Visualized Analysis of Foreign Research on Development of Science and Technology, Economics, and Ecology

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ABSTRACT

Based on the research literature related to the development of science and technology, economy, and ecology in the WOS core library from 2005 to 2020, Citespace software was used to systematically analyze the characteristics of the literature and deeply explore the research hotspots in this field, conducting scientific econometric analysis and visualization research. Research has shown that in terms of the number of publications, the overall number of publications in this field has been on the rise, going through three stages: initiation, growth, and development; From the perspective of institutional cooperation distribution, universities and research institutions in this field cooperate closely, presenting a dispersed team layout, and there has not yet been a representative author or a core author group formed; "management", "dynamics", "sustainable development", "determinations", and "sustainability" are hot keywords; Analyzing hot topics through keyword clustering, the hotspots in this field focus on two aspects: research on the interrelationships between the three and analysis of influencing factors, and evaluation.

Keywords: *Citespace, Science and technology - economics - ecology, Knowledge graph, Research hotspots, Keyword.*

1. INTRODUCTION

In the current social context, science and technology, economics, and ecology are intertwined and complementary to each other, and their development directly affects the overall progress of society. Integrating development of science and technology, economics, and ecology can provide a more comprehensive understanding of the operational mechanisms of social systems, promote interdisciplinary cooperation, and provide more comprehensive and in-depth solutions to the complex problems faced by today's society. To this end, visual analysis and research will be conducted on relevant research journals in the fields of science and technology, economics, and ecology in the Web of Science core database, in order to gain a deeper understanding of the current research status, grasp the research hotspots, frontiers, and future research directions in this field.

2. ANALYSIS OF LITERATURE CHARACTERISTICS

In order to systematically analyze and grasp the research status of the academic field on the development of science, technology, economics, and ecology in China, based on the WOS core database, the literature search topics were selected as "science and technology", "ecology", "environment", and "economic" for literature search. The search time was set as "1998-2020". After excluding literature that was not conducive to visual analysis such as conference interviews, conference reviews, and conference reports, it was found that there were no relevant literature publications in this field from 1998 to 2004. Finally, a total of 162 relevant literature were obtained in this field from 2005 to 2020.

According to “Figure 1”, the overall publication volume of the WOS core database in this research field showed an upward trend from 2005 to 2020, with some fluctuations.

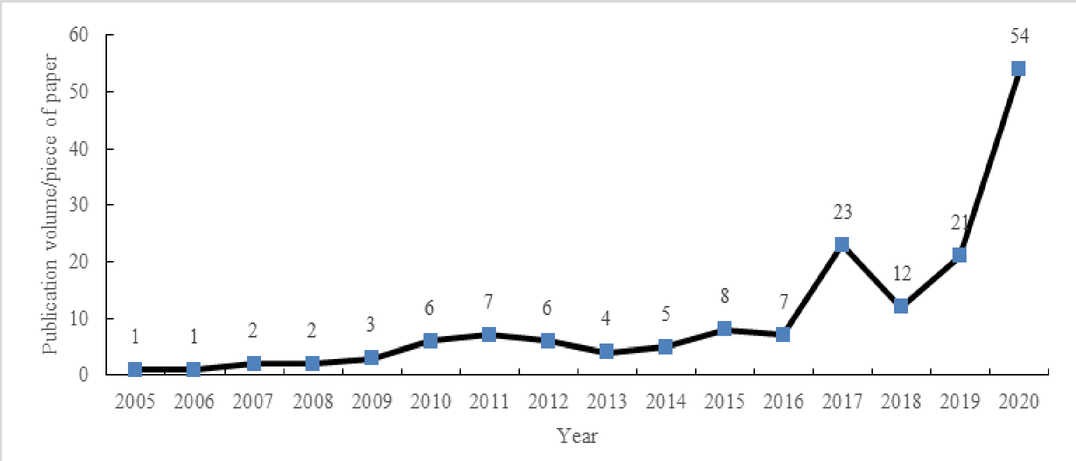

Figure 1 Publication volume of WOS journals in science and technology, economy, and ecology research from 2005 to 2020.

It can be divided into three stages: In the initial stage (2005-2016), scholars did not pay much attention to the development of science and technology, economy and ecology, with a total of 52 papers published, accounting for 32% of the total number of papers, and an average of only 4 papers per year. In the growth stage (2017-2018), the average annual number of papers increased to 17, and the fluctuation trend of research papers was obvious, indicating that scholars' attention to the development of science and technology, economy and ecology began to increase. In the development stage (2019-2020), the number of published papers reached 75, accounting for 46.3% of the total published papers, and the average annual number of published papers increased to 37, indicating that scholars' attention to the development of the three papers has increased significantly. By analyzing the trend of changes in the number of published articles, it can be seen that 2017 was a key milestone for research in this field to receive more attention.

2.1 Distribution of Institutional Cooperation

By using Citespace visualization analysis software, the top eight institutions in terms of publication volume can be obtained (see “Table 1”), as well as a network graph of institutional cooperation (see “Figure 2”).

As shown in “Table 1”, the top 8 universities and institutions in terms of publication volume indicate that from 2005 to 2020, the US Department of Agriculture ranked first in publication volume, accounting for 6.17% of the total; Seven universities or research institutions, including the University of Vermont, State University of New York, and Rensselaer Institute of Technology, ranked second in terms of publication volume. Overall, American higher education institutions are the main research force in the fields of development of science and technology - economy - ecology, with a focus on universities in the eastern United States such as the University of Vermont, State University of New York, Rensselaer Institute of Technology, and Virginia Polytechnic Institute & State University.

Table 1. Number of publications by top 8 universities and research institutions from 2005 to 2020

Serial number	Unit name	Publication volume
1	United States Department of Agriculture (USDA)	10
2	University of Vermont	8
3	State University of New York	8
4	Rensselaer Polytechnic Institute	8
5	Virginia Polytechnic Institute & State University	8
6	United States Forest Service	8
7	Grand Valley State University	8
8	Woodwell Climate Research Center	8

In the institutional cooperation graph, the connections reflect the cooperative relationships between different universities and institutions. The thicker the connections, the closer the cooperation, while the absence of connections indicates no cooperative relationship.[1] As shown in "Figure 2", universities and research institutions engaged in research on the development of science and technology, economics, and ecology cooperate closely, presenting a dispersed team layout.

Figure 2 Institutional collaboration map of WOS journal research on development of science and technology, economics, and ecology from 2005 to 2020.

Among them, research groups mainly composed of research institutions from universities in the United States and China, mainly including: the collaboration group centered around the United States Department of Agriculture (USDA State University of New York Grand Canyon State University, etc.), the collaboration group centered around California General University (California General University Yale University Louisiana University, etc.), and the collaboration group centered on Chinese Academy of Sciences (Chinese Academy of Sciences Tongji University Taiyuan University of Technology, etc.) and Dalian University of Technology (Dalian University of Technology, China Medical University, Asia University, etc.). Each collaboration group includes at least 5 universities or research institutions. In addition, it also includes European institutional cooperation groups, such as the cooperation group composed of universities such as the University of Munich, the University of Salzburg, and Erasmus University.

2.2 Characteristics of Author Collaboration

The author collaboration graph can directly reflect the resource sharing situation in the academic research field, and the higher the degree of sharing, the more conducive it is to enhancing academic influence. At the same time, analyzing the characteristics of cooperation among scholars has important guiding significance for improving their academic influence and the quality of academic achievements in the research field. “Figure 3” shows the knowledge graph of author collaboration in this field from 2005 to 2020. Each node in the graph represents the corresponding author, and each line represents the collaborative relationship between authors. The thicker the line, the closer the collaboration.

Figure 3 Author collaboration knowledge graph of WOS journal of development research on science and technology, economy, and ecology from 2005 to 2020.

From “Figure 3”, it can be seen that there are no representative authors in this field, but a certain number of author collaboration groups have been formed, mainly consisting of multi person collaboration groups, such as Choi Jaewon - Greenfield Eric - Franco Carol - Nordman Erik - Munsell John - Castello Leandro - Olowabi Flavien - Kim Sung kyun - Luzadis Valerie A, etc.

At the same time, drawing on the formula used by renowned scientometric expert Price to define high-yield scholars[2], the core authors of this research field were selected, namely

$$m = 0.749\sqrt{n_{\max}} \qquad (1)$$

In equation (1), represents the lower limit of the number of publications by core authors; nmax is the total number of publications by the most productive scholars in this field.

According to equation (1), due to the limited number of relevant literature in this field, only 2 articles were selected from the author with the highest publication volume in this field, and used as a reference value at once, that is, nmax=2. After calculation, m=1.1, indicating that a core author is one who has published more than 2 articles. According to the screening criteria, the core authors of research in this field can be identified by reviewing the literature, as shown in “Table 2”.

Table 2. Core author of WOS journal for research on development of science and technology, economics, and ecology

Frequency of publication	Core author(s)	Number of people
2	Vinci Concetto Paolo, Chen Yaqiong, Kayis Berman, Long Xingle, Keunyeob, Du Jianguo, Han Insoo, Yigitcanlar Tan, Kara Sami, Kim Seung Aldieri Luigi	11

Due to the limited research on the fields of technology economy ecology, there are only 11 authors with the highest number of publications, such as Vinci Concetto Paolo, Chen Yaqiong, and Kayis Berman. According to Leps' Law, the number of publications by core authors in the research field should account for 50% of the total publications. The central author represents the backbone of this study, as shown in Table 2. The number of core authors has reached 11, accounting for 13.4% of the total number of publications in the WOS core journal of this study. Therefore, this study has not yet formed a stable core author group. According to Leps' Law, the number of publications by core authors in the research field should account for 50% of the total publications.

3. ANALYSIS OF RESEARCH HOTSPOTS

3.1 Hot Keyword Analysis

3.1.1 Keyword Co-occurrence Analysis

The keywords that condense the core research content of a paper can represent the core topics and research areas of the literature, while the frequently occurring keywords in the retrieved literature data can be considered as research hotspots in the field.[3] By conducting keyword co-occurrence analysis on the literature in the core database of WOS journals studied in this field from 2005 to 2020, a keyword co-occurrence network graph was obtained (see "Figure 4").

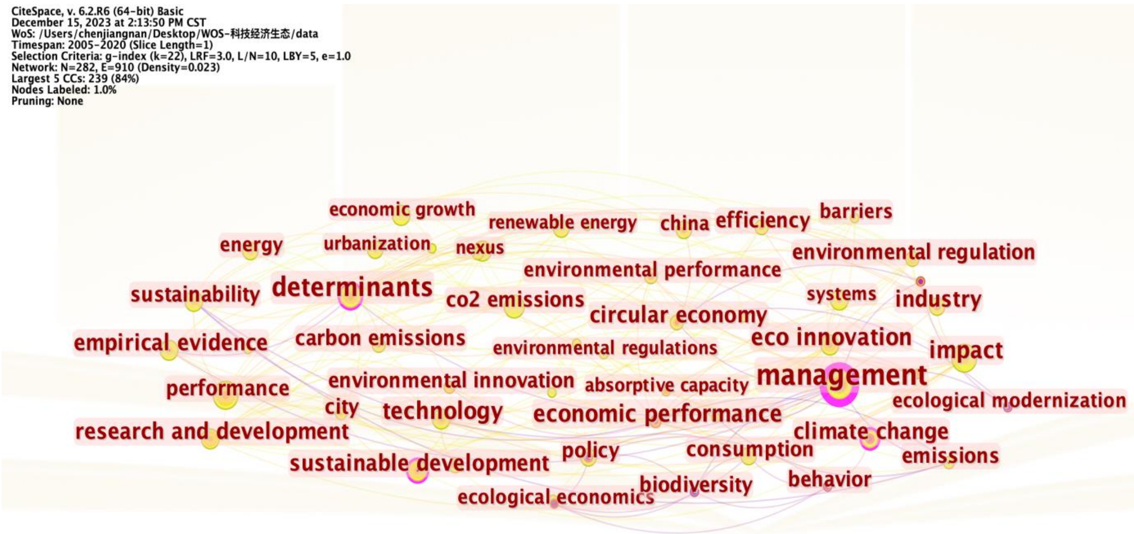

Figure 4 Keywords co-occurrence graph of science and technology, economics and ecology development of WOS journal from 2005 to 2020.

In "Figure 4", the co-occurrence graph of keywords in this research field contains a total of 282 nodes, where the thickness of the nodes is proportional to the frequency of the keywords. The larger the nodes and the larger the font size of the keywords, the higher the overall frequency of the keywords. Among them, the "management" keyword node has the largest circle layer, representing the highest frequency of occurrence. And "determinants", "sustainable development", "eco innovation", and "impact" all have a high research frequency. In addition, the number of connections in the collinear graph reaches 910, with a network density of 0.023. The connections between nodes are rich and tight, indicating a high degree of interconnection between keywords in this field.

In summary, the research on the influencing factors of the coordinated development of science and technology, economy and ecology in the WOS core database from 2005 to 2020 and the research on the development of science and technology, economy and ecology from the perspective of sustainability have attracted the attention of scholars.

3.1.2 Keyword Emergence Distribution

Emergent analysis is commonly used to explore new research problems and trends in a certain research field, reflecting the dynamic changes at the forefront of research. The emergence of keywords can reflect the high-frequency keywords that appeared in different periods, representing the research hotspots and frontiers at that time, and showing the historical background and social factors at that time.[8] Based on “Figure 4”, the mutation distribution of the top 10 keywords in research on technology, economy, and ecological development was obtained (see “Table 3”).

Table 3. Distribution of keywords on scientific and technological, economic, and ecological development in WOS journals from 2005 to 2020

Keywords	Year	Strength	Begin	End	2005—2020
ecological economics	2006	1.09	2010	2011	
dynamics	2006	0.86	2010	2011	
climate change	2014	2.2	2014	2015	
determinants	2010	1.51	2016	2017	
management	2007	2.09	2017	2018	
research and development	2018	2.79	2018	2020	
sustainable development	2005	2.09	2018	2020	
city	2018	0.68	2018	2020	

According to “Table 3”, "ecological economics" and "dynamics" were the forefront of research in this field from 2010 to 2011; Climate change, determinations, and management were the forefront of research from 2014 to 2017; Research and development, sustainable development, and city were the forefront of research from 2018 to 2020. Due to the limited research literature on this field in the WOS core database, there were no prominent keywords from 2011 to 2013, indicating that there was no clear research frontier in this field during this period.

3.2 Hot Topic Analysis

CiteSpace software provides four label extraction algorithms for clustering label extraction: LSI (Latent Semantic Index), TF * IDF weighted algorithm (default automatic label word extraction algorithm), LLR (Log Likelihood Ratio Test), MI (Mutual Information Algorithm). [9] Overall, the labels extracted by clustering using LLR algorithm are more in line with the actual situation and have fewer repetitions. Muscularity measures the degree to which a network can be divided into independent modules. Typically, a value of Muscularity Q between 0.4-0.8 indicates suitability for clustering; Silhouette is used to estimate the uncertainty involved in clustering when explaining clustering properties. Typically, when Silhouette>0.5, clustering is considered reasonable; If Silhouette>0.7, the clustering is convincing.[10] Cluster analysis was conducted on the literature on technology, economy, and ecological development in the WOS core library to obtain “Figure 5”. Among them, Muscularity Q=0.6540 and Silhouette=0.7575 indicate that the clustering results are reasonable.

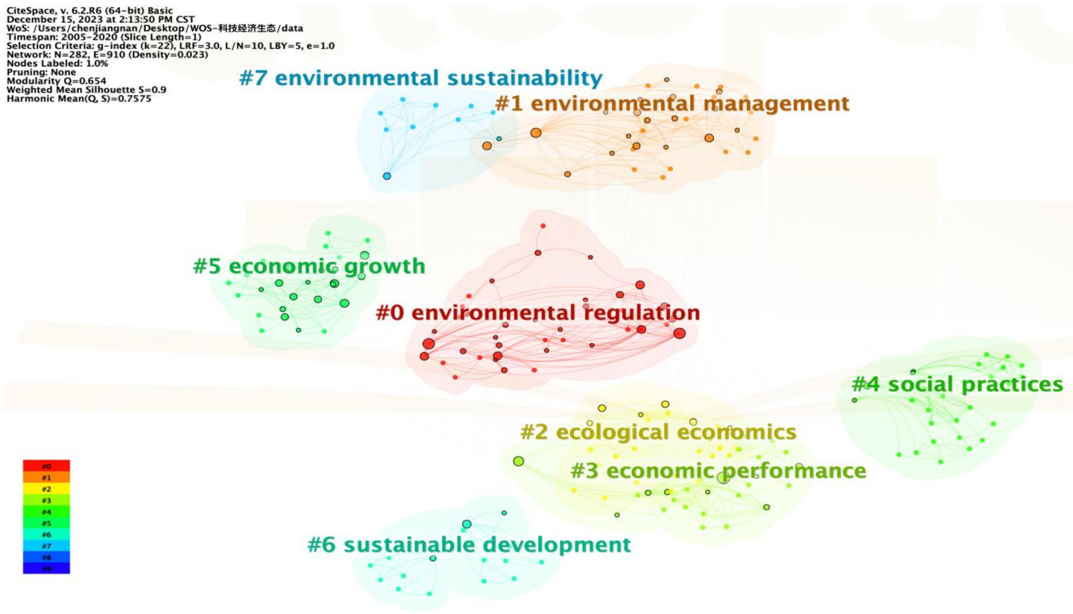

Figure 5 Knowledge graph of keyword clustering for research hotspots in development of science and technology, economics, and ecology of WOS journals from 2005 to 2020.

From "Figure 5", it can be seen that the top 8 clusters with the largest keywords in the research hotspots of science and technology, economy, and ecology in China are #0 environmental regulation, #1 environmental management, #2 ecological economics, #3 economic performance, #4 social practices, #5 economic growth, #6 sustainable development, and #7 environmental sustainability. By clustering the names, it can be observed that in the WOS core database, research in this field focuses more on exploring ecological environment and economic growth compared to technological development.

In order to further summarize the hot research topics related to development of science and technology, economy, and ecology in the WOS core library since 2005, the above 8 clusters and their respective top 5 keyword lists were exported, as shown in "Table 4".

Table 4. Keyword clustering table

Cluster number	Clustering Size	Tag words	S value	Average usage year
#0	40	environmental regulation; spatial panel data model; economic integration; yangtze river delta; techno-economic analysis	0.811	2017
#1	35	environmental management; circular economy; value creation; decomposition; pollution	0.795	2015
#2	28	ecological economics; research trends; environmental technology; water resources; biodiversity	0.947	2009
#3	28	economic performance; dynamic capabilities; technological proactivity; environmental proactivity; environmental uncertainty measures	0.875	2012
#4	27	social practices; behaviour change; ecological citizenship; environmental psychology; climate change	0.985	2013
#5	27	economic growth; kuznets curve; energy innovation; environmental degradation; impulse response function	0.886	2017
#6	18	sustainable development; evaluation method; urban green development; DPSIR model; technology adoption	0.968	2014
#7	10	environmental sustainability; CO_2 mitigation; low-carbon power generation; energy security; resource-economy comprehensive efficiency	0.992	2015

By combining high-frequency keyword clustering and keyword clustering graph, it can be analyzed that the hotspots in the research fields of development of science and technology, economics, and ecology in the WOS core database are mainly focused on the study of their interrelationships, analysis of influencing factors, and evaluation.

The first is the research on the interrelationship among science and technology, economics, and ecology. Scholars in this field have shown that the relationship among science and technology, economics, and ecology is interdependent and mutually restrictive. The relevant research mainly focuses on the theoretical study of the relationship among science and technology, economics, and ecology, as well as empirical research on the relationship between the three in specific situations. Firstly, theoretical research: Wang, Mingyue, and others[11] used the Stackelberg game theory model to explore the correlation between green technology innovation and economic and environmental performance. The results showed that green technology innovation can effectively reduce waste emissions, improve environmental performance, and enhance economic performance; Sauve et al.[12] clarified the concepts of environmental science, sustainable development, and circular economy, analyzed their interrelationships, and identified the opportunities and challenges associated with each concept. Secondly, empirical research, such as Nasrollahi et al.[13], analyzed the relationship between population, industrialization, economy, technology, and sustainable development in the Middle East, North Africa, and OECD countries from 1975 to 2015. The results showed that although there were slight negative impacts from population and industrialization during this period, there were also positive impacts from technology and international environmental agreements, and the sustainability of the Middle East, North Africa, and OECD countries was weak but strong.

The second is the construction of a model for sciencitific and technological, economic, and ecological development and analysis and evaluation of influencing factors. Among the models and methods currently used in the WOS core database for analyzing and evaluating influencing factors in this field, spatial panel data models[14], impulse response[15], and DPSIR models[16] are the main ones. In addition, STIRPAT models[17], Gaussian mixture models[18], structural equation models[19], multiple regression models[20], data envelopment analysis models[21], and TOPSIS methods[22] are also included. Shu-Hong Wang et al.[23] studied the ocean in Qingdao, China and constructed a TERE evaluation model for science and technology (T), environment (E), resources (R), and economy (E) to assess their carrying capacity; Wang Junsong et al.[24] integrated social and economic networks into a spatial Durbin model using prefecture level data and network data to study how economic, environmental regulations, and technology affect pollutant intensity and emissions. The results showed that these factors affect the pollutant emission intensity of neighboring areas through social, economic, and spatial networks, while technology can effectively reduce pollutant emissions through economic networks; Yurdakul et al.[25] constructed a structural equation model to analyze Türkiye's ecological innovation technology capability. The results showed that it has a direct impact on pollution prevention, resource conservation and recovery, and also has an indirect positive impact on economic performance.

4. CONCLUSION

Taking 162 literature related to the development of science and technology, economics, and ecology from 2005 to 2020 included in the WOS core database as the research object, this study adopts a combination of bibliometric and visual analysis methods to analyze the literature characteristics and research hotspots in this field. The research conclusions drawn include three aspects:

According to the analysis of the characteristics of the literature, the overall number of publications in this research field in the WOS core database shows an increasing trend, with some fluctuations. It can be divided into three stages: the initial stage (2005-2016), the growth stage (2017-2018), and the development stage (2019-2020). Based on the trend of publications, it can be seen that the current research in this field is in an upward trend with great development space. From the perspective of institutional cooperation distribution, universities and research institutions in this field cooperate closely, presenting a dispersed team layout. Among them, research groups mainly consist of research institutions from universities in the United States and China, as well as institutional groups engaged in cross-border cooperation. Among the research authors in this field, there is no representative author formed, the number of publications by individual authors is relatively small, and a core author group has not yet been formed.

According to the analysis of research hotspots and research frontiers, the research in this field in the WOS core library is based on "management", "dynamics", "sustainable development", "determinants" and "sustainability". The research on the influencing factors of the coordinated development of economics and ecology and the research on the development of science and technology, economics, and ecology from the perspective of sustainability are the hot issues of research. At the same time, the research frontier in the field of ecological governance can be divided into three stages, mainly including "ecological economics" and "dynamics", "climate change", "determinants" and "management", "research and development", "sustainable development" and "city".

Through keyword clustering for hot topic analysis, research hotspots in the fields of science and technology, economics, and ecology are focused on the study of their interrelationships, analysis of influencing factors, and evaluation. The research on the interrelationship among the three mainly focuses on theoretical research on the interrelationship between technology, economy, and ecology, as well as empirical research on the interrelationship among the three in specific situations; For the analysis and evaluation of influencing factors in this field, relevant models such as spatial panel data model, DPSIR model, and STIRPAT model are mainly constructed.

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