innovation research; secondly, the cooperation groups of institutions have obvious regional characteristics.



Figure 3
 Cooperation map of green technology innovation research institutions from 2007 to 2021

2.3 Author Cooperation Distribution

Co-occurrence analysis of authors can reflect the strength of cooperation between core authors and authors in this field. Run CiteSpace, select “Author” for “Node Types”, slice the time for one year, select TOP50, finally generate the knowledge map of green technology innovation research authors. We obtained 98 nodes with the network density of 0.0105, as shown in Figure 4. According to Price’s law formula, the core authors in the field of green technology innovation are calculated, and the highest number of articles published by authors in the statistical period is obtained. From 2007 to 2021, SHI YIN was the author with the highest number of articles, with 7 articles. It can be seen from Figure 4 that there are many research authors in the field of green technology innovation, but the number of cooperative teams is small, forming a research team with Shi Yin, Baizhou Li, Fangfang Zhang, Herui Cui, Jun Sun, Zhaojun Yang, Yali Zhang, Sangbing Tsai, Christian Rammer and Hui Li as the core.

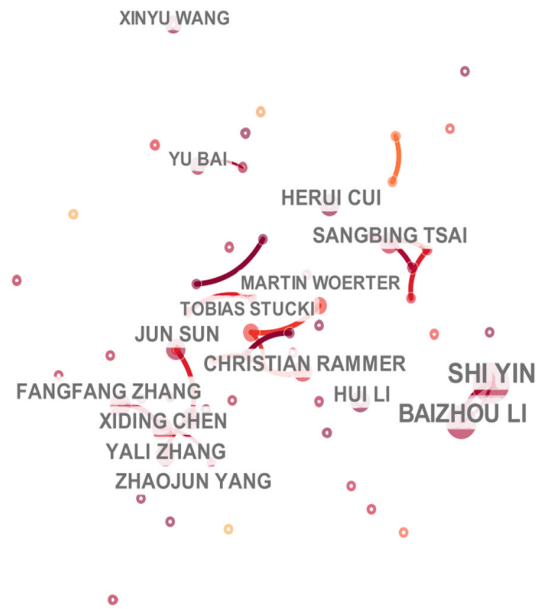


Figure 4
 Cooperation map of authors in green technology innovation research from 2007 to 2021

2.4 keyword Co-Occurrence Mapping Analysis

Key words are the enrichment and refinement of the viewpoints of the thesis. The frequency of their occurrence reflects the research hotspots in this research field for a period of time. The higher the frequency of their occurrence, the higher the research enthusiasm. (Zhang, et al, 2019) Therefore, this paper analyzes the co-occurrence of the key words of green technology innovation, selects the key words as nodes, divides the time segments in years, and prunes them with the Minimum Spanning Tree (MST) [2], and finally generates the timeline map of high-frequency key words of green technology innovation research, as shown in Figure 5. Among them, a circle represents a keyword. The larger the circle means that the frequency of keywords is higher, and the color changes

with time and increases from inside to outside. The more keywords are connected, the more obvious the mediating effect of keywords is. (Pan & Wang, 2011)

It can be seen from the time chart that there are many thick links between high-frequency keywords, which are closely related to each other. The hot topics of research mainly focus on “green technology innovation” and carry out related research around “performance, impact, management, sustainability, polity, environmental regulation and green innovation”. In detail, the research in 2007 mainly focused on “innovation”. In 2008, based on sustainable development strategy, the efficiency of green technology innovation of environmental protection policy was studied. In 2011, we explored green innovative technologies from the perspective of energy. After 2013, much empirical studies were carried out around the green technology innovation of various industries. After 2015, from the perspective of environmental regulation, we will explore the impact on green technology innovation.

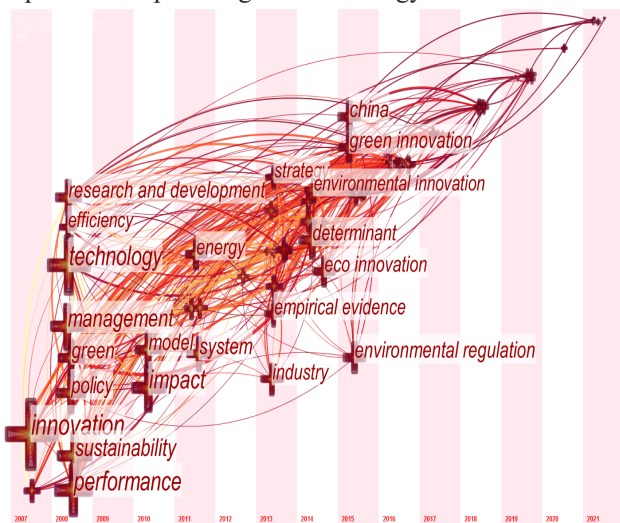


Figure 5
Timeline map of high frequency keywords

The normalized 174 keywords are clustered, as shown in Figure 6. The keywords are green innovation, adoption, energy efficiency, technological change, environmental regulation, green, investment, life cycle assessment and green technology section. It can be found that: #0 and #2 clusters show that green innovation can improve energy efficiency. Cluster #1 and #5 show that with the popularization of green concept, it has an impact on people’s food, clothing, housing and transportation in all aspects, which is gradually adopted and accepted by people. Cluster #3, #4 and #8 show that environmental regulation urges enterprises to carry out technological reform. In order to reduce the production cost caused by environmental pollution, enterprises turn to clean technologies, processes and products; Cluster #6 and #7 show that the product life cycle assessment is carried out to determine the investment strength and produce new

products through green innovation.

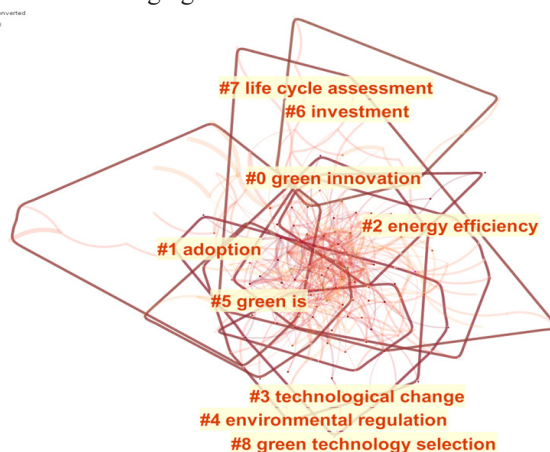


Figure 6
Key words clustering co-occurrence map of green technology innovation research

3. CONCLUSION

In this paper, by using CiteSpace software, the related literature resources of the core database of Web of Science are obtained, and the current situation and hot spots of green technology innovation research in the international area from 2007 to 2021 are comprehensively analyzed and studied.

First, from 2007 to 2021, the international research on green technology innovation showed an increasing trend. This shows that countries pay more and more attention to the construction of ecological civilization and take the road of sustainable development in the face of the severe forms of tight resource constraints, serious environmental pollution and ecosystem degradation. Promote green technology innovation, and promote green development with innovation.

Second, the main country of green technology innovation research from 2007 to 2021 is China, and the research institutions mainly come from Chinese universities. The cooperative relationship between research institutions is relatively weak, showing the characteristics of large dispersion and small cooperation.

Thirdly, the author communities of green technology innovation research are mainly Shi Yin, Baizhou Li, Fanfang Zhang, Herui Cui, Jun Sun and so on, which have obvious time aggregation effect.

Fourthly, through keyword analysis, it can be seen that the research on green technology innovation has strong time characteristics. The research on green technology innovation from 2007 to 2021 is mainly divided into eight aspects: grenn innovation, adoption, energy efficiency, technological change, environmental regulation, green, investment, life cycle assessment and green technology section.

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