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The Relationship between Government Subsidies and Enterprise Innovation Performance: A Visualized Bibliometric Analysis

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Abstract

Innovation serves as the propelling force behind sustainable economic development. Government, business, and academic circles are increasingly recognizing the impact of government subsidies on enterprise innovation performance. However, there is a dearth of studies examining the relationship between government subsidies and enterprise innovation performance, particularly in terms of bibliometric analysis using visual tools. Therefore, this paper aims to bridge this theoretical gap by conducting a statistical analysis of 322 articles from the WoS platform about government subsidies and enterprise innovation performance. The findings reveal that China emerges as the primary country driving research in this field while Anonymous and Zuniga-Vicente JAe stand out as authoritative authors on this topic. Green innovation, environmental regulation and sustainable development; R&D; innovation performance; corporate governance; enterprise heterogeneity; policy, and strategy form seven key research areas within this theme. Additionally, high-frequency keywords include research and development (R&D), development subsidy, and policy. At the same time, the analysis of the aforementioned keywords, namely firm, technology, green innovation, and strategy, has been explosively conducted in recent years. However, research on green innovation and strategy continues to be ongoing till the present day. It can be inferred that these keywords represent or belong to frontier hotspots of research. This study has not only contributed to further scholarly research in this field but also provided a theoretical reference for government and corporate innovation practices.

Keywords: *Government Subsidy; Innovation Performance; Bibliometric; Policy; Green innovation.*

1 Introduction

Sustainable economic development is a crucial objective for governments, yet it poses significant challenges. The achievement of sustainable economic development necessitates a strong impetus for innovation. In 2015, the United Nations formally established the Transforming Our World: 2030 Agenda for Sustainable Development, and the 17 Sustainable Development Goals (SDGs) were outlined. (Chankoson, 2022). The eighth goal emphasizes the paramount importance of innovation as it generates employment opportunities and income growth while enhancing the economy's competitiveness. Moreover, innovation plays a pivotal role in optimizing resource utilization efficiency and facilitating the adoption and diffusion of new technologies.

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Recognizing its significance, an increasing number of countries have elevated innovation to a strategic level with the aim of replacing traditional economic models with innovation-driven approaches to achieve industrial upgrading, economic transformation, and ultimately sustainable development. Since 2009, the US government has implemented various national policies such as the American Recovery and Reinvestment Act and the American Clean Energy Security Act to foster innovation and provide policy support for emerging industries. Similarly, within the European Union (EU), there is a clear focus on promoting low-carbon economies and maximizing green energy utilization through targeted initiatives aimed at developing emerging industries. Japan has also enacted a New National Energy Strategy that prioritizes information technology applications, commercial aerospace ventures, nuclear energy advancements, low-carbon industries as well as new energy sources and vehicles. South Korea has also implemented the New Growth Engine Plan and Development Strategy, which outlines a comprehensive set of 17 initiatives in the areas of green technology, high-value-added services, and cutting-edge industry integration as the new drivers for national economic growth. To promote rapid growth in emerging industries, there is an increased emphasis on industrial support through enhanced financial and taxation measures.

China has introduced the Resolution on Expediting the Growth and Advancement of Strategic Emerging Industries, which defines specific development tasks and industrial divisions. Academic evidence suggests that governments often employ financial subsidies to stimulate social innovation and promote businesses to consistently strengthen their R&D endeavors. (Aschhoff, 2009). This approach is primarily driven by the high-risk nature of investment in innovation, as well as the positive externalities resulting from enterprise(firm) innovation activities that exhibit characteristics akin to public goods. These factors contribute to weak incentives for enterprises to innovate as micro-innovation subjects, thereby impeding economic growth (Arrow, 1962). Government policies are necessary to address market failures associated with this phenomenon, with financial subsidies being an effective measure (Castellacci & Lie, 2015). Consequently, appropriate fiscal policies should be formulated by governments to incentivize enterprise innovation (Batrancea et al.,2022). However, empirical studies on this topic are subject to controversy. Some scholars argue that government subsidies serve as incentives for enterprise innovation performance (Szucs, 2020; Sun et al.). Conversely, other scholars contend that this effect is not valid. Government subsidies may distort resource allocation and discourage R&D enthusiasm among highly innovative enterprises, thereby reducing their innovation performance and resulting in a crowding-out effect (Wallsten, 2000; Catozzella & Vivarelli, 2016). Additionally, some scholars suggest that the relationship between the two is influenced by various factors such as incentive effects, crowding-out effects, threshold effects, or time effects. As a result of these complexities, the relationship between the two variables cannot be characterized as linear (Montmartin & Herrera, 2015; Mariani & Mealli, 2018).

Controversial research has stimulated scholars' interest and motivated them to further explore this field. The bibliometric method is an effective academic tracking and exploration approach, commonly used to identify the development trends in emerging fields (Mehmood et al., 2016). Visualization methods enable researchers to present complex subject data in a user-friendly manner, facilitating easy querying and referencing. Citespace, developed by American scholar Dr. Chaomei Chen in 2004 (Liu & Zhou, 2015), serves as a powerful visualization tool. We have observed a considerable number of studies utilizing cite space to examine the innovation performance of enterprises, such as Hu, Wu, and Chen (2022) and Fang and Zhu (2020). These studies have analyzed the research hotspots, fields, and trends pertaining to enterprise innovation performance. However, there is a dearth of research employing visual tools to statistically analyze literature on the relationship between government subsidies and enterprise innovation performance. This represents an existing gap that can be addressed. Consequently, it holds significant theoretical value to employ the cite space visualization

tool in investigating the connection between them. Thus, this article selects relevant literature on this theme published on the Web of Science from 2013 to 2022 as samples for analysis. Statistical analysis is conducted on changes in the number of publications, authors, institutions, nationalities, references, and keywords. Building upon this foundation, this paper delves into an extensive examination of research focus areas and prominent topics within this domain while also discussing future research directions. It is our hope that these findings will contribute meaningfully to scholars' ongoing investigations as well as inform decision-making processes for governments and enterprises.

The subsequent section of the article is presented below.: Data Sources and Research Methods, which offer comprehensive elucidations of the data origins and research methodologies. In the section on analysis results, an examination is conducted of the basic information, references, and keywords to identify the research focus and hot topics. Finally, a review is presented on the relevant hot topics and development trends.

2 Data and Methodology

2.1 The Data Source

Clarivate's Web of Science (WoS) data retrieval platform houses a comprehensive collection of top-tier publications across various disciplines. The documents encompassed within it serve as a reflection of the cutting-edge advancements in their respective fields, establishing its status as an esteemed evaluation tool within academia (Shi, Zhou, & Chen, 2012). Additionally, this platform encompasses an extensive range of literature information pertaining to authors, citations, journals, and more for analytical purposes. With articles dating back to 1900 included in its vast knowledge base, it stands as one of the largest repositories worldwide. Consequently, this study selects SCI and SSCI from WoS's core collection. These indexes are utilized with "Government subsidies" and "Enterprise innovation performance" serving as search terms to acquire the necessary data. The search timeframe is set from January 2013 to November 2023. Specifically considering this theme falls under social science-related topics, SSCI is chosen accordingly. However, after reviewing relevant literature on this subject matter, we discovered numerous valuable interdisciplinary studies within natural sciences as well; hence SCIE is also incorporated as an option. The search process outlined in this paper focuses on limiting searches to "topic" (including searching through "title," "abstract," and "keywords"), encompassing all English papers related to this specific area. The data in this paper were limited to scientific papers, excluding non-research content such as book reviews, conferences, editorials, and books. Articles from non-academic journals and conferences were excluded due to their low scientific contribution. 322 publications were collected after applying the screening above criterion. After further processing using analysis software, one unqualified record was eliminated, resulting in 322 valid records obtained from 131 journals, involving 951 authors affiliated with 717 academic institutions across 54 countries. These constitute the fundamental data for our study.

2.2 Methodology

Citespace6.2.R4 was utilized for data analysis, as it is a Java application specifically designed for bibliometric statistical analysis. This powerful tool aids in summarizing the trends and patterns within various disciplines (Chen, Ibekwe-SanJuan, & Hou, 2010). The results obtained utilize rigorous quantitative statistical analysis with dependable datasets that encompass a substantial number of peer-reviewed publications from diverse regions and disciplines (Zemigala, 2019). It was selected due to its capability to examine the knowledge structure present in the literature using network visualization, spectral clustering, and automated cluster labeling approaches. (Chen, 2006), which was developed by Chaomei Chen (Li & Chen, 2016). Scholars across multiple fields employ

this tool to examine the progress of co-citation knowledge networks within interconnected fields and determine research hotspots and focal points within their respective disciplines (Chen, 2004). This research methodology is particularly well-suited for academic fields with a substantial volume of publications, particularly in the examination of the intrinsic connections within literature. Visual network analysis employed in this methodology enables the classification of disciplinary scope and structure by identifying influential authors or papers as well as major clusters of ongoing research. These findings are crucial for identifying trending areas and evolving research domains by offering valuable perspectives on developing research domains. Additionally, the Programming Tools have the capability to evaluate several facets of the network, including authors, institutions, nations, keywords, nouns, cited authors, cited references, and cited journals. Moreover, Citespace possesses the advantage of processing WoS source data directly which allows for efficient manipulation of downloaded text and reduces data processing time and steps.

3 Analysis Results

3.1 Descriptive analysis of basic information

3.1.1 Quantity of Articles Published

To a certain extent, the number of articles published each year reflects the active development trend of academic topics and shows the degree of attention paid by scholars to them. To examine the current trajectory of R&D on the topic of government subsidies and enterprise innovation performances, Figure 1 summarizes and shows the number of scholarly articles in this particular area of study from 2013 to 2023. With regard to the data collected, it is evident that the number of articles in this domain showed a significant increase from 2013 to 2023, but the upward trend was relatively gentle from 2013 to 2018, and rapid growth was observed after 2018. From more than 10 articles in 2019, the number of articles has increased to 113 in 2023. This upward trend indicates that this topic will continue to receive academic attention in the current and coming years. It is worth noting that 2013, which is only up to November, does not present the full number of articles in the current year, but the growth is still significant.

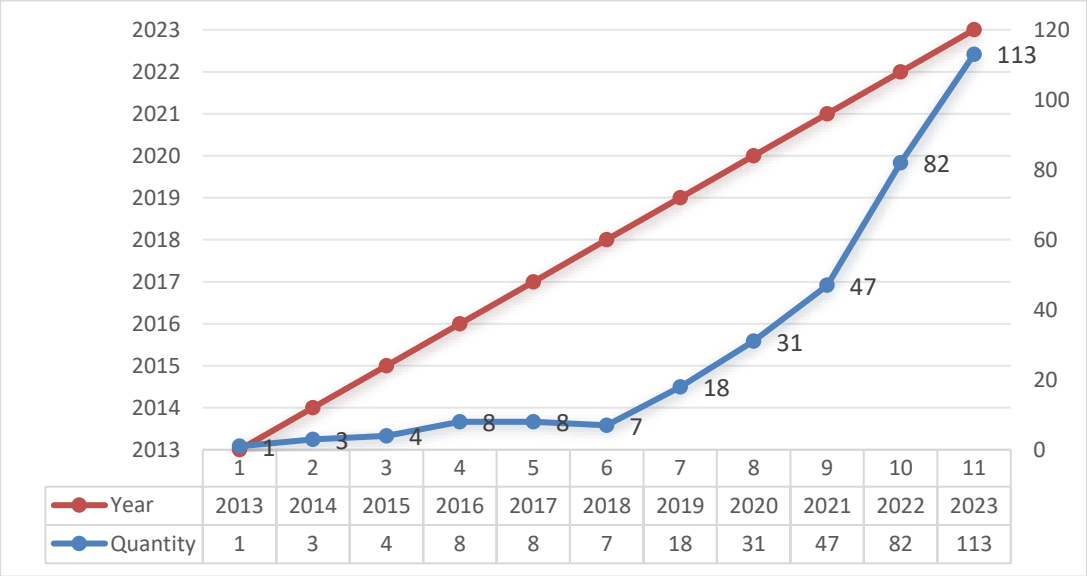

Figure 1. Quantity of Articles (2013-2023)

3.1.2 Analysis of Author

The amount of literature a scholar has in a certain field represents the depth of his or her research in that field, and a visual analysis of the authors can be used to find highly productive scholars in that field of research. In the literature analysis, authors who published more than 3 papers on the same topic from 2013 to 2023 were considered highly productive authors due to the small number of papers published on this topic. In the sample of this paper, there are 5 highly productive authors, among which Jiang Zihao has published the most papers with 5 papers, followed by Xu Xiaofeng with 4 papers. They are the leaders in this field. To see the number of articles published by authors in this particular discipline more intuitively and in detail, authors with more than 3 papers are counted(Table 1).

Table 1. High output of authors' articles

Quantity	Degree	centrality	Author
5	2	0	Jiang, Zihao
4	1	0	Xu, Xiaofeng
4	1	0	Chen, Xiangyu
3	3	0	Lin, Boqiang
3	1	0	Shi, Jiarong
3	1	0	Cheng, Hua

Figure 2 further reveals the macro distribution and cooperation of the authors of this research topic. It can be found that the number of papers produced by authors is generally positively correlated with the frequency of cooperation, that is, high-yield authors are more inclined to cooperate with each other. Meanwhile, we also find that the cooperative relationship in this field is not extensive, and most of the cooperation is small-scale and fixed.

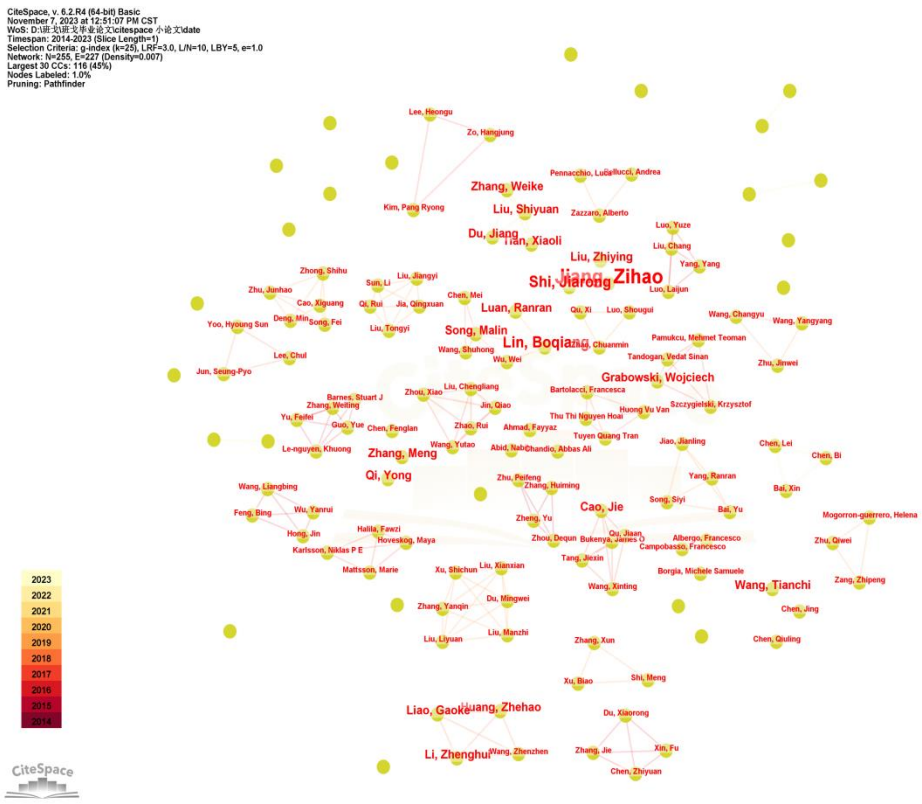

Figure 2. Cooperation of the Authors

3.1.3 Analysis of Distribution and Cooperation of Countries/Regions

Table 2 lists the countries and regions with outstanding contributions in this field from the dimensions of "Freq" and "Centrality." Where "Freq" represents the number of contributions, while "Centrality" is a metric used to assess the significance of nodes inside a network. Nodes in the network structure become more important as the value of "Centrality" increases(Li and Chen,2016), which represents the quality of contributions. It can be seen that China ranks first and far ahead in both dimensions, indicating that China is a positive driving force for research in this field, which is developing rapidly, and the contribution of China is significant. The United Kingdom, Italy, Australia, America, Spain, and South Korea follow closely behind, which could potentially be attributed to the dynamic nature of business operations, cultural context, and the concentrated presence of academic institutions in developed nations. (Zemigala, 2019). Among developing countries, Malaysia, Turkey, India, and Turkey Pakistan also make some contributions, but only Malaysia appears in both dimensions.

Table 2. Distribution and Cooperation of Countries/Regions (Top 9)

Number	Freq	Country	Centrality	Country
1	275	PEOPLES R CHINA	1.11	PEOPLES R CHINA
2	20	SOUTH KOREA	0.18	ENGLAND
3	12	USA	0.13	ITALY
4	11	ENGLAND	0.08	TURKEY
5	8	ITALY	0.08	INDIA
6	8	AUSTRALIA	0.07	SPAIN
7	6	SPAIN	0.03	AUSTRALIA

8	6	MALAYSIA	0.01	USA
9	4	PAKISTAN	0.01	MALAYSIA

Figure 3 shows the network of cooperation between countries. It has 40 nodes, 60 lines, and a density of 0.0769. This shows that the cooperative relationship in the network is good. The People's Republic of China has more cooperative relationships, which means that there are more transnational partners in it. South Korea, England, the United States, Italy, Malaysia, and Australia also have some international cooperation. Other countries do not cooperate much, although they publish a certain number of articles. In addition, the Centrality of China reaches 1.11, signifying its crucial significance in this domain, and England and Italy also exceed 0.1, making certain important contributions.

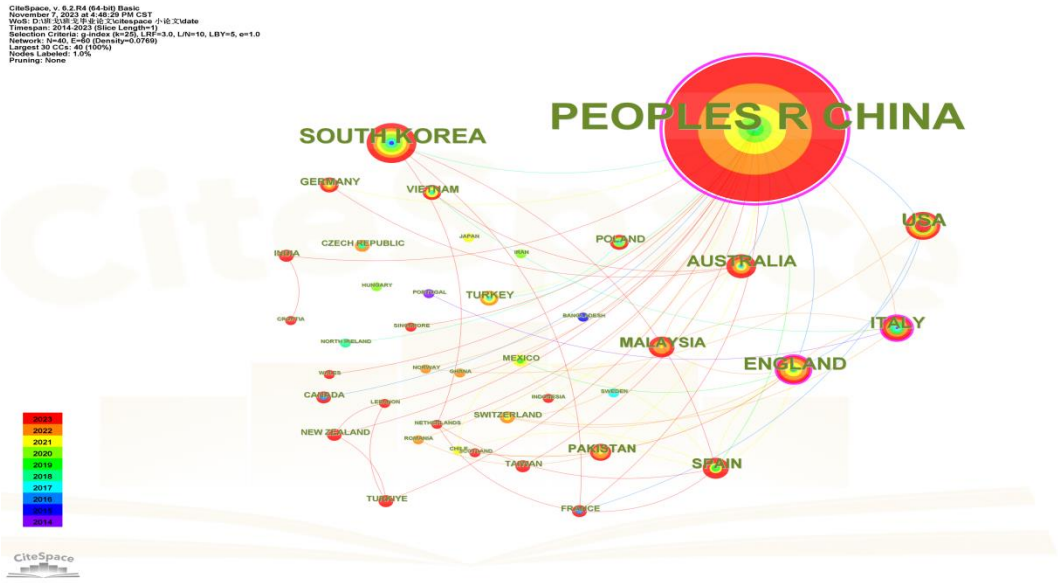

Figure 3. Country collaboration network

3.1.4 Analysis of Issuing Institutions

Figure 4 shows the distribution of issuing institutions of 322 articles. The network has 176 nodes and 154 links with a density of 0.01, which shows that the links among institutions are not close enough.

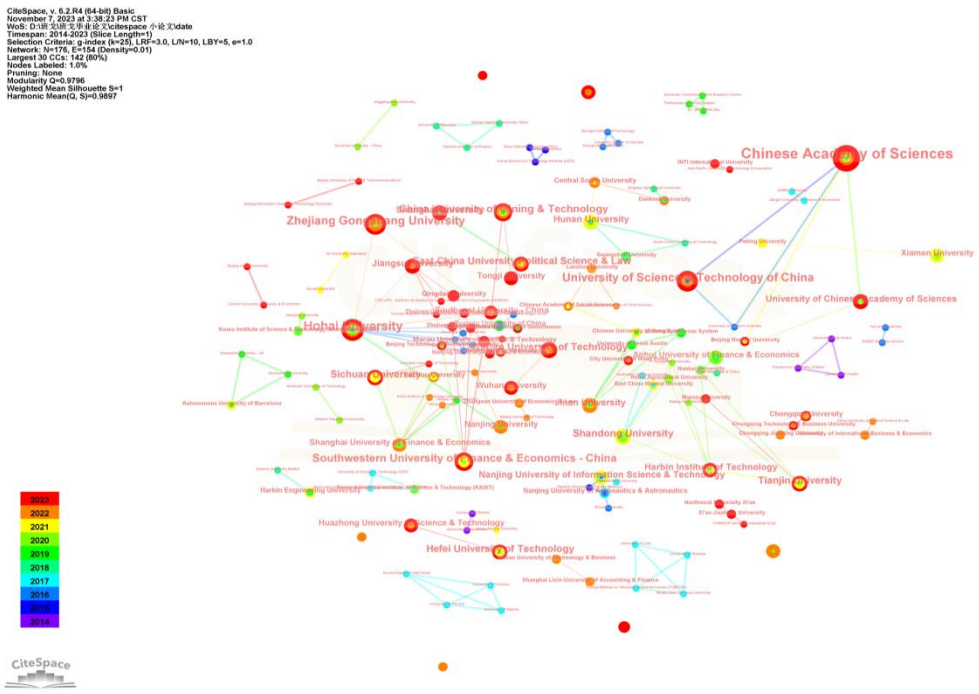

Figure 4. Institution distribution and relation

Table 3. The institutions with outstanding contributions in this field are listed from the two dimensions of "Freq" and "Centrality". In terms of quantity, the Chinese Academy of Sciences, Hohai University, and Zhejiang Gongshang University rank the top three. In terms of importance, Hohai University, Southwestern University of Finance & Economics-China, and Sichuan University take the lead. Hohai University ranked in the top three in both dimensions, indicating that the institution has the most important position in this field. However, it can also be seen that no institution's Centrality exceeds 0.1, indicating that there is no particularly authoritative institution in this field.

Table 3. Number of articles published by institutions

Freq	Institution	Centrality	Institution
18	Chinese Academy of Sciences	0.08	Hohai University
11	Hohai University	0.05	Southwestern University of Finance & Economics - China
9	Zhejiang Gongshang University	0.03	Sichuan University
9	University of Science & Technology of China	0.02	Shandong University
8	Southwestern University of Finance & Economics - China	0.02	Harbin Institute of Technology
7	China University of Mining & Technology	0.02	Jinan University
6	Shandong University	0.02	Southeast University - China
6	Sichuan University	0.02	Nankai University
6	Tianjin University	0.02	Nanjing University of Finance & Economics
6	Wuhan University of Technology	0.01	Chinese Academy of Sciences

3.2 Analysis Based on References

3.2.1 Cited author

Highly productive authors have been analyzed in the previous section, but it should be noted that highly productive authors are not necessarily authoritative in the field, and authoritative authors should be reflected by the quality of their articles. In general, the academic circle classifies authoritative authors by the citations of scholars in a certain field, which is calculated by reference documents. This paper counts the citation situation of authoritative authors, according to the top fifteen of the former "Freq" and "Centrality" categories, as shown in Table 4, among which the most frequently cited is ANONYMOUS, while the contribution of Zuniga-Vicente JA is more important.

Table 4. Citation of the author (Top 15)

Number	Freq	Author	Number	Centrality	Author
1	123	[ANONYMOUS]	1	0.95	Zúñiga-Vicente JA
2	73	CZARNITZKI D	2	0.92	DAVID PA
3	54	HALL BH	3	0.91	AGHION P
4	52	GUO D	4	0.87	WALLSTEN SJ
5	49	AGHION P	5	0.84	HALL B
6	48	PORTER ME	6	0.82	ALMUS M
7	43	BOEING P	7	0.75	BALDWIN J
8	41	BRONZINI R	8	0.74	ACEMOGLU D
9	40	LIN BQ	9	0.72	BERRONE P
10	38	DAVID PA	10	0.72	AMORE MD
11	38	SONG ML	11	0.72	AGUILERA-CARACUEL J
12	38	GUAN JC	12	0.42	LACH S
13	36	ALMUS M	13	0.33	PORTER ME
14	36	XIE XM	14	0.31	ZHANG JJ
15	36	BAI Y	15	0.29	GUELLEC D

In order to make the overall information of this situation clearer, we present Figure 5 below, which also shows the network cooperation in Cited author. The network has 450 nodes, 223 lines, and the density is 0.0022. The node's size corresponds to the author's citation count. And the lines represent the cooperative relationship. It shows that the relationship between cited authors is not close enough to form a fixed cooperative team.

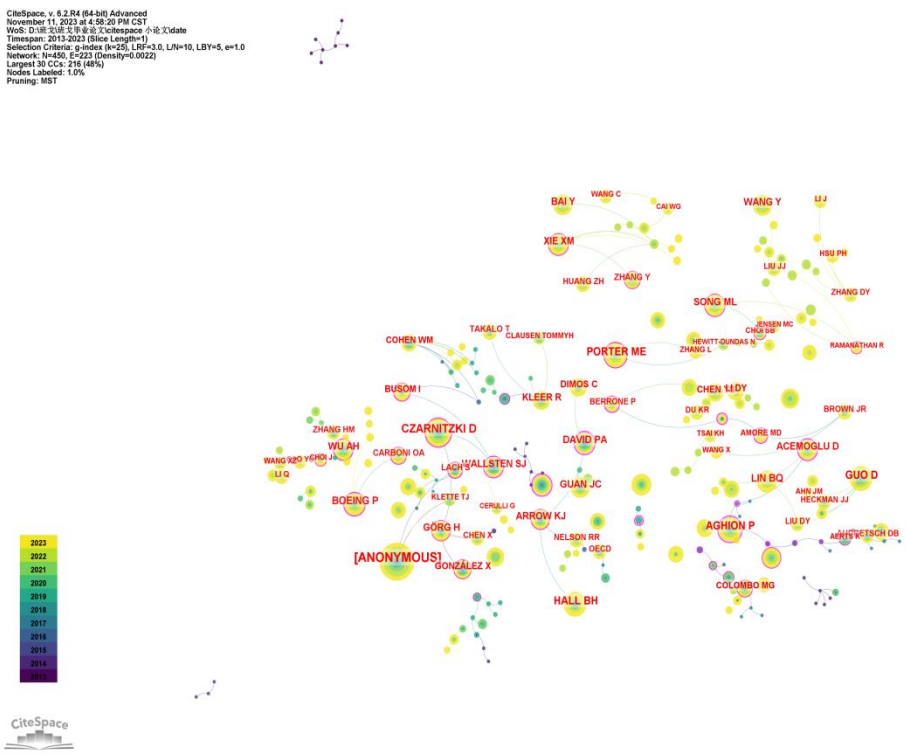

Figure 5. The cooperative relationship of the cited author

3.2.2 Cited journal

Cited journal refers to the publication of references. Both the publication and the publishing unit have a crucial function in the academic sphere and an important collaborators in academic research. The analysis of Cited journals can help scholars find authoritative journals in this field and understand the relevant information of peer research. Table 5 shows the top ten of the three dimensions of "Freq", "Centrality" and "Burst".

Table 5. Cited journal (Top 10)

Freq	Journal	Centrality	Journal	Burst	Journal
244	RES POLICY	0.37	ACAD MANAGE REV	8.45	RAND J ECON
210	TECHNOL FORECAST SOC	0.25	AM ECON REV	8.15	ECON INNOV NEW TECH
186	J CLEAN PROD	0.21	TECHNOVATION	6.12	SMALL BUS ECON
158	ENERG POLICY	0.2	RES POLICY	5.94	J FINANC
149	SUSTAINABILITY-BASEL	0.19	ADMIN SCI QUART	5.85	J BUS ECON STAT
146	AM ECON REV	0.18	J ECON SURV	5.6	ECON TRANSIT
132	TECHNOVATION	0.17	MANAGE SCI	5.53	IND CORP CHANGE
128	STRATEGIC MANAGE J	0.17	WORLD DEV	5.33	J POLIT ECON
114	J BUS RES	0.17	J ECONOMETRICS	5.02	RATE DIRECTION INVEN
104	SMALL BUS ECON	0.16	SMALL BUS ECON	4.81	EUR PLAN STUD

The top three publications are RES POLICY, TECHNOL FORECAST SOC, and J CLEAN PROD, indicating that they are the most interesting journals for scholars and have a high reputation and authority in this field. The top three Centrality journals are ACAD MANAGE REV, AM ECON REV, and TECHNOVATION, indicating that these

three journals are more widely connected with the field, which can also be understood as having a greater influence. The top three of Burst are RAND J ECON, ECON INNOV NEW TECH, and SMALL BUS ECON, indicating that they can always bring new topics and are highly innovative in this field. RES POLICY ranks high in "Freq" and "Centrality", which indicates that it is one of the most important and authoritative journals in this field. Figure 6 shows the cited journals and the connections between them more intuitively. The nodes' size corresponds to the number of publications, while the lines depict the relationships.

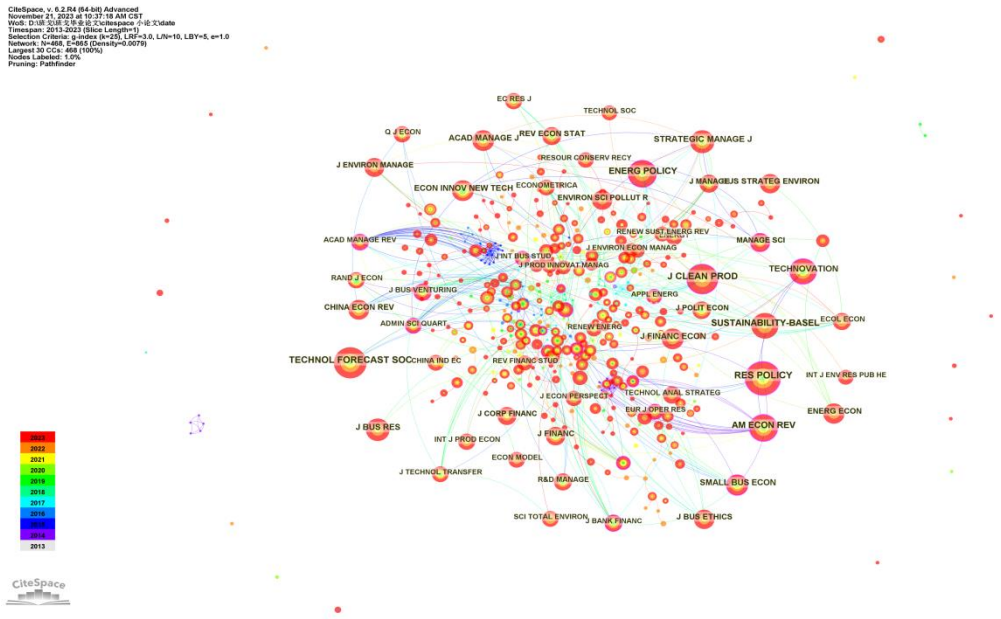

Figure 6 Cited journal network

3.2.3 References Co-citation

The number of references, the degree of connection with other literature, and the innovativeness of the topic can reflect the academic value of the literature on this research theme and are also important indicators to reflect the level of the author of the literature. Figure 7 shows its visual structure.

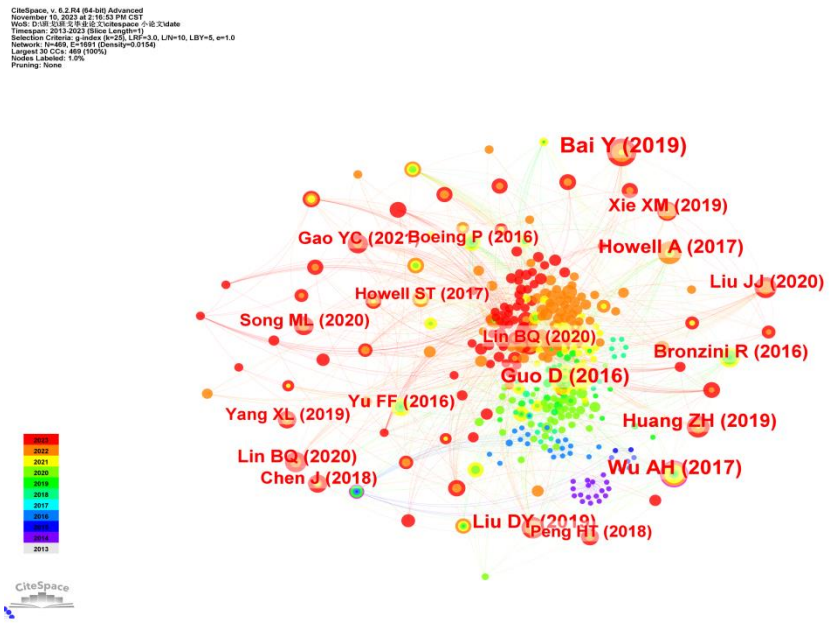

Figure 7. Co-citation of References and Its Relationship Network

For further analysis, according to the three dimensions of "Freq", "Centrality" and "Burst", this paper organizes the top ten contributions with high citation rates into Table 6.

Table 6. Co-citation of References(Top 10)

Freq	Author	Title	Centrality	Author	Title	Burst	Author	Title
32	Bai Y（2019）	The impacts of government R&D subsidies on green innovation: Evidence from Chinese energy-intensive firms	0.29	Jiang CL (2018)	The effectiveness of government subsidies on manufacturing innovation: Evidence from the new energy vehicle industry in China	9.93	Guo D (2016)	Government-subsidized R&D and firm innovation: Evidence from China
25	Guo D (2016)	Government-subsidized R&D and firm innovation: Evidence from China	0.23	Boeing P (2016)	The allocation and effectiveness of China's R&D subsidies-Evidence from listed firms	6.37	Bronzini R (2016)	The impact of R&D subsidies on firm innovation
25	Wu AH (2017)	The signal effect of Government R&D Subsidies in China: Does ownership matter?	0.2	Peng HT (2018)	How government subsidies promote the growth of entrepreneurial companies in the clean energy industry: An empirical study in China	5.61	Yu FF (2016)	The impact of government subsidies and enterprises' R&D investment: A panel data study from renewable energy in China
20	Howel A(2017)	Picking 'winners' in China: Do subsidies matter for indigenous innovation and firm productivity?	0.2	Huergo E (2017)	Subsidies or loans? Evaluating the impact of R&D support programs	5.18	Wu AH (2017)	The signal effect of Government R&D Subsidies in China: Does ownership matter?

19	Liu DY (2019)	Do more subsidies promote greater innovation? Evidence from the Chinese electronic manufacturing industry	0.18	Zúñiga-Vicente JA (2014)	Assessing the effect of public subsidies on firm R&D investment: a survey	4.85	Boeing P (2016)	The allocation and effectiveness of China's R&D subsidies-Evidence from listed firms
19	Huang ZH (2019)	Loaning scale and government subsidy for promoting green innovation	0.17	Cai X (2020)	Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies	4	Dimos C (2016)	The effectiveness of R&D subsidies: A meta-regression analysis of the evaluation literature
17	Bronzini R(2016)	The impact of R&D subsidies on firm innovation	0.16	Castellacci F (2015)	Do the effects of R&D tax credits vary across industries? A meta-regression analysis	3.71	Zúñiga-Vicente JA (2014)	Assessing the effect of public subsidies on firm R&D investment: a survey
17	Liu JJ (2020)	Impacts of government subsidies and environmental regulations on green process innovation: A nonlinear approach	0.13	Amore MD(2016)	Corporate governance and green innovation	3.52	Huergo E (2017)	Subsidies or loans? Evaluating the impact of R&D support programs

16	Xie XM (2019)	Green process innovation, green product innovation, and corporate financial performance: A content analysis method	0.11	Howell A (2017)	Picking 'winners' in China: Do subsidies matter for indigenous innovation and firm productivity?	3.36	Lin BQ (2020)	Are government subsidies effective in improving innovation efficiency? Based on the research of China's wind power industry
16	Lin BQ (2020)	Do government subsidies promote efficiency in technological innovation of China's photovoltaic enterprises?	0.11	Zhao X (2016)	The influence of Chinese environmental regulation on corporation innovation and competitiveness	2.7	Guan JC (2015)	Effects of government financial incentives on firms' innovation performance in China: Evidence from Beijing in the 1990s

It can be seen that The top three articles in this field in "Freq" are The Impacts of Government R&D Subsidies on Green Innovation: Evidence from Chinese Energy-intensive Firms by Bai(2019), Government-subsidized R&D and Firm Innovation: Evidence from China by Gu D(2016)and The signal effect of Government R&D Subsidies in China: Does ownership matter? By Wu(2017) .These three articles make the greatest contribution to this field. The top three articles in terms of "Centrality" are The Effectiveness of Government Subsidies on Manufacturing Innovation: Evidence from the New Energy Vehicle Industry in Chinaby Jiang(2018), The allocation and Effectiveness of China's R&D Subsidies - How Evidence from listed firm by Boeing(2016)and government subsidies promote the growth of entrepreneurial companies in clean energy industry: An empirical study in China by Peng (2018), shows that these three articles are closely related to other literature, relatively more important, and their contributions are more meaningful. The top three articles in "Burst" are Government-subsidized R&D and Firm Innovation: Evidence from China by Guo D (2016), The Allocation and Effectiveness of China's R&D Subsidies -Evidence from Listed Firm by Boeing P(2016), and impact of government subsidies and enterprises' R&D investment: A panel data study from renewable energy in China by Yu (2016). They bring a newer topic and are more innovative. No article appeared in the top ten of all three dimensions, but Howel (2017) 's article Picking 'Winners' in China: Do Subsidies Matter for Indigenous Innovation and Firm Productivity? Bronzini (2016) 's article The Impact of R&D Subsidies on Firm Innovation appeared in the top ten of the two dimensions of "Freq" and "Centrality" at the same time, which can be understood that these two articles were cited a lot. They are also important. Government-subsidized R&D and firm innovation: Evidence from China by Gu D (2016) appears in the top ten of "Freq" and "Burst" at the same time, indicating that this article is very meaningful and innovative for other scholars. the same goes for Assessing the effect of public subsidies on firm R&D investment: a survey by Zuniga-

Vicente (2014) and The allocation and effectiveness of China's R&D subsidies-Evidence from listed firms by Boeing (2016). They are the five most valuable articles in this field.

Cluster analysis of the references of these articles gives some insight into the key areas of research that have been formed. Further analysis revealed that these articles formed 15 large research areas, as shown in Figure 8.

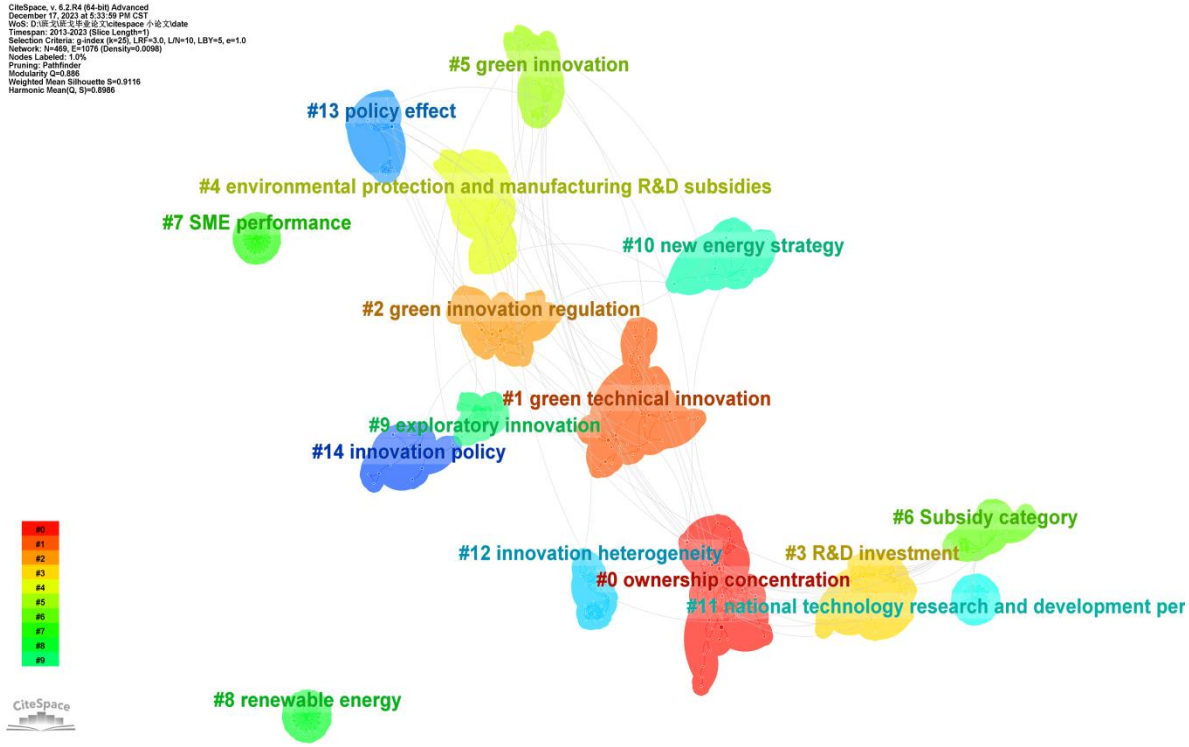

Figure 8 References co-citation network relationship

Combined with professional knowledge, the above 15 fields can be further classified into green innovation research(#1,#2,#4,#5,#8,#10) and research on enterprise heterogeneity innovation(#0,#7,#12), Research on innovation policy(,#6,#14,#15) and exploratory innovation performance (#3,#9,# 11). Green innovation is currently the most prominent area of study. At present, most scholars in this field like to carry out interdisciplinary research with green, environmental protection, new energy, and other fields, and the second joint research field is public policy.

3.3 Key analysis

Keywords are a concise reflection of the research content of the paper, which effectively captures the key points of the paper. Through the examination of the co-occurrence and strength of certain keywords within a particular research subject, one may identify growing areas of research interest and cutting-edge topics. (Chen & Li, 2016). Therefore, by collating and analyzing the keywords in the literature, we can systematically grasp the research hotspots in a specific field, which plays a crucial role.

3.3.1 Hot Spot Analysis

The research hotspots are realized by keyword co-occurrence analysis. It is found that there are 334 keywords in the atlas(N=334, E=791) and the density is 0.0142, indicating that there are various connections between these keywords. Keywords with larger nodes and more lines represent more frequent occurrences. The high-frequency keywords in Figure 9 mainly include "performance", "research and development", "impact", "innovation" and so on.

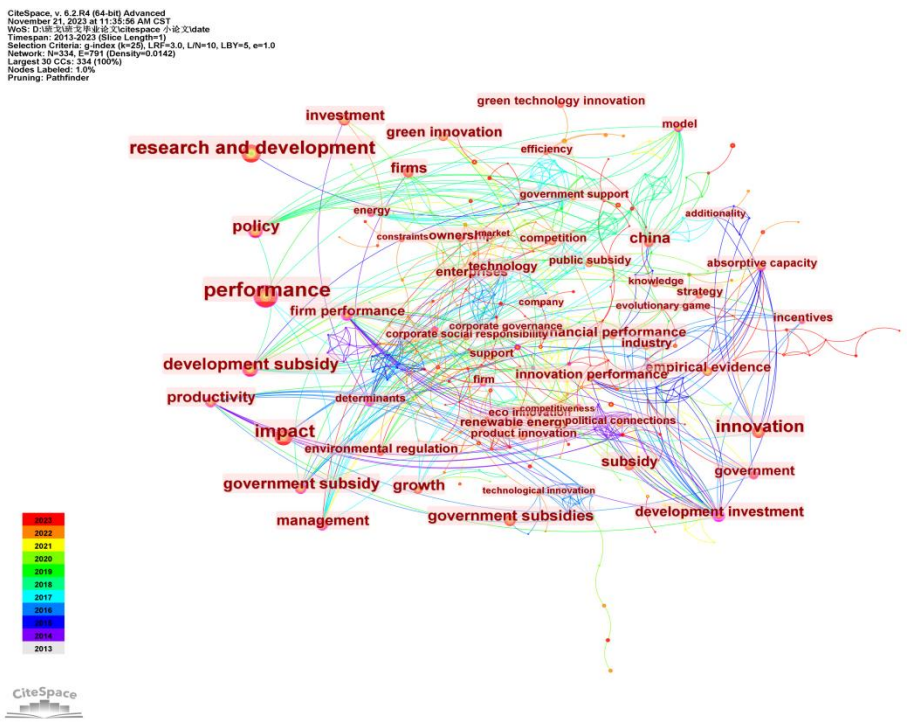

Figure 9. Co-occurrence analysis of keywords

In order to more accurately summarize the research field under this topic. The present article will be consistent with the search keywords such as performance, innovation performance, government subsidy, government subsidies, and other keywords without specific significance such as: After deleting firm, enterprise, management, etc, the high-frequency keywords in the two dimensions of "Freq" and "Centrality" are analyzed in detail. The top ten keywords are shown in Table 7:

Table 7. Keyword Co-occurrence (Top 10)

Freq	Keyword	Centrality	Keyword
110	research and development	0.44	development investment
61	development subsidy	0.2	determinants
52	policy	0.19	development subsidy
44	productivity	0.19	technology
44	China	0.19	state ownership
41	growth	0.15	productivity
36	investment	0.14	capability
31	green innovation	0.13	incentives
30	development investment	0.13	economic growth
28	empirical evidence	0.13	advantage

It can be seen that the top three in the Freq dimension are research and development (110), development subsidy (61), and policy (52). It can be seen that academia pays more attention to R&D and policy research. Frequently, these approaches involve the integration of government subsidies and corporate innovation performance, as well as the examination of the mediating influence of R&D investment and public policy performance. In the "Centrality" dimension, development investment, determinants, and development subsidy rank the top three, which indicates that many studies are related to

these three keywords and they have great influence. development subsidy, productivity, and development investment all appear in the top ten of the two dimensions, indicating that they are also very important and are hot topics of general concern in this field.

3.3.2 Fields and Trend

The analysis of key fields is realized through the clustering of keywords (LLR). This resulted in Figure 10, which shows that 17 major clusters were found.

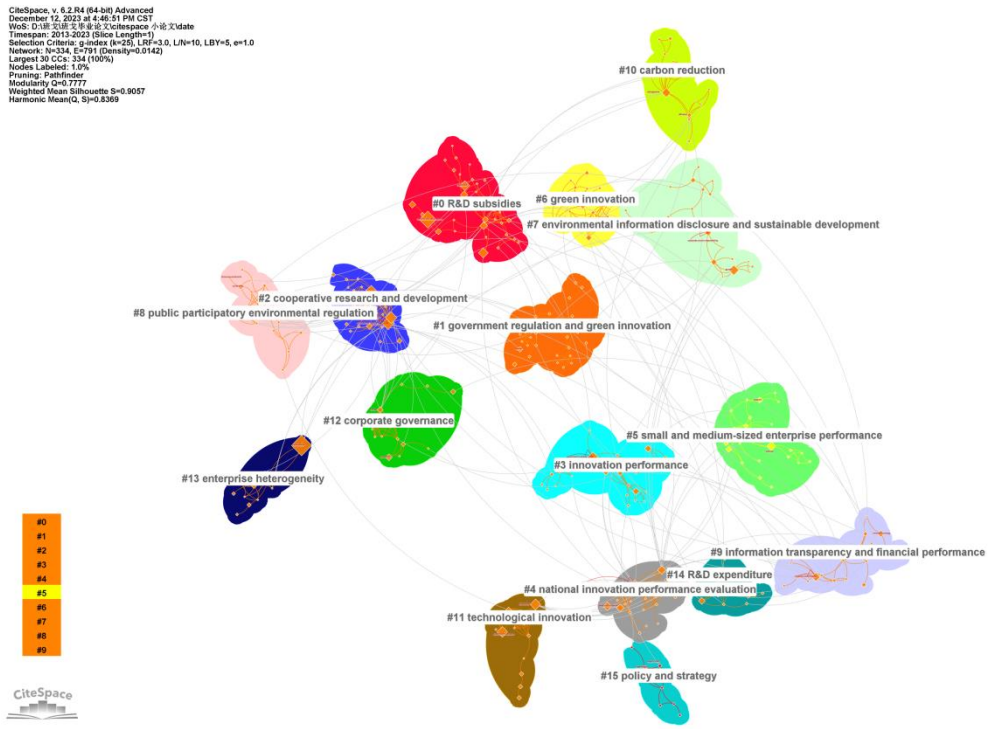

Figure 10. Cluster analysis of keywords

Further details of these clusters are given in Table 8. It should be noted that because of the limited intelligence of the tool, some categories have been redefined in combination with professional knowledge. The Silhouette range (0.5-1) is commonly employed to assess the internal homogeneity of clusters, specifically the degree of similarity between an item and other clusters relative to its cluster. A higher number indicates a more efficient formation of the cluster and a better fit of the item within its cluster. This figure in Table 8 shows that clustering is appropriate.

Table 8. Cluster analysis of keywords

ID	Freq	Silhouette	LLR	Definition
0	34	0.91	r& (12.18, 0.001); d subsidies (12.18, 0.001); food industry (8.11, 0.005); investment (4.7, 0.05); government involvement (4.58, 0.05)	R&D subsidies
1	31	0.927	maritime supply chain (6.9, 0.01); moderating role (6.9, 0.01); impacts (6.9, 0.01); product innovation (6.9, 0.01); firm age (6.9, 0.01)	government regulation and green innovation
2	31	0.925	carbon tax (9.09, 0.005); uric (4.54, 0.05); negative cooperation (4.54, 0.05); synergy green innovation effect (4.54, 0.05);	cooperative research and development

			dynamic evolutionary game model (4.54, 0.05)	
3	26	0.848	evolutionary game (8.72, 0.005); government subsidy (8.04, 0.005); environmental regulation (7.63, 0.01); state ownership (5.13, 0.05); regulatory capture (5.13, 0.05)	innovation performance
4	25	0.986	innovation performance (11.22, 0.001); innovative input (5.63, 0.05); government funding (5.63, 0.05); regulatory pressure (5.63, 0.05); government r&d subsidy (5.63, 0.05)	National Innovation Performance Evaluation
5	25	0.926	support (11.25, 0.001); small and medium-sized enterprises (7.83, 0.01); penalties for breach of contract (5.62, 0.05); is) (5.62, 0.05); local authority (5.62, 0.05)	Small and medium-sized enterprise performance
6	23	0.923	green innovation (21.15, 1.0E-4); exploratory innovation (16.33, 1.0E-4); exploitative innovation (16.33, 1.0E-4); environmental regulation (8.62, 0.005); manufacturing enterprise (6.37, 0.05)	green innovation
7	21	0.887	employment (7.89, 0.005); life cycle (7.89, 0.005); carbon neutrality (7.89, 0.005); environmental information disclosure (7.89, 0.005); sustainable development (6.64, 0.01)	environmental information disclosure and sustainable development
8	20	0.809	r&d subsidies (16.65, 1.0E-4); behavioral additionality (10.54, 0.005); green industrial policy (8.87, 0.005); external collaborative networks (7.13, 0.01); public participatory environmental regulation (7.13, 0.01)	public participatory environmental regulation
9	20	0.781	information transparency (12.27, 0.001); green governance (8.55, 0.005); high-tech (6.12, 0.05); internal and external factors (6.12, 0.05); community innovation survey (6.12, 0.05)	information transparency and financial performance
10	18	0.929	carbon reduction (10.47, 0.005); government grant (7.1, 0.01); coal supply chain (7.1, 0.01); decisions (7.1, 0.01); preferential taxation (7.1, 0.01)	carbon reduction
11	16	0.954	innovation efficiency (17.36, 1.0E-4); technological innovation (11.51, 0.001); government subsidies (9.68, 0.005); corporate innovation (9.54, 0.005); government subsidization (5.53, 0.05)	technological innovation

12	15	0.918	corporate governance (9.01, 0.005); Chinese government subsidies (7.2, 0.01); green building material industry (gbmi) (7.2, 0.01); revenue-sharing contract (7.2, 0.01); green buildings (7.2, 0.01)	corporate governance
13	12	0.989	listed companies (4.27, 0.05); firm performance (3.98, 0.05); digitalization (3.88, 0.05); length of doing business (3.88, 0.05); interventions (3.88, 0.05)	enterprise heterogeneity
14	9	0.918	r&d expenditure (6.19, 0.05); government subsidies (5.91, 0.05); standardization (4.91, 0.05); mses (4.91, 0.05); market expectation (4.91, 0.05)	R&D expenditure
15	8	0.954	ordinal regression (9.06, 0.005); contingency factors (9.06, 0.005); talent gathering (9.06, 0.005); policy mixes (9.06, 0.005); miles and snows strategy (9.06, 0.005)	policy and strategy

Further analysis found that these clusters were obviously excessive and repeated, so we used our professional knowledge to re-cluster. Specifically, the research fields of this topic should be #1green innovation(#1,#6),#2environmental regulation and sustainable development t(#7,#8,#10), #3R&D(#0,#2,#14),

#4innovationperformance(#3,#4,#5,#9),#5corporate governance(#11,#12),#6enterprise heterogeneity(#13) and #7policy and strategy(#15).

To further examine the temporal pattern of how keyword clustering evolves over time, presenting trends in the development of this topic, we converted the text into a timeline view(Figure 11).

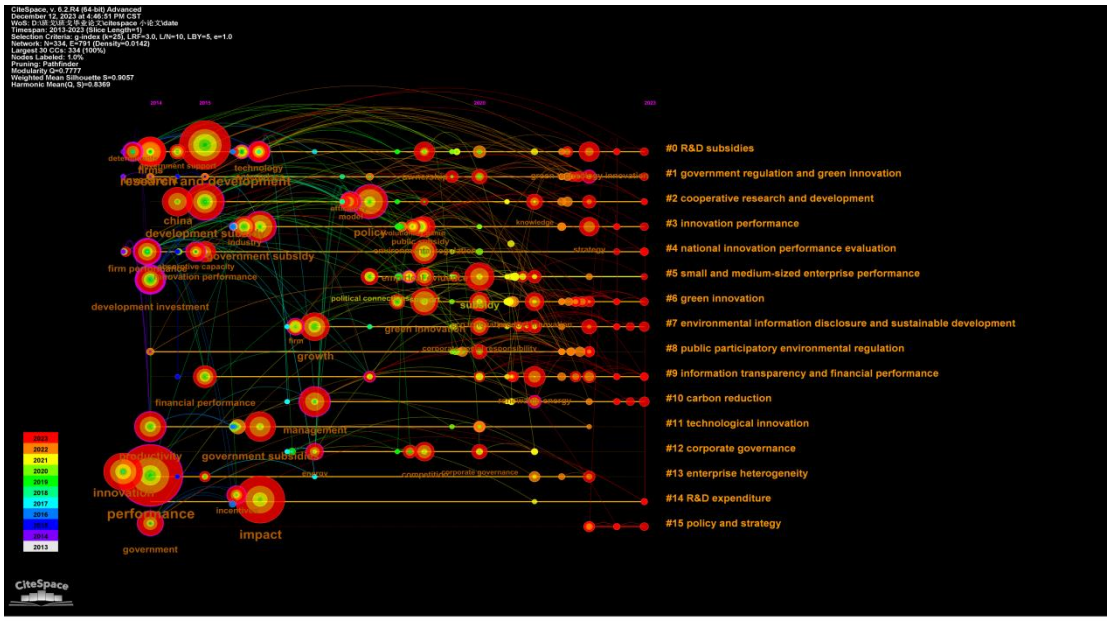

Figure 11 Timeline view

Most of the clusters started in 2014 and lasted until 2023, but they were not active enough in 2023. However, #5 small and medium-sized enterprise performance and #6 green innovation appeared in 2018, and #15 policy and strategy appeared in 2022. Indicating

that these three fields are relatively cutting-edge research fields so far. However,# 8,# 11,#12, and #13 have not been extended to 2023, indicating that the research in these four fields is no longer the focus. Researchers should pay full attention to this trend in order to make reference for their own research.

3.3.3 Research Frontier Analysis

Keyword emergence map can intuitively see the past research objects and current hot spots and dynamics of this field according to the emergence keywords at each time, which is an effective tool for frontier analysis of this field. Figure 12 shows 11 keywords that have emerged in recent years on this topic.

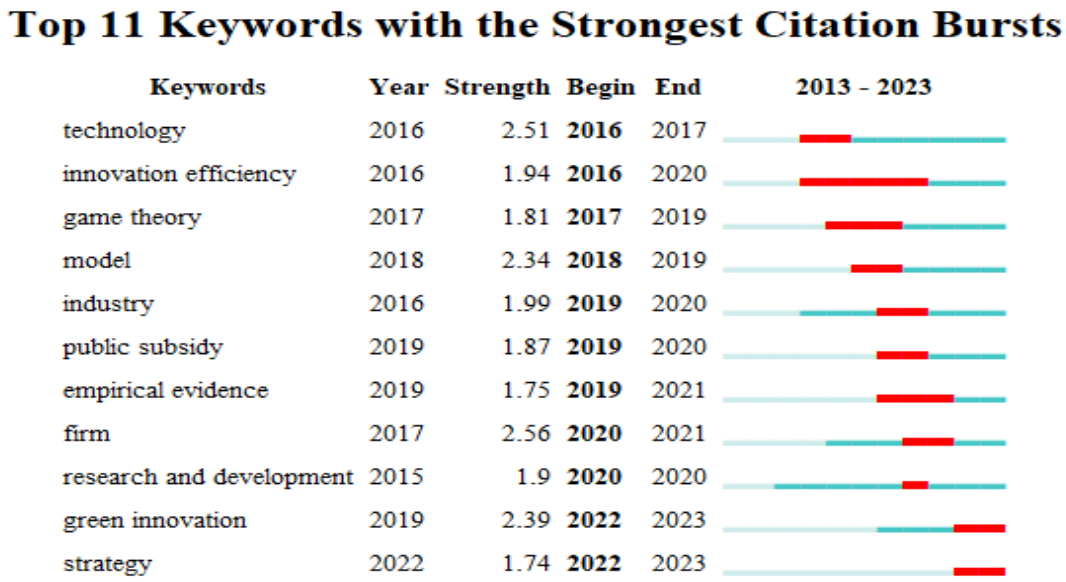

Figure 12. Citation burst of keywords over time

From the perspective of the Strength dimension, the strongest are firm, technology, and green innovation; This shows that the research on technology showed explosive growth from 2016 to 2017, and it was the most popular research field in this year, but this research did not extend beyond 2017. In 2020-2021, scholars suddenly became interested in the field of firms and focused on a large number of studies. The research in the field of green innovation started from 2022 to 2023 and has not yet finished. It can be considered a relatively active field at present and in the future, even if the research hotspots are relatively cutting-edge topics. From the perspective of the year, only green innovation and strategy are the keywords that will continue to emerge in 2023, which are the hot topics and frontier directions of current research. In 2016 and 2019, there were the most emergent keywords, but only one keyword continued to 2023, indicating that the research hotspots were relatively short and changed rapidly. In 2022, strategy-related research has become a new field with strong innovation, which together with green innovation constitutes the future research direction of this topic.

4 Conclusion

The present study employs CiteSpace software to provide a comprehensive overview and structural analysis of the research topic concerning the relationship between government subsidies and enterprise innovation performance. This is achieved through cooperative network analysis, co-occurrence analysis, and co-citation analysis. Furthermore, this paper explores the prominent research field, hotspots, as well as emerging frontiers within this domain.

1) From the perspective of the number of articles, only 322 articles were published on this topic from 2013 to 2023, and the research on this topic began to grow rapidly in 2019, indicating that there are few studies on this topic, and there are still many fields to be developed.

2) From a global perspective, China is the main country to promote research in this field. The frequency, overall quality, foresight, and centrality of Chinese publications are much higher than those of other countries, indicating that Chinese scholars have made significant contributions in this field, which may be related to China's fiscal and innovation policy orientation. South Korea, England, the United States, Italy, Malaysia, and Australia have also made some contributions. Jiang, Zihao, and Xu, Xiaofeng are prolific authors on this topic. The Chinese Academy of Sciences is the institution that publishes the most papers, while Hohai University's research is of higher quality.

3) Based on the analysis of references, the most authoritative authors on this topic are Anonymous and Zuniga-Vicente JAe. Res Policy, TechnoLl Forecast SOC, and J Clean PROD are the journals that scholars are most interested in contributing to and are authorities on the topic, but ACAD Manage Rev, AM Econ Rev, and Technovation journals are superior in quality of articles. The impacts of government R&D subsidies on green innovation by: Evidence from Chinese energy-intensive firms(Bai,2019), The effectiveness of government subsidies on manufacturing innovation by Evidence from the new energy vehicle industry in China(Jiang,2018) is the most important reference on this topic.

4) Through comprehensive analysis, it is found that this theme forms green innovation, environmental regulation and sustainable development, R&D, innovation performance, corporate governance,#6enterprise heterogeneity, and policy and strategy seven key research areas. research and development, development subsidy, and policy are all high-frequency keywords. Simultaneously, by doing a thorough and dynamic examination of the aforementioned keywords, firm, technology, green innovation, strategy, and other keywords have been the focus of research in recent years, but the research on green innovation and strategy has persisted to the present time. The fields to which these keywords pertain or symbolize can be deduced are the frontier hot spots of research.

5) By sorting out the relevant research on green innovation and strategy, the relevant research is discovered to be highly comprehensive, with a meticulous breakdown of knowledge points. Hence, it is imperative to incorporate a systematic approach in future research endeavors in order to streamline the intricacies involved. This would greatly facilitate the decision-making processes of both businesses and governments. we will explore the topic discussed in this article based on green, policy and strategy, so as to make this research more sustainable and practical.

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