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Analysis of OFDI Industry Linkage Network Based on Grey Incidence: Taking the Jiangsu Manufacturing Industry as an Example

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Abstract: Based on the outward direct investment data of each manufacturing industry segment in Jiangsu Province from 2000 to 2020, this paper establishes a correlation network by constructing a grey incidence model with the average value of absolute grey incidence as the threshold. We further analyze the relationship between each manufacturing industry segment in Jiangsu Province in the process of outward direct investment from two perspectives, namely, point and surface. The study shows that from the perspective of each node, the correlation coefficient between equipment manufacturing and other industries is significantly higher, i.e., the influence of equipment manufacturing on other industries is significantly greater. Chemical raw materials and chemical products manufacturing, general equipment manufacturing, special equipment manufacturing, and transportation equipment manufacturing are the important nodes in the network. From the perspective of the network as a whole, the Jiangsu manufacturing OFDI affiliation network is not concentrated. Still, it has small-world characteristics, which are conducive to disseminating information. In contrast, the close nature of the industry has more commonalities, leading to it being more easily divided into the same module in the network block model analysis.

Keywords: absolute degree of incidence; Jiangsu OFDI; association network

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1. Background

Jiangsu Province has always been a large economic province in China, with extremely strong overseas investment strength. Its overseas non-financial outward, forward direct investment (outward forward direct investment, hereinafter referred to as OFDI) ranked sixth in the country (source: China Outward Investment Statistical Bulletin). In 2007, Jiangsu Province's manufacturing OFDI was only US 1.49 billion. However, at the end of 2019, the amount of OFDI in Jiangsu Province reached US 8.9 billion, including more than US 4.6 billion in manufacturing. Driven by the national policy and affected by the COVID-19, the OFDI in manufacturing in Jiangsu fell back to US 3.3 billion in 2020 but still accounted for more than half of the total investment (source: Jiangsu Statistical Yearbook). It can be seen that manufacturing is an important sector in OFDI in Jiangsu province.

Current academic research on the factors influencing manufacturing OFDI has mainly focused on the host country's environment and image. However, we believe that in addition to the factors already studied by scholars, there is likely to be herd-following behaviour in enterprises' investment decisions, which is reflected in the industry spillover phenomenon. At the same time, as Jiangsu Province is the largest economic province in China, its economic behaviour will affect other provinces. Therefore, we chose Jiangsu

Province's manufacturing OFDI as the research object and study the correlation of each sub-sector within the manufacturing industry in the OFDI process from the perspective of a social network, which helps to understand the closeness of industry linkage in OFDI from an overall perspective as well as the influence of each industry itself and the relationship between each other.

This paper contributes to the study of OFDI in Jiangsu Province in two ways. Firstly, we adopt the grey incidence method to study the inter-industry association of OFDI in manufacturing in Jiangsu Province and visualize it after taking the threshold values to form a binary network of the industry association in OFDI manufacturing in Jiangsu Province. We use both the grey incidence and social network methods to analyse the relationship between the various industries of OFDI in Jiangsu Province. Secondly, the inter-industry association network analysis is carried out from point and surface perspectives. Therefore, the third part of the paper builds a grey incidence system and analyses the inter-industry correlation based on the OFDI data of each manufacturing industry segment in Jiangsu from 2008 to 2020. In the fourth part, based on the results of the grey correlation calculation in the previous section, a 0–1 binary matrix is created with the average correlation as the threshold. The network is visualized and analysed in terms of the characteristics of the network nodes and the network as a whole, i.e., both points and surfaces, and conclusions are drawn.

2. Literature Review

2.1. On the Use of Social Networks Analysis in the Economic Sphere

Social Network Analysis (SNA) uses complex networks to analyse social problems or to view social phenomena from the perspective of networks. Furthermore, it analyses the internal structural characteristics of the object of study and studies the relationships between the actors within it. It also visualizes them and then analyses the position of each actor in the network and the overall structure of the network [1–3]. As a new research method, SNA is often used in the fields of economics and sociology: it allows for the analysis of the relationships between members of a network and the degree of closeness of the relationships [4], the speed of information dissemination between members [5,6], the impact of changes in the relationships between members on information dissemination [7], and the impact of changes in the network environment on its members of the network environment [8].

2.2. Research on Inter-Industry Linkages

This paper uses inter-industry linkages as links, thus forming a network of inter-industry linkages. There are two main approaches to constructing industry linkages: one is the input–output approach (I-O), an economic–quantitative method of measuring the interdependence of inputs and outputs [9] which uses the output of industry i as a raw material to input n units into industry j, thereby generating an input–output association between industries [10–12]. The analysis of input–output data reveals that the transport industry is closely linked to its forward and backward sectors and has become an important sector in developing the national economy [13]. In contrast, as one of the service sectors, the transport industry absorbs more output from other sectors but has a pull effect on the development of other sectors [14]. Q.P Mei, Y.J Kim, et al. analyse the sub-sectors within the logistics industry and their linkages with other industries and found that the logistics industry is internally interdependent among the sub-sectors and has formed a service ecosystem. Externally, the logistics industry is closely related to other industries, and the synergy with the leading industry is conducive to improving the efficiency of the leading industry [15,16]. On the other hand, an econometric approach can measure industry correlation. Huang, Wei Qiang, et al. explored the dynamic correlation pattern of volatility spillover among financial industries based on VAR-GARCH-BEKK [17].

This paper uses the OFDI data of each manufacturing industry segment in Jiangsu Province as the basis for inter-industry correlation analysis, so using the input-output

method is impossible. At the same time, there are discontinuities in the OFDI data of the industry segments within the province, which makes it difficult to meet the data stability requirements. It is also not possible to use the measurement method. Therefore, this paper adopts the grey correlation method to study the correlation between industries.

Grey incidence, one of the foundations of grey systems theory, measures the degree of association between two factors based on the degree of similarity or dissimilarity of their trends, also known as the 'grey incidence'. In the economic field, it is often used to study the impact of multiple factors on a certain research object. The grey incidence method is used to study the impact of industry, and macroeconomic factors on the impaired loan rate of banks, especially when the impact of different industries varies greatly [18]. The financial and insurance industry, communication and transportation industry, storage industry, and the post and telecommunication industry in the tertiary industry have the greatest impact on the economic development in Jiangsu province; therefore, it is suggested that the government correctly chooses leading industries to promote the faster development of its economy [19].

2.3. Research on OFDI in Jiangsu Province

Long-term economic development has enabled non-state enterprises in Jiangsu Province to develop well and have the strength to carry out OFDI. Compared with OFDI by state-owned enterprises, there are obvious market-seeking characteristics in the OFDI process of these enterprises, and there is an obvious preference for countries with good investment systems and industrial bases [20–22]. OFDI generates technology spillover to the home country, but this spillover effect is limited by economic development, financial development, and economic openness. There are threshold restrictions; that is, when the home country's economic development, financial development, and economic openness are at the moderate scale stage, the reverse technology spillover effect of OFDI can be better realized. Jiangsu Province has a good economic development foundation and better technological strength than less economically developed regions; therefore, it is stronger than other regions in its technological absorption capacity to the host country [23–27].

There are many articles in the SCI library on China's OFDI research involving spatial spillover, industry spillover, technology spillover, and location choice, but not many studies are devoted to OFDI in the provincial context. There are even fewer studies on OFDI, specifically in Jiangsu province, and there is no research on industry spillover and linkage [28,29].

Therefore, this paper fills in this gap by focusing on OFDI in the manufacturing sector in Jiangsu Province. Through this paper, we can understand the interrelated effects of each industry in the OFDI process in Jiangsu's manufacturing sector and tap into the key industries. At the same time, based on the discontinuity of provincial industry investment data, this paper avoids the traditional econometric and input–output method. It adopts the grey correlation and social network research method, which achieves an innovative methodological approach and provides ideas for other research on correlation effects.

3. Data Sources and Study Design

3.1. Data Sources

This paper selects the manufacturing industry segments published in Jiangsu Statistical Yearbook from 2008 to 2020 as the research object. "Automobile, railway, ship, aerospace and other transportation equipment manufacturing" are combined into "transportation equipment manufacturing". The final 30 manufacturing industry segments were obtained, namely: (1) agricultural and sideline food processing industry, (2) food manufacturing industry, (3) beverage manufacturing industry, (4) textile industry, (5) textile garment, shoes and hats manufacturing industry, (6) leather, fur, feather (down) and its products industry, (7) wood processing and wood, bamboo, rattan, palm and grass products industry, (8) furniture manufacturing industry, (9) paper and paper products industry, (10) printing industry and reproduction of recording media, (11) education and sports

goods manufacturing industry, (12) petroleum processing, coking and nuclear fuel processing industry, (13) chemical raw materials and chemical products manufacturing industry, (14) pharmaceutical manufacturing industry, (15) chemical fiber manufacturing, (16) rubber products industry, (17) plastic products industry, (18) non-metallic mineral products industry, (19) ferrous metal smelting and rolling processing industry, (20) non-ferrous metal smelting and rolling processing industry, (21) metal products industry, (22) general equipment manufacturing, (23) special equipment manufacturing, (24) transportation equipment manufacturing, (25) Electrical machinery and equipment manufacturing industry, (26) Communication equipment, computer and other electronic equipment manufacturing industry, (27) Instrument and cultural and office machinery manufacturing industry, (28) Handicraft and other manufacturing industry, (29) Waste resources and waste materials recycling and processing industry, and (30) Electricity and heat production and supply industry. This paper uses the numbers 1–30 to indicate the above 30 industries; for example, 1 indicates the agriculture and food processing industry.

3.2. Absolute Degree of Incidence

Granger causality test can determine whether there is a causal relationship between two or more variables from a time-series perspective. This is done by testing whether the historical information of one variable can enhance the predictive power of another variable to determine whether there is a causal relationship between them. However, the Granger test applies to smooth data; it cannot be used on non-continuous and non-smooth data. Through validation, it was found that the OFDI data in this paper could not pass the stationarity test, hence it was not possible to comprehensively analyse whether there was a spillover relationship between the OFDI industries in Jiangsu Province as a whole, but only to obtain the association before some industries. Additionally, the use of grey incidence analysis can make up for the shortcomings of the Granger test.

However, provincial-wide OFDI for each industry segment is not a continuous and stable economic behaviour. This results in frequent fluctuations in OFDI data for each manufacturing industry segment in Jiangsu Province. The authors then used Granger's test to determine the association between industries. Still, through verification, we found that the OFDI data of some industries in this paper passed the smoothness test and were able to make causal judgments. Still, we had to exclude the non-smooth industries when building the association network. This made it impossible to analyse whether there was a spillover relationship between the OFDI industries in Jiangsu Province but only obtained some of the industries before the correlations.

The use of grey incidence analysis can make up for the shortcomings of the Granger test. It does not have harsh requirements on the sample size, nor does it require the smoothness of the data, which blurs the data requirements. If the data requirements under Granger are black or white, then the data requirements under the grey incidence method are grey.

Grey correlation analysis is one of the basic theories of grey system theory, based on the degree of similarity between the geometry of different time series curves to judge whether the development trend between the series is consistent with judging the closeness of the connection between the two, reflected in the graphical representation of the closer the geometry of the folds. The higher the degree of synchronous change, the greater the correlation between the corresponding series and vice versa [30,31].

Therefore, grey incidence analysis measures the degree of incidence between factors based on the similarity of the trends between the series, also known as the "degree of grey incidence". The degree of grey incidence is the main indicator to determine the degree of incidence between the corresponding series. According to the grey incidence theory, there are several incidences, such as Dunn's grey incidence, grey absolute incidence, grey relative incidence, comprehensive grey incidence, etc. The calculation methods and requirements of different incidences are slightly different. Based on the discontinuity of OFDI industry data,

this paper adopts the degree of absolute incidence to judge the closeness of the spillover relationship between industries [32].

Grey incidence theory assumes that X_i is a systematic factor whose observations at the moment k for factor i are noted as $x_i(k), k = 1, 2, \ldots t$. In this paper, we call

$$X_i = (x_i(1), x_i(2), \ldots, x_i(t)) \tag{1}$$

The time series of the behaviour of the factor X_i and in this paper $x_i(k)$ is the observed data of industry i in year k. The grey absolute incidence between factors X_i and X_j is calculated as follows [33]:

(1) Transform the sequences X_i and X_j into isochronous sequences

If the series X_i and X_j have the same time span but the number of observations is not the same, then we call the series X_i and X_j non-equal time span series. In this case, we can use the method of completing the shorter series X_i to make the series X_i and X_j into a series of the same length. The method is as follows:

$$x_i(k) = \frac{1}{2}(x_i(t_1) + x_i(t_2)) \tag{2}$$

$x_i(t_1)$ and $x_i(t_2)$ are the two adjacent data before and after $x_i(k)$. In the process of completing the insufficient data, priority is given to calculating the data where both $x_i(k-1)$ and $x_i(k+1)$ exist, and then calculating the data where the positions are adjacent, finally making the sequence X_i and X_j equal in time distance.

(2) The sequence X_i starts with zero image to get x_i^0 and computes $|s_0|, |s_i|, |s_i - s_0|$

$$x_i^0(k) = x_i^0(k) - x_i^0(0) \qquad k = 1, 2, \ldots, t \tag{3}$$

$$s_i = \int_1^n (X_i - x_i(1))dt \tag{4}$$

(3) Obtaining absolute degree of incidence

$$\varepsilon_{oi} = \frac{1 + |s_0| + |s_i|}{1 + |s_0| + |s_i| + |s_i - s_0|} \tag{5}$$

ε_{oi} denotes the incidence between series i and series 0 (in the following, the incidence or grey incidence refers to the absolute grey incidence), taking series 0 as the object of investigation and taking the value between 0 and 1. As the degree of incidence increases, the influence between the factors also increases; therefore, the grey incidence method is used to study the correlation between OFDI industries in Jiangsu Province, which is the degree of mutual influence between industries in the process of OFDI [34].

3.3. Social Networks Analysis

3.3.1. Industry Affiliate Network Building

Social Network Analysis (SNA) is an important method for the accurate quantitative study of networks and relationships. It uses graphical tools and algebraic models to study patterns of relationships in networks. SNA emphasizes the interaction between social actors and uses graphs and matrices to portray social networks, enabling accurate analysis of relationships, including network density, centrality, and the spatial and temporal evolution of cohesive subgroups.

In this paper, we mainly judge the correlation between the OFDI of each manufacturing industry segment in Jiangsu Province by the method of grey incidence, which is expressed by the grey absolute correlation ε_{ij}. Therefore, we take the manufacturing industry segments as nodes, the correlation between industries as edges, and the grey absolute correlation between industries as weights and establish the industry OFDI incidence matrix A.

$$A = (a_{ij})_{N \times N} \tag{6}$$

where $a_{ij} = \varepsilon_{ij}$, that is the degree of incidence between industries. Industries are the linkage weight between network nodes, so the Jiangsu manufacturing OFDI industry association network is a weighted network. Using the software of Ucinet to visualize Jiangsu manufacturing OFDI industry association network A, we can get the incidence network of manufacturing OFDI industry segments in Jiangsu Province from 2008 to 2020.

3.3.2. Analysis of Network Characteristics Indicators

(1) Point-based character indicators

Metrics commonly used in social network analysis to describe the nature of network nodes include Degree Centrality (DC), Betweenness Centrality (BC), Closeness Centrality (CC), Eigenvector Centrality (EC), Huber Influence and Structure holes and other metrics.

Degree Centrality is used to describe the importance of a node. The more neighbours a node has directly connected to it, the more influential it is. This is the simplest metric to characterize the importance of a node in a network. The centrality of the feature vector is from the point of view of the neighbouring nodes. Closeness Centrality refers to how close node i is to the centre of the network. The higher the Closeness Centrality, the closer the node is to the network's core, and the more important it is [35,36].

The Huber influence index is calculated by considering the number of relationships a node has received and the number of relationships it has issued. In matrix language, the actor with the greater "column sum" in the matrix has the greater influence and higher status [35,37].

A structural hole is a non-redundant link between two actors [38]. The four metrics of effective size, efficiency, constraint, and hierarchy are often used to determine whether a node is a structural hole. A node that acts as a structural hole can link two other nodes that are not linked to each other, playing a role of a bridge. (1) Information advantage, the node occupying the structural hole, can obtain non-repetitive information from many aspects and become the information collection and distribution centre. The location advantage brought by the structural hole makes the node occupying the structural hole obtain more favourable information resources. (2) Control advantage, from the location of the structure hole, the nodes occupy the critical path and can determine the flow direction of various resources. The node of the structural hole links two otherwise unconnected parties and that node has a control advantage and a say in front of the linked parties [35,39,40].

(2) Characteristic indicators based on "facets"

There are many analyses of the topological properties of networks in SNA, mainly in terms of network centrality, closeness, small world, and modularity.

Tightness: measured using network density, it refers to how closely the various spatial units in a graph are connected, with larger values indicating that the spatial units in the graph are more closely connected.

Centrality is usually expressed in a diagram's degree centrality and proximity centrality. The degree of centrality potential reflects the tendency of the graph to concentrate on a particular point. In contrast, the proximity centrality potential reflects the tendency of the entire network graph to concentrate at the core of the network. These two central potentials take 0 to 1, with larger values indicating a greater tendency to centralize the network [35].

Small World: A network in which the nodes are sparsely related, without a core but highly clustered. It is mainly measured by the clustering coefficient and the average path length. The smaller the value, the smaller the number of connections that need to be made between any two industries in the network, that is, the more industries in the network are directly connected. The smaller the value, the smaller the number of links between any two industries in the network. The more direct linkages between industries in the network, the more efficient the network is in terms of connectivity and organization [35,36,41,42].

Modularity: This is mainly achieved through block models analysis, which was first proposed by White, Boorman and Breiger (1976) [43] and is often used to identify the different actors in a network and their interaction patterns, and as a social structure within the network. Block model analysis reduces the complex relationships between network

nodes to intra and inter-block relationships by dividing nodes with similar structures into blocks based on structural reciprocity. The correlation coefficient matrix is obtained by the same method, and so on iteratively; the correlation coefficients in the final matrix are only 1 and −1. The chunking is carried out, and after chunking, each area's density matrix table is calculated, then divided into intra-block density (the density value on the diagonal of the matrix) and inter-block density (the value on the non-diagonal) [35,44,45].

4. Jiangsu Province Manufacturing OFDI Industry Linkages and Associated Networks Analysis

4.1. Jiangsu Province Manufacturing OFDI Industry Linkage Analysis

In this paper, 30 sub-sectors of the manufacturing industry in Jiangsu province are selected as the research object, and the sample period is 2008–2020. Among the 13 years of sample data of 30 industries, only one industry, namely, special equipment manufacturing (23), has OFDI every year. The remaining industries have an OFDI amount of 0 in some years; thus, the neighbouring mean method is adopted to make up for the insufficient data of the shorter series X_i, to establish the grey system X [46].

(1) Create a grey system X and analyse

The grey system X contains the system factor X_i, $(i = 1, \ldots n, n = 30)$, and the observations for each system factor X_i are $x_i(k)$, $(k = 1, 2, \ldots t, t = 13)$; thus, the grey system matrix can be created as follows:

$$X = \begin{bmatrix} x_0(1) & \cdots & x_0(13) \\ \vdots & \ddots & \vdots \\ x_{30}(1) & \cdots & x_{30}(13) \end{bmatrix} \tag{7}$$

(2) Zero-imaging the data series of system factor X_i to obtain the zero-imaging matrix

$$X^0 = \begin{bmatrix} {x_1}^0(1) & \cdots & {x_{30}}^0(13) \\ \vdots & \ddots & \vdots \\ {x_{10}}^0(1) & \cdots & {x_{30}}^0(13) \end{bmatrix} \tag{8}$$

(3) Compute $|s_0|, |s_i|, |s_i - s_0|$ and the absolute degree of incidence ε_{ij} The absolute degree of incidence ε_{ij} $(i \neq j,\ i,\ j = 1, \ldots n, n = 30)$ between the system factors x_i and x_j, and the correlation matrix R, were obtained by calculation.

$$R = \begin{bmatrix} \varepsilon_{11} & \cdots & \varepsilon_{113} \\ \vdots & \ddots & \vdots \\ \varepsilon_{301} & \cdots & \varepsilon_{3013} \end{bmatrix} = \begin{bmatrix} 1 & \cdots & 0.609 \\ \vdots & \ddots & \vdots \\ 0.609 & \cdots & 1 \end{bmatrix} \tag{9}$$

Since the absolute degree of incidence $\varepsilon_{ij} = \varepsilon_{ji}$, the incidence matrix R is a symmetric matrix with a diagonal of 1. The mean absolute degree of incidence reaches an average correlation of 0.6722. The mean correlation between individual industries and other industries is between 0.53 and 0.73, indicating a certain correlation between industries in the OFDI process in Jiangsu Province. There is a certain incidence between all industries in OFDI, and there is a mutual influence between industries in the process of OFDI. That is, there is an industry spillover effect [47].

The industry with the highest average absolute grey incidence among other industries is the general equipment manufacturing industry, at 0.73. The industry's largest absolute grey incidence is 0.999, which is the correlation between the ferrous metal smelting and rolling processing industry and the general equipment manufacturing industry. The two industries are the most relevant to OFDI, indicating that the ferrous metal smelting and rolling processing industry and the general equipment manufacturing industry are mutually influential in OFDI. The influence reaches 0.999, mainly because these two industries are raw materials and manufactured products, respectively, and the inter-industry links are

close, which influence each other in the OFDI process. The development of OFDI in general equipment manufacturing requires the supporting development of raw material supply industries, thus driving OFDI in the ferrous metal smelting and rolling processing industry. At the same time, OFDI in the ferrous metal smelting and rolling processing industry will also constrain the general equipment amount of OFDI and investment efficiency in the manufacturing industry (see Table 1).

Table 1. Descriptive analysis of the absolute degree of incidence between OFDI industries.

Mean	0.67	**Skewness**	0.63
Standard Error	0.01	**Area**	0.50
Median	0.63	**Min**	0.50
Plural	0.72	**Maximum**	0.999
Standard deviation	0.14	**Summation**	312.56
Variance	0.02	**Number of observations**	465
Kurtosis	−0.72	**Confidence level (95.0%)**	0.01

The smallest absolute degree of incidence is 0.5012 (see Table 1) for the leather, fur, feather (down), and its products industry and furniture manufacturing. Industries with the lowest incidence (see ε_6 in Figure 1), were food manufacturing, beverage manufacturing, wood processing and wood, bamboo, rattan, palm and grass products, petroleum processing, coking and nuclear fuel processing, and petroleum processing industries. It was found that OFDI, combined with the raw data analysis, showed a steep growth or decline in the leather, fur, feather (down), and its products industry with an average investment of US 1.514 million from 2008 to 2013, while investment surged to US 8 million in 2014 and US 63.94 million in 2016 but was zero in 2018 and 2019. With changes in investment in other industries inconsistent, according to the meaning and analysis of grey incidence, low incidence values indicate that leather, fur, and feathers (down) are more independent and have less influence on OFDI in other industries, as well as being less influenced by OFDI in other industries.

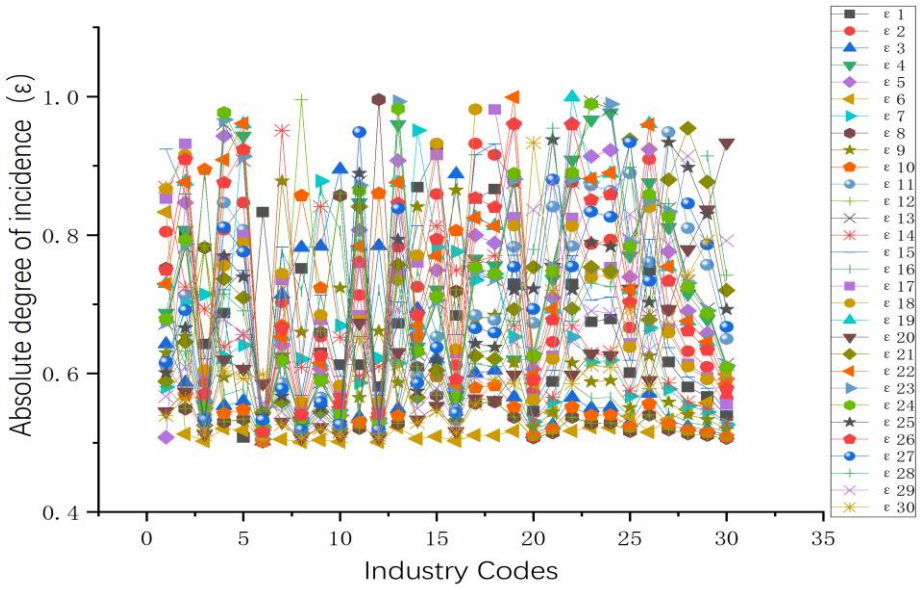


Figure 1. Absolute degree of incidence between industries.

An analysis of the correlation between individual industries and other industries shows that most industries' absolute degree of incidence is between 0.5 and 0.8 (see Figure 2), with the highest degree of incidence of 0.99 between general equipment manufacturing and ferrous metal smelting and rolling processing industries. The industries with the degree of incidence with other industries above 0.95 include the textile industry, textile garment, shoes and hats manufacturing, chemical raw materials and chemical

products manufacturing, ferrous metal smelting and rolling processing industry, general equipment manufacturing, special equipment manufacturing, transportation equipment manufacturing, communication equipment, and computer and other electronic equipment manufacturing. In summary, it is easy to find that the industry with a high degree of incidence is mainly concentrated in textile, machinery and electronics, chemical, and metal. These are the strong export industries in Jiangsu Province.

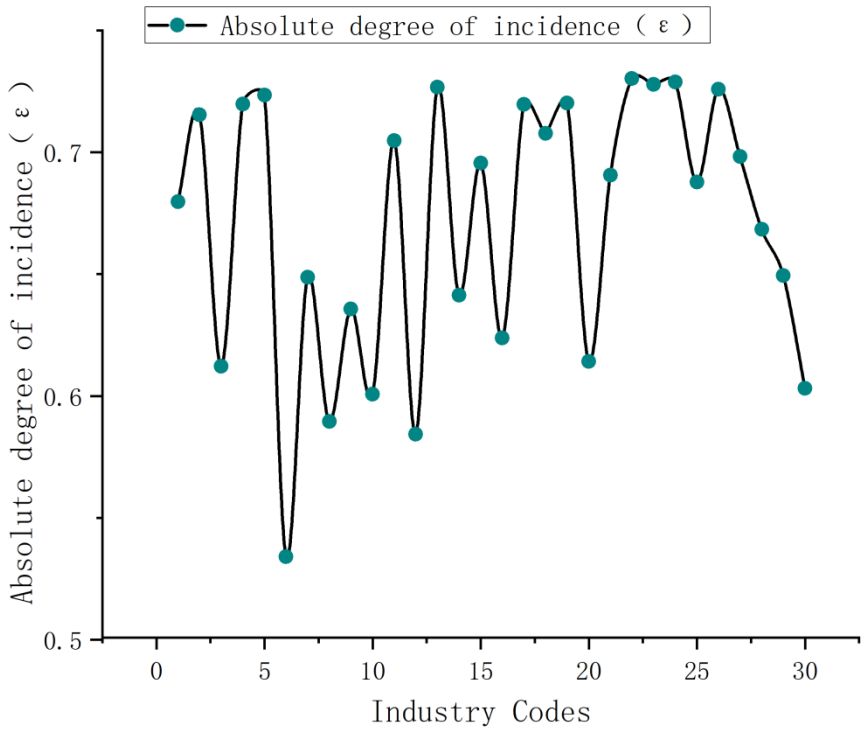


Figure 2. Average absolute degree of incidence across 30 industries.

4.2. Basic Nature of Affiliated Networks in the Manufacturing OFDI Industry in Jiangsu Province

The network obtained after visualizing the correlation matrix R is a fully linked network, and at the same time, the link weights of this network are in the range of 0.5~1. The analysis data of points and surfaces obtained on this basis will be very close, and it is impossible to clarify the various characteristics of the network and its nodes. Therefore, this paper adopts the threshold method, taking the average value of the link weights between two nodes. Thus, the average value of inter-industry correlation is 0.67. When $\varepsilon_{ij} > 0.67$, we believe that there is a strong association between industries in the process of outward foreign direct investment in manufacturing in Jiangsu Province, at which time $a_{ij} = 1$ and vice versa. We obtain the strong association matrix A and visualize it (see Figure 3). The strong association network can be analysed to get a clearer picture of the association between industries.

4.2.1. Characterization Based on 'Points'

To understand the characteristics of nodes within the OFDI industry-linked network of manufacturing industries in Jiangsu province, we obtained the data of degree centrality, feature vector centrality, proximity centrality, Huber influence index, and structural hole indicators of the network nodes by formula operation and software processing, which illustrate the characteristics of the network nodes from different perspectives, respectively (see Table 2).

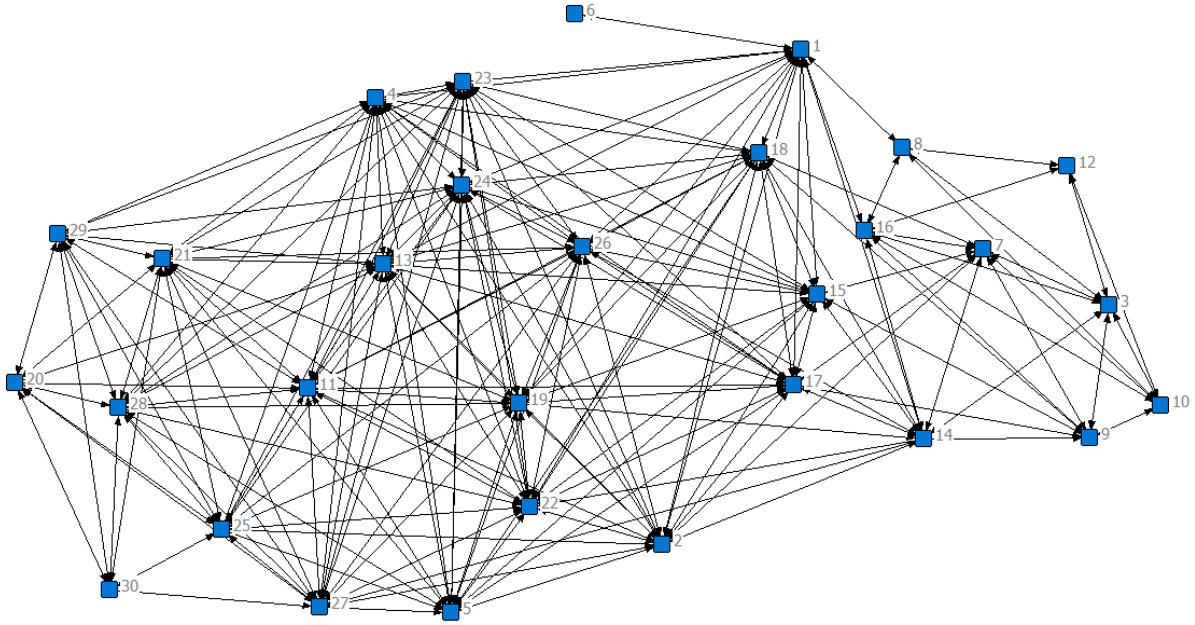


Figure 3. Jiangsu Province Manufacturing OFDI Industry Linkage Network.

Table 2. Analysis of the basic characteristics of the nodes.

Node	DC	EC	CC	Hubble Influence	Structural Hole Measures			
					EffSize	Efficie	Constra	Hierarc
1	0.52	0.18	65.18	1.02	6.67	0.44	0.16	0.01
2	0.59	0.24	67.44	1.010	4.79	0.28	0.19	0.01
3	0.24	0.02	43.32	1.023	3.08	0.44	0.37	0.03
4	0.59	0.24	65.18	1.021	4.67	0.28	0.19	0.01
5	0.55	0.24	58.59	1.02	3.19	0.20	0.20	0.01
6	0.03	0.01	40.00	1.002	1.00	1.00	1.00	1.00
7	0.31	0.07	51.79	1.013	4.00	0.44	0.25	0.02
8	0.17	0.02	45.31	1.006	2.22	0.44	0.44	0.03
9	0.28	0.06	50.02	1.011	3.63	0.45	0.27	0.01
10	0.21	0.01	37.95	1.007	2.46	0.41	0.43	0.04
11	0.59	0.24	60.42	1.023	4.71	0.28	0.19	0.01
12	0.14	0.01	34.53	1.006	1.25	0.31	0.54	0.00
13	0.66	0.26	67.48	1.025	5.47	0.29	0.19	0.02
14	0.45	0.14	61.22	1.015	5.83	0.45	0.19	0.02
15	0.52	0.20	63.74	1.020	4.53	0.30	0.19	0.01
16	0.28	0.03	49.17	1.011	4.25	0.53	0.31	0.01
17	0.55	0.21	65.91	1.021	4.94	0.31	0.19	0.01
18	0.55	0.21	65.91	1.021	4.94	0.31	0.19	0.01
19	0.59	0.24	67.44	1.023	4.77	0.28	0.18	0.01
20	0.28	0.10	45.69	1.010	1.57	0.20	0.29	0.02
21	0.52	0.20	54.72	1.020	4.20	0.28	0.21	0.01
22	0.62	0.25	67.50	1.024	4.61	0.26	0.19	0.01
23	0.62	0.25	67.44	1.024	4.78	0.27	0.19	0.01
24	0.62	0.25	67.44	1.024	4.78	0.27	0.19	0.01
25	0.55	0.22	55.24	1.019	4.48	0.28	0.21	0.02
26	0.59	0.24	67.44	1.023	4.24	0.25	0.19	0.01
27	0.59	0.22	60.65	1.023	5.71	0.34	0.19	0.02
28	0.48	0.19	53.70	1.019	3.86	0.28	0.21	0.01
29	0.38	0.14	49.58	1.014	2.64	0.24	0.24	0.01
30	0.21	0.07	40.92	1.009	1.00	0.17	0.33	0.00

A node with a high degree of centrality indicates that more nodes are associated with it and more nodes are influenced. By comparing the degree of centrality of each node, it is

found that node 13 (chemical raw materials and chemical products manufacturing) has the highest degree of centrality, followed by nodes 22, 23, and 24 (general equipment manufacturing, special equipment manufacturing, and transportation equipment manufacturing respectively) and then nodes 2, 4, 11 and 19 (food manufacturing, textile, education and sporting goods manufacturing, ferrous metal smelting, and calendaring). The high degree of centrality indicates that these industries strongly influence other industries in the OFDI industry linkage network of manufacturing in Jiangsu Province.

The importance of the node is underlined by the importance of its neighbours, which is also one of the main indicators to evaluate the node's importance. The nodes 22, 23, 24, 4, and 19 (respectively, the nodes with high centrality in general equipment manufacturing, special equipment manufacturing, transportation equipment manufacturing, textile industry, literary, educational and sporting goods manufacturing) were found to be among the nodes most relevant to node 13, and the eigenvector centrality of these nodes was still high, second only to node 13. Thus, we can initially judge nodes 13, 22, 23, 24, 4, 19, and 2 as the most important nodes in the network.

The higher the proximity centrality, the closer the node is to the centre of the network and the more important it is. The proximity centrality index analysis found that nodes 22, 13, 2, 19, 23, and 24 ranked high, and thus these six nodes were at the centre of the network. Through the Huber influence index results in Table 2, the nodes that have a greater impact on other industry associations are still 13, 22, 23, and 24.

Judging based on the above analysis, the most important and also the most influential nodes in the inter-industry correlation network of OFDI in manufacturing in Jiangsu province are 13, 22, 23, and 24 (chemical raw materials and chemical products manufacturing, general equipment manufacturing, special equipment manufacturing, and transportation equipment manufacturing). Among them, the chemical raw materials and chemical products manufacturing industry positions in the economy cannot be ignored. Jiangsu is China's chemical industry traditional province. Its chemical industry's technology and profitability have been firmly in the top three with the economic strength of foreign direct investment. While China's long-term economic development and trade are in a surplus, the demand for basic chemical raw materials is great. The chemical raw materials and chemical products manufacturing industry has been increasing its OFDI to obtain a stable supply of chemical raw materials and their manufactured products from abroad when domestic resources cannot be met. Therefore, the basic position of the chemical raw materials and chemical products manufacturing industry in economic development determines that it will also have a significant impact on the investment of other industries in OFDI. With the increase of OFDI in this industry, the domestic demand will be met, driving the development of other industries, which provides the possibility of OFDI in other industries. The general equipment manufacturing industry, special equipment manufacturing industry, and transportation equipment manufacturing industry belong to the equipment manufacturing industry, whose manufactured products involve many industries in industrial development. The quality of their products directly affects the quality of products in other industries. This affects the quality of products of the relevant industries, creating the possibility of OFDI in the relevant industries.

They occupy a very important position in the development of the national economy and also have the characteristics of locking the low end of the global value chain of China's equipment manufacturing industry [48], which is conducive to the upgrading of high-end manufacturing technology and the expansion of foreign markets through OFDI.

Using the Burt Structural Hole Index, the UCINET tool was used to analyse the inter-industry correlation network of OFDI in the manufacturing industry in Jiangsu Province. There are obvious gaps in the effective scale indicators, with the highest being 1, 14, 27, 13, 17, and 18 (respectively, agriculture and food processing industry, pharmaceutical manufacturing industry, instrumentation and cultural and office machinery manufacturing industry, chemical raw materials and chemical products manufacturing industry, material products industry, and non-metallic mineral products industry), with a minimum of 9.005

(node six, leather, fur, feather (down) and its products industry). From the perspective of efficiency indicators, except for nodes 6 and 16, the efficiency values of all nodes are below 50%, indicating that the effective size of most nodes does not account for more than 50% of the total size. The limit regime refers to the ability of this node to employ structural holes in its network and takes a value limited to between zero and one. It is also the sum of the limits imposed on node *i* from all associated nodes (including direct and indirect associations). Its value is inversely proportional to the number of structural holes within the node group and between groups. In terms of the restriction regime metric, all nodes have restriction regime nodes below 0.5. Except for nodes 6 and 12, nodes 1, 19, 17, and 18 have the smallest restriction regimes. Finally, we analyse the rank degree indicator in the structure hole, which further analyses an indicator based on the restriction system. It indicates how much node restriction is concentrated on one node.

The higher the rank degree, the greater the node is restricted by one node, combined with the restriction system and effective scale values. We found that node six is special; it is only linked to one node. As a result, its rank degree, restriction system, and effective scale are all one, completely limited by node one (see Figure 1). Therefore, this node is not a structural hole in the inter-industry linkage network of OFDI in the manufacturing industry in Jiangsu province. Following the analysis of other nodes, it is found that only five nodes have a rank degree of more than 0.002 (excluding node six), while all other nodes are less than 0.002, indicating that the restrictions on each node of the inter-industry linkage network of OFDI in manufacturing in Jiangsu province are relatively scattered. The probability of concentrating on a single node is very low. The industries in manufacturing in Jiangsu province are affected by the OFDI process from multiple industries [49].

In summary, the structural hole utility of nodes 1, 14, and 27 (agriculture and food processing industry, pharmaceutical manufacturing industry, instrumentation and cultural and office machinery manufacturing industry) in the OFDI industry linkage network of the manufacturing industry in Jiangsu province is very obvious, among which the effective scale and efficiency of nodes 1 and 27 are relatively high. This shows that their non-redundant links are less, while their restriction system and rank degree are low, indicating less restriction. Regarding node 13 (chemical raw material and chemical product manufacturing), although its effective size is high, its efficiency is low, indicating more redundant links in the group it belongs to. Nodes 1, 14, and 27, which are structural holes, are not important nodes in the OFDI industry association network of the manufacturing industry in Jiangsu province to which they belong (obtained by degree centrality, proximity centrality, and eigenvector centrality analysis). However, its location in the structural hole can gain advantages, including information and control advantages. Through the information advantage, it can obtain more useful information, including technical information and host country system information generated and encountered in OFDI in related industries. By acquiring such information, the agriculture and food processing industry, pharmaceutical manufacturing industry, instrumentation and culture, and office machinery manufacturing industry can promptly adjust the amount of OFDI in this industry.

4.2.2. Characterization Based on 'Facets'

To understand the overall characteristics of the inter-industry linkage network in the process of outward foreign direct investment in the manufacturing industry of Jiangsu, we listed some of the indicator values that show the overall characteristics of the network in Table 3 after the formulae and software processing.

Table 3. Network Characteristics Indicators.

Index	Density	Degree Centralization	In/Out Centralization	Clustering Coefficient	Average Distance
VALUE	0.431	22.91%	26.45%/23.59%	0.750	1.846

Through the density data in Table 3, we can see that the linkage density of each industry in the linkage network between industries in the process of OFDI in the Jiangsu manufacturing industry is not particularly high. Thus, the linkage tightness between the 30 industries is only 43.1%. Both the network degree central potential and the incoming (outgoing) degree close to the central potential do not exceed 30%, indicating that this network has little tendency to concentrate towards the centre. Therefore, combining the results of Figure 1, network density, and central potential data analysis, we can conclude that the network of industry linkages of OFDI in the Jiangsu manufacturing industry is sparse. At the same time, the tendency to concentrate on a certain node or nodes is not obvious. The relationship between the nodes in the network is sparse, there is no core but a high degree of concentration, and the average path is relatively short. The network can be considered a small-world network. In the Jiangsu manufacturing OFDI industry linkage network, the network clustering coefficient is 0.75. Still, the average path is only 1.846, so we can consider the network a small-world network. The speed of information transfer in a small-world network is faster than either a completely regular network or a completely random network [36]. Combined with the results of node distance analysis (see Table 4), it is found that 43.1% of the nodes are most distant from each other between links (a distance of 1), 34% of nodes have only one indirect link, and 99% of nodes are within four. Links between nodes are achieved through shorter distances, which is particularly beneficial to disseminating information between nodes; therefore, the speed of information dissemination between industries in OFDI in Jiangsu manufacturing is fast. Once there are minor changes in individual or several industries, through short-distance links, information related to the industry OFDI will be rapidly disseminated throughout the network, which will affect the entire network's structure.

Table 4. Frequencies of Geodesic Distances.

Distances	Frequen	Proport
1	375.000	0.431
2	296.000	0.340
3	159.000	0.183
4	38.000	0.044
5	2.000	0.002

The block model analysis allows us to obtain the chunking of each industry's impact on the OFDI process. Using iterative correlation convergence for the block model analysis of the OFDI industry linkage network in Jiangsu province [50], we find that the network is divided into eight modules (see Figure 4 and Table 5, where the diagonal line is the density value within the module and the non-diagonal line is the density between this module and other modules). Each module contains a different number of nodes; even a node can be a separate module. Modules 6 and 8 have no internal density because there is only 1 node, so there is no density data at the corresponding diagonal position. Thus, module six has the least connection with other modules. The nodes within module six (node six, leather, fur, feather (down) and their products industry) are not influenced or very little influenced by the other modules.

In terms of the connections between modules, module one is connected to modules two, three, five, six, seven, and eight. The densities between module one and modules eight and two are 0.975 and one respectively, indicating that module one is most closely connected to modules eight and two. Still, the densities between module one and modules three, five, and six are no more than 0.2, which is significantly lower. Thus, module one is less connected to modules three, five, and six. Regarding the connections within modules, the density between the internal nodes of modules one, three, four, and seven is one, indicating that the internal connections between the nodes within these four modules are higher than the connections with the external nodes of other modules.

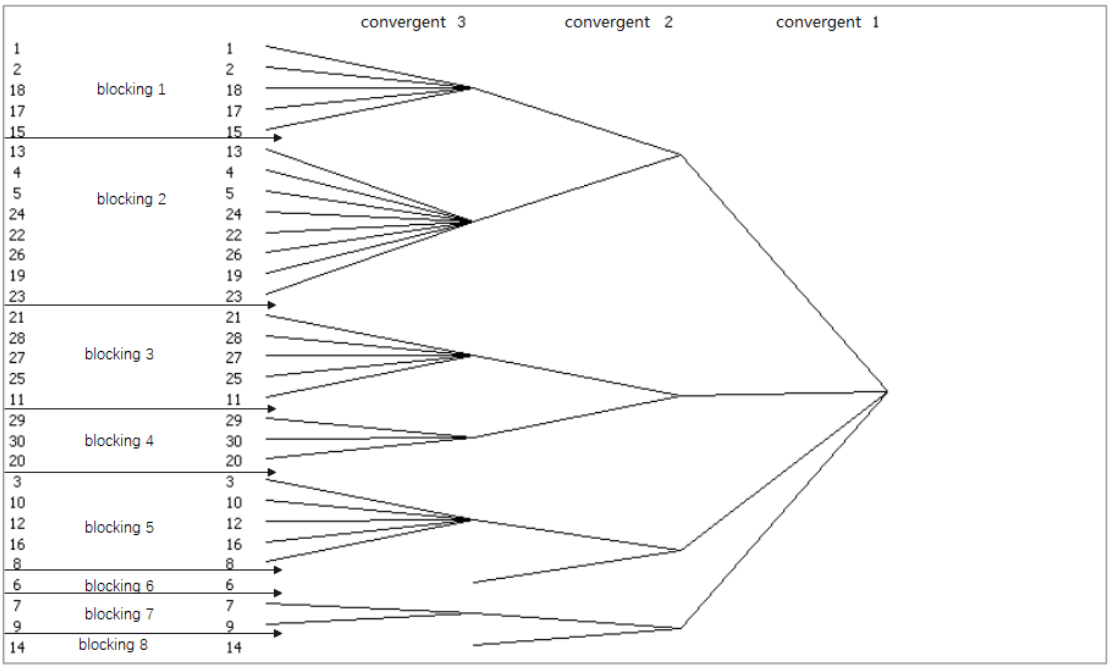


Figure 4. The results of blocking the OFDI industry in Jiangsu Province.

Table 5. Density Matrix of the Blocked Network of OFDI Industry in Jiangsu Province.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	1	0.975	0.2	0	0.08	0.2	0.7	1
2	0.975	0.964	0.925	0.125	0	0	0	0.25
3	0.16	0.975	1	0.933	0	0	0	0
4	0	0.208	0.933	1	0	0	0	0
5	0.08	0	0	0	0.95	0	0.6	0.4
6	0.2	0	0	0	0		0	0
7	0.7	0	0	0	0.5	0	1	1
8	1	0.375	0.2	0	0.4	0	1	
				(*R* — *squared* = 0.787)				

5. Conclusions and Recommendations for Countermeasures

5.1. Conclusions

This paper obtained the following results through analysis.

Firstly, the correlation coefficient between the equipment manufacturing industry and other industries in the process of manufacturing OFDI in Jiangsu Province is significantly higher. The influence of the equipment manufacturing industry on other industries is significantly greater than that of other industries. The top three are all equipment manufacturing industries, which is closely related to the important role of the equipment manufacturing industry in developing the national economy. The average absolute relevance of the textile industry is also high because textiles are a traditional industry in Jiangsu, with Changzhou City, Nantong City, and Suzhou City all being major textile players. In addition, there are two raw material industries with high correlation, namely chemical raw material and chemical product manufacturing (13) and the ferrous metal smelting and rolling processing industry (19).

Secondly, through the analysis of network node degree centrality, feature vector centrality, and proximity centrality, nodes 13, 22, 23, and 24 (chemical raw materials and chemical products manufacturing, general equipment manufacturing, special equipment manufacturing, and transportation equipment manufacturing) are important nodes in the OFDI industry association network of manufacturing industries in Jiangsu province.

Through structural hole analysis, it is found that nodes in the OFDI industry-linked network of manufacturing industries in Jiangsu Province, agriculture and food processing industry (1), pharmaceutical manufacturing industry (14), instrumentation and cultural and office machinery manufacturing industry (27) have more information advantage and control advantage. It is easier to obtain information or control information flow in the process of information flow, thus providing OFDI activities in this industry support.

Thirdly, through the analysis of the central potential and density of the network, it can be concluded that the tendency of the network to concentrate on the centre is relatively weak. The links between industries are not very dense, indicating that the strong links between the industries of OFDI in manufacturing in Jiangsu province are not concentrated in one or a few industries. At the same time, the agglomeration coefficient of the network is high, and the average path coefficient is small, with typical small-world characteristics and relatively fast information dissemination among industries. The results of the block model analysis show that the chunking results of the OFDI industry-linked network of manufacturing industries in Jiangsu province are related to the characteristics of the industries themselves, with equipment manufacturing concentrated in one block and wood, bamboo, rattan, palm and grass products and paper industry subordinated to one block.

5.2. Limitations

This paper establishes a network based on grey correlation theory for the OFDI industry in the Jiangsu manufacturing industry. However, the industry correlation obtained by the grey incidence method is undirected, which leads to the links in the social network being undirected. This is a limitation of this paper. This paper only analyses the characteristics of a single network and does not explain why the network shows such characteristics. Therefore, subsequent research in this paper could start with these two points and optimise the choice of industry association methods to create directional links and use appropriate methods to analyse the reasons for these network characteristics.

5.3. Recommendations

Based on the characteristics of the network, which is the fast dissemination of information among industries in the OFDI process in Jiangsu Province, the government should consider the guidance of the dissemination of positive investment information to prevent blind investment when guiding the OFDI policy. The information about the investment crisis should prevent the contagion of the crisis because investment enterprises are afraid of the emergence of a similar crisis and are deterred from moving forward.

In addition, the chemical raw materials and chemical products manufacturing industry, general equipment manufacturing industry, special equipment manufacturing industry, and transportation equipment manufacturing industry, as key industries in Jiangsu's OFDI industry-related network, have a greater impact on other industries. Still, the fact that they are at the lower end of the global value chain affects other industries' technological development [51]. Therefore, the authors believe that when the government formulates policies to support enterprises' technological innovation and development towards intelligence, it can tilt towards key industries and improve the technological level of other industries through the inter-industry spillover effect to improve the quality of OFDI in the entire manufacturing industry.

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