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Research Progress and Hot-spot Analysis of The Economic Complexity Research Based on CiteSpace

Rui Xue[1], KeYu Li[1], FeiFei Wang[1*] and Claude Baron[2]

Abstract

Economic complexity has been one of the key topics in evolutionary economic geography recently. It focuses on the structural transformation of industries and endogenous growth paths contributes to the understanding of the process of structural transformation of regional economies and is important for the deepening of theories such as development economics. However, little attention is currently being paid to the quantitative description of the evolution of this rapidly developing field of study. Therefore, to reveal the development process, hot topics and evolutionary trends of economic complexity research, a bibliometric approach and the visual analysis software CiteSpace were implemented based on 403 literatures related to economic complexity in the Web of Science core database from 1998-2022. The results show that the overall trend of economic complexity is on the rise, with hot topics involving diversity, export complexity, ecology and environment, international trade and many other fields. At the same time, the overall distribution of authors is relatively fragmented, and there is less interdisciplinary collaboration between highly productive authors. Most publishers have formed collaborative relationships with other institutions, and those that publish more have formed close partnerships.

JEL classification numbers: F14.
Keywords: Economic complexity, Research progress, Hot-spot analysis, Bibliometric approach, CiteSpace.

[1] College of Economics and Management, Beijing University of Technology, 100124, Beijing, China.
[2] Université de Toulouse, ISAE-SUPAERO, LAAS-CNRS, 31400, Toulouse, France.

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1. Introduction

The study of Economic complexity aims to reveal a country's competitive advantage and potential in the global trading system. Economic complexity is a new measure of a country's economic development level. The theory of economic complexity believes that the level of national economic development depends on its industrial structure and complexity. This complexity not only refers to the quality of the industry but, more importantly, to the connections and interdependence between industries and the complexity of technology, knowledge, and other aspects. In theory, countries with higher economic complexity have more significant economic growth potential because they have more opportunities to engage in high-value industrial activities. Economic complexity was first proposed in Hidalgo and Hausmann's (2009) article and later systematically explained from the perspectives of the concept, measurement methods, and practical significance of the economic complexity index in the book "Atlas of economic complexity: mapping paths to prosperity" published by Hausmann et al. (2014). Due to the high industrialization level and more complex production structures and processes, developed countries often export products that contain more different types of intermediate product inputs. Therefore, the economic complexity of developed countries is higher than developing countries. Numerous studies have shown that these countries exporting higher technology products subsequently achieve faster economic growth, so the concept of economic complexity is an excellent predictor of economic growth.

A lots researchers have also attempted to explain economic complexity from different economic theories. Since David Ricardo's theory of comparative advantage, he has tried to explain why different countries choose to specialize in different types of products from the differences in production technology and factor endowments and the resulting differences in relative costs, and his theory has also successfully explained part of the reasons for international trade. Hausmann et al. (2007) first proposed the concept of economic complexity in his paper and expanded the theoretical analysis framework of "cost discovery" established in another 2003 paper. Starting from the process of "cost discovery", he explained that the "demonstration effect" generated by export enterprises in the development and production of high-tech products could attract the transfer of production factors to related industries, thereby driving overall productivity improvement. Enterprises produce products with low production costs and high technical complexity through technological innovation and continuous exploration. At present, research on economic complexity can be generally divided into two categories: The first category focuses on the impact of increased economic complexity on the social economy, such as how increased economic complexity can effectively predict economic growth (Hidalgo and Hausmann, 2009; Stojkoski et al., 2016; Tacchella et al., 2018; Poncet and De Waldemar, 2013; Domini, 2022; Ourens, 2012), income inequality (Hartmann et al., 2017; Zhu et al., 2020; Sbardella et al., 2017; Bandeira Morais et al., 2018; Fawaz and Rahnama-Moghadamm, 2019), carbon emissions as well as energy consumption (Neagu, 2019; Can and Gozgor, 2017; Lapatinas et al.,

2019). The second category focuses on decomposing economic complexity indicators and analyzing their influencing factors individually, as well as which factors will promote the country's ability to produce more complex products. For example, some scholars explore the impact paths of increasing economic complexity from the perspectives of different tax models (Lapatinas et al, 2019), intermediate input quality (Liu et al., 2023), intellectual property and innovation (Sweet and Maggio, 2015), economic institutions (Vu, 2022), domestic population diversification (Bahar et al., 2022), and trade structure reforms (Demir, 2019).

However, even studying economic complexity has profound practical significance and it has been one of the key topics in evolutionary economic geography recently, little attention is currently being paid to the quantitative description of the evolution of this rapidly developing field of study. Therefore, considering the importance of such a research direction, this paper reveal the development process, hot topics and evolutionary trends of economic complexity research. In order to achieve the above objective, we first collect 403 research papers related to economic complexity research in the Web of Science (WoS) core database from 1998-2022. Then a bibliometric approach and the visual analysis software CiteSpace are implemented to examine the development process, hot topics and evolutionary trends.

The remainder of this paper is organized as follows. Section 2 presents the data sources and the methodologies that will be used in this paper. Section 3 invests the trends of economic complexity research from the bibliometric analysis, evolution of knowledge structure, research hotspots and frontier domains perspectives. Section 4 summarizes the research results and presents the viewpoints of the study.

2. Data Sources and Methods

2.1 Data Sources

Web of Science is a commonly used database in literature analysis, which includes approximately 12000 high-quality literature from mainstream journals and covers 256 disciplinary systems. Because WoS collects a large number of high-quality literature and journals and provides complete basic information about authors, institutions, and journals, scholars often regard it as an ideal database for literature analysis (Van Leeuwen, 2006).

This article uses the WoS core collection database as the data source. Documents published with the words “Complexity”, “Product Sophistication”, and “Economic Complexity” in titles, abstracts, author keywords, and keywords were downloaded. The literature type is selected as article and review, and the search time is 1996-2022. After searching, 730 articles were obtained from the WoS database. To ensure the literature data's validity, we obtained 403 WoS database articles after removing duplicate literature and literature unrelated to the research topic.

2.2 Methods

The CiteSpace software will be used to convert and deduplicate the WoS core collection database literature and set the time slice to 1 year. This study selects node types such as “Minimum Spanning Tree” and “Pruning slice networks” and draw visual networks of author and institutional collaboration, keyword co-word, and keyword bursts. In the generated visual knowledge network, if a node has a purple circle, it indicates that the node has a relatively high centrality and has more links with other nodes; In addition, in the following visualization network, nodes with red circles indicate that the citation of the corresponding journal at this node has increased rapidly over some time.

3. Empirical Results

3.1 Bibliometric Analysis

A preliminary analysis of the number of publications on economic complexity in recent years can provide a rough understanding of when scholars began their research in this field and the changing process of research enthusiasm. As shown in Figure 1, based on the literature search results of the WoS database, the literature research on economic complexity can be roughly divided into three stages.

From the analysis of the number of articles published by the authors in Figure 1, it can be seen that research in the field of economic complexity began with Hausmann's paper “What you export matters” published in 2006. However, due to the relatively limited research on economic complexity in the academic community, the popularity of related research remained the same in the following years of his publication. From 1998 to 2011, the number of related paper publications remained around zero in the first stage.

From 2012 to 2018, scholars' attention to economic complexity began to increase in the second phase, and the annual publication volume began to proliferate. At this point, scholars mainly focused on innovating and developing the construction method of economic complexity indicators proposed by Hausmann. The number of posts also exceeded 10 in 2013 and gradually increased in the following years, reaching 48 in 2018.

The third stage is from 2019 to the present, during which the number of papers related to the field has shown explosive growth. The number of articles published temporarily decreased from 48 in 2018 to 33 in 2019 and continued to increase after 2020, ultimately reaching 94 in 2022, the highest number in history. At this stage, many scholars analyze the potential impact of economic complexity on various aspects of the economy and explore the factors that may cause changes in economic complexity. This indicates that scholars are increasingly paying attention to economic complexity in the third stage.

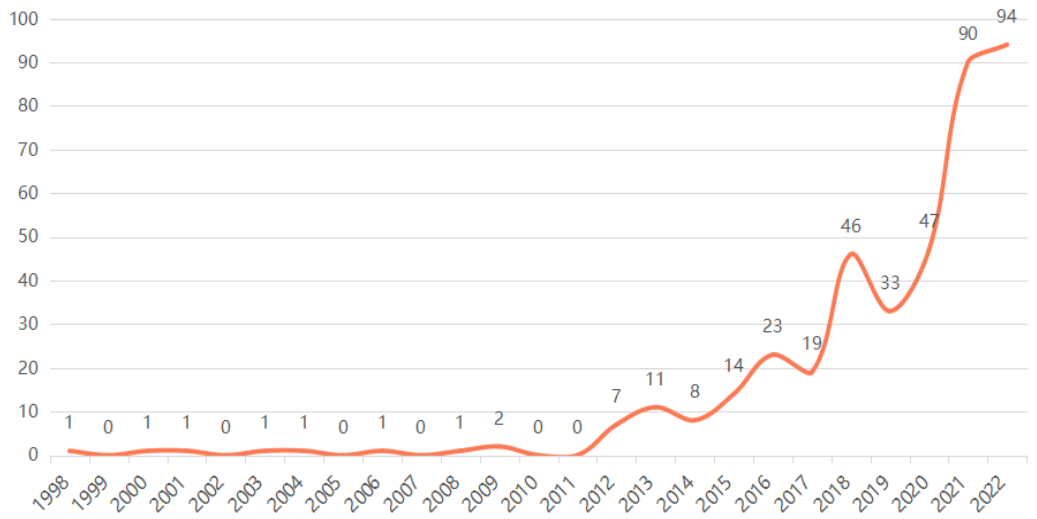

Figure 1: Trends in overall publication volume of economic complexity

3.2 Author and institutional collaboration

The author collaboration network showcases authors' contribution to economic complexity and the collaborative relationships between authors. In CiteSpace, select Author as the node type and generate an author collaboration network, as shown in Figure 2. In addition, Table 1 provides a detailed presentation of the top 10 authors in the study of economic complexity. Figure 2 contains 291 nodes and 168 connections, with a network density value of 0.004, indicating that the overall distribution of authors is relatively scattered and there is less cross-domain cooperation among high-output authors. The font size of the nodes in Figure 2 represents the strength of the author's centrality, the size of the node's wheel ring represents the author's publication amount, and the thickness and number of connections between authors represent the tightness of the cooperation relationship.

Figure 2: Author Collaboration Network

From the perspective of the overall research team's publication volume, the research team represented by Pietronero (12) has the highest publication volume. Pietronero is committed to finding different mathematical models to construct economic complexity indicators and further evaluate the export competitiveness of various countries. Pietronero maintains a close cooperative relationship with other high-yield authors, and among the authors who form cooperative relationships with Pietronero, Tacchella (6), Zaccaria (7), and Pugliese (4) all have the highest publication volume in the field. The research team Shahzad (7) has the second-highest number of publications. Shahzad studies the relationship and impact mechanism between economic complexity, energy consumption, and environmental pollution from the perspective of economic complexity. The third highest number of publications is a three-person research team represented by Lapatinas, with authors Garas and Adam maintaining close collaboration with Lapatinas. Lapatinas mainly focuses on the influencing factors and mechanisms of economic complexity, such as the impact of the Internet and tax levels on economic complexity.

Table 1: Top 10 authors in terms of publication frequency

No.	Author	Frequency	No.	Author	Frequency
1	Pietronero	12	6	Dogan	6
2	Shahzad	7	7	Tacchella	6
3	Cristelli	7	8	Balsalobre	5
4	Zaccaria	7	9	Ahmed	5
5	Lapatinas	6	10	Liao	5

Table 2 provides a detailed display of the top 10 research institutions regarding publication volume. The size of nodes is directly proportional to the number of documents issued by institutions, and the connections between nodes represent the intensity of cooperation between different institutions.

Table 2: Top 10 research institutions' publication frequency

No.	Institution	Frequency
1	European Commission	9
2	Anhui Univ Finance & Econ	9
3	Univ Fribourg	8
4	CNR	8
5	Cyprus Int Univ	6
6	Harvard Univ	6
7	Wuhan Univ	6
8	ILMA Univ	5
9	Shenzhen Univ	5
10	Russian Presidential Acad Natl Econ & Publ Adm	5

The generated institutional cooperation network is shown in Figure 3, which includes 285 nodes and 167 connections, with a network density value of 0.0041. Figure 3 shows that most institutions with a large number of publications have formed close cooperative relationships with other institutions. Among them, the institutional research team represented by European Commission and CNR, and the institutional research team represented by Anhui Univ Finance&Econ, are the two most influential groups of institutional collaborations. Other smaller teams such as Univ Fribourg, MIT, and Shenzhen Univ have also published a large number of articles in the field of economic complexity. From the perspective of institutional publication volume, the institutions with the highest publication volume are European Commission and Anhui Univ Finance&Econ, with nine publications. Other institutions with a publication volume of over five articles are Univ Fribourg (8), CNR (8), Univ Castilla La Mancha (7), Wuhan Univ (6), Cyrus Int Univ (6), Harvard Univ (6), ILMA Univ (5), Shenzhen Univ (5), Russian Presidential Acad Natl Econ&Public Adm (5), and Beijing Inst Techno (5), which play an essential role in promoting research on economic complexity.

Figure 3: Institutional Collaboration Network

3.3 Evolution of Knowledge Structure

3.3.1 Highly-cited Journals

By analyzing the citation of journals, we can delve deeper into which journals are representative and dominant in economic complexity research.

As shown in Figure 4, we can see that the journal with the highest citation frequency in economic complexity is “Journal of Economic Growth”, with 277 citations. The second most cited journal is “Proceedings of the National Academy of Sciences”, with 231 citations. The third-ranked journal is “World Development” with 211 citations. It also indicates the authoritative position of these three most cited journals in the research field of economic complexity. The other eight most cited journals are “American Economic Review” (203), “Quarterly Journal of Economics” (161), “Science” (152), “Review of Economics and Statistics” (142), “Journal of International Economics” (142), “Journal of Development Economics” (140), “Econometrica” (139), and “Review of Economic Studies” (135).

The nodes with both high citation frequency and high centrality are “American Economic Review” (0.30), “Econometrica” (0.22), “Journal of Economics” (0.15), “World Development” (0.14), “Quarterly Journal of Economics” (0.14), “Review of Economics Studies” (0.13), and “Journal of Economic Growth” (0.11). In the journal co-citation network, the citation frequency of many journals has increased rapidly over some time. For example, the citation frequency of the journal “China Economic Review” has rapidly increased, from 9 times in 2019 to 14 times in 2020 and then to 22 times in 2021; The number of citations for the journal “Applied Economics” increased from 0 in 2018 to 11 in 2019, and finally to 20 in 2021. The

sudden increase in journal citation frequency within a short period indicates that the author has published high-level papers during this period.

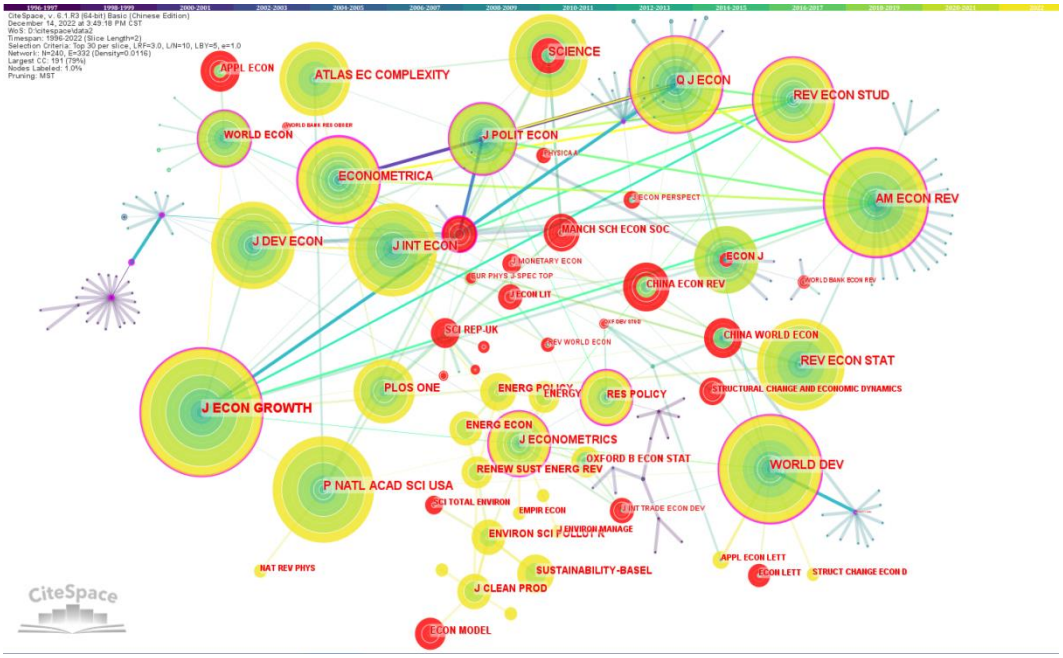

Figure 4: Journal co-citation network

3.3.2 Highly-cited Documents

Documents citation analysis is the basis of co-citation and its coupling analysis. Scholars cite the research achievements of their predecessors in their papers, and the references in their papers represent their respect for their research methods and theories. Citing other papers in a paper can be seen as the transfer of professional knowledge from a previous person's research field to the current research field, which is the process of generating new knowledge from a knowledge unit in a state of dissociation to recombination. The citation of published papers by other scholars is a continuation of this process, thus forming a citation network for literature. Through literature co-citation network analysis, it is possible to identify representative literature in the current research field and its distribution over time. One can trace back to the source or trend of development through citation networks, thus gaining a rough understanding of the entire research field.

Figure 5 shows the network structure formed based on author citation behavior in economic complexity, with a period of 1996 to 2022 and other settings remaining unchanged. Each node represents a piece of literature, and the link between the two nodes represents that these two pieces of literature are simultaneously cited by the third literature, thus forming a co-citation relationship between these two pieces of literature.

Figure 5 shows that the most frequently cited literature on economic complexity is Hartman's article titled “Linking economic complexity, institutions, and income

inequality" published in "World Development" in 2017, cited 68 times. Hartmann further studied the relationship between economic complexity and economic growth and income inequality based on the Economic Complexity Index (ECI) constructed by Hidalgo and Hausmann (2009). Research suggests that economic complexity strongly predicts subsequent economic growth and correlates with income inequality in countries and regions. Specifically, countries and regions with more complex production structures have a very high degree of industrialization. These countries can export more complex products and have more sound economic systems and higher levels of human capital to ensure reasonable income distribution. Therefore, from the empirical results, countries with higher economic complexity indices often have lower income inequality indices. Hartmann linked the economic complexity index with the income inequality index, laying a solid theoretical foundation for further research by scholars later on.

Hidalgo (2021) systematically summarized two significant branches of literature on economic complexity over the past decade: constructing economic complexity indicators and evolving specialization models. In recent years, research on the relationship between the ecological environment and carbon emissions has gradually been valued by scholars. For example, the second cited literature is Can's "The impact of economic complexity on carbon emissions: evidence from France" published in 2017. This literature differs from Hartmann's previous focus on the impact of economic complexity on economic growth and income inequality. Taking France as an example. Can considers the impact of economic complexity and energy consumption on carbon emissions and proves that the increase in economic complexity significantly suppresses carbon emissions in the long term.

The literature that forms a co-citation relationship with Can and Gozgor (2017) and ranks third in citation quantity is "The link between economic complexity and carbon emissions in the European Union countries: a model Based on the Environmental Kuznets Curve (EKC) approach" published by Neagu (2019). This literature still focuses on the impact mechanism of economic complexity on carbon emissions. It applies the EKC to analyze how the increase in economic complexity in European countries initially increases carbon emissions. When economic complexity increases to a certain level, it will enter a turning point, and continuing to increase economic complexity will begin to suppress carbon emission levels. That is, the impact of economic complexity on carbon emissions shows a typical inverted U-shaped curve.

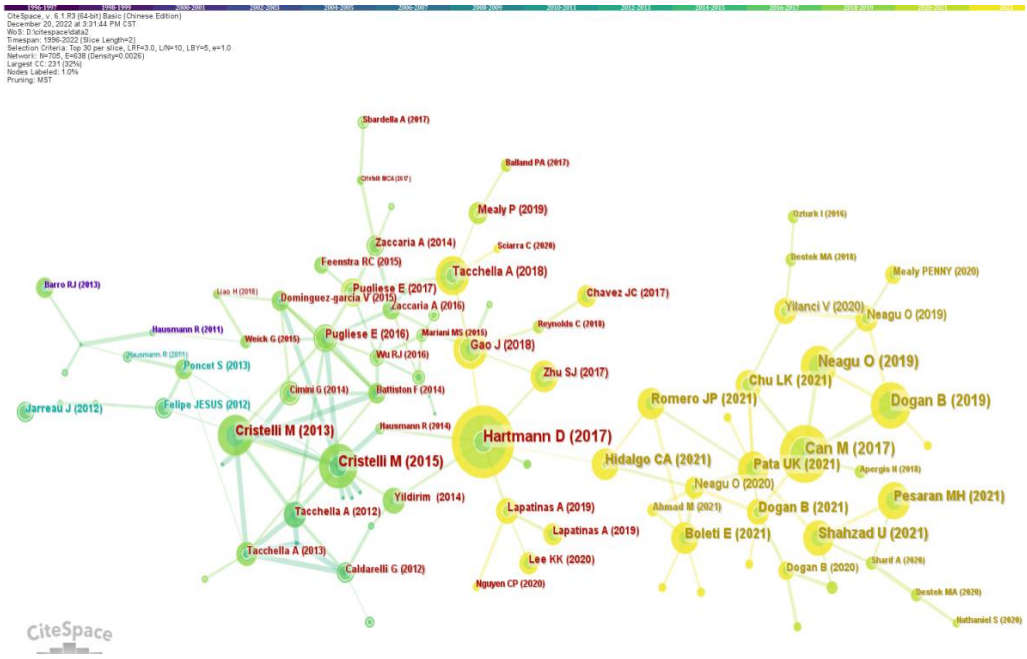

Figure 5: Documents co-citation network

3.3.3 Highly-cited Authors

The analysis of the author citation frequency focuses on the interrelationships between co-citations among different authors. After each author completes a paper, they will include the names of other authors cited in their references, indicating that they have referred to other authors' viewpoints, research findings, or research methods and also representing recognition of their research findings. The higher the co-citation frequency between the two authors, the more similar their research fields are. The different citation relationships among authors in this research field form a vast network of author citations. CiteSpace's role is to visualize this citation network, allowing people to intuitively observe which authors have authoritative research status and what co-citation relationships are with which authors.

Figure 6 lists the top thirty authors with the highest frequency of citations. The size of a node is proportional to its citation frequency, and nodes with a purple outer ring have a high centrality, indicating that the author is often critical and forms a co-citation relationship with many authors. In the author-co-cited visualization network, the node with the highest frequency of citations is Hausmann, with 308 citations. Due to improvements made by Hausmann, based on the comparative advantage of display, he constructed the product technical complexity index for the first time. He proposed the "cost discovery" theory, making him one of the earliest authors to conduct research on economic complexity. In the development and evolution of the research field, the frequency of citations by an author does not necessarily mean a high degree of centrality. When an author has a high frequency of citations and a high degree of centrality, he is one of the most representative authors in this field.

The second most frequently cited node is Hidalgo, with 246 citations. At the same

time, this node has a purple outer ring with a centrality of 0.16. This node has a high frequency of citations and many connections with other authors, indicating that Hidalgo is a critical author in this field. Hidalgo made outstanding contributions to the development of economic complexity indicators and conducted in-depth discussions on product production space and geographical location (Hidalgo et al., 2007). It is worth mentioning that in 2009, Hidalgo and Hausmann jointly proposed the concept of economic complexity in their co-authored paper "The building blocks of economic complexity", so there is a collaborative relationship between the two authors.

The third most frequently cited author is Balassa, who proposed the Revealed Comparative Advantage Index in 1965 and used it to determine which industries in a country have more export competitiveness, thereby revealing a country's comparative advantage in international trade (Balassa, 1965). The Revealed Comparative Advantage Index is the most straightforward indicator for measuring the competitiveness of a country's products or industries in the international market. It aims to quantitatively describe the relative export performance of various industries or product groups within a country. Later, this index was also adopted by Hausmann et al. (2007), who used the revealed comparative advantage formula as a weight to calculate the export technical sophistication for each country.

Rodrik ranked fourth in the frequency of citations, with 101 citations. In the same year that Hausmann jointly proposed the Export Sophistication Index, Rodrik then measured China's export sophistication and found that the sophistication of China's export products was already much higher than that of countries with the same income, similar to countries with per capita GDP three times higher (Rodrik, 2006). Moreover, this discovery has led many scholars to study why China's export technical sophistication is so high that it far exceeds its economic development level. For example, Amiti and Freund (2010) found that China's reliance on processing trade products for export is the main reason for its high export sophistication; Assche and Gangnes (2010) excluded the impact of processing trade when calculating the export technical sophistication, and found that there was no significant upgrade in the export structure of Chinese electronic products. The research of these scholars has widely applied the concept of export sophistication and considered the influencing factor of processing trade when using economic complexity for research, thus promoting the development of international trade theory. Other authors with a high frequency of citations include Tacchella (93), Lall (85), Cristelli (78), Hartmann (74), Grossman (65), and others, all of whom have had a significant impact in the field of economic complexity.

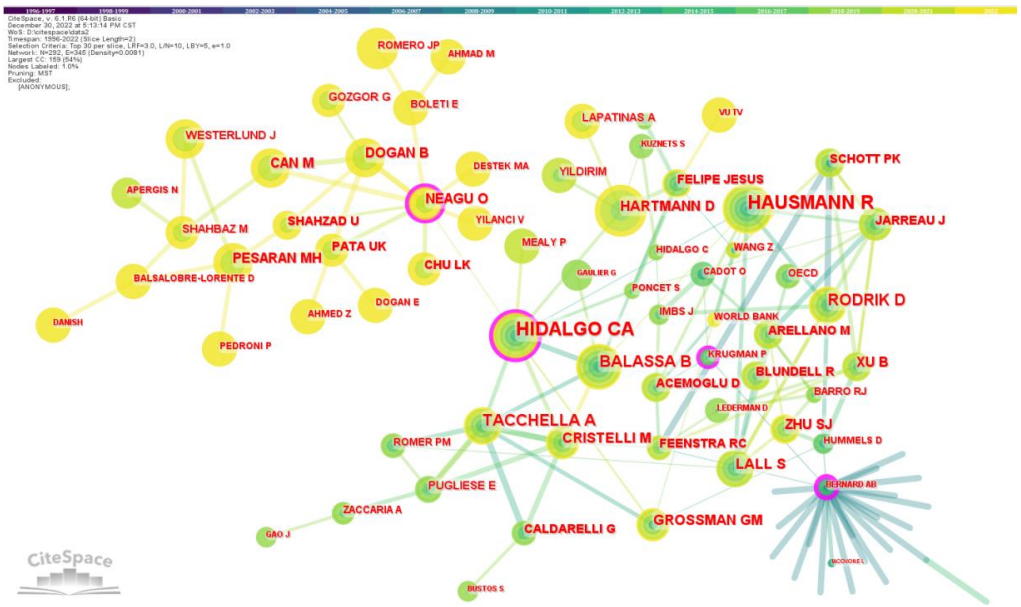

Figure 6: Author co-citation network

In addition, based on the geographical distribution of the institutions where the cited authors are located, the top 30 frequently cited authors are mainly distributed in North America, Asia, and Europe. Moreover, the distribution of authors in these three continents is the same, with nine authors in North America, ten in Europe, ten in Asia, and one in South America among the highly cited authors. In addition, these authors are mainly concentrated in the United States (9), Türkiye (5), Italy (4), Britain (3), and China (3). From the distribution of the author's country, there is no doubt that the United States holds an overwhelming advantage, with almost one-third of the top 30 cited authors indicating that American scholars are leading and leading in economic complexity research. In addition, there are other countries with one author each, namely France (1), Spain (1), Switzerland (1), Brazil (1), Vietnam (1), and Pakistan (1).

3.4 Research Hotspots and Frontier Domains

3.4.1 Keyword Co-word Analysis

The keywords in an article often reflect the research topic of the article. As a refined expression of the research topic in an academic paper, their relevance can reveal the internal connections of knowledge in the subject field. The knowledge structure graph of keyword co-occurrence is beneficial for analyzing hotspots and their evolution, especially in conjunction with using emergent words to identify hot vocabulary from different years. Compared to co-citation and coupling in literature, the results obtained from co-occurrence word analysis are very intuitive. People can directly analyze the themes of their research field through the results of the co-word analysis.

We switch the node type to Keyword, select Minimum Spanning Tree for Pruning, and generate a keyword co-word network. After performing the above operations, the generated keyword co-word network is shown in Figure 7, which includes 303 nodes and 479 links.

Each node represents a keyword, and the links between nodes indicate that the keywords represented by these two nodes appear simultaneously in the same literature, and the thickness of the links is proportional to the frequency of co-occurrence of the corresponding keywords of these two nodes; The color of the link represents the year when two keywords first appeared together. The size of each node is proportional to the co-occurrence frequency of the corresponding keywords, and a series of time-sliced tree rings represent each node. CiteSpace provides two indicators, module value (Q value) and average contour value (S value), based on network structure and clustering clarity, which can serve as a basis for us to evaluate the network rendering effect. The Q value of this keyword visualization result is 0.8269>0.3, indicating that the community structure divided is significant. The S value is 0.959, indicating that clustering is efficient and convincing.

Figure 7 shows the keyword co-word network, while Table 3 details the top 10 keywords in the word frequency ranking. Due to the use of "economic complexity" and its synonyms as keywords in literature retrieval, "economic complexity" has the highest frequency, with a frequency of up to 122. The other top ten high-frequency keywords are "growth" (117), "trade" (81), "economic growth" (57), "CO2 emission" (45), "panel data" (42), "innovation" (38), "foreign direct investment" (35), "impact" (35), and "export education" (33). The frequency of "economic complexity" and "growth" is more significant than 100, indicating that the exploration of "economic complexity" and "growth" is the core of research in the field of economic complexity.

Keyword centrality is essential in the entire keyword co-word network and represents the core research topic for a certain period. From a centrality perspective, there are a total of 13 keywords with centrality above 0.1, with the highest centrality being "model" (0.22), "growth" (0.17), "conversion" (0.15), "quality" (0.14), "trade" (0.12), "financial development" (0.12), and "export education" (0.11). These keywords are the core nodes of the entire research field, and their surroundings are densely covered with research networks from different periods, indicating that they have always been a hot topic in this research field.

Figure 7: Keyword co-word network

Table 3: Top 10 keywords in word frequency ranking

No.	Keyword	Centrality	Frequency	Beginning time
1	Economic complexity	0.09	122	2013
2	Growth	0.17	117	2013
3	Trade	0.12	81	2004
4	Economic growth	0.11	57	2013
5	CO2 emission	0.09	45	2017
6	Panel data	0.10	42	2016
7	Innovation	0.05	38	2013
8	Foreign sophistication	0.11	35	2009
9	Impact	0.03	35	2019
10	Export sophistication	0.11	33	2012

3.4.2 Staged Frontier Fields Analysis

We obtain prominent words through the Burst function of CiteSpace. Emergence words are hot words determined based on the word frequency growth rate of titles, abstracts, and keywords, and the degree of the emergence of these words reflects the strength of the hot words. As shown in Figure 8, research on economic complexity has so far seen the emergence of prominent terms such as “quality”, “trade”, “economic development”, and “visualization” from 2012 to 2020, which can be divided into two stages in this research field.

The first stage is from 2012 to 2019, and the keywords for this stage are “quality” and “trade”. At this stage, how to promote the upgrading of export product quality

and explore the factors and mechanisms that affect the upgrading of export product quality have gradually become research hotspots. Afterward, scholars began to link export technical sophistication with product quality, believing that products with higher complexity will have higher quality and better achieve export trade upgrading in international trade (Antimiani et al., 2012). At the same time, some scholars have focused their research on constructing appropriate methods to measure product quality. (Khandelwal et al., 2013) Calculate the annual price of each product at the export destination for each enterprise as the basis for estimating product quality.

The second stage is from 2016 to 2021, during which there has been a surge in research on "economic development" and "communication". Many scholars have studied the factors and channels promoting economic growth. For example, Eck and Huber (2016) believes that FDI can promote the economic development of host countries through technology and knowledge spillover effects. One of the mechanisms of spillover effects is that FDI can enhance the ability of local manufacturing enterprises in host countries to produce more complex products. Similar to Eck's viewpoint, Arbia et al. (2023) argue that although FDI has no significant impact on economic development in the short term, it has a positive contribution to economic development in the long run. Subsequently, Hartmann et al. (2017) linked economic development to income inequality and used a series of research methods to argue that producing more complex products can promote a country's economic development and narrow the income inequality gap.

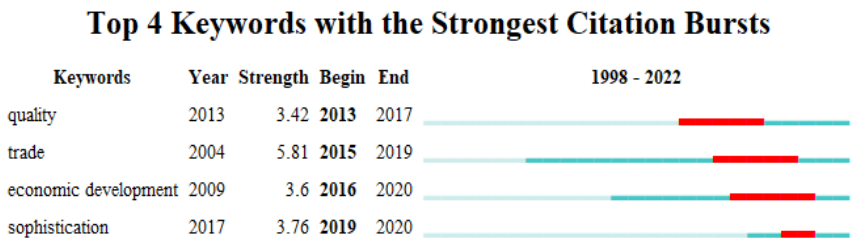

Figure 8: Keywords with citation bursts

3.4.3 Development Path and Research Theme

Figure 9 shows the timeline view of clustering. The timeline view of clustering is presented as a "Timeline" based on the clustering view, outlining the relationship between each cluster and the period of each cluster and displaying the trend of the entire cluster development. The network timeline view of each cluster is arranged on the horizontal timeline, with the time direction moving to the right. From the timeline graph, keyword clustering is mainly concentrated on the significant clusters of "renewable energy", "export visualization", "economic complexity", "ecological footprint", "diversification", "international trade", "competitiveness", and "economic development".

The keywords consistently maintained high popularity in Cluster # 5 Economic Complexity, including economic complexity, growth, and panel data. Currently, there is a wealth of literature on economic complexity. In the beginning, scholars mainly explained the concept and constructed indicators of economic complexity (Hidalgo and Hausmann, 2009), and gradually developed to analyze the influencing factors of economic complexity. Based on the economic complexity indicator constructed by Hidalgo, some scholars have subsequently improved this indicator's calculation method further to enhance economic complexity's predictive ability for economic growth. Economic complexity is usually associated with economic development and income distribution. For example, Hartmann found through multiple regression analysis methods that countries with higher economic complexity have significantly lower levels of income distribution inequality than those with lower economic complexity (Hartmann et al., 2017). From the perspective of productivity, some scholars believe a significant positive correlation exists between a country's economic complexity and productivity. And this viewpoint is consistent with the absorbent capacity theory (Sweet and Eterovic, 2019). After measuring the economic complexity indicators of some provinces in China over the past 25 years, Gao found that increasing regional economic complexity can promote economic development and reduce income distribution inequality (Gao and Zhou, 2018). Some scholars have also found that the industrial upgrading effect of products with high production complexity is limited, especially for products with high complexity produced through processing trade that do not bring direct benefits (Poncet and De Waldemar, 2013).

Cluster # 1 Export Sophistication and Cluster # 2 International Trade are two branches that scholars have paid more attention to in recent years, among which Cluster # 1 and Cluster # 2 are often placed together as research objects by scholars. The essential keywords in the two clusters include quality, trade, domestic inputs, specialization, foreign direct investment, etc. What impact will increase the export complexity have on future economic development? How do we construct export complexity indicators? These issues have always been the focus of discussion among scholars. Hausmann has made groundbreaking contributions to the construction of export complexity indicators. Hausmann et al. (2007) calculated the export complexity of products produced by each country by weighted average per capita GDP based on the revealed comparative advantage of each country. Later, scholars further expanded their research on the impact of increasing technological complexity on the economy based on the complexity index of export technology. Hausmann et al. (2007) pointed out that measuring export complexity can effectively explain and predict economic growth. Countries exporting higher technological content and more complex products are expected to experience faster economic growth in the long term. Lin studied the impact of export technology complexity on the per capita GDP of sub-Saharan African countries and found that increasing complexity can indeed increase local per capita GDP (Lin et al., 2017). Jarreau and Poncet (2012) used China's provincial panel data from 1997 to 2009 to examine the relationship between export technology complexity and economic

growth. The study shows that improving export technology complexity promotes regional economic growth. The growth benefits brought about by export upgrading are not unconditional. Specifically, the technological innovation of domestic enterprises engaged in general trade is an important driving force for economic growth. However, neither processing trade activities nor importing highly complex products from foreign companies will bring direct benefits. It indicates that the source of product upgrades is essential, and domestic embedding is the key to promoting growth (Poncet and De Waldemar, 2013). However, the following question is, what factors affect or determine the complexity of export products? Previous studies have shown that foreign direct investment can effectively increase the export sophistication of host countries, with an increase in the proportion of foreign investment from developed countries significantly promoting the export sophistication of Chinese industries (Bin and Jiangyong, 2009). Zhang and Chen (2020) found that the impact of China's OFDI on the export sophistication in different regions of the home country is different. That is, OFDI can significantly increase export sophistication in coastal areas, but its impact on inland areas is insignificant. Moreover, export sophistication plays a different role for developed and developing countries. The higher complexity in developed countries is mainly due to income levels and economic growth (Lall et al., 2006), higher quality of human capital, and growth in R&D investment (Zhang and Yang, 2016). Unlike developed countries, the increase in export sophistication in developing countries is mainly due to the spillover effects of FDI (Eck and Huber, 2016).

Cluster # 0 Renewable Energy and Cluster # 3 Ecological Footprint have been popular since 2012, with deterministic environmental degradation, CO2 emission, energy consumption, EKC hypothesis, and others as the focus of scholars' research. In recent years, some countries have exploited a large number of natural resources in order to achieve rapid economic development while neglecting the importance of protecting the environment, resulting in worsening environmental degradation, increasing carbon emissions, and increasingly prominent environmental problems caused by the greenhouse effect. To achieve carbon emission reduction targets, green technology innovation is one of the important ways (Wu et al., 2023). According to the EKC hypothesis proposed by Grossman and Krueger (1991), the level of environmental pollution in a region is inverted U-shaped with the local per capita income. Some scholars have started with the relationship between economic complexity and carbon emissions and have found through research that globalization, the development of new energy, and the increase in economic complexity all reduce carbon emissions. On the contrary, economic growth will exacerbate carbon emissions (He et al., 2021; Iwuoha and Onochie, 2023). Romero and Gramkow (2021) empirically demonstrated that increasing economic complexity helps reduce greenhouse gas emission intensity as well as per capita emissions. They innovatively constructed the Product Emission Intensity Index. When per capita income is at a lower level, the pressure of environmental pollution will increase with the increase of per capita income. However, when per capita income increases above a certain level, the pressure of environmental pollution

decreases (Grossman and Krueger, 1991). In other words, developed countries with higher economic complexity often require the accumulation of knowledge and human capital due to their advanced production technology and more skilled labor force than developing countries. Its manufacturing industry will emit less pollution. Therefore its environmental quality is relatively higher (Can and Gozgor, 2017). Therefore, the EKC hypothesis is widely used to study the relationship between economic complexity and environmental pollution.

The research hotspots of Cluster # 4 Diversion of Economy, and Cluster # 6 Diversion, mainly include export, product space, comparative advantage, nexus, etc. There is a close connection between economic diversification and economic complexity. Economic diversification reflects the changes in production structure from a horizontal dimension, while economic complexity, to some extent, reflects the changes in production structure from a vertical dimension. According to the endogenous growth theory, expanding product categories can improve productivity by expanding the range of production products and effectively using idle resources, thus promoting economic growth. At the same time, portfolio theory suggests that export diversification also disperses various risks in promoting economic growth, reduces trade uncertainty, and effectively avoids the "resource curse" effect. Currently, the primary methods for measuring economic diversification include direct counting, the Herfindahl-Hirschman index, the entropy index (Saviotti and Frenken, 2008), and Feenstra's relative product diversification index (Feenstra, 1994). After empirical analysis, Imbs and Wacziarg believe that a country first experiences a stage of production diversification and then a stage of production specialization in its development stage (Imbs and Wacziarg, 2003).

The impact of upgrading exports through highly complex products on economic development varies depending on the country's development stage. Developed countries already have a complex production structure and skilled labor force, resulting in an inverted U-shaped relationship between export upgrading and economic growth. For developing countries with lower per capita income, participating in producing highly complex products through processing trade cannot achieve industrial upgrading. Therefore, developing countries should prioritize export diversification in the early stages of development rather than increasing the complexity of export products to achieve economic development (Chakroun et al., 2021).

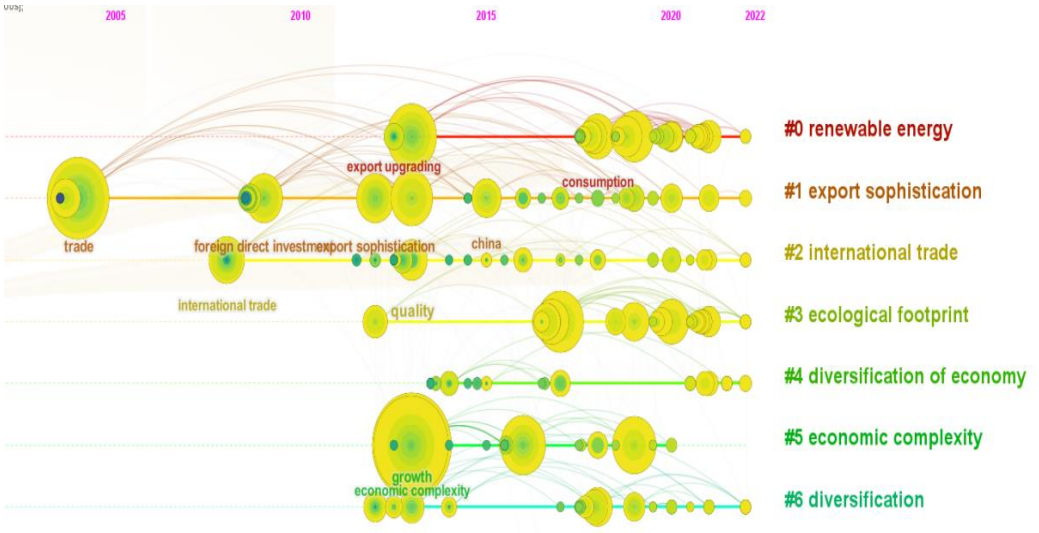

Figure 9: Timeline graph of keyword clustering

4. Conclusions

The mutual influence between economic complexity and economic development has attracted in-depth research from scholars from different countries worldwide, and it has important practical significance. This paper explores the development of economic complexity by using 403 documents in the WoS core database from 1998 to 2022 and the co-citation and co-citation methods of CiteSpace literature metrology software. By analyzing the frequency of publications between journals and authors, we can gain a general understanding of high-yield journals and authors. Keyword co-word analysis and cluster analysis enable us to understand the constantly changing core content of economic complexity research; Institutional co-occurrence analysis and institutional cooperation analysis allow us to identify the primary sources of contribution from institutions; Journal co-citation and author co-citation analysis describe the knowledge network connecting journals and authors.

From the analysis of the number of publications, scholars' attention to economic complexity has significantly increased since 2012 and reached its peak in 2021. This article proposes that research in the field of economic complexity can generally be divided into three parts: the initial stage (1998-2011), the high-speed growth stage (2012-2018), and the mature stage (2019-2022), which has specific reference significance for future related research. At the same time, the overall distribution of authors is relatively scattered, and there needs to be more cross-disciplinary cooperation among high-output authors. From the perspective of institutional cooperation, most publishing institutions have formed cooperative relationships with other institutions, and institutions with many publications have formed close cooperative relationships with other institutions.

From the analysis of the citation frequency of journals and authors, it can be concluded that the top three journals with the highest citation frequency are “Journal

of Economic Growth", "Proceedings of the National Academy of Sciences", and "World Development", which dominate research in the field of economic complexity. In addition, Hausmann, Hidalgo, and Balassa are the top three most representative and leading scholars. Their published papers have played an essential role in the evolution and development of this research field.

In analyzing research topics and development paths, this article summarizes the main research topics and development processes in economic complexity, where economic complexity is often closely related to research directions in international trade, economic development, environmental quality, and income inequality. Scholars focus on constructing economic complexity indicators and their measurement issues in the initial research stage. In the subsequent stages of rapid growth and maturity, scholars shifted to exploring the influencing factors of economic complexity.

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