Literature Review on Systemic Risk in the Financial Sectors:

Based on Bibliometrix and VOSviewer

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Abstract

Once systemic risk occurs, it will first have a significant impact on the financial field. This paper aims to analysis the current research status of systemic risk in the financial field and provide research direction for further research on this issue. bibliometrix and VOSviewer are used to efficiently analysis the literature related to the subject of this study. The main contents of this paper include literature sources, authors, cooperation, and keywords. Based on the analysis of hot papers and keywords, the hot topics of current research and points out the shortcomings of existing research are discussed. Finally, the results of the paper are summarized, and a new research direction for the experts and scholars who study the systemic direction of the financial field in the future is provided.

Keywords

financial sectors, systemic risk, bibliometrics, visual analytics

1. Introduction

When systemic risk occurs, the financial system is the first to be impacted. Systemic risk is contagious because the financial system is composed of numerous interconnected financial institutions (Staum et al., 2012; Greenwood et al., 2015; Benoit et al., 2017), once a single financial institution is affected by systemic risk, the adverse effects can quickly spread to the entire financial system and affect the real economy (Billio et al., 2012; Staum et al., 2016; Xu et al., 2017; Benoit et al., 2017; Grundke et al., 2019).

At present, after the impact of the new crown pneumonia epidemic, drop in demand, supply has contracted, financial markets are in turmoil, the global economy is in a downturn. Systemic risk is rapidly contagious in the world's financial markets. Effectively identifying and preventing systemic risk in the financial sectors is a long-term task. Measuring systemic risk in the financial field and studying the mode of contagion are helpful to deeply study their causes and provide directions and measures for preventing and resolving systemic risk in the financial field.

Now many experts and scholars have published a lot of articles on systemic risk in the financial field. However, due to the fact that the financial industry includes many sub-fields such as banking, insurance and securities industry, and there are many research objects and research topics, it is difficult to comprehensively and efficiently analyse the focus and shortcomings of current research through qualitative and structured literature analysis. Bibliometric methods can provide a relatively quick and comprehensive understanding of the current state of the research field. Li et al. (2023) detailed

bibliometric software including two categories analysis software and analysis software based on social network clustering. In addition, a large number of researchers have applied bibliometric methods to study the research status or research hotspots in many fields (Niknejad et al., 2023; Owolabi & Sajjad, 2023; Ampah, 2021). This study uses R-package bibliometrix and VOSviewer software to analyse the research articles of systemic risk in the financial field by comparing and analysing the characteristics of different types of software and combining the research content of this paper.

Based on two bibliometric software, this paper analyses the articles related to systemic risk in the financial field in recent years, introduces the research status and the research hotspots, and excavates the research gaps. The specific research contains four parts: literature source analysis, author analysis, collaborative analysis, and keyword analysis. Based on the analysis results, researchers are provided with a list of core journals, important researchers in the field, and countries and institutions with high contribution rates. This paper aims to quickly grasp the direction and theme of the latest research on systemic risk in the financial field, and put forward the key issues that still need further research.

2. Datasets and Research Methods

The data source of this paper are the articles related to systemic risk in the financial field retrieved from the Web of Science core collection. Because it is too simple to use "systemic risk" as the search term alone, and according to the previous preparation, it is found that there are many keywords such as "network" and "contagion" in the related studies of systemic risk. So the following search formula "(TS=("system* risk" OR "system* risk network*" OR "system* risk contagion"))" was used for literature selection. There are hundreds of thousands of retrieved literatures, including a large number of medical and other literature unrelated to the research topic of this paper, so the literature research field is further limited, and *Mathematics Interdisciplinary Applications*, *Operations Research Management Science*, *Economics*, *Social Sciences Mathematical Methods*, *Multidisciplinary Sciences*, etc., 14 categories of articles related to the financial field, and finally obtained 1041 articles (search time is July 5, 2023). Since journals in the general field are not excluded, there are a very small number of articles that are quite different from the research topic, and such articles have been excluded by specific analysis. *Bibliometrix* and VOSviewer are the tool for bibliometrix analysis. *Bibliometrix* created by Massimo Ariaa and Corrado Cuccurullob (2017) is a R-package which is programmed in the R language. It can be used to quantitative research in scientometrics and bibliometrics that includes all the main bibliometric methods of analysis. The tool is highly flexible and can be rapidly upgraded and integrated with other statistical R-packages. Using this tool, we can perform descriptive analysis, network visualization analysis and collaborative analysis on the acquired data.

VOSviewer which is a software developed by Van Eck and Waltman (2010) can construct and view bibliometric map. The software is written entirely in Java and can be applied on virtually any hardware and operating system. VOSviewer can be used to construct networks of scientific publications, scientific journals, researchers, research organizations, countries, keywords, or terms. (Perianes, et al., 2016) and supports multiple types of reference documents as input data. The study data is obtained from the core collection of Web of Science and its visual analytics is though the software.

3. Results and Visual Analysis

3.1 Descriptive Statistical Analysis

The information of articles related to systemic risk research in the financial field obtained from the core collection of Web of Science is showed in Table 1. From 2007 to 2023, there are 1041 articles related to the research topic of this paper, and the types of articles are mainly articles and reviews. Table 2 illustrates the detailed information on the types and quantities of articles. The average annual growth rate of the number of published articles is 12.81%, and the average number of citations per article is 25.19, that is, an average article can provide 25 articles with relevant help for the research of "systemic risk in the financial sectors".

As can be seen from Table 3, there are 2669 authors. The number of authors of single-authored documents is 85, but the number of single-authored documents is 95, that is, some authors have published multiple articles independently. The average number of collaborators per article is about 3, indicating that most of the articles are jointly completed by multiple researchers.

Table 1. The Main Information of the Data Set

Data characteristic	Description
Timespan	2007:2023
Sources (Journals, Books, etc)	217
Documents	1041
Annual Growth Rate %	12.81
Document Average Age	5.17
Average citations per doc	25.19
References	34181

Table 2. Different Document Types from the Core Collection of Web of Science

Document Types	Number of documents
article	961
article; book chapter	2
article; early access	42
article; proceedings paper	19
correction; early access	1
review	15
review; early access	1
Total	1041

Table 3. The Number of Authors of Single-authored Documents and Muti-authored Documents

Authors	Value
Authors	2669
Authors of single-authored documents	85
Authors of multi-authored documents	2587
Single-authored documents	95
Co-Authors per documents	3.2

Based on Figure 1, it is easy to obtain the number of articles published each year and the percentage of articles published in each year. From 2007 to 2020, the number of published articles remained within

100, and in 2021, the number of articles related to the research topic of this paper increased rapidly to exceed 100. From 2007 to 2023, the number of annual publications experienced three peaks, namely 2008, 2013, and 2016. Combined with the international situation and the social and economic development situation at that time, it is found that the number of publications is closely related to the economic situation. For example, the subprime mortgage crisis that began in the United States in 2007 spread around the world; the financial crisis of 2012; China's stock market crash in 2015 had a significant impact on China and the global economy; the pandemic in 2019 led to disruptions in global supply chains, turmoil in financial markets, and global economic activity has slowed. The occurrence of these events has had a serious impact on the financial sectors, so the research of experts and scholars on systemic risk in the financial sectors has continued to increase, and the number of publications in 2022 has reached a record high. 2019-2022 is also the fastest growing cycle in the number of publications.

The total number of citations per year and the average number of citations per year is shown in Figure 2. From the perspective of the total number of citations per year, the number of citations increased year by year from 2007 to 2014, and decreased slightly in 2015. In 2016, the total number of citations increased sharply, about 1.4 times that of 2014. This may be because after the 2015 "stock market crash" in China, many scholars and experts have conducted research on topics related to systemic risk. At the same time, there is a certain lag in the citation of literatures, which is inseparable from the emergence of systemic risk in the financial system and the emergence of new studies after they are affected according to Figure 1. From the perspective of the average annual citations, the highest annual average citations of each article in 2014 were 8.93, higher than 7.51 in 2016, indicating that the number of articles in 2014 was smaller, but the citation rate was higher, which reflected the high influence of the articles published in that year.

It can learn more about the connections of research topics, issuing institutions, and countries by the three field analyses. Figure 3 presents the three-fold analysis of system risk with key research themes in the middle, countries on the right, and affiliation on the left side. Figure 3 presents the three-fold analysis of system risk with key research themes in the middle, countries on the right, and affiliation on the left side. The main research directions are systemic risk, contagion, financial network and so on according to Figure 3. This further indicates that the research on systemic risk in the financial field is mainly based on the financial industry such as banking and insurance. The countries with the largest research contributions are the United States, China, and the United Kingdom. The main affiliations are University of London, Cornell University, Columbia University and so on.
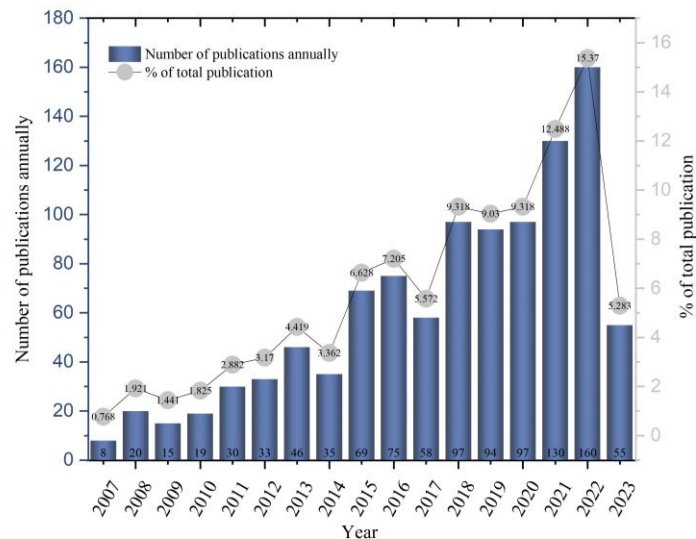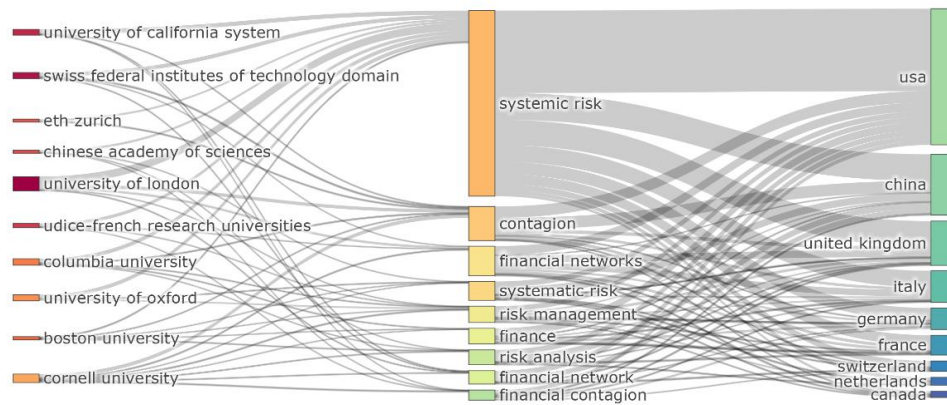
Figure 1. The Number of Publications Annually

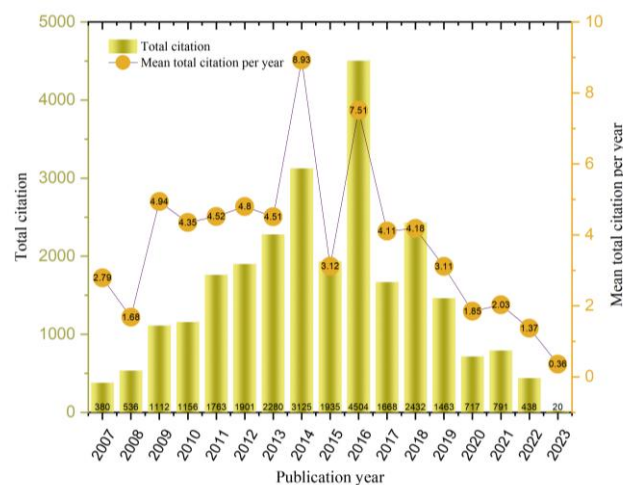**Figure 2. Annual Total Citations Trend and Annual Mean Total Citation**

Figure 3. Three Field Analyses of Theoretical Documents

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Literature source analysis

From the Figure 4, we can know the number of articles published in the top 10 journals most relevant to the research topic of this article. Analysing the number of articles published in each journal can provide a preliminary understanding of the journals that have a greater impact on the research topic. *Quantitative Finance* is the journal with the largest number of publications during the study period, the second is *Plos One*, and the third largest number of publications is *Scientific Reports, Complexity*. *Management Science*, *Annals of Operations Research* and other magazines have less difference in the number of articles. *Computational Economics* is the magazine with the fewest articles.

The top10 most local cited sources is shown in Figure 5. The top three Local Cited Journal are *Journal of Finance, Journal of Banking & Finance* and *Journal of Financial Economics*. Compared Figure 4 and Figure 5, we can find that the number of citations in journals related to the research topic of this paper is not related to the number of citations, and the total number of citations of journals with a large number of articles may be lower than that of journals with a small number of articles.

Figure 6 is the co-citation analysis of cited sources. A co-citation of the publication is defined as a case in which two different documents are cited by a third article. Co-citation is a citation of an essay from two independent articles from two different publications. (Owolabi, 2023; Niknejad, 2023). The link in Figure 6 represents the relation of publications, and the node size means the number of citations of articles published by the corresponding journal. The larger the node corresponding to the journal, the more citations. The co-citation network is made up of 35 items and divided into 5 clusters, including 574 links and total link strength of 5786. The colors of the first to fifth categories are gray, orange, blue, yellow, and purple, and the number of items included in every cluster is 9, 9, 8, 5 and 4, respectively.

The publications of the top 10 most relevant in Figure. 6 are coordinated with Figure. 4, and Figure. 6 supports the findings shown in Figure 4. What's more, co-citation network analysis can reveal which sources are closer based on the citation sources of articles in different clusters. For instance, the most cited journal is J Financ in the gray sluster, and it also cites the documents of J Bank Financ and Manage Sci, which are the dominant in their respective cluster (orange and yellow).
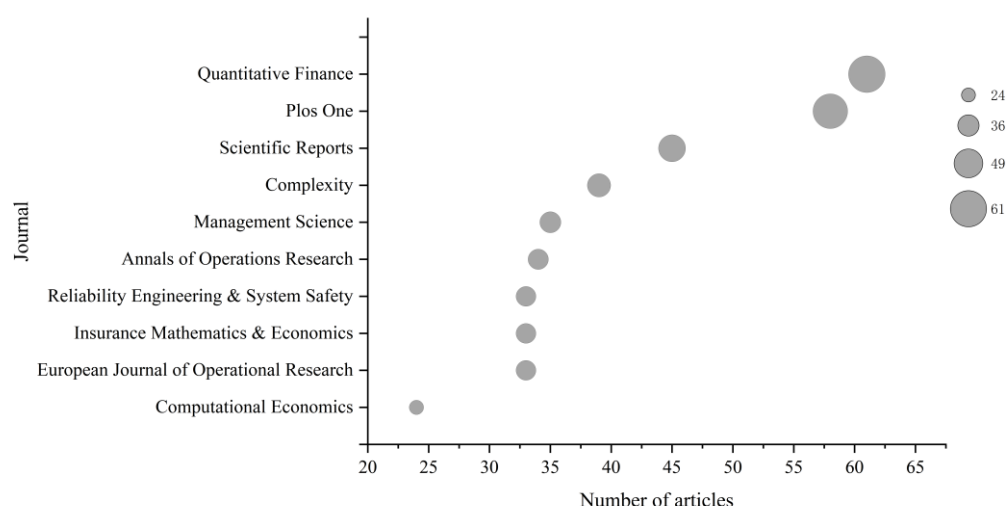
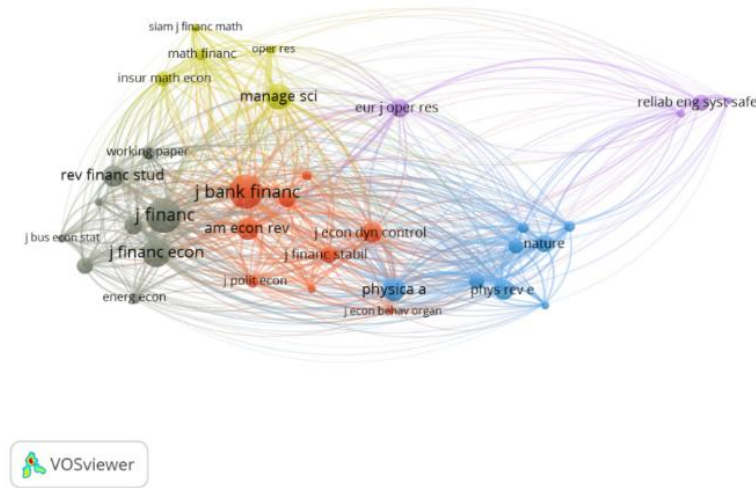

Figure 4. Most Relevant Sources
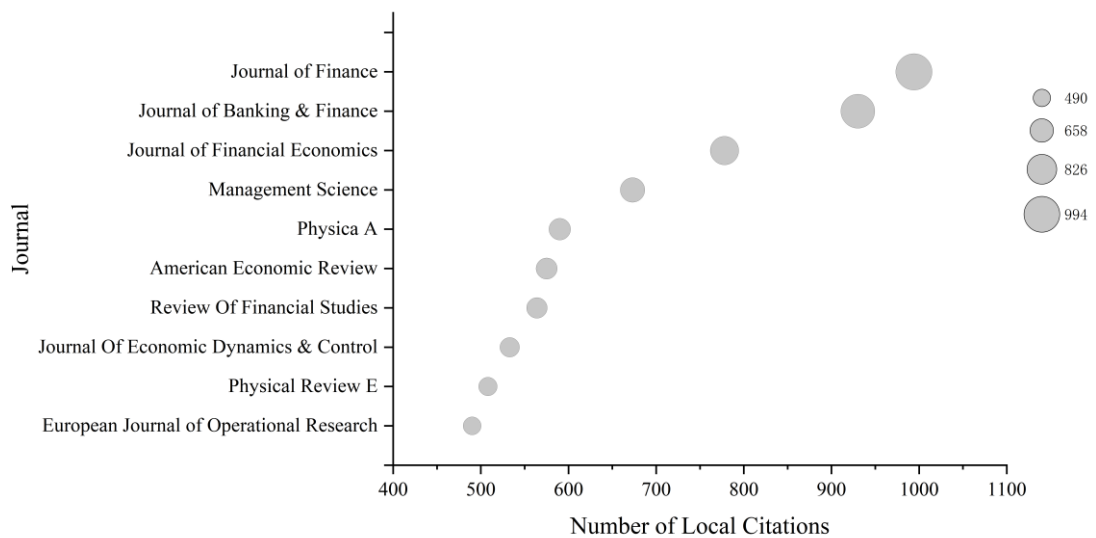
Figure 5. Most Local Cited Sources

Figure 6. Co-Citation by Source Analysis

This network analysis is carried out using VOSviewer software

By analysing cumulate occurrences, the top 10 most productive journals related to the research topic can be obtained. They are *Quantitative Finance*, *Plos One, Scientific Reports*, *Complexity*, *Management Science*, *Annals of Operations Research*, *European Journal of Operational Research*, *Insurance Mathematics & Economics*, *Reliability Engineering & System Safety* and *Computational Economics*.

As can be seen from Figure 7, we know the trend of the cumulative number of articles published in journals (publication sources) over time during the study period (2007-2023). The source growth indicates the progression of the most productive journals in this study field. From the comparison of the

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number of cumulated occurrences and the number of documents in the most relevant source in Figure. 4, it can be found that they are extraordinarily similar. Additionally, the cumulative number of occurrences of each journal is increasing by Figure 7. The two journals with the highest number of published articles are: *Quantitative Finance* and *Plos One*, and their cumulative occurrence has increased rapidly since 2014. At present, they are the main source of research publications related to systemic risk and have important research contributions. *Complexity*, a journal that appeared after 2016, has reached 39 cumulative occurrences by 2023, ranking 4th with high potential productivity. The cumulative number of occurrences of several other journals increased at a relatively flat rate, and the one with the least cumulative appearance is *Computational Economics*.
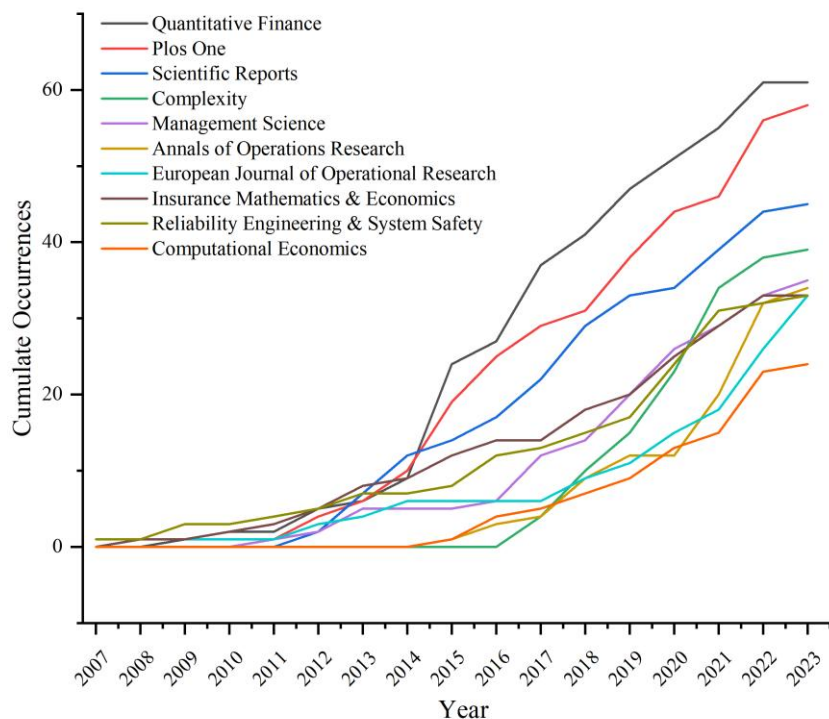

Figure 7. Sources' Production over Time

3.2 Significant Source (Journal) Analysis

Table 4 provides the list of top 10 research journals based on h-index, total citations (TC), number of publications (NP), total publications (TP) and publication starting year (PY-start). h-index is a mixed quantitative index about the amount of literature and the number of citations. The h-index is a widely accepted indicator to measure the impact of scholars, journals, organizations, countries and so on, with the advantage of being objective (Hirsch, 2005). It was originally defined as h of N papers have at least h citations, while the other (N–h) papers have ≤ h citations (Shi et al., 2020).

The top three journals are: *Quantitative Finance*, *Scientific Reports* and *Journal of Econometrics*, where the h-index of *Quantitative Finance* and *Scientific Reports* are both 19, but *Scientific Reports*'s total citation is more than Quantitative Finance's. Among the top three journals, *Journal of Ecnometrics* has the lowest h-index, and the number of published articles is about one-third of *Quantitative Finance*, but

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its total citation is the highest, which is more than twice that of *Quantitative Finance*, indicating that the articles published by *Journal of Ecnometrics* have a high impact.

From the perspective of the types of these 10 journals, the main ones are Economics and Management Science, followed by comprehensive journals, and very few of them are engineering technology and computer science journals, as shown in Table 5. As the data collection contains many papers with different research directions, it is not guaranteed to completely exclude research papers that are not related to the topic of this paper, so there are a small number of journals that are not related to the topic, and this paper does not consider such articles in the specific analysis.

Current research on systemic risk in the financial system or financial industry mainly include measuring systemic risk, the contagion of systemic risk, and the spread of systemic risk in the financial industry network. The research methods are mainly based on a lot of mathematical methods, and due to the difficulty of obtaining relevant data in the financial industry, some of the research is completed by simulation analysis, so some of the articles are published in comprehensive journals, mathematics journals and computer science journals. For example, Battiston et al. (2012), according to the concept that systemic risk is the risk of default of a large portion of the financial system, which depends on the network of financial exposures among institutions, and combined with complex networks, proposed a new method, DebtRank that is a measure of systemic impact inspired by feedback-centrality, for determining important nodes between networks. Wang et al. (2017) used CAViaR tool and the Granger causality risk test, built an extreme risk spillovers network to analyse the interconnectedness of financial institutions. Their method provides an early warning when systemic risk increases in the financial system. Albuquerque et al. (2019) constructed the industry equilibrium model and tested the model prediction. Their research results show that CSR can reduce the system risk and increase the company value.

There are also a few researchers who have studied systemic risk in other industries. Sadorsky et al. (2012) looked at the factors that affect changes in systemic risk for renewable energy companies, with changes in sales volumes and oil prices being the main influences. Based on their findings, they suggest ways for governments to reduce systemic risk for renewable energy companies. For example, governments purchase renewable energy directly or enact policies that stimulate consumers to purchase renewable energy directly. Meng et al. (2014) applied the Random Matrix Theory (RMT) to study the systemic risk of the US real estate market, and found that the sharp increase in systemic risk is inseparable from the transformation of securities, providing a method for detecting early real estate bubbles

Table 4. Top 10 Journals according to Source Impact

Journal	h-index	TC	NP	PY-start
Quantitative Finance	19	1220	61	2009
Scientific Reports	19	1584	45	2012
Journal of Econometrics	15	2513	21	2008
Management Science	15	1397	35	2011
Plos One	15	727	58	2011
Reliability Engineering & System Safety	15	1357	33	2007
Safety Science	13	603	21	2008
Expert Systems with Applications	11	601	15	2008
Insurance Mathematics & Economics	11	341	33	2008
Siam Journal on Financial Mathematics	11	322	21	2013
Energy Policy	10	416	12	2009

Table 5. The Type of the Top 10 Journals according to Source Impact

Journal	Research Areas
Quantitative Finance	*Business & Economics;* *Mathematics;* *Mathematical Methods in Social Sciences*
Scientific Reports	*Science & Technology-Other Topics*
Journal of Econometrics	*Business & Economics;* *Mathematics;* *Mathematical Methods in Social Sciences*
Management Science	*Business & Economics;* *Operations Research & Management Science*
Plos One	*Science & Technology-Other Topics*
Reliability Engineering & System Safety	*Engineering;* *Operations Research & Management Science*
Safety Science	*Engineering;* *Operations Research & Management Science*
Expert Systems with Applications	*Computer Science; Engineering;* *Operations Research & Management Science*
Insurance Mathematics & Economics	*Business & Economics; Mathematics;* *Mathematical Methods in Social Sciences*
Siam Journal on Financial Mathematics	*Business & Economics;* *Mathematics; Mathematical Methods in Social Sciences*
Energy Policy	*Business & Economics;* *Energy & Fuels;* *Environmental Sciences & Ecology*

3.3 Core Journal Analysis

The journal classification based on Bradford's law which classifies the journals based on their productivity level is presented in Figure 8. The core journal groups are illustrated by shaded sections and named core sources. Bradford's law is to group journals according to how many papers they have, which is divided into three sections including the core journal group, the intermediate journal group, and the broad journal group.

Journals belonging to the core journal group can be calculated according to Bradford's law (Bradford, 1934). The calculation formula is $P = 2\ln\left(e^E \cdot Y\right)$, where *P* is the number of core, *E* is the Euler coefficient, *E*=0.5772, *Y* is the number of articles published in the journal with the largest number of publications. In this paper, *Y*=61, $P = 2\ln\left(1.781 * 61\right) = 9.3761$, that is the top 9 journals are in the core area. Journals that fall into this category are the most productive for the research topic of this article. Table 6 lists the relevant information of the 9 journals in the core area, including the number of publications, research fields, JCR divisions, and proportion (%). The top three journals are *Quantitative Finance*, *Plos One* and *Scientific Reports*, where *Quantitative Finance* has the highest number of 61 articles. This is the same as the result in Figure 4. However, it should be noted that the JCR partition of the top three journals in the core area is not the highest, so the overall influence of the journal should be considered comprehensively. It is not entirely reliable to judge the quality of a journal by the number of articles published. Also, the 9 journals in the core area are not completely consistent with those included in Table 4, but their research fields are very similar (Table 5 and Table 6). It proves again that the current research on systemic risk is mainly concentrated in the financial field. We can conclude that out of 217 research journals, 9 journals in zone 1, 24 journals in zone 2, and 184 journals lie in zone 3.

As the most influential and productive journal in the core area, *Quantitative Finance*'s main research topic is the impact of systemic risk on financial institutions such as banks and insurance companies and the stock market, as well as the contagion effect in different institutional networks. In addition to the literature mentioned above, the CAViaR tool and the Granger causality risk test applied by Wang et al. (2017) to study the interconnectedness of financial institutions extreme risk spillovers network, lots of important research articles have been published by it. Bargigli et al. (2015) assesses interbank systemic risk based on multilayer network theory. The results show that the interbank network or the specific layer represents other layers, which cannot accurately reflect the connection of the interbank market, and thus cannot determine whether the estimation of systemic risk is reliable. Interbank contagion is a fundamental channel in many of the stress tests gauging systemic risk. Considering that the maximum-entropy (ME) approach would mask the true structure of the connections in the network, Anand et al. (2015) proposes a method which could produce a more realistic inter-bank network to retain the important features of the original inter-bank market.

Plos One is a journal with the second highest productivity level, its published articles mainly focus on the connection between network structure and systemic risk, for example, whether the network structure of the stock market network bank will affect the contagion of systemic risk. The research topics of these articles are like those of influential articles published by *Quantitative Finance* which also provide journal directions for exploring hot topics in the study of systemic risk in the financial field.

Scientific Reports, as the third-ranked journal in terms of productivity, publishes important articles on systemic risk communication, complex networks, and systemic risk. Huang et al. (2013) constructs a model for stress testing the systemic risk of the banking system, which is a binary network model consisting of banks and bank assets. The authors specially study the cascading failure process in banking system and apply the cascading failure model to simulate the process of crisis spreading in the network. But beyond this, the model can be used to study other complex systems such as the impact of deteriorating sovereign debt values on the global banking system. A node connection failure on the network may cause a cascading failure. Roukny et al. (2013) analysed the impact of network topology on systemic risk.
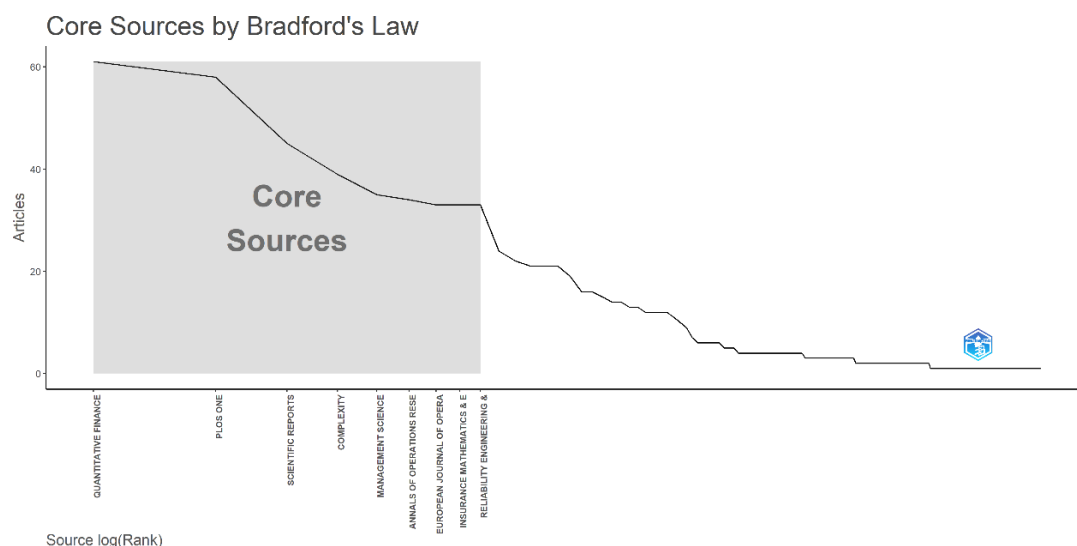

Figure 8. Core Sources by Bradford's Law

Table 6. The Information of Journals in the Core Journal Group

Source Journal	Number of published papers	Research Interests	JCR partition	Occupancy（%）	Zone
Quantitative Finance	61	Economics, Social Sciences, Mathematical Methods	3/4	5.877	Zone 1
Plos One	58	Multidisciplinary Sciences	2	5.491	Zone 1
Scientific Reports	45	Multidisciplinary Sciences	2	4.335	Zone 1
Complexity	39	Mathematics, Interdisciplinary Applications	2	3.757	Zone 1
Management Science	35	Operations Research & Management Science	1	3.372	Zone 1
Annals of Operations Research	34	Operations Research & Management Science	1	3.276	Z one 1
European Journal of Operational Research	33	Operations Research & Management Science	1	3.179	Zone 1
Insurance Mathematics Economics	33	Social Sciences, Mathematical Methods	2	3.179	Zone 1
Reliability Engineering System Safety	33	Operations Research & Management Science	1	3.179	Zone 1

3.4 Analysis of the Issuing Agency

Figure 9 are the top 10 institutions in terms of the number of publications. In first place was the University of London with 34 articles, followed by Eth Zurich and Udice-French Research Universities with 30 and 26 articles respectively. These 10 institutions mainly focus on financial networks and systemic risk, systemic risk identification, analysis and contagion, network structure and systemic risk, risk spillover, risk measurement, systemic risk contagion model, complex networks (single-layer networks, multi-layer networks, etc.) and systemic risk.
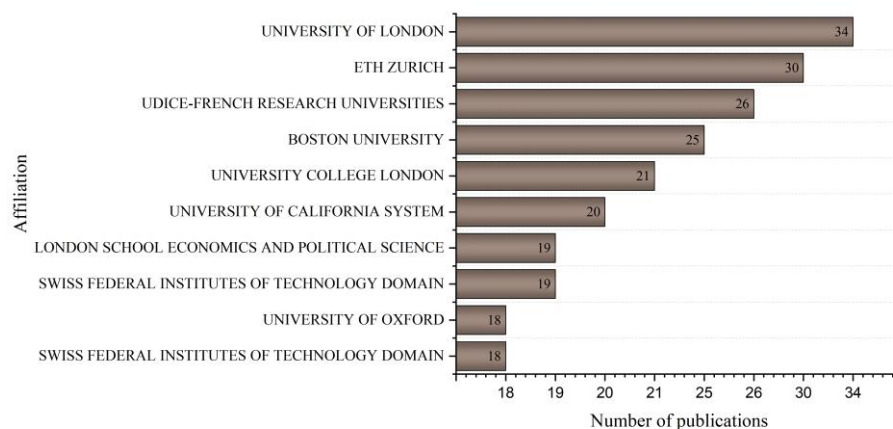
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Figure 9. Top 10 the Most Relevant Affiliation

3.5 Country Analysis

Table 7 is country scientific production on the paper's research theme. There are 6 countries with more than 100 articles, of which USA has the largest number of articles with 555, followed by China and UK, with 551 and 238 articles. Comparing the number of articles published by the first three countries, it is found that there is a small gap between the United States and China, while the United Kingdom, which ranks third, has a large difference with the top two countries. The United States more than twice as many articles as United Kingdom.

The Most Cited Country is USA which total citations reached 7236, followed by UK (3237) and Netherlands (2992). USA's total citations far outperform the second and third countries. China, which ranks second in terms of the number of published articles and fifth in terms of total citations, indicating that China has more research on systemic risk. But the influence of the article is far behind that of the United States and the United Kingdom, and the influence of the articles needs to be further improved. In addition, the Netherlands has a mediocre number of publications, ranking third in terms of total citations, but its Average Article Citations is 100 which is far larger than other countries, reflecting the high impact of its publications. Other countries can study the research results of these two countries and find the shortcomings of their own research to improve the influence of research articles.

Top 10 corresponding author's countries can be seen in Figure 10, where the meanings of SCP and MCP are single authored publications and multi-authored publications. The countries where the top three corresponding authors reside are CHINA, USA and ITALY respectively, and the number of SCP in all three countries is greater than that of MSP. Table 8 provides detailed information on the publications of the top 10 corresponding authors in their countries. Table 9 provides detailed information on publications in the countries of the top 10 corresponding authors. The number of SCP and MCP in Netherlands and Australia is same. Only France and Switzerland have fewer SCP than MSP. There is less cooperation between authors from different countries, and the international cooperation on the study of systemic risk in the financial field is not close enough.

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Table 7. Countries' Scientific Production

Rank	Country	Frequency
1	USA	555
2	CHINA	551
3	UK	238
4	ITALY	221
5	GERMANY	126
6	FRANCE	123
7	SWITZERLAND	84
8	NETHERLANDS	71
9	CANADA	64
10	SPAIN	56

Table 8. Most Cited Countries

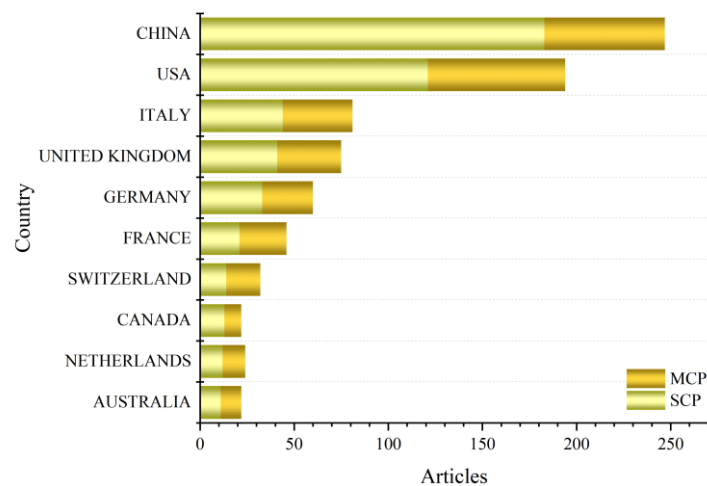| Country	TC	Average Article Citations
USA	7236	37.30
UNITED KINGDOM	3237	43.20
NETHERLANDS	2992	124.70
ITALY	2344	28.90
CHINA	2170	8.80
GERMANY	1794	29.90
SWITZERLAND	1581	49.40
FRANCE	861	18.70
AUSTRIA	644	32.20
CANADA	524	23.80

Figure 10. Top 10 Corresponding Author's Countries

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Table 9. The Information of Top 10 Corresponding Author's Countries

Country	Articles	SCP	MCP	Frequency	MCP_Ratio
CHINA	247	183	64	0.237	0.259
USA	194	121	73	0.186	0.376
ITALY	81	44	37	0.078	0.457
UNITED KINGDOM	75	41	34	0.072	0.453
GERMANY	60	33	27	0.058	0.45
FRANCE	46	21	25	0.044	0.543
SWITZERLAND	32	14	18	0.031	0.563
NETHERLANDS	24	12	12	0.023	0.5
AUSTRALIA	22	11	11	0.021	0.5
CANADA	22	13	9	0.021	0.409

3.6 Analysis of the Author of the Post

Table 10 is the top 10 authors ranked by h-index, publication starting year and the number of publications. Battiston is the most influential author, as follow is Caldarelli and Feinstein. The fourth and fifth authors are Minca and Stanley respectively.

The co-citation of author analysis can effectively identify highly cited authors and clusters of authors. By the articles published by the highly cited authors, we can quickly understand the focus and hotspots of current research. Each author cluster represents a school of thought, and there are generally multiple different but related schools of thought in the results of author co-citation analysis. Thus, it can know the structure and development of the current research literature by the analysis of different clusters.

Figure 11 is the co-citation of author network. The minimum number of citations of an author is set to 5. Thus 1387 authors meet the threshold. The number of authors with the greatest total link strength is 1000. The authors' co-citation network consists of 8 clusters with different colours and size. Every cluster's colour and the number of items is shown in Table 11. Every node represents an author, and the larger the node, the more cited the author's published article. The link between two nodes represents two authors being cited by a third author. The density of links between nodes represents the closeness between the same cited authors, which is the reason for the formation of research clusters. The link strength indicates the total strength of a given researcher's co-citation connections with other researchers (Owolabi & Sajjad, 2023). The top 5 cited authors are Baittison, Allen, Adrian, Eisenberg and Lasserman, where Baittison and Lasserman belong to cluster 1, Allen belongs to cluster 2, Adrian belongs to cluster 3, and Eisenberg belongs to cluster 4.

Table 10. Most Local Cited Authors

Authors	h-index	TC	NP	PY-start
Battiston S	12	1098	13	2008
Caldarelli G	12	1114	14	2012
Feinstein Z	7	168	16	2016
Minca A	7	238	11	2015
Stanley HE	7	495	8	2013
Caccioli F	6	316	7	2012
Kim J	6	75	6	2012
May RM	6	1158	6	2010
Amini H	5	205	9	2015

| Cimini G | 5 | 209 | 5 | 2015 |
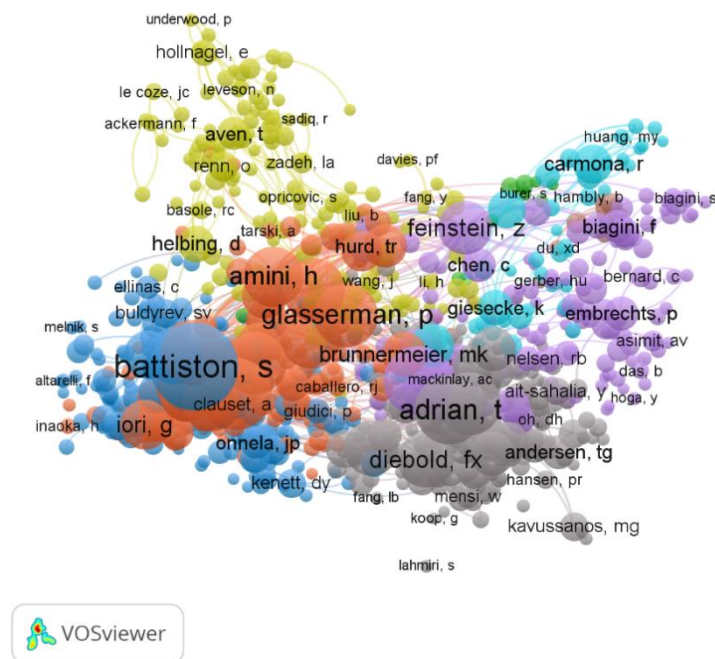
Figure 11. The co-citation Network of Author

Table 11. Every Cluster'S Information

Clusters	Colour	Items
1	gray	263
2	orange	184
3	blue	174
4	yellow	170
5	purple	142
6	lake blue	45
7	green	11
8	brown	11

3.7 Collaborative Analysis

It can discuss the countries and institutions that are most active in publishing, as well as the authors and their partnerships by co-authorship analysis. It has played an essential role in the bibliometric review in recent years (Geng et al., 2022; Li et al., 2022).

The analysis of cooperating countries in this section is to identify the major contributors to the study of systemic risk in the financial field from a macro perspective. Through the analysis of partner institutions, the main research institutions can be identified. Furthermore, the co-author analysis reveals the major contributors to the field of systemic risk at the micro level. Furthermore, by analysing the collaboration network, we can fully understand the collaboration situation and evolution characteristics of collaborators in the research field.

3.8 Analysis of Country Collaboration

Figure 12 is the chord diagram of collaboration country. The strings between countries indicate the existence of cooperative relations, and the thickness of the strings represents the number of documents issued by the two countries. The top four countries with more cooperation with multiple countries are

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USA, UK, China, and Italy. Among them, the countries that have the closest cooperation with the USA are China, the UK and the Netherlands, the countries that have the closest cooperation with China are USA UK and Australia, the countries that have the closest cooperation with the UK are USA, Germany and France, and the countries that have the closest cooperation with Italy are UK, the Netherlands, France, and Germany. It was found that among the top four countries, China had less cooperation with Italy. Compared with other partner countries, the cooperation relationship between the USA and China is very close. Overall, international cooperation is insufficient, and the main cooperative countries are also countries with many publications. International cooperation on systemic risk research in the financial sectors needs to be strengthened.

Figure 13 is the collaborative clustering network map between countries, which contains 6 clusters and 276 items. One color in the diagram represents one category. Top three clusters' color and the number of items is gray with 12, green with 10, blue with 8, respectively. The sixth cluster only contains 1 item which is Iran.

A node represents a country, and the node size represents the number of posts, the link between nodes indicates that there is a cooperative relationship between two countries, and the link strength represents the number of posts that are cooperative. Obviously, China and the United States belong to the same cluster and have the closest cooperation. The analysis conclusion follows the Figure 12. The clustering results of Figure 13 also prove that the cooperation between countries studying the topic of this paper is not close enough.
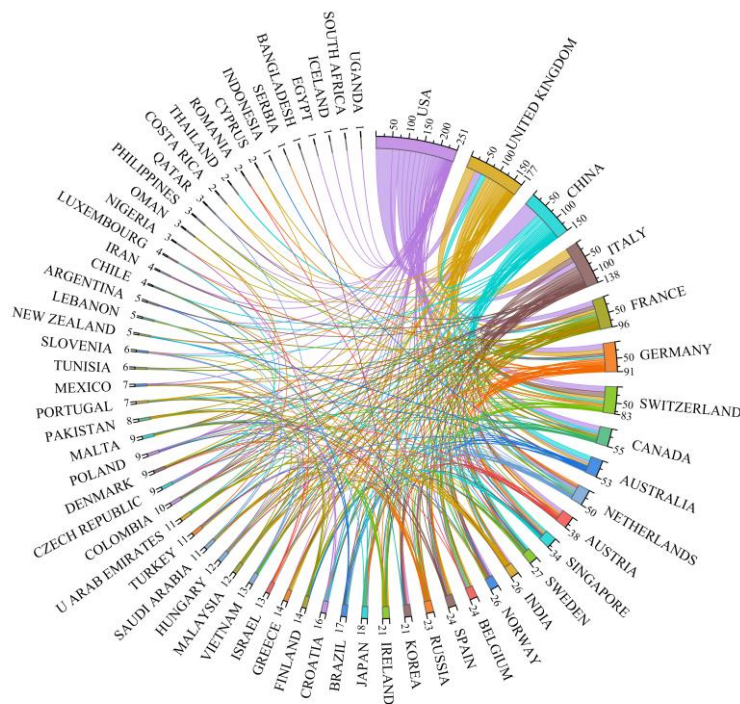

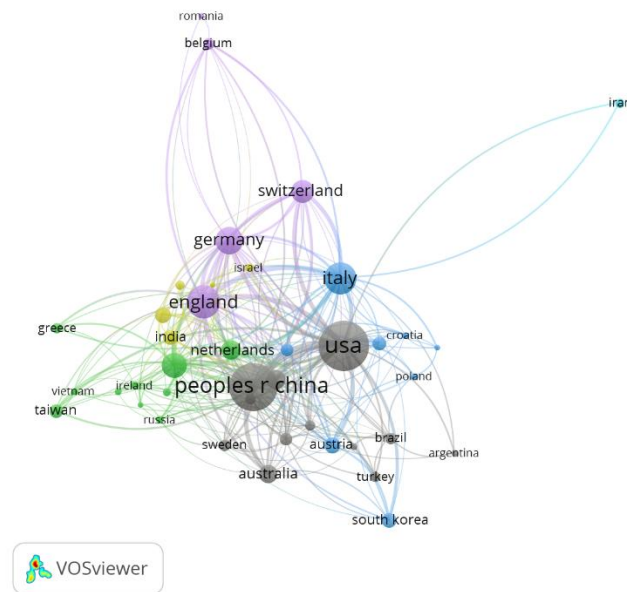**Figure 12. Intercountry Collaboration Chord Diagram**

Figure 13. Countries' Collaborative Network Diagram

3.9 Institutional Collaboration Analysis

Minimum number of documents of an organization is set as 8. There are 35 institutions meet the thresholds. Figure 14 is the institutional collaboration network diagram which is made of 7 clusters, 34 items. The institutions included in the diagram are not only universities, but also some financial institutions, such as Bank England, European central bank and so on. From the network map, we know that there is less cooperation between institutions, and the connection is not close. The number of papers published by universities and institutions is relatively small. Thus, there is still a lot of room for improvement in inter-institutional cooperation in systemic risk in financial sectors research.
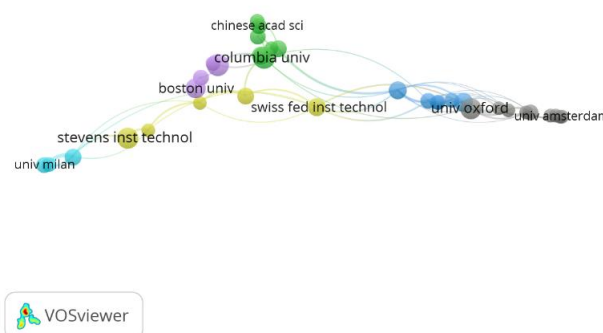

Figure 14. Institutional Collaboration Network Diagram

3.10 Authors Collaborate on Analysis

Figure 15 is authors' collaborative relationships. There are 13 clusters of author collaboration network. The color and number of authors in the first five clusters are respectively: i) gray, 8 authors; ii) orange, 7 authors; iii) blue, 7; authors iv) yellow, 7 authors; v) purple, 7 authors.

Caldarelli and Battiston have published the most papers and collaborated the most closely. They belong to cluster 2. Their research focuses on financial networks and systemic risk (Musmeci et al., 2013; Puliga et al., 2014).

Thurner is the author with the third highest number of posts, belonging to cluster 1. He has few co-authored articles with other cluster authors, mainly with authors in this cluster, and his research focuses on systemic risk measurement and risk prevention in the network (Poledna et al., 2016; Diem et al., 2022).

Caccioli published articles on systemic risk contagion published (Grigat et al., 2017). As the fourth most published author in cluster 3, he works closely with Caldarell and Battiston, who have published articles on dilemma propagation models on complex networks (Bardoscia et al., 2016; Banwo et al., 2016).

With the same number of publications as Caccioli, May, Robert m is the most productive author in cluster 4, and apart from working with authors in his own cluster, he mainly collaborates with authors in cluster 2. He studied systemic risk in banks to reduce the impact of systemic risk (Haldane & May, 2011; May & Arinaminpathy, 2010).

Through the analysis, it is found that the high-yield authors in each cluster cooperate more with the authors in cluster 2, but have little or no cooperation with the authors in other clusters. This indicates that Caldarelli and Battiston are the main contributors to the study, and there are many scholars who cooperate with them. It also reflects that they have very close communication with experts and scholars, and reading their published articles can quickly understand the current research mainstream topics.
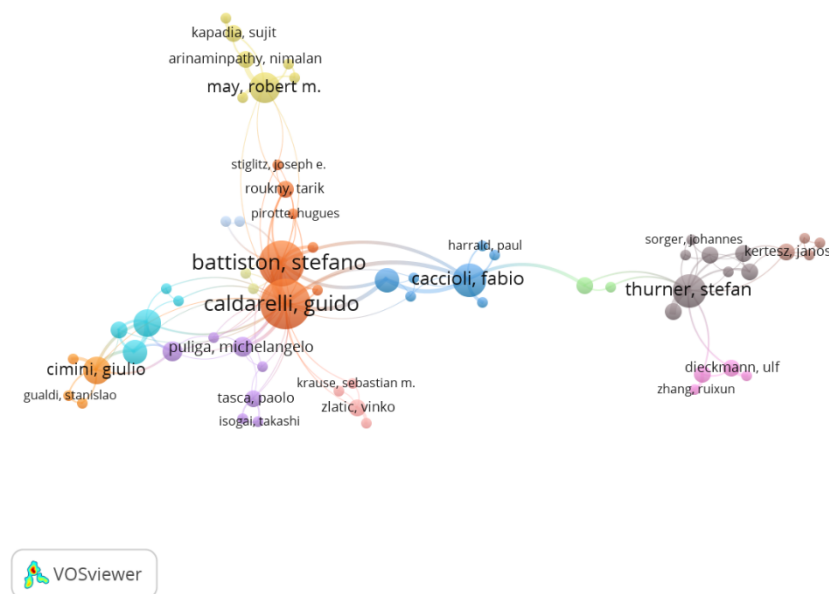

Figure 15. Co-authorship of Author

3.11 Keyword Analysis

This section analyses the frequent keywords of all articles. Table 12 is the frequent keywords appeared in Keyword Plus, Author's keyword, Abstract and Titles. "risk" and "systemic" appear most frequently in the four types of keywords. Among Keyword Plus and Author's keyword, the most frequent occurrence is systemic risk, contagion, and model. This leads to the main research theme of "systemic risk contagion (infection model)". Moreover, risk, financial and systemic are the top three keywords in the frequency of occurrence in abstract and titles, indicating that the current research mainly focuses on finance-related systemic risk, which are basically generic terms and have low availability to the research topics of analysis articles.

VOSviewer software is used to the keywords co-occurrence of keywords plus. Figure 16 is the analysis result, which contains 5 clusters and 635 items. Each color represents one cluster, and the colors of cluster 1-clister 5 are gray, orange, blue, yellow and purple. "systemic risk", "contagion" and "model" are the three keywords that appear most frequently, and both "systemic risk" and "model" belong to cluster 3.

Word cloud can clearly and comprehensively display the hot topics in the research field, and directly display the high-frequency keywords of the research field papers. Figure 17 highlights the top 50 keywords in terms of number of occurrences, and the keyword size is positively correlated with the frequency of their occurrence in the dataset. According to the word cloud, the hot words are "systemic risk", "contagion", "model", "risk", "market" and so on. Also, Figure 17 provides the result support for Figure 16.

Table 12. Most Frequent Keywords

| Keyword Plus	Frequency	Author's keyword	Frequency
systemic risk	234	systemic risk	271
contagion	124	contagion	48
model	114	systematic risk	38
risk	94	financial networks	35
market	51	risk management	35
models	50	finance	21
stability	49	financial network	21
management	44	risk analysis	21
dynamics	41	financial contagion	20
volatility	41	covar	19
Abstract	**Frequency**	**Titles**	**Frequency**
risk	2975	risk	493
financial	1103	systemic	246
systemic	1023	financial	171
network	940	network	134
model	874	networks	133
system	816	analysis	94
market	636	model	93
banks	509	market	87
paper	500	contagion	82
analysis	487	approach	75
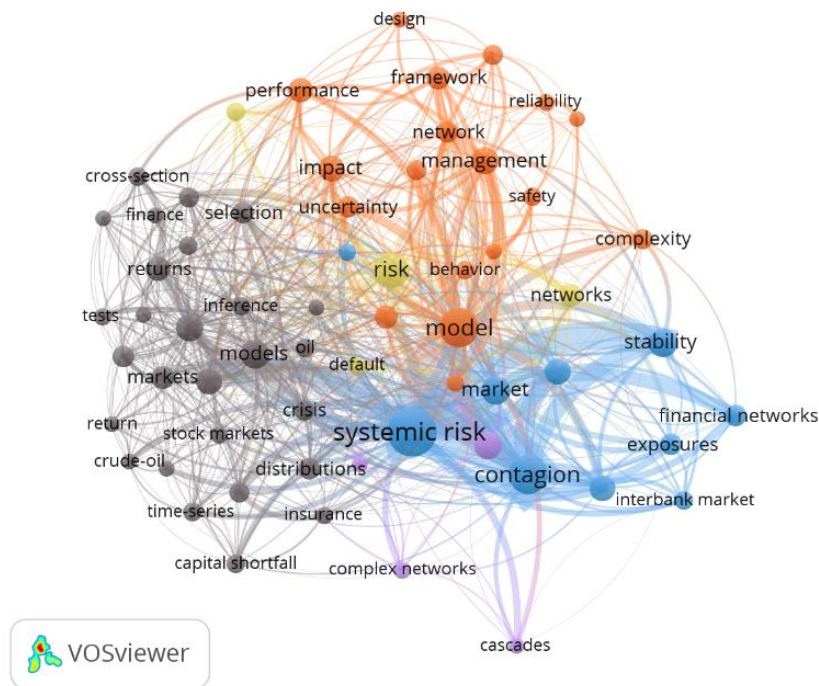
Figure 16. The Keyword Co-occurrence of Keywords Plus

Figure 17. Word Cloud (Keyword)

4. Conclusion

This study conducted a bibliometric analysis of 1041 articles on systemic risk in financial sectors from 2007 to 2023 using R-package bibliometrix and VOSviewer software. The analysis results show that scholars and experts will pay more attention to the study of systemic risk after the financial crisis or the events that affect the economic development in a wide range. Since the global economic development slowed down in 2019, a large number of scholars have continued to pay attention to systemic risk issues, and then the number of relevant research articles has continued to rise, reaching a record high in 2022. Furthermore, research shows that *Quantitative Finance*, *Plos One* and *Scientific Reports* are the most

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influential journals for publishing research papers on systemic risk in the financial sectors. The top three leading publishing countries related to the research topic of this paper include the USA, China and the UK, and the cooperation among the three countries is relatively close. The visual analysis found a total of 13 author clusters, with Caldarelli and Battiston as the main contributors to systematic risk research, and the most influential authors in all clusters cooperated with the two authors, which provided the direction for consulting and studying classical literature on systemic risk. The analysis results also show that the high-frequency keywords in this paper are systemic risk, contagion, model, etc., indicating that the current research on preventing systemic risk contagion is relatively mainstream. The results of this study provide a comprehensive summary of the current research status of systemic risk in the financial field, and can provide some help for relevant researchers and scholars.

This study is scientific, but there are some limitations. The article data obtained from the Web of Science core collection may not be comprehensive enough, and there may be literature that is completely irrelevant to the research topic of this paper. Although irrelevant literature was excluded in the specific analysis of this study, there may be omissions.

Although the research on systemic risk in the financial field is increasing every year, its main research objects are the banking, insurance, and securities industries. Compared with the number of publications before and after the occurrence of systemic risk, there are relatively few studies when systemic risk does not occur, indicating that the research on preventing systemic risk still needs to be strengthened. In addition, the application of relevant mathematical models to measure systemic risk and simulate the transmission process of systemic risk between financial and real industries or between enterprises still need further research. Specific contents include:

(1) The methods of measuring systemic risk include the index method of value at risk (VaR) and its improved model (CoVaR, etc.) and the Copula model method of undetermined equity analysis (CCA), etc. These methods have their own advantages and disadvantages, but the accuracy of the above models in measuring systemic risk still needs to be further improved. Previous studies on the systemic risk of banking, insurance and stock market are abundant, but the research on the measurement of systemic risk in the financial industry is relatively lacking.

(2) At present, most scholars mainly focus on the construction of systemic risk networks in the financial industry or related industries, and there are few researches on the systematic risk networks in other industries, and the network models constructed are mainly single-layer static network. However, because of the spillover effect of systemic risk, the single-layer static network is not enough to fully reflect the complex characteristics of systemic risk. The construction of multi-layer network will help to display the systemic risk network and its evolutionary characteristics comprehensively and accurately.

(3) The transmission mechanism of systemic risk is almost identical to that of the infectious disease model (May et al., 2008; Garas et al., 2010). However, the research on the application of infectious disease model to simulate risk transmission mainly focuses on public opinion communication, credit risk communication, supply chain disruption risk and so on. Using infectious disease model to study the spread of systemic risk on the industry network will help to identify the important nodes and paths of the spread risk in the network, understand the transmission process, and then provide targeted measures to prevent and resolve the risk.

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