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Research on Authors' Co-authorship Network in Supply Chain Finance in China Based on Social Network Analysis

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<u>**Full Research Paper**</u>

Research on Authors' Co-authorship Network in Supply Chain Finance in China Based on Social Network Analysis

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Abstract: This paper used social network analysis method to analyze the high frequency author-co-author network in domestic supply chain finance field. In this study, relevant literatures on supply chain finance collected by CNKI from 2005 to 2019 were selected and key information was extracted. This paper used SATI, the literature citations information statistical analysis tool, to build correlation matrix. Social network analysis software UCINET was used to draw the map of co-authored network. The authors' subnet patterns, network density, centrality, cohesive subgroups and structural holes were analyzed, and the scientific collaboration network characteristics in this field were elaborated to promote academic exchange and development in the field of supply chain finance. The analysis results showed that the authors of supply chain finance in China is not connected enough, the overall network connectivity is weak, and there are few core nodes that play a key role. Therefore, scholars in this field should strengthen cooperation appropriately in the future.

Keywords: Social network analysis, Supply chain finance, Cohesive subgroup, Structural holes

1.   INTRODUCTION

Supply chain finance is an interdisciplinary discipline in supply chain, finance, logistics and other fields. It is a specific micro category of comprehensive financial activities based on industrial supply chain and targeted at participants of supply chain based on business flow, logistics and information flow in supply chain operation [1-2]. There are three typical models of supply chain finance, which are logistics enterprise leading model, enterprise group cooperation model and commercial bank service model [3]. The rapid development of supply chain finance has brought great opportunities and challenges to the current business model innovation and sustainable development of enterprises. At the same time, it has also proposed many new problems and new directions for the research of management theory, method and technology innovation, which has attracted wide attention in the academic circle.

So far, many scholars at home and abroad have conducted in-depth discussion on the research of supply chain finance, analyzed the development process of supply chain finance, elaborated the characteristics and elements of supply chain finance, put forward the research theme framework of supply chain finance, and studied various specific issues under this framework. Zhang et al. empirically tested the relationship between supply chain finance and enterprise performance by studying the relationship between supply chain finance and enterprise performance and bankruptcy risk, and also expanded the knowledge of supply chain finance [4]. Hugo K.S. Lam et al. studied the impact of supply chain finance firms with unique characteristics (i.e., enterprise characteristics, cooperation mechanism and service types) on the market value of service providers [5]. Zhou Han starting from the theory and practice experience of supply chain finance is introduced, and emphatically analyzes the risk of supply chain finance, especially in the participation main body based on the analysis, found that supply chain finance from the bank general financing specific risk and the corresponding risk prevention and methods, and on this basis puts forward some countermeasures and Suggestions on the development of supply chain finance [6]. Xia Yu et al. used

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the method of literature research and logical analysis to sort out and review the existing research literature with the evolution of supply chain finance theory as the context, and based on this, made an outlook for the future research [7]. It can be seen that supply chain finance has been fully studied and discussed by scholars in related fields. However, to our knowledge, there is currently no literature using social network analysis to analyze the co-authored network of supply chain authors. In order to fill this literature gap, this study uses the social network analysis method to discuss the characteristics of co-authorship networks in domestic supply chain fields from five aspects: subnet mode, network density, centrality, cohesive subgroup and structural hole based on the papers published in 2005-2019 collected from CNKI.

2.   METHODOLOGY AND DATA

2.1 Data sources

Data source selection is a very important step in social network analysis. CNKI (China Academic Literature Network Publishing Database) was initiated by Tsinghua University and Tsinghua Tongfang in June 1996, aiming at realizing the dissemination, sharing and value-added utilization of knowledge resources in the whole society. With its high-quality content resources, leading technology and professional services, CNKI enjoys a high reputation in the industry. Based on this, this paper selected CNKI as the retrieval database, searched with "supply chain finance" as the main topic, and selected the period from 2005 to 2019. A total of 4,697 pieces of data were retrieved, and 4,678 pieces of data were finally obtained after screening 4,697 pieces of data and removing irrelevant data such as essays, notices and advertisements.

2.2 Data processing tools

The data processing tools used in this paper are SATI and UCINET.

SATI (Statistical Analysis Toolkit for Informatrics) is a visual software for statistical analysis of bibliography information developed by Liu Qiyuan from Information Resource Management Department of Zhejiang University using C#. This software can deal with common data in Endnote, NoteFirst and NoteExpress formats. Its main functions include three parts: (1) field information extraction. In the "Options" panel, you can select the field information specified in the bibliography (such as subject word, key word, author, citation, institution, publication year, etc.) and you can choose to store it as a text document; ② Item frequency statistics. According to the field information extracted from the "Options" panel, the frequency of the elements in the entry (such as subject word, keyword, author, citation, organization, publication year, etc.) is counted and sorted in descending order. ③ Construction of co-occurrence matrix. Can decide for themselves in the SATI Shared output rows and columns of the matrix, and the frequency of the corresponding number in the descending order table entry element as a matrix of knowledge unit operations, to build knowledge unit co-occurrence matrix and generate EXCEL format document, which can be based on the matrix import documents UCINET, NETDRAW and visualization analysis software to generate the co-occurrence network knowledge map.

UCINET (University of California at Irvine Network) is a social network analysis software written by Linton Freeman, an authoritative scholar of social network research at University of California at Irvine. It comes bundled with software such as Pajet, Mage and Netdraw. UCINET is capable of processing raw data in matrix format, and the software itself includes data management and transformation tools. UCINET itself does not contain tools for network visualization, but it can be visualized by exporting the results of data processing to software such as NetDraw. The main functional modules of UCINET are: ①Network density analysis. ② Network centrality analysis. ③Analysis of cohesive subgroups.

2.3 Research Methods

This paper used the social network analysis method to discuss the coauthor relationship in the field of supply chain finance in China. Social network analysis is a method in anthropology, psychology, sociology, mathematics

and statistics, and other fields of development used in the measurement and investigation of the social system (" points ") the characteristics of each part and the relationship between each other (" connection "), to indicate it in the form of a network, and then analyzes the relationship between the mode and characteristics of the analysis method [8]. The "point" represents the social actor, which can be any social unit or social entity, and the "connection" represents the connection between the actors or the substantive relationship that shows the occurrence. The basic assumption of social network analysis is that the structure and characteristics of social network, the relationship among them, the distribution and location of points, etc. will influence the behavior and attitude of points to some extent. The types of social network analysis include: ① main network analysis. Starting from one point (subject) of social network, the relationship between it and other points (object) is analyzed. ② Analysis of relation. Analyze the time, content, intensity, affinity and direction of the relationship between two points. The overall network analysis. Considering the relationship between all points, the structure of the integrated network is analyzed [9].

In this article, using the method of social network analysis studies the domestic financial sector, the author co-author network of supply chain relationship, the relationship between the individual, "micro" network with the "macro" structure of the massive social system, combining with the software will be the author of the relationship between using network graph representation, and analyze the results.

3.   Basic statistical analysis of co-authorship

3.1 Basic statistical analysis

This paper summarized the number of co-authored papers and the total number of published papers in supply chain finance in China from 2005 to 2019 through a preliminary statistical analysis of a data sample composed of 4,678 articles in supply chain finance in China. The statistical results are shown in Figure 1. It is easy to know from Figure 1 that both the total number of published papers and the number of co-authored papers in the field of supply chain finance in China show an obvious growth trend. The overall growth period can be divided into two stages. The first stage is from 2005 to 2011, which is the stage of rapid growth. The second stage is from 2011 to 2015. In this stage, the number of publications and co-authored papers per year does not change much. The third stage is 2015-2016, during this period, the data on the number of publications and co-authored papers increased dramatically. The fourth stage is 2016-2019, which is a period of fluctuation. In this stage, the growth of domestic research literature in the field of supply chain finance fluctuates relatively steadily. The total number of published papers and the number of co-authored papers in this stage both reached the highest value in 2016, which were 765 and 248 respectively. It is easy to know from the analysis of Figure 1 that domestic research in the field of supply chain finance has been relatively mature and stable in the second stage.
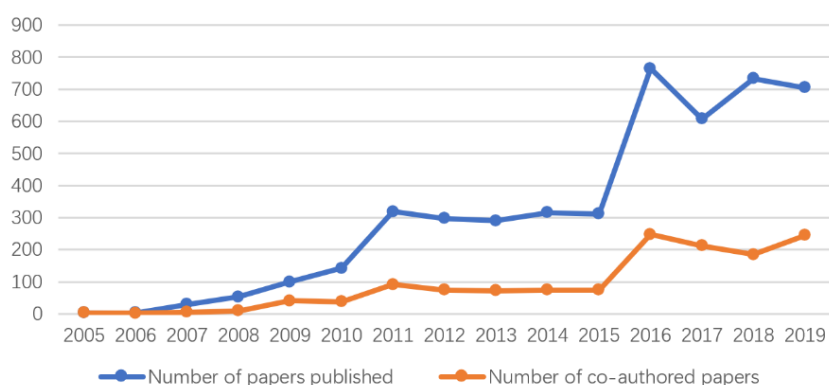

Figure 1.   Statistics on the number of papers published and co-authored papers

The top 20 published papers by authors with co-author relationships were statistically analyzed, and the statistical results were shown in Table 1.

Table 1.　Ranking of the number of articles published by core authors with co-author relationships

Ranking	Author	Number of Papers	Ranking	Author	Number of Papers
1	Hua Song	40	11	Yuefei Hu	9
2	Peng Xu	15	12	Yong Luo	9
3	Chaofeng Jiang	13	13	Yun Shen	9
4	Xuejian Chu	12	14	Xuehui Yi	9
5	Yongzhi Zhan	12	15	Lei Wang	9
6	Jinlong Chen	12	16	Wei Wang	8
7	Qiang Lu	11	17	Jie Liu	8
8	Juan He	11	18	Taifeng Xia	8
9	Wenli Hu	10	19	Xuxu Gao	8
10	Xuan Yang	10	20	Tao Chen	8

3.2 Subnet pattern analysis

The cooperative network of core authors in the domestic supply chain finance field is shown in Figure 1. Each node in the network represents a researcher, and the lines between nodes represent the cooperative relationship between researchers. The thicker the lines, the closer the connection between researchers is. Unconnected nodes represent independent researchers, which are on the left side of the image.

From the perspective of network mode, there are four subnet modes in the figure. (1) Single point mode. Single-point network refers to that researchers have completed the research work in the field independently. It is easy to know from the observation of the pictures that 21 researchers in the network belong to the single-point subnet. (2) Double karyotype mode. Double karyotype subnet network refers to a two-way network composed of two researchers, that is, two researchers cooperate in publishing papers. In Figure 2, 24 researchers collaborated in pairs to form 12 double karyotype subnets. (3) Bridge mode. A bridge network refers to one researcher who acts as a connecting node, such as a four-person subnet represented by Song Hua, who is the key node connecting the other three people. In the bridge subnet, the contact is the key node. If the contact node breaks, it means the relationship of the whole subnet breaks. There are two bridge-type subnets in the figure. (4) Complete mode. In a complete subnet, any two researcher nodes cooperate, that is, an edge connection. As shown in the subnet composed by Haiqing Hu et al., the four researchers had at least one collaborative experience. Complete subnet is a relatively ideal subnet mode, which represents a wider range of exchange opportunities [10]. There are six complete subnets in the figure.

Through the further analysis of the network diagram of the core authors in the field of supply chain finance, the following characteristics can be found in the overall network. (1) Poor network connectivity of co-authors. According to the above analysis, in the overall network, most of the subnets are single-point type (21) and double karyotype (12), while the number of bridge type (2) and complete type (6) subnets is small. This indicates that researchers in the field of supply chain finance have strong independence, poor relevance and weak connectivity of the whole network structure. (2) The number of cooperative groups is small, and the scale of subnet is small. In the overall co-authorship network, the largest subnet is composed of Hua Song, Qiang Lu, Sijie Chen and Xuan Yang, and Liang Chen, Haiqing Hu, Lang Zhang and Daohong Zhang. The rest of them are small teams of three or two people. This shows that the research team in the field of supply chain finance in China has not formed a scale. Most of the research work is carried out by independent researchers or small teams, and there is a lack of large-scale and closely connected research team.
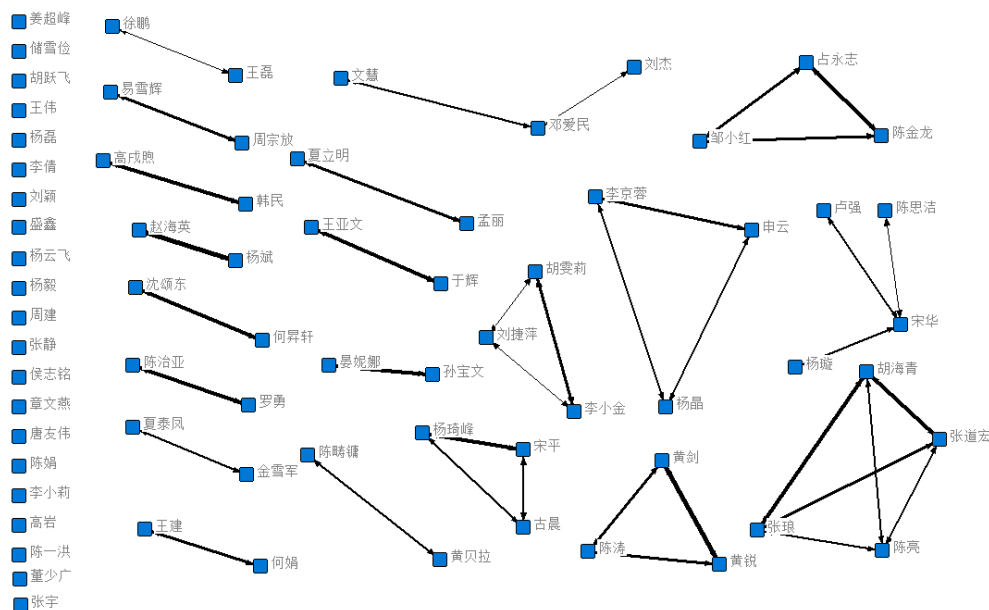
Figure 2. Network diagram of co-authorship relationship of core authors

3.3 Network density analysis

This paper mainly uses two indexes, network density and standard deviation, to measure the degree of coauthor network cohesion in domestic supply chain finance field. Among them, network density refers to the close correlation between researchers in a certain category, which represents a certain number of complex network relationships [11]. Its calculation formula is as follows:

$$\rho = \frac{2L}{N*(N-1)} \tag{1}$$

Where N represents the number of researchers in the network, and L represents the actual number of connections between researchers in the network.

Standard deviation is the square root of the arithmetic mean of the square difference between the standard value of each unit of the population and its mean. It reflects the degree of dispersion between individuals in a group. Its calculation formula is as follows:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{2}$$

Where N is the number of researchers in the network, x_i is the data value attached to the i_{th} researcher in the network, μ is the average value of the data value attached to all subjects in the network.

According to the calculation results of UCINET, the network density and network standard deviation of the domestic co-author network in the field of supply chain finance is 0.0036 and 0.0478, which is significantly higher than the network density value, indicating that the relationship between researchers in this field is relatively loose, with poor cohesion and less cooperation and communication.

3.4 Centrality analysis

Network centrality is an important indicator to measure the whole degree of network centrality, which is used to describe the social status or importance of individuals or organizations in the social network. Network centrality can be divided into three indexes: degree centrality, closeness centrality and between centrality [12]. Among them, the degree of point-degree centrality is used to measure the activity of a specific node, representing the degree of influence of a certain node in a social network in which nodes are related to each other in a certain scale. The

higher the centrality of the degree, the greater the influence of the node in the social network. Closeness centrality is a centrality represented by distance. The smaller the value, the higher the degree to which a node directly influences other nodes in the network, and the greater its communication influence in the social network. Between centrality refers to the degree to which a node in the network controls the resource information, and represents the degree to which the whole network is centralized, that is, the degree to which the whole network operates around a node or a group of nodes. The size of between centrality is proportional to the amount of resource information controlled. The higher the intermediate centrality of a node is, the greater the degree that the node acts as a medium. Table 2 shows the top 15 researchers in the ranking of point-centricity, near-centricity and intermediate centricity.

Table 2. The centrality ranking of core authors

Degree Centrality				Closeness Centrality			Between Centrality		
Author	Absolute value	Relative value	Proportion	Author	Absolute value	Relative value	Author	Absolute value	Relative value
Haiqing Hu	1.833	1.852	0.051	Hua Song	9603.000	1.031	Hua Song	3.000	0.062
Daohong Zhang	1.758	1.776	0.049	Lang Zhang	9603.000	1.031	Aimin Deng	1.000	0.021
Rui Huang	1.625	1.641	0.046	Haiqing Hu	9603.000	1.031	Peng Xu	0.000	0.000
Jian Huang	1.625	1.641	0.046	Daohong Zhang	9603.000	1.031	Chaofeng Jiang	0.000	0.000
Lang Zhang	1.563	1.578	0.044	Liang Chen	9603.000	1.031	Yongzhi Zhan	0.000	0.000
Tao Chen	1.250	1.263	0.035	Xuan Yang	9605.000	1.031	Jinlong Chen	0.000	0.000
JinLong Chen	1.194	1.206	0.033	Qiang Lu	9605.000	1.031	Xuejian Chu	0.000	0.000
Yongzhi Zhan	1.194	1.206	0.033	Sijie Chen	9605.000	1.031	Juan He	0.000	0.000
Ping Song	1.024	1.034	0.029	Tao Chen	9702.000	1.020	Wenli Hu	0.000	0.000
Haiyan Zhao	1.000	1.010	0.028	Jinlong Chen	9702.000	1.020	Xuan Yang	0.000	0.000
Xiaohong Zou	1.000	1.010	0.028	Yongzhi Zhan	9702.000	1.020	Yuefei Hu	0.000	0.000
Bin Yang	1.000	1.010	0.028	Ping Song	9702.000	1.020	Yong Luo	0.000	0.000
Qifeng Yang	1.000	1.010	0.028	Qifeng Yang	9702.000	1.020	Qiang Lu	0.000	0.000
Yun Shen	0.911	0.920	0.026	Xiaohong Zou	9702.000	1.020	Xuehui Yi	0.000	0.000
Xuxu Gao	0.875	0.884	0.025	Jieping Liu	9702.000	1.020	Lei Wang	0.000	0.000

3.4.1 Degree centrality

According to the above introduction, the higher the degree centrality, the greater the influence of the node in the social network. In combination with Table 2, it is easy to observe that Haiqing Hu with the highest degree entrality with the value of 1.833, and Daohong Zhang with the second degree centrality with the value of 1.758. These two authors have a lot of cooperation with other researchers, which is consistent with the results presented in Figure 1. Table 2 shows that most researchers in the field of supply chain finance have a low degree centrality, which indicates that most researchers conduct independent research and few core nodes play a key role.

3.4.2 Closeness centrality

In combination with the above introduction, the smaller the value of closeness centrality is, the higher the degree to which a node directly influences other nodes in the network, and the greater its communication influence in the social network is. It can be seen from Table 2 that Hua Song, Lang Zhang, Haiqing Hu, Daohong Zhang and Liang Chen have the lowest degree of closeness to the center. They are the core nodes of the collaborative network of integrated supply chain finance and have the greatest communication influence in the collaborative network. According to the analysis in Figure 1, the researchers with the lowest closeness centrality to the center belong to the larger cooperative subnet, which indicates that the establishment of the cooperative subnet is conducive to the scientific researchers to better play the role of information dissemination.

3.4.3 Between centrality

According to the statistical results in Table 2, it is easy to know that the scholars with high between centrality are Hua Song and Aimin Deng. This indicates that these researchers have strong resource control ability and act as an important medium in the whole supply chain financial co-authorship network, which is the key node of the co-authorship network. However, except for the above two authors, between centrality of other authors is 0, which indicates that most researchers in the domestic supply chain finance field do not have the ability to control and connect resources, and the overall connectivity of the co-authorship network is weak.

3.5 Analysis of cohesive subgroups

In social network analysis, cohesive subgroup analysis is also called "small group" analysis. A small group is a subset of actors in which the actors have relatively stable, direct, close, frequent or positive contact [13]. The analysis of cohesive subgroups in social networks is to analyze the relationships and characteristics within and between small groups. By using UCINET's N-Clique analysis, this paper calculates the clique of authors in the field of supply chain finance, so as to analyze the clique characteristics of domestic authors in the field of supply chain finance.

A total of 8 groups were obtained through N-Clique analysis, and the result was consistent with the characteristics presented in Figure 1. (1) Group 1. Group 1 is composed of Hua Song, Qiang Lu, Xua Yangn and Sijie Chen. Except for Qiang Lu from Business School of Beijing Technology and Business University, the other researchers are all from Business School of Renmin University of China. The main research directions of this group are supply chain finance, risk management and financing performance. (2) Group 2. Group 2 consists of three researchers Yongzhi Zhan, Jinlong Chen and Xiaohong Zou, all of whom are from the School of Business Administration of Huaqiao University. The main research directions of the group are network effects, platformer supply chain finance and evolutionary game. (3) Group 3. Group 3 consists of Wenli Hu, Jieping Liu and Xiaojin Li, all of whom are from the School of Finance, Accounting and Finance, Guangdong Academy of Science and Technology. Their research directions are B2B e-commerce, online supply chain finance, and credit model. (4) Group 4. Group 4 consists of three researchers Yun Shen, Jingrong Li and Jing Yang, all from the School of Economics of Sichuan Agricultural University, whose research directions include supply chain finance, poverty reduction effect, multidimensional poverty, and PSM-DID. (5) Group 5. Group 5 is composed of three researchers, Jie Liu, Aimin Deng and Hui Wen, all of whom are from the School of Economics and Trade of Hunan University.

The main research directions of the group are third-party logistics and credit evaluation. (6) Group 6. Group 6 consists of three researchers, Tao Chen, Jian Huang and Rui Huang, all from South China Institute of Finance, Guangdong University of Finance. The three researchers mainly study Internet supply chain finance, organizational form and financial model. (7) Group 7. Group 7 is composed of four scholars: Lang Zhang, Liang Chen, Haiqing Hu and Daohong Zhang. The four researchers are all from the School of Economics and Management, Xi 'an University of Technology. Their main research interests include supply chain finance, credit risk assessment, and support vector machines. (8) Group 8. Group 8 consists of three scholars, Qifeng Yang, Ping Song and Chen Gu, all of whom are from the School of Economics, Wuhan University of Technology. Their main research directions are online supply chain finance and confirmed warehouse financing mode.

3.6 Analysis of structural holes

Structural hole theory is a branch of the school of network analysis. It was proposed by Burt in his book Structural Hole: Social Structure of Competition in 1992 [14]. Among them, structural hole refers to the absence of relations between non-redundant contacts, that is, some individuals or individuals in the social network have direct contact with some individuals, but do not have direct contact with other individuals or the relationship is broken. Caves appear from the observation of the whole social network [15].

The four measurement indexes of structural holes are: effective size, efficiency, constraint and hierarchy [16].

Effective scale refers to the degree of non-redundancy in the network. Efficiency is measured in structural holes, the efficiency of a point is equal to the effective size of the point divided by the actual size of the point in the individual network. Constraint represents the ability of the actor to use structural holes in his network, that is, the degree of direct or indirect closeness between a node in the network and other nodes. Hierarchy represents the extent to which the restriction revolves around the actor.

Table 3.   Orders of the four indexes of the core author structure hole

Ranking	Author	Effective size	Efficiency	Constraint	Hierarchy
1	Jieping Liu	2.891	0.964	0.937	0.964
2	Liang Chen	2.586	0.646	0.725	0.153
3	Chen Gu	2.451	0.817	0.807	0.389
4	Hua Song	2.092	0.523	0.789	0.528
5	Jing Yang	1.947	0.649	0.841	0.236
6	Lang Zhang	1.654	0.413	0.804	0.139
7	Daohong Zhang	1.588	0.397	0.781	0.124
8	Haiqing Hu	1.577	0.394	0.784	0.131
9	Jingrong Li	1.576	0.525	0.896	0.234
10	Tao Chen	1.542	0.514	0.909	0.007
11	Yun Shen	1.541	0.514	0.857	0.176
12	Xiaohong Zou	1.530	0.510	0.875	0.041
13	Wenli Hu	1.512	0.504	0.986	0.433
14	Aimin Deng	1.486	0.495	0.903	0.536
15	Xiaojin Li	1.360	0.453	0.979	0.433
16	Yongzhi Zhan	1.274	0.425	0.880	0.055
17	Jinlong Chen	1.274	0.425	0.880	0.055
18	Ping Song	1.258	0.419	0.973	0.282
19	Qifeng Yang	1.251	0.417	0.984	0.291
20	Jian Huang	1.179	0.393	0.909	0.044

4. Conclusion

In this paper, using social network analysis method, based on CNKI retrieval library, use SATI, UCINET software for 2005 to 2019 in the field of domestic supply chain finance co-author network systematic analysis and visual display, and from the subnet model, network density, centricity, condensing subgroup, structural holes in the five aspects of domestic co-author network features in-depth in the field of supply chain.

The number of coauthored papers in the field of supply chain finance increased rapidly from 2005 to 2011, and reached a stable period from 2011 to 2015. In 2016, both the total number of published papers and the number of co-authored papers reached the highest value. From 2016 to 2019, the data is in a state of fluctuation The most published co-authors were Hua Song, Peng Xu and Chaofeng Jiang. In terms of the subnet mode of the co-authorship network, the connectivity of the co-authorship network is poor. In the whole network, most of the subnets are single point mode and double karyotype mode, while the number of bridge mode and complete mode subnets is small. At the same time, the number of cooperative groups is small, and the size of the subnet is small. In terms of network density, according to the calculation results of UCINET, the network standard deviation value is significantly higher than the network density value, which indicates that the relationship between researchers in this field is relatively loose, the cohesion is poor, and the cooperation and communication are less. In terms of centrality, most researchers conduct independent research and do not have the ability to control and connect resources. The overall connectivity of the co-authored network is weak and there are few core nodes that play a key role. In terms of cohesive subgroups, a total of 8 groups were obtained through the N-clique of UCINET, and all of the 8 groups were scientific research groups with a total number of 3-4 people. In terms of structure hole, from the calculation results of effective scale, efficiency, constraint and hierarchy. Jieping Liu and Liang Chen et al are located at the core of the network, have a relatively strong control over the network and have greater authority in the field of supply chain finance.

This study has significant theoretical and practical implications. From the perspective of theoretical implications, this study is the first academic paper to analyze and study the co-author networks of authors in the field of supply chain finance in China by using social network analysis method. This study, supported by abundant data, comprehensively discusses the major coauthor networks in the supply chain finance field in the past 15 years, which provides a foundation for future research. From the perspective of practical significance, researchers in the field of supply chain finance in China have less cooperation and exchanges, and the relationship is relatively loose. Therefore, academic exchanges and cooperation between various research institutions should be strengthened to promote the development and innovation of theoretical research on supply chain finance in China.

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