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Analysis of Network Characteristics of BDI under Dynamic Complex Network

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Abstract

To reflect the long-period BDI index time series changes on the dynamic complex network, the article symbolizes the BDI time series data that changes continuously in time into a modal form, obtains the BDI index time fluctuation sequence, and then performs the time scale Coarse-grained processing, construction of time sliding data window to get the BDI index dynamic complex network. By analyzing the dynamic characteristics of the dynamic complex network such as the modal strength and distribution, network structure entropy, weighted clustering coefficient, average path length, betweenness, the general laws and characteristics of the Baltic dry bulk index network are studied .Studies have shown that: the Baltic Dry Index shows periodicity, power law, small-world characteristics, scale-free, and homogeneity. There are some small groups in the modal conversion cycle. The average period of modal conversion is 3~5 months, and there are more cases of slight fluctuations. The research on the characteristics of the Baltic Dry Bulk Index network can provide forecasts and warnings for the shipping market and shipping port and shipping companies.

Keywords

Waterway Transportation; Shipping Market; Dynamic Complex Network; Dry Bulk Index; Fluctuation Characteristics.

1. Introduction

The international shipping market occupies an important role in the world trade. More than 90% of the world trade is completed through sea transportation, and the dry bulk shipping market is the most mature and long-established shipping market among the shipping market segments. The Baltic Dry Index (BDI) is a global authoritative comprehensive Index, which is calculated by weighting spot freight rates of several major shipping routes[1]. BDI index is a bellwether of the international shipping market, and is also regarded as a leading index and economic barometer of international trade.

Research on BDI index mainly focuses on the influencing factors of BDI index, long-term memory[1] or fuzzy[2], single-step[3] or multi-step prediction[4], and the fluctuation of BDI index according to the different shipping freight or rate of different ship types. Research of scholars both at home and abroad show that the Baltic dry index is mainly affected by seasonal fluctuations, short-term market imbalance, major events, market transport capacity changes, cycle fluctuations and other factors. BDI index has the characteristics of fluctuation, concentration[5], periodicity, power law and ravioli, etc., and it can be predicted by single or multi-step based on the market capacity, the long-term trend of BDI index, the transformation of international trade direction and other factors, and the prediction results are constantly accurate.

Dynamic complex network is not dependent on the specific location of nodes and the specific shape of edges, which is the topological property of dynamic network, so it is widely used in biological, computer, traffic flow distribution and other systems. To apply it to the BDI index that changes according to the time series, it is necessary to build a large-scale dynamic network with variable fluctuation mode group. Paper take the BDI index for nearly 20 years of continuous time changes in coarse graining processing, converting sequential change into finite mode sequences, with variable transformation mode, combined with the large time scale to grasp the timing of change, build the time variable wave mode group dynamic network, through the analysis of the statistical properties of dynamic network, including attitude distribution and the network structure entropy and the mode point intensity and its distribution, average shortest path distance, the mode point betweenness and aggregation coefficient, etc., to explore the general rule of BDI wave dynamic network, and its characteristic analysis its can offer reference for shipping market and shipping companies such ports of a new direction, Make the enterprise can grasp the market dynamic change better.

2. Dynamic network model construction of BDI index

2.1 BDI index coarsening process

For the research on the change of time series data, scholars usually convert the state of change into specific symbols according to certain rules, such as seasonal change, and symbolically describe it, and then establish the change symbol sequence based on time series[6]. Symbolized time series analysis does not need to make any assumptions. The sequence expressed in the form of real numbers is transformed into a symbol sequence represented by abstract symbols with certain physical significance. Each symbol can represent a basic and relatively independent change mode of time series, which can avoid accurate data analysis[7]. Therefore, we select the daily data of BDI index from 2000 to July 2020 from Clarkson. Due to the large number of daily data (total of 5115 data), the data were processed and converted into monthly data (a total of 247 data). The difference of BDI index in two adjacent months was defined as the range of freight rate fluctuation, i.e.

$$\Delta E_{BDI}(t) = E_{BDI}(t) - E_{BDI}(t-1) \tag{1}$$

In the formula, $E_{BDI}(t)$ A is the BDI value of time t, and $E_{BDI}(t-1)$ is the BDI value of the previous period of time $t-1$, the time fluctuation of the BDI sequence, as shown in figure 1.

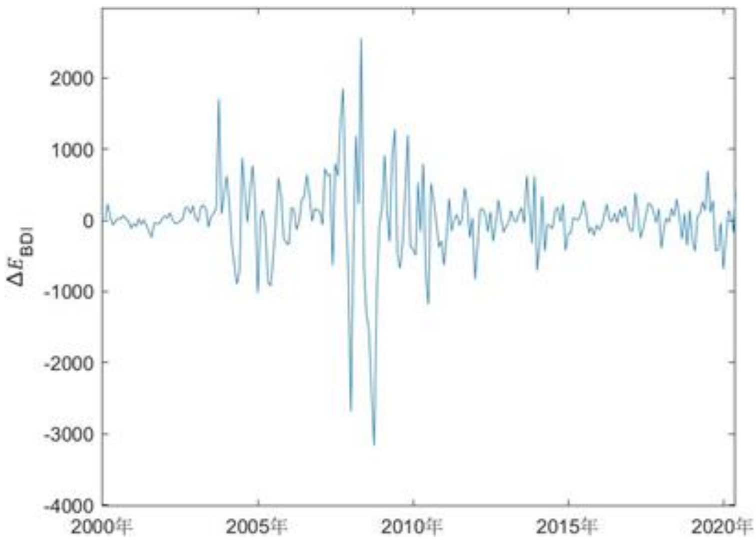

Fig. 1 BDI index time fluctuation range series

In complex network of research on time series, researchers usually use the most primitive time-series data analysis, to the maximum extent while it preserves the complex network of temporal information, but the time span is small, can't analyze the data for a long period of time, not universal, so the selection of time-series data discretization processing time scales, the build time sliding window data. Volatility in BDI time sequence using mode method, mode analysis method the basic idea is to put the time series of different value mode, divided into several possible from high resolution data

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generated in the low resolution mode, is beneficial to seize the key features of the large-scale changes to the original data to extract the key mode play a key role, reconstruct the sequence of the same length as the original symbol sequences. So the BDI index volatility data are coarse graining processing, due to the dry bulk market in 2007 is very superior, BDI index topped 10000 in October, and now 1000 fluctuate of BDI index is far, full consideration to the future research, consider coarse graining process control diagram "$\mu+\sigma$" principle, the BDI fluctuation state is divided into five kinds of state, namely the abnormal rise (B), increase (h), flat (m), fall (l), abnormal decline (S), to make every fluctuation state corresponding to a symbol, is

$$S_a=\begin{cases} B,\Delta E_{BDI}\geq\mu+\sigma \\ h,0\leq\Delta E_{BDI}\leq\mu+\sigma \\ m,\Delta E_{BDI}=0 \\ l,\mu-\sigma\leq\Delta E_{BDI}\leq 0 \\ S,\Delta E_{BDI}\leq\mu+\sigma \end{cases}, \tag{2}$$

μ is the average value of ΔE_{BDI}, σ is the standard deviation of ΔE_{BDI}. So $\sigma=552.345$, where $\mu+\sigma$ is the critical value of the fluctuation range of BDI index, and a is No. a value of the fluctuation amplitude sequence.

Therefore, the time fluctuation amplitude series of BDI index is transformed into the time series of the corresponding symbol, $S_a=\{s_1,s_2,s_3,\cdots s_a\cdots,s_{246},\}$, and,. $S_a\in\{B,\mathrm{h},\mathrm{m},\mathrm{l},\mathrm{S}\}$.

2.2 BDI index fluctuation dynamic network construction

The BDI index reflects the spot market, the index will be affected by seasonal impact of dry bulk carrier, so choose a quarter symbol as a symbol of BDI fluctuations sequence (called a mode), from January 2000 to step length as the data slip sliding window, once every three months to merge, forming a mode group, and so on, the BDI index fluctuation symbol coarse graining processing, get 244 BDI wave mode group. Theoretically, the mode combination consisting of 3 adjacent S_a should appear in $5^3=125$ forms, but in reality only 49 forms appear, including:

$$S=\{BBB,BBh,BBl,BBS,BhB,Bhh,bhl,BhS,Bll,BlS,BSB,BSl,BSS,hBh,hBl,hBS,hhB,\\ hhh,hhl,hlB,hlh,hll,hlS,hSh,hSl,hSS,lBB,lBh,lBS,lhB,lhh,lhl,lhS,llB,llh,lll,\\ llS,lSl,lSS,SBB,SBh,Shh,SlB,Slh,Sll,SSB,SSh,SSl,SSS\}.$$

Table 1. BDI index fluctuations time series mode group

Date	E_{BDI}	ΔE_{BDI}	sign	Mode
Jan-2000	1368			
Feb-2000	1393	25	h	
Mar-2000	1621	228	h	
Apr-2000	1667	46	h	hhh
May-2000	1602	-65	l	hhl
Jun-2000	1589	-14	l	hll
Jul-2000	1618	30	h	llh
Aug-2000	1639	21	h	lhh
Sep-2000	1712	72	h	hhh
Oct-2000	1734	23	h	hhh
Nov-2000	1722	-12	l	hhl
Dec-2000	1609	-113	l	hll
Jan-2001	1566	-43	l	lll
Feb-2001	1479	-87	l	lll
…	…	…	…	…
May-2020	489	489	h	lh
Jun-2020	1146	657	B	hB
Jul-2020	1633	486	h	hBh

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From January 2000 to July 2020, abnormal rising modes appeared three times, respectively in May, September and October 2007 (here refers to the period of the last mode). Before the financial crisis in 2007, the global trade demand for iron ore and coal was very urgent and strong, and the BDI index rose sharply and exceeded 10000.Abnormal declining modes appeared from August to November 2008 and June 2004.With the American subprime mortgage crisis intensified and eventually evolved into a once-in-a-century global financial "tsunami", coal, ore and other freight prices have been all the way down. Abnormal rise and abnormal fall of the situation exists, because 2000-2010 dry bulk market exuberant, but at the same time facing the financial crisis, the national government adjustment means is not mature, so the BDI index volatility is extremely large. In contrast, nearly 10 years, at the end of 2019 COVID - 19 outbreak, and spread to the world, in 2020 the global state and people bring serious losses of lives and property, but there is no downs or abnormal fluctuations, shows that in recent years, the national government issued effective policies to adjust the dry bulk market, national government macro regulation role increasingly obvious. Within every 3 months, the BDI index fluctuates steadily on the whole, without significant fluctuation.

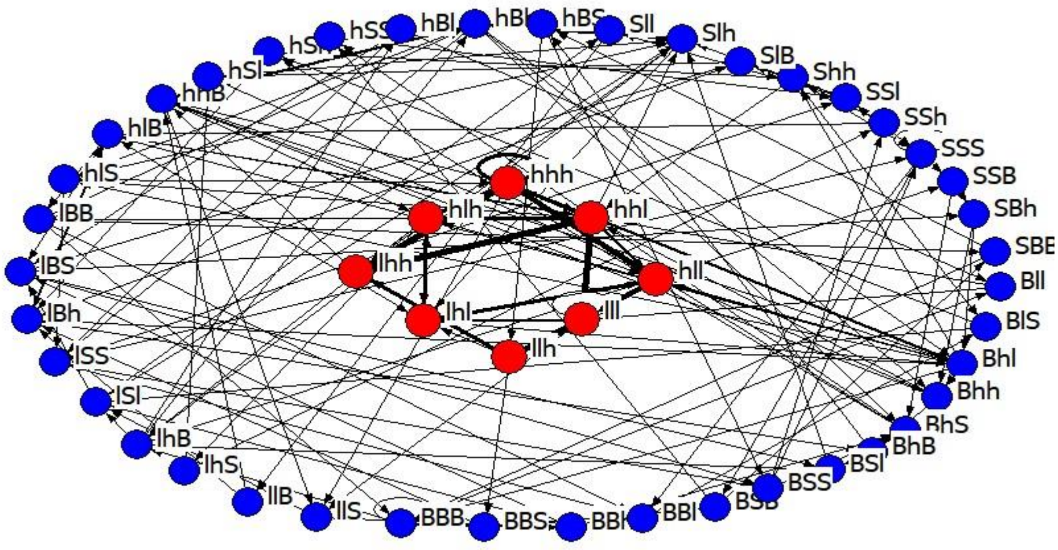

Fig. 2 BDI's volatility directed timing dynamic network

In the construction of the fluctuating time-series dynamic network, the undulating mode group is taken as the node, the directional conversion between the modes groups is turned into the edge, and the conversion times between the modes groups is the weight of the directional weighted time-series dynamic network. The coarse-grained time-series dynamic network can present some network structure characteristics and related indicators. As shown in Fig. 2, the thickness of the line in the figure reflects the weight of directed edges between two modes. The more conversion times between modes, the thicker the line. Transformation relation between the mode group a total of 88. The figure 2 shows that red dynamic network diagram for the correlation between strong eight mode, It forms a closed loop centered on h and l series: $hhh \rightarrow hhl \rightarrow hll \rightarrow lll \rightarrow llh \rightarrow lhl \rightarrow lhh \rightarrow hlh$ .the closed loop offer the most wave mode conversion relationship, and we have since the wave mode conversion between circulation, two-way, triangle and so on form, its most around the six volatility mode back to the original mode, showed normal increases and the normal fall is the norm of BDI index volatility. In addition, there is a small closed loop with a series B of modes centered, within hhB,which the number of mode transitions is mostly 2 or 3, and it is connected to the closed loop centered on the h series. It indicates that even if the abnormal rising BDI index exists, it will return to the normal rising or falling mode through the transformation between modes, that is, the market has a recovery, and BDI will return to the normal range of rising or falling. The BDI index is carried on in a gradual way, indicating that the fluctuation of BDI index is gradual, periodic and cyclic.

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3. BDI fluctuation evaluation index analysis

In the evaluation index, according to the basic concept of complex network, five indexes, namely mode attitude distribution and network structure entropy, mode strength and its distribution, weighted aggregation coefficient, average path length and mode point number, are selected for comparative analysis. The meanings of each index are as follows.

3.1 Degree distribution and Network structure entropy

For a scale-free BDI complex network with power-law degree distribution, there are very few core nodes with a large number of connections and most terminal nodes with a small number of connections. Such a network is not uniform, which is mainly reflected in the node degree distribution, namely, the curve of degree distribution is in a decreasing state.As an order measurement method of the system, structural entropy can objectively analyze the composition and non-uniform state of nodes in the network effectively from the whole point of view, and then reflect the importance of nodes.

In the network, the degree of mode isk_i, then its importance is defined as:$I_i = \frac{k_i}{\sum_{j=1}^{N} k_j}$, Therefore, the network structure entropy can be defined as:

$$E = -\sum_{i=1}^{N} I_i \cdot ln\, I_i \tag{3}$$

In the formula, i is the mode of a node, $i \in \{1,2,3,\cdots,49\}$, j is the number of edges with conversion relationship between the two modes, regardless of the number of times, $j \in \{1,2,3,\cdots,88\}$, N is the total number of conversion edges. The larger the size of the local area network structure in which the nodes of the complex network are located, the larger the value of the local area structure entropy will be. Therefore, the number of nodes in a local area network is large and the connections between nodes are dense. Such a local area network has a greater influence on the whole network of the complex network. The distribution of BDI mode strength and point strength is shown in Table 2.

Table 2. BDI model attitude and importance distribution

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mode	hhh	hhl	lhh	lll	hll	llh	hlh	lhl	Bhl	hBh	hlB	Slh	SSS	hhB	BBB	lBh	lhB
k_i	3	4	3	3	2	2	4	3	4	3	3	3	3	1	3	2	2
I_i	0.034	0.045	0.034	0.034	0.023	0.023	0.045	0.034	0.045	0.034	0.034	0.034	0.034	0.011	0.034	0.023	0.023
Structure entropy	0.115	0.141	0.115	0.115	0.086	0.086	0.141	0.115	0.141	0.115	0.115	0.115	0.115	0.051	0.115	0.086	0.086

Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mode	lSl	SSl	Bhh	BhS	BSS	hlS	lBB	lBS	llS	lSS	Shh	BBh	BBl	BBS	BhB	Bll	BlS
k_i	1	3	2	2	2	1	2	2	1	2	1	1	1	1	1	1	1
I_i	0.011	0.034	0.023	0.023	0.023	0.011	0.023	0.023	0.011	0.023	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Structure entropy	0.051	0.115	0.086	0.086	0.086	0.051	0.086	0.086	0.051	0.086	0.051	0.051	0.051	0.051	0.051	0.051	0.051

Number	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Mode	BSB	BSl	hBl	hBS	hSh	hSl	hSS	lhS	llB	SBB	SBh	SlB	Sll	SSB	SSh
k_i	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
I_i	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Structure entropy	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051

According to the formula of network structure entropy, the structure entropy $E = 3.756$ is calculated. According to the maximum value of network structure entropy is $E_{min} = \ln N = 4.48$, and the minimum value is $E_{min} = \frac{\ln 4(N-1)}{2} = 2.926$. So the network structure entropy of BDI complex network is within its range, and the network connectivity is good at this time, the small world is becoming more and more obvious, and the structure of complex network is orderly.

3.2 Modal strength and strength distribution

Point strength is used to analyze the mode importance of the BDI directionally weighted dynamic network. This paper mainly considers the transformation relationship between modes, so only the

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degree is considered. Point strength is analyzed from the mode number of the mode outputs and the weight of the mode edges connected to the outputs [8]. Point strength is defined as:

$$S_i = \sum_{j \in N_i} w_{ij} \tag{4}$$

In the formula: N_i is the set of modes indicated by i adjacent to mode i; $i \in \{1,2,3,\cdots,49\}$; w_{ij} is the weight of modes from i to j. The higher the intensity and intensity distribution of the mode, the more important the mode is in the BDI fluctuation network, and the higher the probability of occurrence and the higher the probability of transition to adjacent modes. If the mode strength distribution of the dynamic network follows a power-law distribution, that is $P(k) \propto k^{-\gamma}$ (k is point strength,γ is a power index), then it is a scale-free network. The distribution of BDI mode strength and point strength is shown in Table 3.

The mode strength and intensity distribution of BDI complex network are shown in Table 1. We can see that point intensity values of modes hhh,hhl,lhh,lll,hll,llh,hlh,and lhl are much higher than those of other modes, all of which are above 5%, and the cumulative intensity distribution reaches 64.20%, indicating that there are many times of their occurrence in the BDI fluctuation network and their conversion to other modes, which play an important role in the conduction of freight fluctuation. The point intensity of mode A is the largest, which is 27, indicating that the probability of BDI rising normally for three consecutive months is the largest, and it plays the most important role in freight rate fluctuations. The point intensities of modes hhl,lhh,lll are also large. It can be seen that BDI fluctuations during 2000-2020 mostly show normal rise and fall. At the same time, the modes with high degree of point form a ring and are connected with each other, indicating that the network has positive correlation.

Table 3. BDI mode intensity and point intensity distribution

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mode	hhh	hhl	lhh	lll	hll	llh	hlh	lhl	Bhl	hBh	hlB	Slh	SSS	hhB	BBB	lBh	lhB
Point intensity	27	23	22	20	18	17	16	13	6	6	6	6	5	4	3	3	3
Intensity distribution	11.11%	9.47%	9.05%	8.23%	7.41%	7.00%	6.58%	5.35%	2.47%	2.47%	2.47%	2.47%	2.06%	1.65%	1.23%	1.23%	1.23%

Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mode	lSl	SSl	Bhh	BhS	BSS	hlS	lBB	lBS	llS	lSS	Shh	BBh	BBl	BBS	BhB	Bll	BlS
Point intensity	3	3	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
Intensity distribution	1.23%	1.23%	0.82%	0.82%	0.82%	0.82%	0.82%	0.82%	0.82%	0.82%	0.82%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%

Number	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Mode	BSB	BSl	hBl	hBS	hSh	hSl	hSS	lhS	llB	SBB	SBh	SlB	Sll	SSB	SSh
Point intensity	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intensity distribution	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%	0.41%

The statistical characteristics of the degree distribution of mode strength present a power function distribution (as shown in Figure 3). In order to verify its power law, the unary linear regression model and the least square method are used to obtain the empirical regression linear equation $y = -0.905x = 0.0156$ of $\ln P$ versus $\ln k$, as shown in the figure 4. The scattered points basically conform to the trajectory of the linear regression equation.

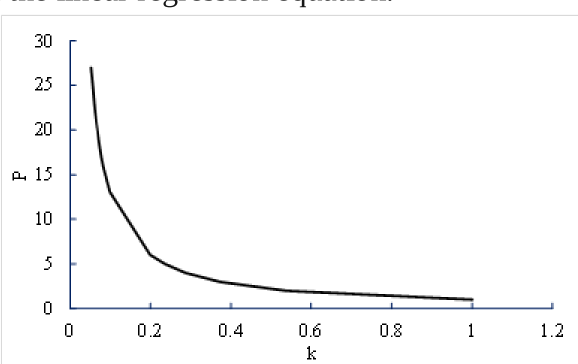

Fig. 3 Power law function diagram of mode strength

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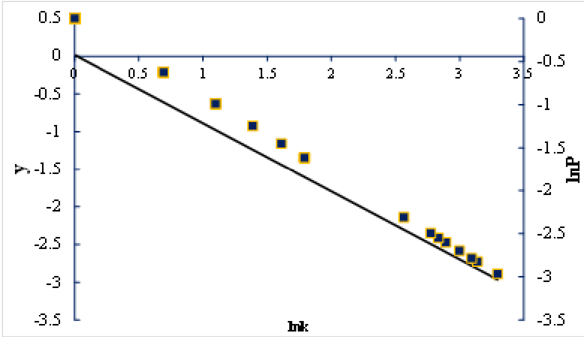

Fig. 4 Logarithmic relationship diagram of mode intensity distribution

Perform logarithmic processing on the degree distribution of the BDI index fluctuation mode node, as shown in Figure 4. The power exponential function appears as a straight line with a negative slope in the logarithmic coordinate, and the scattered points basically conform to the trajectory of the linear regression equation. This distribution and The characteristic length of the system is irrelevant, so it can be judged that the mode intensity of the BDI index fluctuation is power law, and the BDI fluctuation dynamic network has the characteristics of scale-free. The strong network in the BDI volatility dynamic network gathers most of the strength, similar to the rule that a few people gather a lot of wealth, and the wealth of most people is very small. There are a few high-strength in the fluctuation of the BDI index. But it occupies most of the intensity, and most of the low-intensity modes only occupy a small part of the intensity. At the same time, it is robust. When the dry bulk market can effectively tolerate certain uncertain factors, it will become more sensitive to other uncertain factors that are not considered, such as the financial crisis and the new crown pneumonia epidemic.

3.3 Weighted clustering coefficient

The clustering of the network can be measured by the clustering coefficient (network clustering coefficient), which indicates the transitivity of the network graph, namely the proportion of all closed dual channels in the network. The higher the clustering coefficient is, the stronger the clustering of the complex network [8]. Weighted aggregation coefficient is mainly used to measure the aggregation degree of nodes in a directed weighted dynamic network to determine the core mode transformed in the network. It reflects the local information rather than the overall information of the complex network. Defined as:

$$CC(i) = \frac{2\left|E\left(G(i)\right)\right|}{\deg(i)\cdot(\deg(i)-1)} \tag{5}$$

In the formula, $\deg(i)$ is the degree of mode i, and $\left|E\left(G(i)\right)\right|$ is the adjacent mode node directly connected to mode i.

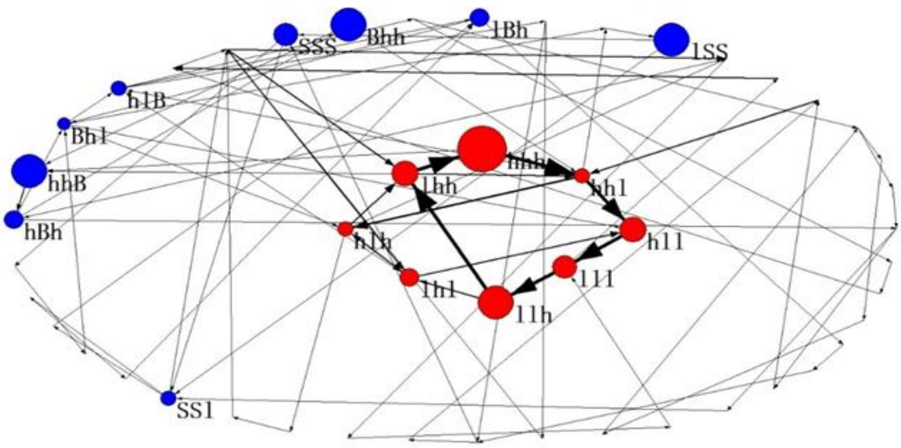

Fig. 5 Weighted clustering coefficient graph of BDI's volatility dynamic network

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The weighted clustering coefficients of the 49 modes of the BDI volatility directed dynamic network are shown in Table 4. The total clustering coefficient of the BDI volatility network diagram is 0.034, and the weighted total clustering coefficient is 0.045. There is a small group aggregation. It can be seen from Table 3 that the weighted clustering coefficients of a total of 17 modes are not 0, and the weighted clustering coefficients of the top 11 modes of point intensity account for 65.2% of the total weighted clustering coefficient. The maximum weighted aggregation coefficient of the mode hhh is 0.33, which is also the mode with the highest point intensity, which means that the weighted aggregation coefficient of the mode with high point intensity is correspondingly large, the aggregation effect is better, and it presents a core role in the network. In the figure, the weighted aggregation coefficients of the 8 modes in the series h and series l in the central area are not 0, which account for 48.3% of the total weighted aggregation coefficient, and has a greater guiding role in the network. Among them, the coefficients of hhB, Bhh and lSS are relatively large, because they respectively connect series B and series h; series h and series l the conversion modes of series have a large number of connected edges, which have a cohesive effect in the entire network. Among them, there are three groups of modes presenting a triangular state, namely hhh, hhl, lhh , lll, llh, hll,lBh, hlB, Bhl. These three groups of modeities can be converted to each other, which are the core modes of series B, series l and series h, networks. At the same time, the nodes with high point strength in the dynamic network tend to be connected with its similar nodes, just like the three groups of modes above, so the BDI dynamic complex network has the same matching.

Table 4. BDI mode weighted clustering coefficient statistics

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mode	hhh	hhl	lhh	lll	hll	llh	hlh	lhl	Bhl	hBh	hlB	Slh	SSS	hhB	BBB	lBh	lhB
Weighted clustering coefficient	0.33	0.04	0.1	0.08	0.1	0.2	0.03	0.05	0.11	0.05	0.17	0	0.08	0.17	0	0.05	0

Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mode	lSl	SSl	Bhh	BhS	BSS	hlS	lBB	lBS	llS	lSS	Shh	BBh	BBl	BBS	BhB	Bll	BlS
Weighted clustering coefficient	0	0.03	0.17	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0

Number	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Mode	BSB	BSl	hBl	hBS	hSh	hSl	hSS	lhS	llB	SBB	SBh	SlB	Sll	SSB	SSh
Weighted clustering coefficient	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

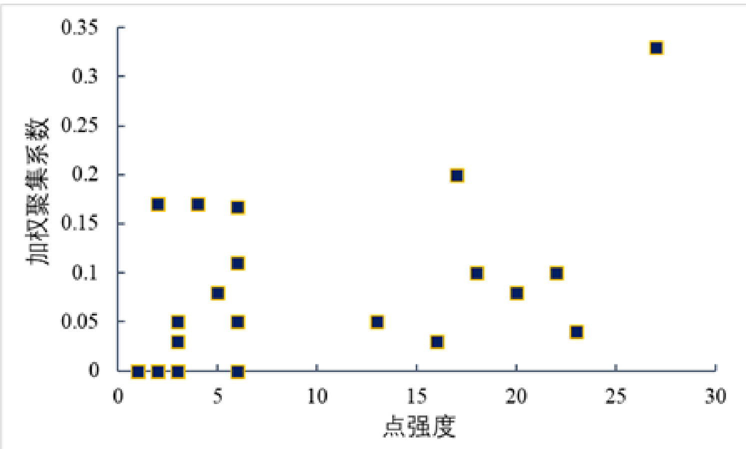

Fig. 6 Correlation between weighted clustering coefficient and point intensity

In order to further study the relationship between the mode point intensity and the weighted clustering coefficient, linear processing is performed, as shown in Figure 6. It can be seen from Figure 6 that the point intensity of the mode and the weighted aggregation coefficient are not linearly correlated,

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showing strong dynamics. For the mode with low point intensity, the weighted aggregation coefficient is relatively small and stable, and the mode with high aggregation coefficient will not appear, and the high aggregation coefficient must appear in the mode with high point intensity.

3.4 Average path length

In a dynamic network, the average path length of the network represents the closeness of the modes in the BDI dynamic complex network and the conversion efficiency of the BDI index fluctuation, which can be used to measure the efficiency of information transmission within the network. The expression is:

$$L = \frac{1}{C_N^2} \sum_{1 \le i < j \le N} d_{ij} \tag{6}$$

In the expression, N is the number of modes in the network, and d_{ij}, which is the distance between modes i and j, is defined as the number of edges on the shortest path connecting i and j.

The average shortest path distance of the BDI fluctuating directional dynamic network is 4.986, the compactness (distance-based cohesion coefficient) is 0.256 (range from 0 to 1, the larger the value, the greater the cohesion), and the width (weighted distance coefficient) is 0.744. The minimum distance is small and the weighted aggregation coefficient is large, which again shows that the BDI fluctuation dynamic network has the small-world characteristic. Mode transformation of BDI index number scale distribution as shown in figure 7, convert the number to 3, 4, 5 times the probability of 52.0%, the conversion number is 5 times the probability of largest, accounting for 20.1% of the total probability, that between the BDI index specified mode transformation is commonly 3~5 months, provide certain warning role for shipping companies to predict freight rate. Shipping companies adjust shipping capacity, freight rates of liner companies, and newly signed orders of ships according to the rise, stability and decline of BDI index [9].

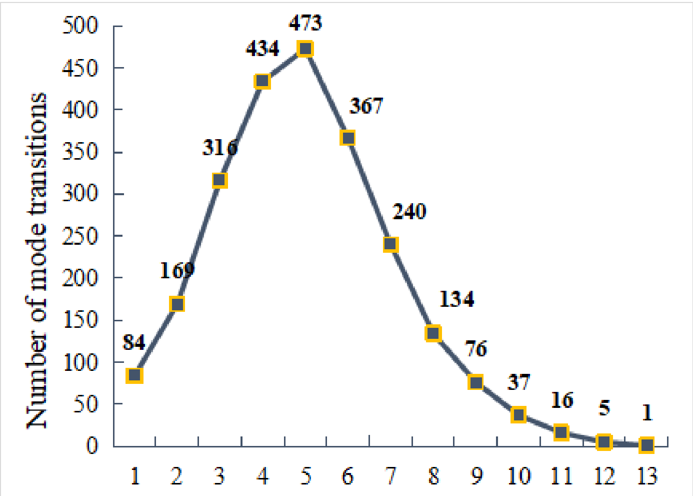

Fig. 7 BDI dynamic network mode conversion edge ratio distribution

3.5 Mode point betweenness

Mode point betweenness in BDI dynamic network reflects the information processing capability of the mode nodes to some extent. The importance degree of each mode in BDI fluctuating dynamic network system is different. In order to measure the importance of modes in the network -- centrality, the mode point intermediate number is used to calculate, and the expression is:

$$C(i) = \sum_{j \ne i \ne k \in S} \frac{\sigma_{jk}(i)}{\sigma_{jk}} \tag{7}$$

In the formula, $\sigma_{jk}(i)$ is the number of modes i through the shortest path from j to k, and σ_{jk} is the number of shortest paths from j to k.

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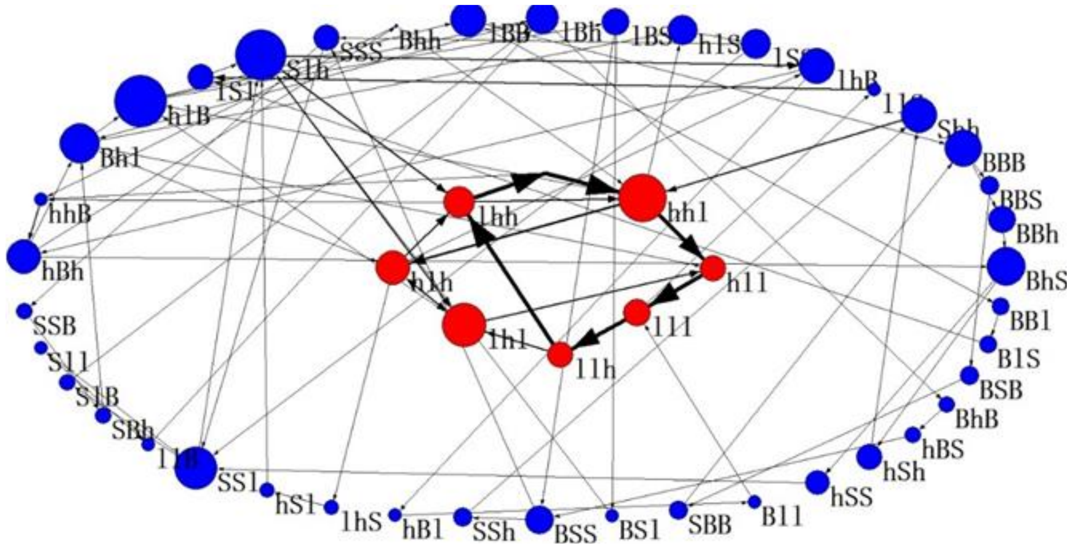

Fig. 8 Mode point betweenness of BDI dynamic network

BDI fluctuation of dynamic network mode point betweenness as shown in figure 8, we can see intuitively that the mode which has the biggest point intensity isn’t the mode has the biggest mode point betweenness. The mode point betweenness which is top 8 modes in point intensity (hhh, hhl, lhh, lll, hll, llh, hlh, lhl, that is 16.33% of the total number of mode) accounted for 22.1% of the total number of interfaces. Therefore, these modes have a certain importance in the network and have certain information transmission effects on other modes. In addition, because there are many edges connected by other modes, such as Slh, hlB, SSl, etc., the number of mode point interfaces of other modes is also large, which indicates that there are multiple subgroups in the network, and each subgroup is transmitted through some important modes, so that the whole network cycle continues.

Table 5. Mode betweenness of BDI fluctuation dynamic network

Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mode	hhh	hhl	lhh	lll	hll	llh	hlh	lhl	Bhl	hBh	hlB	Slh	SSS	hhB	BBB	lBh	lhB
Mode point betweenness	0	0.25	0.11	0.08	0.08	0.08	0.13	0.21	0.17	0.13	0.29	0.29	0.08	0.02	0.15	0.12	0.13

Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mode	lSl	SSl	Bhh	BhS	BSS	hlS	lBB	lBS	llS	lSS	Shh	BBh	BBl	BBS	BhB	Bll	BlS
Mode point betweenness	0.08	0.19	0	0.16	0.09	0.1	0.14	0.08	0.02	0.1	0.14	0.09	0.03	0.04	0.03	0.02	0.03

Number	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Mode	BSB	BSl	hBl	hBS	hSh	hSl	hSS	lhS	llB	SBB	SBh	SlB	Sll	SSB	SSh
Mode point betweenness	0.04	0.02	0.02	0.03	0.08	0.02	0.07	0.02	0.02	0.04	0.03	0.03	0.02	0.03	0.04

4. Conclusion

This article draws the following conclusions: (1) Most of the fluctuations in the Baltic Dry Bulk Index are in a normal rising or falling state. Even if an abnormally rising BDI index exists, it will return to the normal rising or falling time through one or more conversions between modes. That is, the dry bulk market is recoverable, and the BDI index continues in this way, which is gradual, cyclical and cyclical. (2) In the fluctuation of the BDI freight index, the combination between normal rise and normal fall is the majority. Its mode strength in the entire network is the largest, and it has an important guiding role. At the same time, the large point intensity mode and large scale mode can make a ring, which indicating that the network has a positive correlation. (3) Modes with high point strength have correspondingly large weighted aggregation coefficients, and have better aggregation

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effects, which play a core role in the network; at the same time, the connections between nodes have the same matching. (4) There are some small groups in the mode conversion cycle. The average period of mode conversion is 3 to 5 months, which provides a certain warning effect for shipping companies to predict freight rates. (5) The national government's macro-control of the increase in freight rates is increasing, effectively curbing the abnormal rise or fall of the BDI index and avoiding major losses caused thereby.

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