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Exploring the spillover effects between the cargo market and shipping market: the case of the dry bulk market

Yifeng Li

WORLD MARITIME UNIVERSITY

Shanghai, China

Exploring the spillover effects between the cargo market and shipping market：the case of the dry bulk market

By

LI YIFENG

China

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Declaration

I certify that all the material in this research paper that is not my own work has been identified, and that no materials are included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

Supervised by

Professor Zheng Shiyuan

Shanghai Maritime University

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Thanks to everyone I met in WMU and SMU.

And best regards to my parents and relatives.

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List of Abbreviations

BDI **Baltic Dry Bulk Index**

IOI **Iron Ore Index**

CI **Coal Index**

CGI **Cereal Grain Index**

Abstract

Title of Research Paper: Exploring the spillover effects between the cargo market and shipping market: the case of the dry bulk market

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Dry bulk shipping market plays an important role in international shipping market. The main cargoes of the dry bulk shipping market are the necessities of people's living and production, and the minerals such as iron ore and coal are unevenly distributed. Therefore, due to the lack of certain minerals, some countries or regions need to import Bulk goods from other regions throughout the year. When the economic development of a certain region is good and the domestic supply cannot fully meet the domestic demand, it is necessary to import some of the bulk cargo from other regions.

Dry bulk shipping market can reflect global demand for primary products. Thus, it is regarded as an outstanding indicator of the economy. It also has high gross profit and large price fluctuations. When the global economic situation is good, there will be a greater demand for iron ore, coal, grain and other items. Then, sufficient supplies will be produced to meet the demand. Therefore, the dry bulk shipping market will be prosperous. In contrast, when the situation of global economy is not

good, the situation of dry bulk shipping market will also be floundering.

Considering about the realistic market situation, it can be apparently to see that volatility spillover effect truly exists between bulk cargo market and shipping market. The spillover effect of the dry bulk shipping market is caused by a lot of reasons, such as global economic conditions, market supply and demand, and development of technology. At the same time, during the period of transmitting the dry bulk market information, because of the uneven spreading, volatility spillover effect exists between the cargo market and shipping market. Volatility spillover effect increases the risks in the dry bulk shipping market. Therefore, it is particularly necessary to study the spillover effects of the dry bulk shipping market.

This article divides the entire dry bulk shipping market into cargo market and shipping market, and then subdivides the cargo market into three main markets: iron ore, coal, and grain. This article uses the multivariable GARCH-BEKK model widely used in financial research to apply to the study of spillover effects between different cargo markets and shipping markets. Not only considering the volatility sensitivity and continuity of different markets, this dissertation also analyzes the volatility spillover effect between different cargo markets and shipping markets, and analyzes the cause of the volatility spillover effect.

The main work of this article includes: Firstly, it qualitatively investigated the dry bulk shipping market starting with the supply, demand, characters and freight

rate index and then macroscopically analyzed influence factors of the dry bulk freight index volatility from a global perspective.

Secondly, after defining the concept of volatility spillover effect, this paper introduced the Stochastic Volatility model, Bi-gram GARCH-BEKK model and Copula model, which are often used to analyze the volatility spillover effect of different markets. By comparing the advantages and disadvantages of three kinds of model, this thesis picked up the most suitable model, which is Bi-gram GARCH-BEKK model, to study the volatility spillover effect existing between cargo market and shipping market.

Thirdly, after collecting the data of two markets, it got the dry bulk daily returning rates series and described the trends of two returning rates series with their descriptive statistics, so as to grasp the basic features of returning rates series from overall view. It applied the Bi-gram GARCH-BEKK model to analyze the persistence, sensitivity and volatility spillover effect of cargo and shipping markets. And then it accounted the causes of volatility spillover effect existing between cargo markets and shipping markets.

Fourthly, regarding to how to avoid the risk which volatility will bring, this paper suggested that the related government should give more supports to market participants, meanwhile, shipping industries should also enhance their ability to resist risks.

Finally, the general conclusions of the thesis were presented: there is a two-way volatility spillover effect between the dry bulk shipping market and the iron ore market, coal market and grain market, that is, there is a risk transmission between the two markets. When one market fluctuates, this kind of market volatility will spread to another market.

Studying the fluctuation characteristics of the dry bulk shipping market, countermeasures are proposed to avoid risks in the dry bulk shipping market. On the one hand, the government needs to strengthen support for the dry bulk shipping market. On the other hand, shipping companies must strengthen their ability to resist risks by themselves.

Keywords: Dry Bulk Shipping Market; Freight Rate Index; Volatility Spillover Effect; BEKK Variance Model

Chapter 1 Introduction

1.1 Background

After World War II, global dry bulk market was separated from the grocery market and became a relatively independent market. This market segmentation is carried out from both geographical and ship types. In dry bulk transportation, the differences in trade regions cause differences in operating income.

Dry bulk shipping market plays an important role in global shipping market. Its cargos, including iron ore, coal, and gains, have significant impacts on people's life. It reflects the global demand for primary products, therefore, is regarded as a leading indicator of the economy. It also has high gross profit and large price fluctuations.

When the global economic situation is good, there will be a greater demand for iron ore, coal, grain and other items. Then, sufficient supplies will be produced to meet the demand. Thus, the dry bulk shipping market will be prosperous. In contrast, when the global economy is in a downturn, the dry bulk shipping market will also be floundering. For instance, in 2008, due to the impact of the US subprime crisis, the global economic development declined rapidly. The dry bulk freight price index, which has always been rising all the way, dropped from more than 11,000 points to a historical low of 663, which led to the bankruptcy of many dry bulk shipping companies.

1.2 Significance

The spillover effect of the dry bulk shipping market is caused by many reasons, such as global economic conditions, market supply and demand, and development of technology. At the same time, during the period of transmitting the dry bulk market information, because of the uneven spreading, there is a spillover effect between the cargo market and the shipping market. The existence of the spillover effect increases the risks in the dry bulk shipping market. Thus, it is particularly important to learn the spillover effects of global dry bulk shipping market.

In recent years, the spillover effect in the dry bulk shipping market has attracted attention from scholars at home and abroad. A lot of researches have been done on the market and market forecasting. However, few of them has been done on the spillover effects between the cargo market and the shipping market in the dry bulk shipping market.

Studying the spillover effect between the dry bulk cargo market and the shipping market can quantify the interaction between them, understand the interaction mechanism, and improve the ability of the dry bulk shipping market to resist risks. This study can help to predict more accurately the trend of the freight index in the dry bulk shipping market, which will help decision makers to formulate strategies, investors to invest effectively, government and other relevant departments to formulate reasonable regulatory policies, and effectively respond to financial crisis and other issues.

1.3 Literature review

At the beginning of study of spillover effect in dry bulk market, some scholars were interested in freight market. A forecasting econometric model is established for dry cargo freight and shipping market (Beenstock & Vergottis, 1989). However, it does not distinguish between the quasi-oligopoly liner market and the highly competitive market. And combined with the research which has been done by previous scholars, a vector autoregressive model was established for the sample ocean dry bulk freight prices, and the evidence provided by the cointegration test showed that between the series there is a stable long-term relationship. (Veenstra & Franses, 1997). An assessment of the forecasts derived from the model suggests that the specification of these long-term relationships does not improve the accuracy of short-or long-term forecasts.

1.3.1 Seasonality exists in dry bulk shipping market

Seasonality influences dry bulk shipping freight rate market. The seasonal fluctuations in freight rates under different market conditions are the results of the expected supply elasticity under various market conditions (Kavussanos & Alizadeh-M, 2001). The freight contracts with different durations provides ship-owners, operators and charterers with options for trading risks and returns based on the characteristics provided by each contract at the utility boundary (Kavussanos & Alizadeh-M, 2002). Zhao Dawei uses BFI index as basic data to do quantity

analysis to sum up seasonality rules in dry bulk market (Zhao, 2002).

1.3.2 Relationship between cargo market and shipping market

As for the relationships between cargo market and shipping market, Ma Shuo finds that shipping markets cycle changed during the period of 2002 and 2008, the reasons are the changing of shipping demand and supply (Ma, 2009). Shi Ruli did research on four major indexes of global shipping market, the BCI, the BPI, the BSI and the BHSI, propose some diffusion models able to analyze the special features of its trajectories, namely large swings, continuity, leverage effect and fractal characteristics (Shi, 2014).

1.3.3 Relative research about spillover effect in stock markets

About spillover effects in stock markets and how dry bulk shipping market interacts with stock market are as follows. Although there is a statistically significant average spillover effect from the US stock market to the Canada, United Kingdom and Germany, and then from the Japanese stock market to Germany, it is statistically significant. No relationship was found between conditional market fluctuations and expected returns (Theodossiou & Lee, 1993). Most emerging market economies have spillover effects from regional and global markets. However, the nature of cross-market links varies by country and region all over the world. Although the spillover effect of average returns dominates in emerging Asia and Latin America, the differential spillover effect seems to be of great significance for emerging Europe.

(Beirne, Caporale, Schulze-Ghattas, & Spagnolo, 2010) During the Asian financial crisis, the volatility spillover between the US market and the Asian market was more intense and bidirectional. In addition, in the past five years, the connection between the Japanese market and emerging Asian markets has become more apparent (Li & GILES, 2015). There is a strong correlation and information spillover effect between the shipping dry bulk market and the Chinese stock market, at the same time, this information spillover effect, as an important link between the two markets, has a large effect on the formulation of shipping freight rates (Wang, Tang, & Yang, 2016). And when analyzing the inner factors either in the Brent oil market or the stock market, it is of great significance to consider the spillover effect between the two markets (Yu, Wei, Peng, & Guan, 2019).

1.3.4 Outside spillover effect of dry bulk shipping market

Some scholars focus on the relationships and spillover effect between dry bulk shipping market and other markets. There is a positive correlation between freight market and shipbuilding market, and the lags from freight rate to shipbuilding price are approximately three to six months (Cai, 2013). Ma Chuanping studies both static and dynamic dependence, empirical study shows that dependence between two markets is strong, asymmetrical and time-varying (Ma, 2017). The product chain, the supply of goods in the dry bulk shipping market and the capacity demand of the container shipping market affect each other, thereby causing the index fluctuations in

the shipping market (Wang & Zhou, 2017).

1.3.5 Inside spillover effect in dry bulk shipping market

Some scholars focus on the spillover effect inside dry bulk shipping market. It is found that the cape dry bulk shipping market has a volatile spillover effect on the portable and Panama dry bulk shipping markets, while the flexible and Panama dry bulk shipping markets have a cape dry bulk shipping market. There is no volatility spillover effect. There is a two-way volatility spillover effect between the convenient dry bulk shipping market and the Panamanian dry bulk shipping market (Fan, Yang & Yang J., 2012). In another research, two versions of the bivariate asymmetric mixed normal GARCH model were used to calculate the skewness and kurtosis detected in the conditional and unconditional return distribution of dry bulk freight prices. Combined with the empirical results of the long-term memory effect on returns, it can not only better describe the dynamic behavior of freight market prices, but also have great significance on improving the understanding of the return dynamics. (Sang & Jong, 2013). Different from previous studies, Fu Boling analyzes volatility spillovers in the dry bulk market from the vector angle. He does not only analyze the direction of volatility spillover, but also can analyzed strength of volatility spillover based on Copula model. At the same time, due to the economic crisis such as extreme events, the shipping market will exhibit asymmetric market characteristics. Meanwhile Copula model can capture the correlation between the

various types of ship market (Fu,2014).

In summary, the spillover effect in the dry bulk shipping market has attracted attention from scholars at home and abroad. A lot of researches have been done on the market and market forecasting. However, few of them has been done on the spillover effects between the cargo market and the shipping market in the dry bulk shipping market.

1.3.6 Existing problems & Amendments

In recent years, the spillover effect in the dry bulk shipping market has attracted attention from scholars at home and abroad. A lot of researches have been done on the market and market forecasting. However, few of them has been done on the spillover effects between the cargo market and the shipping market in the dry bulk shipping market. Meanwhile, there are some existing problems in this field.

Lack of analysis about how spillover effect influences the future tendency in bulk cargo market and shipping market. For instance, few of those studies analyze the influence that spillover effect causes to bulk shipping freight in the future.

Considering that bulk shipping market is an enormous market which covers several ship types markets, most research only focus on one or two types in bulk shipping market. Quantity methods are used to analyze market correlation. Few of them are used to give suggestion to risk aversion.

In accordance with existing problems above, here are some amendments:

Specific to the spillover effects existing between cargo market and shipping market, collect relative data and establish quantity methods to analyze the influence in dry bulk shipping market.

Add finance analysis about how spillover effect will influence dry bulk freight market in the future. Forecast the possible tendency to realize the rule of market.

Consider the whole dry bulk market and choose the most representative data to do the quantity method, and get the model which has wide applicability to analyze the spillover effect in dry bulk market.

Add risk aversion after model analysis and give shipping companies reliable and practical suggestions to avoid risks.

1.4 Dissertation structure

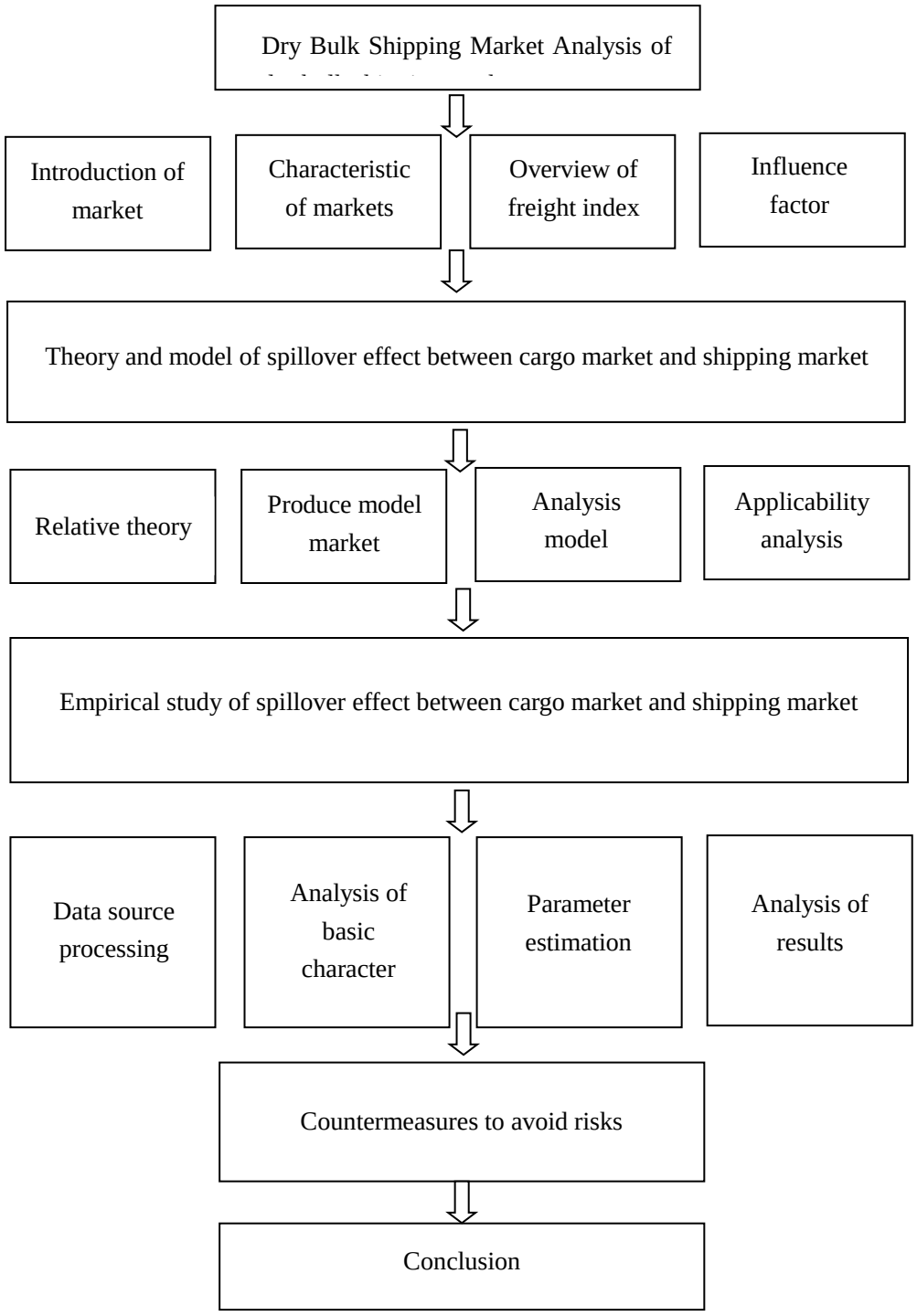


Figure 1.1 Dissertation structure

Source: Own Composition

The rest of the thesis is organized as follows: Chapter 2 illustrates the basic analysis of dry bulk shipping market. Chapter 3 introduces the theory and model of spillover effect between cargo market and shipping market. Chapter 4 shows the empirical studies of spillover effect between cargo market and shipping market. Chapter 5 tells the countermeasures to avoid risks from spillover effect. Chapter 6 is the conclusion of the total thesis.

Chapter 2 Analysis of dry bulk shipping market

2.1 Characteristic of cargo market

Due to the differences in the reserves and distribution of mineral resources, economic and industrial structure, and the level of scientific and technological development in countries around the world, their trade needs are different. As three major dry bulk cargoes, iron ore, coal and grains, these three dry bulk trade flows basically determine the main dry bulk shipping trade routes.

From the overall flow of international dry bulk shipping trade, the main exporters of iron ore are Brazil, Australia, Canada, Sweden and South Africa, the main importers are Japan, the European Union, China and South Korea; and the main exporters of coal are Australia, South Africa, the United States, Canada, Colombia and Indonesia, the main importing countries (regions) are Japan, South Korea, China and the European Union; the main grain exporting countries are the United States, Canada, Argentina, Australia and the European Union, the main importing countries For

Russia, North Africa, Japan, South Korea, China, and some Middle Eastern countries, the world's major dry bulk origins and trade flows are summarized in Table 2.1.

Table 2.1 Dry bulk imports and exports

Type of dry bulk	**Main exporters**	**Main importers**	**Proportion**
Iron Ore	Brazil, Australia, South Africa	China, Japan, EU	31%
Coal	Australia, South Africa, North America	Japan, South Korea, China, Europe	24%
Grain	America, Canada, Argentina	Middle Eastern, Japan, South Korea, Africa	7%

Source: Clarksons Research

As can be seen from the above table, Brazil, Australia, South Africa, North America, etc. are the world's main producers and exporters of dry bulk cargoes. Among them, Brazil and Australia are important international hubs for dry bulk trade transportation because of their extremely rich mineral resources and convenient geographical location; the three countries of Asia, China, Japan, and South Korea, and the EU region are the main demand countries for dry bulk cargo in the world. Therefore, important routes for dry bulk seaborne trade are formed between these countries and regions. This article will use Iron ore, Coal and Grain as main influential cargoes in markets to explore the spillover effect between cargo market

and shipping market. The following analyzes are about different dry bulk demand.

2.1.1 Demand of Iron Ore

As one of most important mineral resource, iron ore, because of the uneven distribution in the world and the economic development of different countries, the demand for iron ore resources is not exactly the same. Some countries need a large amount of iron ore resources, but the country's stored iron ore resources are insufficient. Therefore, a large amount of iron ore resources needs to be imported from abroad every year. Some countries or regions with high demand for iron ore include: 15 countries in Europe, Japan, South Korea, China, the United States, Turkey and other countries. The annual demand of each country is shown in Table 2.2 below.

Table 2.2 Seaborne iron ore imports by main importers (,000 Tonnes)

Year	Japan	South Korea	China	EU Seaborne	Latin America	Turkey	Africa	US
2009	105,504	42,079	614,606	76,747	5,369	7,772	6,325	700
2010	134,334	56,296	602,561	113,562	10,312	7,221	6,998	1,900
2011	128,487	64,852	665,403	109,539	10,471	6,644	4,815	1,362
2012	131,105	65,987	723,928	104,366	9,263	7,842	5,568	1,330
2013	135,881	63,373	794,938	110,830	10,036	8,114	6,060	1,156
2014	136,436	73,505	913,785	113,738	10,819	8,550	5,147	2,288
2015	131,005	73,280	939,716	109,126	12,287	10,011	2,916	2,510
2016	130,037	71,740	1,007,886	104,869	11,192	10,421	5,669	2,522
2017	126,600	72,427	105,791	106,592	9,090	10,962	7,087	5,412
2018	123,867	73,093	1,047,705	105,789	9,141	10,736	9,264	4,655
2019	79,532	49,457	1,047,418	98,491	8,481	10,124	8,506	4,655

Source: Clarksons Research

Table 2.2 shows that China has become the largest importer of maritime iron ore in recent years, and the iron ore imported from abroad has grown rapidly each year, which accounts 75% of the total volume of international seaborn iron ore importing. With the acceleration of China's modernization process, China's seaborne iron ore imports will further increase. Therefore, China occupies a pivotal position in the shipping market of iron ore, which has a great impact on the global iron ore trade.

2.1.2 Demand of Coal

Coal is one of the essential energy substances in people's lives and occupies an important position in production. As one of the main bulk dry bulk, it accounts for about 15% of the total dry bulk shipping market. Seaborne coal transportation is

divided into coking coal transportation and steam coal transportation, of which steam coal transportation accounts for a large proportion and is the main component of coal shipping. The main import regions of seaborne coking coal are the European Union, the three major Asian countries, Brazil, etc., and the coking coal Asian regions mainly refer to Japan, South Korea and Taiwan, the main import regions of steam coal are the 15 EU countries, Asia and the United States. The main importers of coal mainly refer to Japan, South Korea, Taiwan and Hong Kong. The main importing countries of seaborn coal are shown in Table 2.3.

Table 2.3 Seaborne Coal imports by main importers (,000 Tonnes)

Date	Asia Steam Coal	EU Steam Coal	US Steam Coal	Brazil Coking Coal	EU Coking Coal	Asia Coking Coal
2009	423,983	129,088	19,324	11,512	32,411	130,370
2010	516,159	112,741	15,863	12,840	45,576	156,614
2011	575,355	135,060	10,104	12,715	45,500	145,548
2012	666,904	147,554	6,898	12,356	42,244	157,195
2013	707,687	145,136	6,829	12,825	42,498	188,441
2014	737,684	142,568	8,464	14,497	42,192	185,457
2015	679,405	129,196	8,311	13,950	41,095	176,929
2016	701,440	105,986	7,717	14,439	37,878	181,203
2017	752,424	106,069	6,169	14,291	39,209	189,490
2018	810,574	97,272	4,553	14,577	39,562	198,014
2019	854,306	76,187	461	11,600	38,210	205,687

Source: Clarksons Research

As can be seen from Table 2.3, whether it is in seaborne coking coal or steam coal major import regions, the imported deadweight tons in Asia accounts for about 50% of total coal seaborne. Among the coking coal shipping, Japan's seaborn coking coal accounts for more than 80% of the total Asian’s, and the annual coking coal shipping volume is maintained at about 50 million tons, South Korea's annual shipping volume is about 20 million tons. Taiwan’s seaborn coking coal volume does not exceed 10 million tons. Similarly, Japan also accounts for a large proportion of steam coal imports among these regions, and it is Asia’s largest importer of steam coal in the world. This is due to Japan ’s inferior coal resources and its large coal consumption. South Korea's imports of steam coal have increased significantly in

recent years, especially in 2010, the imports of steam coal exceeded 90 million tons.

2.1.3 Demand of Grain

Grain, as a necessity of daily life, occupies an extremely important position in the national economy and people's livelihood. The major grain importing countries are also mainly concentrated in several countries with insufficient grain production, such as the United States, Canada, Australia, etc. The United States imports grain by shipping each year, accounting for about 40% of the seaborne grain volume, which accounts for a large proportion. Canada, Australia and Argentina imported the nearly same amount of grain by sea, which is more than 10 million tons, and the maximum is not more than 30 million tons. Table 2.4 shows the main importers of seaborne grains.

Table 2.4 Seaborne Grain imports by main importers (,000 Tonnes)

Date	Canada	Australia	Japan	US	Argentina
2009	22,000	20,000	27,716	84,000	23,000
2010	20,000	16,000	28,379	81,000	22,000
2011	14,000	18,000	27,254	78,000	19,000
2012	13,000	12,000	26,636	74,000	18,000
2013	19,000	26,000	26,685	84,000	21,000
2014	18,000	19,000	25,879	78,000	25,000
2015	23,000	21,000	25,557	86,000	20,000
2016	22,000	10,000	25,778	97,000	27,000
2017	21,000	13,000	25,973	90,000	27,000
2018	23,000	20,000	26,550	73,000	22,000
2019	20,000	24,000	26,783	84,000	24,000

Source: Clarksons Research

2.2 Characteristic of shipping market

The market share of dry bulk shipping accounts for more than one third of the entire maritime trade and is a major component of the entire shipping market. The transportation objects of dry bulk shipping are mainly raw materials and semi-finished products required for industrial production, so the market conditions are greatly affected by economic factors, and usually show a similar market trend to the global economic trend or the regional economic trend. According to the batch size of goods, the transportation objects of dry bulk shipping can be divided into bulk cargo and small bulk cargo, of which bulk cargo accounts for about two-thirds of the dry bulk shipping volume. According to different ship type, dry bulk shipping ships can be divided into four types: Cape type, Panama type, Handymax type and Handysize type. Among them, the Cape type and Panama type are used for transporting bulk cargo, so they occupy the main market share. Handysize and Handymax type have a relatively small market share because they are relatively small and are used to transport small batches of bulk cargo.

The actual transportation service of dry bulk shipping is provided by the shipping company, and the actual transportation needs come from the owner of the dry bulk cargo. The contract is concluded in two forms: voyage charter and time charter. The main difference is that the freight settlement of the voyage charter is based on the voyage, while the time charter is based on the charter time.

The dry bulk shipping market includes the spot market and the forward market. The forward market appears to respond to the high risks of the spot market. Shipping companies can operate in the forward market to lock in future revenue and reduce the risks in spot market, which are caused by uncertainty fluctuations. With the continuous development of practice and theory, the functions of the forward market have become more abundant. Hedging, speculation, price discovery and other functions have been derived, but risk management is still its most basic and important function.

2.2.1 Competitive liberalization

Compared with other markets, the dry bulk shipping market is almost completely competitive and has high level transparent. In an imperfectly competitive market, the market is often controlled by oligarch demanders or suppliers. It is more difficult for new suppliers to enter the market. Unfair competition in the transaction always happens between the two parties. For dry bulk shipping market, the market is not controlled by the shipowner or cargo owner, and also both parties have no obstacle to enter the market. No matter how large the shipping capacity is, the shipowner can freely enter or exit the dry bulk market, so as the cargo owner. In addition, due to the use of advanced communication equipment and the global business involved in the transaction process, shipowners and cargo owners have high transparency in trades.

2.2.2 Relatively fixed routes

Dry bulk cargo ships concentrate on iron ore, coal, grain and other small batches of bulk cargoes. Those countries or regions where the supply and demand of goods are relatively fixed, so the routes are relatively fixed. For example, the main routes for seaborne iron ore are: China-Australia, China-Brazil.

2.2.3 Related to global economy

Iron ore, coal, and grain are necessary in production industry and people's lives. They reflect the global demand for primary products and therefore are leading indicators of the economy. They are characterized by high gross profit and large price fluctuations. When the global economic situation is good, there is a large demand for iron ore, coal, grain and other items, the market has sufficient supply, and the dry bulk shipping market is prosperous. On the contrary, when the global economy is in a downturn, the dry bulk shipping market will be in a downturn, either. For example, in 2008, affected by the US subprime mortgage crisis, the global economic development declined rapidly, and the dry bulk freight price index fell from more than 11,000 points to a historical low of 663 points, causing lots of dry bulk shipping companies to go bankrupt.

2.2.4 High market volatility

The infrastructure of the dry bulk shipping industry, such as the construction of ships, docks and berths, which need large investment and long construction period. When there is a slight change in a certain link, it often causes large fluctuations in

dry bulk shipping, specifically in the fluctuation of dry bulk freight price index. Figure 2.1 shows the trend of dry bulk freight price index statistics from the Baltic Maritime Exchange since 1985.

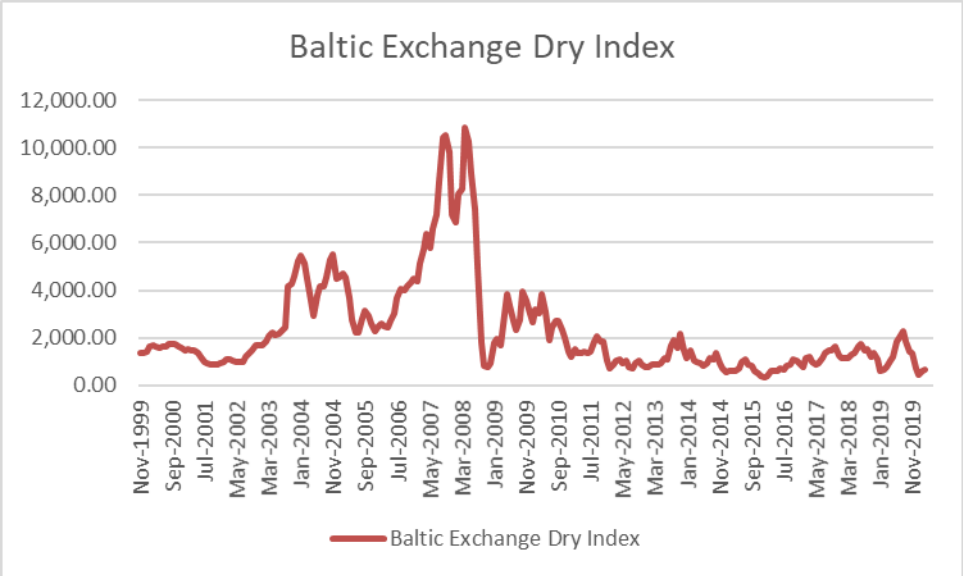


Figure 2.1 BDI trend chart

Source: Clarksons Research

It can be seen from Chart 2.5 that the dry bulk freight price index fluctuated violently. Especially in recent years, with the complication of the international situation, the dry bulk freight price index has experienced huge fluctuations. It suggests that the dry bulk shipping market has a multiple effect on external forces.

2.3 Overview of index

2.3.1 Baltic dry bulk index

The BDI Baltic Index is calculated by weighting the spot freight rates of several major routes and reflects the market conditions of the spot market. Therefore, the

level of freight prices will affect the rise and fall of the index. Therefore, assume that the original materials. The increase in demand means that the demand for freighter transportation in various countries has also increased. In this case, if the increase in freight rates can exceed the increase in the cost of oil prices, of course, its profit can be maintained. Under this premise, the BDI Baltic Index will rise, and the stock price of transportation stocks will also rise; assuming that the demand for raw materials continues to increase, but the supply of freighters will increase and destroy the freight market. At this time, the Baltic Dry Bulk Index will fall. Of course, the stock price of transportation stocks. It will also fall, so the impact of freight rates is far more important than the rise and fall of raw materials.

The BDI index has always been the freight index of bulk raw materials. Bulk shipping is mainly based on the transportation of steel, paper pulp, grains, coal, ore, phosphate rock, bauxite and other civilian and industrial materials. Therefore, the operating conditions of the bulk shipping industry are closely related to the prosperity of the global economy and the raw material market. Therefore, the Baltic Index can be regarded as a leading indicator of the economy.

2.3.2 Iron ore price index

The Platts price index is set by Platts Energy Information (Platts). Platts Energy Information and credit rating agency Standard & Poor's belong to the US McGee Group Corporation. According to materials reported by the media, Platts Energy

Information is the world's leading provider of energy, petrochemical and steel information, and an important institution for assessing benchmark prices in the spot and futures markets. This information includes: carbon emissions, coal, electricity, oil, natural gas, steel, nuclear energy, petrochemicals, and shipping markets, affecting energy companies in more than 150 countries around the world. Platts Energy ’s valuation of iron ore has become the basis of global iron ore pricing; its valuation of crude oil has been adopted by the international crude oil market as the basis for trading and pricing; it is also expanding its influence in coking coal, alumina, and shipping market.

The Platts iron ore price index is developed by Platts Energy Information (Platts) and collects data from miners, steel mills and steel traders through telephone enquiries, among which 30 to 40 “most active” enterprises by making an inquiry Its valuation is mainly based on the highest buyer's inquiry and the lowest seller's price on that day, regardless of whether the actual transaction occurs. In 2010, the Platts Price Index was selected as the basis for iron ore pricing by the world's three largest mines.

2.3.3 Coal price index

The BJ index is a significant coal spot price index for the Asian market released by Barlow Jonker Pty Ltd, a famous consultancy of coal and energy in Sydney, Australia. It reflects the contract price of coal buyers and sellers for spot thermal coal.

The port of delivery is. The port of Newcastle, Australia, the destination port is uncertain, released once a week. It has now become an important reference price basis to guide Japan-Australia coal price negotiations and spot negotiations. Although many domestic newspapers quote the BJ thermal coal price index, few people know the specific index release work. The index is mainly used in Japan-Australia coal trading, but it has now become an important reference for China to import coal from Australia.

2.3.4 Cereal grain price index

This index is a summary of the International Grain Council (IGC) wheat price index (which is itself an average of 10 different wheat prices), 1 corn export price and 16 rice prices. The rice price is divided into. Four categories, including high-quality and low-quality sugar rice, japonica rice, and fragrant rice varieties, calculate the simple average value of the relative price of the quoted price in each variety; the weights are aggregated a. Finally, the International Grain Council 's wheat price index (converted according to the 2002-2004 base period), the relative price of corn and the calculated average relative price of the rice group are calculated according to their respective 2002-2004. The average export trade proportion is obtained by weighted summarization.

2.4 Influence factor

Lots of factors can affect the fluctuation of the dry bulk freight price index. The

main influencing factors are: the global economic situation, dry bulk cargo market demand, shipbuilding and demolition markets, political factors and sudden events.

2.4.1 Global economy

As a part of global shipping market, the demand of the dry bulk shipping market is a derivative demand of global trade. Therefore, the development of the cargo market can greatly influence the dry bulk shipping market. When the global economic situation is positive, the dry bulk shipping market will also be prosperous. The supply of goods is sufficient, the demand for ships is large. If when the global economic crisis occurs, the dry bulk shipping market will also drop with that. For example, the 2008 financial crisis had a great impact on the dry bulk shipping market, a large number of shipping companies were forced to go bankrupt at that time.

2.4.2 Demand of cargo market

The main goods in the dry bulk shipping market are basic for people's lives and production, and the minerals such as iron ore and coal are unevenly distributed and have limited reserves in different areas. Some countries or regions, due to the lack of a certain mineral, always need to import the required dry bulk from other regions annually. When the economic development of a certain region is good and the domestic supply cannot fully meet domestic demand, it is necessary to import some kind of dry bulk cargo needed from other regions. For example, China has changed from a net exporter of iron ore to a net importer, which stimulated the development

of certain routes. Meanwhile, China increased the demand for the dry bulk market.

2.4.3 Shipbuilding and demolition market

Shipbuilding and demolition market are two significant factors that affect ship's amount in the dry bulk shipping market. Shipbuilding market mainly provides the capacity supply of dry bulk shipping. When the amount of ships is less compared to the cargo, the primary way to supplement capacity is to order the ship required. The role of the ship recycling market is to scrap ships with excess capacity, when the capacity is relatively surplus. Demolition market is often negatively correlated with the market of the dry bulk shipping market, that is, when the dry bulk shipping market is better, the demolition market is relatively sluggish, and when the dry bulk shipping market is at a low point, it is necessary to resort to demolition market to balance the supply of capacity in the dry bulk shipping market.

2.4.4 Political factors and emergencies

Political factors are another significant factor that affects the development of the dry bulk market. Many countries achieve political goals through economic means, such as the import and export restrictions of strategic materials, defense technology products, or additional conditions for most-favored-nation treatment. In particular, some developed countries often use this method to intervene in their international trade in order to interfere in the internal affairs of developing countries, thus adversely affecting the shipping industry. In addition, some sudden events have a

greater impact on the dry bulk shipping market. For instance, the occurrence of local wars has caused the dry bulk shipping market in a certain region to be greatly affected. If it is an important transportation junction, then the future development of the global dry bulk shipping market will be greatly affected.

Chapter 3 Theory and model of spillover effect between cargo market and shipping market

3.1 Overview of spillover effect

3.1.1 Spillover effect

Return and volatility are two primary indicators that reflect market returns and risks. The correlation of returns includes two aspects, one is the correlation of conditional mean, and the other is the correlation of conditional variance. The relevance of conditional mean illustrates that the return of a market is not only affected by its own previous income, but also by the previous period of other related markets. The transfer of income between markets is called the spillover effect. Correspondingly, the so-called volatility spillover effect means that the degree of market volatility is not only affected by its previous volatility, but also may be affected by other related market volatility. The transmission of such volatility between markets is called the volatility spillover effect. That is the Granger causality of the second moment of return. In an economic sense, the essence of the volatility spillover effect is the transfer of risk between different markets. From the

mathematical model, the change of conditional variance is not only affected by a single market, but also by the conditional variance of its related markets.

Volatility spillover effects reflect the interrelationship of volatility between two or more markets. The study of the volatility spillover effect first appeared in financial markets, for example, to study the volatility linkage between stock markets in different countries and regions, or the volatility spillover effect between the stock market and the interest rate market in the same region, or it may be different volatility interaction between stocks with different market capitalization sizes.

3.1.2 Cause of Spillover effect between cargo market and shipping market

One of the obvious characteristics of the financial market is the dramatic fluctuations of the market income index. The fluctuation of the income index usually represents the behavior trend of the entire market. The traditional classic market theory believes that market volatility is an irregular and random volatility behavior, but the actual financial market exhibits concentrated and complex behavioral characteristics, such as cusp and thick tail, long-term memory, and volatility aggregation. At the same time, the variance of the market return sequence is not static, and the variance of the return sequence will reflect the characteristics of changing with time according to different market periods.

Since the dry bulk market is a transportation and service market derived from the international economy and trade market, its market conditions are directly affected

by the global economy and trade environment. For instance, when the real economy is prosperous, that is, large industrial projects such as automobiles and shipbuilding are booming, the demand for industrial raw materials such as steel and coal will increase greatly, thereby stimulating the import of raw materials such as iron ore, so the freight rate of goods will gradually. On the contrary, when the economic environment is sluggish, demand has shrunk, causing the shipping market to struggle. Of course, in addition to the conditions affected by economic factors, dry bulk transportation is also subject to a combination of political, cultural, weather and other factors. Therefore, there will be periodic fluctuations in the shipping market, and this market fluctuation is mainly manifested through the BDI index.

3.1.3 Characteristic of spillover effect

3.1.3.1 Higher peak and fat tail phenomenon

Due to the leading position of the normal distribution in statistics, and the convenience and accuracy of its statistical research, scholars often assume that the market return sequence follows the normal distribution when studying the fluctuation of the return sequence. But in fact, the tail of the density function curve of the yield distribution of the dry bulk shipping market is far from the mean, and it is also located above the normal distribution curve. This distribution pattern shows that the return rate sequence of the dry bulk market does not obey the assumption of normal distribution. The probability of abnormal values of the return rate sequence is greater

than the probability given by the normal distribution, and it has the characteristics of obvious peaks and thick tails. Therefore, most scholars now gradually discard the normal distribution hypothesis (or as an additional hypothesis) when making error estimation assumptions, and choose distribution assumptions such as t distribution and generalized error distribution.

3.1.3.2 Aggregation

Fluctuation aggregation refers to the aggregation of fluctuation amplitudes, that is, after a larger fluctuation, other large fluctuations often occur; and the fluctuations that occur after small fluctuations are often small fluctuation. The traditional multiple linear regression model mostly uses the assumption that the residual value is zero and is independent of the same variance. Therefore, the situation and characteristics of the market return rate series over time cannot be objectively and accurately described.

3.1.3.3 Long term memory

Before explaining the long-term memory of financial market fluctuations, we first need to introduce the autocorrelation characteristics of the market return series, because the autocorrelation of the return series fluctuations not only exists in the short-term market, but also exists between long time intervals. The autocorrelation function of the return rate series, so the autocorrelation function of the return rate series presents a slow decay pattern, which is the manifestation of the long-term

memory of volatility, specifically manifested that the impact of historical events will exist for a long time.

The long-term nature of the market return sequence contains two aspects of information. On the one hand, there is a correlation between the observed values of the return rate series. The future return rate value can be predicted from the previous return value. On the other hand, this also means that the market fluctuations can be predicted to some extent, so as to achieve the original intention of the financial market to avoid risks.

3.1.3.4 Leverage

Leverage refers to the fact that the positive and negative information of the market presents a different level of asymmetry, which affects the fluctuation of the return distribution sequence. However, most of the time, this kind of asymmetric leverage tends to have a negative impact, that is, relatively speaking, the market volatility caused by "bad news" is greater than the positive impact of "good news". The specific explanation is that when "good news" appears, investors and market participants will generally raise freight rates (or rents) and increase expected returns, which will weaken the positive direction of the actual promotion of the market by positive news. On the contrary, "bad news" will have a superimposed effect, driving freight rates (or rents) to fall step by step.

3.2 Spillover effect model

3.2.1 Stochastic volatility models

Stochastic volatility models always apply to analyze volatility spillover effect between different markets:

Supposing a N-dimensional stochastic process Y_t, $Y_t = (y_{1y}, \ldots\ldots, y_{rt})$

$$y_i = \mu_i + \varepsilon_i v_i \ (i = 1, \ldots, n) \tag{3-1}$$

Thereinto, μ_i is unconditional mean of y_i, ε_i is white noise. And, $\varepsilon_t \, | I_{t-1} \sim N(0, H_t)$, I_{t-1} is an information set at time $t-1$. Command $W_t = (\log v_{1t}, \ldots, \log v_{nt})$, and $W_t \sim VAR(1)$, that is:

$$W_t = \emptyset W_{t-1} + \varepsilon_t \tag{3-2}$$

Including, ε_t is an independent identically distributed white noise, when the off-diagonal elements of coefficient matrix $\emptyset$ have nonzero element, volatility spillover effects exist in markets.

3.2.2 GARCH-BEKK models

3.2.2.1 Single variance GARCH-BEKK model

The idea of using the univariate GARCH model to test the volatility spillover effect is: according to the characteristics of the market under study. First of all, establish a reasonable GARCH model to examine the volatility of each market; then, the estimated GARCH model of a market. Residual squared or conditional variance as a measure of market volatility is brought into the research model of other markets, and the model parameters are estimated to test and examine the significance and size

of the volatility spillover effect between two or more markets. Homao, Masulis, and Ng used the GARCH-M model to analyze and study the volatility spillover effect between New York, Tokyo, and London. The GARCH-M model they built was based on the univariate GARCH model.

The formula of the $\mathrm{GARCH}\ (\mathrm{p}, \mathrm{q})$ models are:

$$\begin{cases} R_t = \omega + \varphi h_t + \delta D_t + \gamma \sum_{i=1}^{q} \varepsilon_{t-i} + \varepsilon_t, \varepsilon_t | I_{t-1} \sim N(0, \sigma^2) \\ \varepsilon_t = \sigma_t \eta_t, \eta_t \sim i.i.d.N(0,1) \\ h_t = \alpha + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{I}^{p} \beta_i h_{t-i} \end{cases} \tag{3-3}$$

Thereinto, $\mathrm{p} \geq 0$, $\mathrm{q} \geq 0$; $\omega \geq 0$, $\alpha \geq 0$, $\mathrm{d} \geq 0$, $\alpha_i \geq 0$, $\mathrm{i} = 1,2,\ldots,\mathrm{q}$; $\beta_i \geq 0$, $i = 1,2,\ldots,\mathrm{p}$. p is the coefficient of GARCH term. q is the coefficient of ARCH term. R_t is the explanatory variable of period t. ε_t is the residual term, it is an independent and identically distributed white noise process, which represents the role of accidental factors; I_{t-1} is the information set at time t-1. h_t is the conditional variance.

The volatility spillover effect model can be obtained by using the residual square or conditional variance estimated by the GARCH (p, q) model into other market research models. For example, the GARCH-M models are:

$$R_t = \omega + \varphi h_t + \delta D_t + \gamma \sum_{i=1}^{q} \varepsilon_{t-i} + \varepsilon_t, \varepsilon_t | I_{t-1} \sim N(0, H_t)$$

$$\begin{cases} \varepsilon_t = \sigma_t \eta_t, \eta_t \sim i.i.d.N(0,1) \\ h_t = \alpha + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{I}^{p} \beta_i h_{t-i} + f X_t \end{cases} \quad (3\text{-}4)$$

In the models, f is the parameter to be estimated describing the magnitude of the market volatility spillover effect, and X_t is the squared residual estimated from the GARCH model.

3.2.2.2 Multivariate GARCH-BEKK model

Multivariate GARCH-BEKK model are based on Single variance GARCH-BEKK model. Because spillover effects exist in two or more markets, many scholars choose multivariable volatility models to search spillover effect.

As for a vector sequence $\{Y_t\}$ of $N \times 1$ dimensions

$$Y_t = \mu_t + \varepsilon_t \quad (3\text{-}5)$$

In the formula, μ_t is the unconditional mean of Y_t; $\{\varepsilon_t\}$ is $N \times 1$ dimension conditional residual vector. And, $\varepsilon_t | I_{t-1} \sim N(0, H_t)$, I_{t-1} is an information set at time $t-1$.

Bollerslevetal first put forward the $\mathrm{Vech}(H_t)$ modality of GARCH model:

$$\mathrm{Vech}(H_t) = C + \sum_{i=1}^{q} A_i Vech(\varepsilon_{t-i} \varepsilon'_{t-i}) + \sum_{j=1}^{p} B_j Vech(H_{t-j}) \quad (3\text{-}6)$$

There into, H_t is $\mathrm{N} \times \mathrm{N}$ dimension positive definite matrix; $\mathrm{Vech}(H_t)$ is the formed by arranging the lower triangular matrix of H_t as one column with forward sequence; C is the constant matrix of $\mathrm{N} \times \mathrm{N}$; A_i and B_j both have $\frac{N \times (N+1)}{2}$ dimensions. Those elements in A_i and B_j can reflect the volatility spillover effects in different markets. The disadvantage of the model is that there are lots of estimated parameter, and the positive definition only can be satisfied by dereferencing of elements in A_i and B_j. Therefore, the application of the model is limited.

Some scholars have improved GARCH model. Engle and Kroner put forward BEKK model in GARCH model, which has overcome the limitation greatly in the GARCH model above. If conditional variance conforms to the $\mathrm{GARCH}(1,1)$ model, then the BEKK model which can reflect spillover effect is:

$$H_t = C^T C + A^T \varepsilon_{t-1}^T \varepsilon_{t-1} A + B^T H_{t-1} B \tag{3-7}$$

Thereinto, H_t is $\mathrm{N} \times \mathrm{N}$ dimension symmetric matrix, which illustrates the variance-covariance matrix of condition of residual of index returns series of cargo market and shipping market in the t period; ε_{t-1} is conditional residual vector of $\mathrm{N} \times 1$ dimension in $t-1$ period; C, A and B are $\mathrm{N} \times \mathrm{N}$ dimension parameter matrix. C is lower triangular matrix. A is the coefficient matrix of ARCH term's coefficient. B is coefficient matrix of GARCH term.

Apply to binary GARCH-BEKK model, in the formula:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix},\ A_t = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix},\ B_t = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix},\ C_t = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}.$$

(3-8)

H_t is the 2×2 order variance-covariance matrix of the conditional residual at time t. Both A and B are 2×2 order parameter matrices to be estimated, where A is the ARCH term and B is the GARCH term. The diagonal elements a_{ii} and b_{ii} in A and B represent the sequence's residual squared lag period to the current fluctuation band. a_{ij} and b_{ij} $(i \neq j)$ reflect the change and overflow of the conditional fluctuations of one variable in the past due to the abnormal shock of another variable in the past. C is a 2×2 order constant triangular matrix to be estimated.

3.2.3 Copula model

There are two main types of Copula functions commonly used in financial correlation analysis: Elliptic Copula Function and Archimedes Copula Function. Elliptical Copula Function can be obtained from an ellipsoidal distribution, and it is easy to generalize from the binary case to the multivariate case. The binary Archimedes Copula contains many parameter families, and each Archimedes Copula family can be obtained by the corresponding generator function. And when the generator function satisfies certain conditions, the multivariate Archimedes Copula function can be obtained. In addition, extreme Copula functions and mixed Copula

functions are commonly used Copula functions in theoretical research and applied research.

3.2.3.1 Elliptic Copula Function

The Elliptic Copula function is derived from the elliptic distribution function, so it inherits the excellent properties of the elliptic distribution function and is the basic model for studying the dependent structure of financial assets. The normal Copula (Normal Copula) function and the t-Copula function are typical representatives of the elliptic Copula function.

The normal Copula function is the most commonly used Copula function, and its expression is:

$$C(u_1, u_2, \ldots, u_n; \rho) = \emptyset_\rho\left(\emptyset^{-1}(u_1), \emptyset^{-1}(u_2), \ldots, \emptyset^{-1}(u_N)\right) \qquad (3\text{-}9)$$

In the formula, ρ is a symmetric matrix with all elements on the diagonal being 1, $\emptyset_\rho$ indicates that ρ is the standard normal distribution function of the correlation coefficient matrix, and $\emptyset^{-1}$ is the inverse function of $\emptyset$.

Since the normal distribution Copula function can be used to fit the return series distribution, in most cases, people often use the binary normal Copula function to describe the correlation between variables.

The density function of the binary normal Copula function is:

$$C_t(u,v,p) = \int_{-\infty}^{\emptyset^{-1}(u)} \int_{-\infty}^{\emptyset^{-1}(v)} \frac{1}{2\pi\sqrt{(1-\rho^2)}} exp\left\{\frac{-(r^2+s^2-2\rho rs)}{2(1-\rho^2)}\right\} drds$$

(3-10)

However, many empirical studies show that the normal distribution is not a good model. There are three main reasons: first, the edge normal distribution cannot describe the sharp peaks and skew in financial data; second, the normal distribution. The correlation structure is limited to a symmetric structure; third, there are a large number of non-linear correlations among financial assets. The Pearson correlation coefficient in the normal distribution is a measure of linear correlation and cannot measure complex non-linear correlation.

The expression of t distribution Copula function is:

$$C(u_1,u_2,\ldots,u_N;\rho,v) = T_{\rho,v}\left(T_v^{-1}(u_1), T_v^{-1}(u_2), \ldots, T_v^{-1}(u_N)\right) \qquad (3\text{-}11)$$

Among them, the meaning of ρ is consistent with the normal distribution Copula function, which is a symmetric matrix with all elements on the diagonal being 1, and $T_{\rho,v}$ represents the standard multivariate t distribution function with correlation coefficient matrix ρ and degree of freedom v. $T_v^{-1}(u_N)$ represents the inverse function of the unary t distribution $T_v(u_N)$ with the degree of freedom v.

The density distribution of the t-Copula function is:

$$C_t(u,v;\gamma,\rho) = \int_{\infty}^{-\frac{1}{v}(N)} \int_{\infty}^{-\frac{1}{v}(V)} \frac{1}{2\pi\sqrt{(1-\rho^2)}} \left\{1 + \frac{s^2 - 2\rho st + t^2)}{v(1-\rho^2)}\right\} dsdt$$

(3-12)

As the binary Copula function, compared with the normal Copula function, the Copula function under the binary t distribution also has symmetry, which can describe the correlation between symmetric markets, and its advantage is that it has more generosity of the tail of the market, so it can quickly and objectively depict the tail correlation of each market rate of return sequence.

3.2.3.2 Archimedes Copula Function

The Archimedes Copula function is a very important type of Copula function, which is widely used in many fields. Mainly because the Copula function has a simple structure and many types, and compared with the elliptic Copula class function Archimedes Copula function can analyze the asymmetric, linear and uncorrelated market return distribution series. Therefore, the Archimedean Copula function is the most widely used Copula function in the financial field. It is derived from a generating function, also known as the generator of the Archimedean Copula function, rather than the multivariate joint distribution function determined by Sklar theory.

In many Archimedes Copula function families, this article focuses on three types of nonlinear Archimedes Copula functions according to the needs of the article,

namely: Frank Copula function, Gumbel Copula function and Clayton Copula function. The Frank Copula function is characterized by a sensitive overall grasp of the relevant characteristics of the tail of the income sequence. The distribution function of the binary Frank Copula function is as follows:

$$C(u,v) = -\frac{1}{\lambda}\log\left(1 + \frac{(e^{-\lambda_N}-1)(e^{-\lambda_v}-1)}{e^{-\lambda}-1}\right) \quad (3\text{-}13)$$

Among them, $\lambda \in [-1,1]$ represents the relevant parameters; u, v represents the return distribution sequence of the two markets after the probability integral transformation. The advantage of the Frank Copula function is to completely describe the characteristics of the entire tail, but it is beyond the power to cause sudden changes in the tail. Therefore, the following focuses on the Gumbel Copula function and Clayton Copula function that are more sensitive to capture the upper and lower tails.

The Gumbel Copula function has outstanding performance in characterizing the upper-tail dynamic correlation between two financial market return distribution sequences. The distribution function of the binary Gumbel Copula function is:

$$C(u,v) = \exp\left(-\left[(-\log u)^{\frac{1}{\alpha}} + (-\log v)^{\frac{1}{\alpha}}\right]^{\alpha}\right) \quad (3\text{-}14)$$

Among them, $\alpha \geq 1$ represents the relevant parameters; u and v represent the two market returns distribution sequence obtained after the probability integral transformation.

When $\alpha = 1$, the random variables u and v are independent of each other; when α is near positive infinity, the random variables u and v gradually tend to be completely correlated.

The main feature of the binary Gumbel Copula model is that it can quickly capture the upper-tail correlation between the two financial market return distribution sequences, and the upper-tail correlation coefficient and the corresponding parameters show a corresponding relationship, the specific relationship is:

$$\lambda^{u} = 2 - 2^{\frac{1}{\alpha}} \tag{3-15}$$

When $\lambda^{U} \in (0,1]$, there is a certain upper tail phase characteristic between the two market return distribution series; when $\lambda^{L} = 0$, there is no upper tail correlation.

Next is the Clayton Copula model, which is similar to the above-mentioned Gumbel Copula model. The focus is on the analysis of the lower tail correlation between market return rates.

$$C_{CI}(u, v; , \theta) = \left(u^{-\theta} + v^{-\theta} - 1\right)^{-\frac{1}{\theta}}, \theta \in (0, +\infty) \tag{3-16}$$

Among them, $\theta \in (0, +\infty)$ illustrates the relevant parameters; u and v are the sequence of returns distribution of the two markets obtained after the probability integral transformation.

When θ tends to 0, u and v gradually tend to be independent of each other; when θ tends to infinity, u and v gradually tend to be completely related.

The main feature of the binary Clayton Copula model is that it can quickly capture the lower tail correlation between the two financial market return distribution sequences. The lower tail correlation coefficient and the corresponding parameters shows a corresponding relationship. The specific relationship is:

$$\lambda^{L} = 2^{-\frac{1}{\theta}} \tag{3-17}$$

When north $\lambda^{L} \in (0,1]$, there is a certain lower tail correlation between the two market return distribution sequences; when $\lambda^{L} = 0$, there is no lower tail correlation.

3.3 Applicability of spillover effect model

3.3.1 Applicability of GARCH-BEKK (1,1) formula

As for a vector sequence $\{Y_t\}$ of $N \times 1$ dimensions

$$Y_t = \mu_t + \varepsilon_t \tag{3-5}$$

In the formula, μ_t is the unconditional mean of Y_t; $\{\varepsilon_t\}$ is $N \times 1$ dimension conditional residual vector. And, $\varepsilon_t | I_{t-1} \sim N(0, H_t)$, I_{t-1} is an information set at time $t-1$.

Bollerslev first put forward the $\mathrm{Vech}(H_t)$ modality of GARCH model (T.&R.M,

1988):

$$\mathrm{Vech}(H_t) = C + \sum_{i=1}^{q} A_i Vech(\varepsilon_{t-i}\varepsilon'_{t-i}) + \sum_{j=1}^{p} B_j Vech(H_{t-j}) \quad (3\text{-}6)$$

There into, H_t is $\mathrm{N} \times \mathrm{N}$ dimension positive definite matrix; $\mathrm{Vech}(H_t)$ is the formed by arranging the lower triangular matrix of H_t as one column with forward sequence; C is the constant matrix of $\mathrm{N} \times \mathrm{N}$; A_i and B_j both have $\frac{N\times(N+1)}{2}$ dimensions. Those elements in A_i and B_j can reflect the volatility spillover effects in different markets. The disadvantage of the model is that there are lots of estimated parameter, and the positive definition only can be satisfied by dereferencing of elements in A_i and B_j. Therefore, the application of the model is limited.

Some scholars have improved GARCH model. Engle and Kroner put forward BEKK model in GARCH model, which has overcome the limitation greatly in the GARCH model above. If conditional variance conforms to the $\mathrm{GARCH}(1,1)$ model, then the BEKK model which can reflect spillover effect is:

$$H_t = C^T C + A^T \varepsilon_{t-1}^T \varepsilon_{t-1} A + B^T H_{t-1} B \quad (3\text{-}7)$$

Thereinto, H_t is $\mathrm{N} \times \mathrm{N}$ dimension symmetric matrix, which illustrates the variance-covariance matrix of condition of residual of index returns series of cargo market and shipping market in the t period; ε_{t-1} is conditional residual vector of $\mathrm{N} \times 1$ dimension in $t-1$ period; C, A and B are $\mathrm{N} \times \mathrm{N}$ dimension parameter matrix. C is lower triangular matrix. A is the coefficient matrix of ARCH term's

coefficient. B is coefficient matrix of GARCH term.

3.3.2 Applicability of multivariable GARCH-BEKK model

The idea of using the single variance GARCH model to search the volatility spillover effect is: first, to model a single variable and a single market, and then to model the data obtained from the first modeling to study the volatility spillover effect between different markets. In contrast, the multivariable GARCH model directly expands a single variable to multiple variables, and studies the volatility spillover effect of the volatility and risk characteristics of multiple variables and multiple markets. Compared with the single variable model, the multivariable GARCH model can avoid the problems related to the need to estimate the regressor and improve the testing potential and efficiency of the volatility spillover effect between different markets. In addition, the multivariate model treats the information status between multiple markets uniformly, which embodies the essence of the volatility spillover effect, that is, the impact of information on the market. Therefore, in studying the volatility spillover effect, the multivariable GARCH model is superior to the univariate GARCH model. Compared with the SV model, because the SV model assumes a constant correlation, this is not consistent with the time-varying conditional correlation.

Through the above comparative analysis, it can be seen that the multivariable GARCH model is superior to other models in analyzing the volatility spillover effect.

Therefore, this paper chooses the multivariable GARCH model to analyze the volatility spillover effect between cargo markets and shipping markets in dry bulk markets.

In many research literatures on the dry bulk shipping market, the variance of the sample is assumed to be constant according to the traditional econometric model. In recent years, with the deepening of research, more and more scholars have discovered that the variance of the dry bulk shipping market is not static, but depends on the degree of variance in the past. Therefore, the traditional model with independent homoscedasticity assumption is not suitable for studying the fluctuation law of dry bulk freight price index. The research of some scholars shows that the data of dry bulk freight price index shows obvious "clustering" of fluctuations, that is, large fluctuations are followed by large fluctuations, and small fluctuations are followed by small fluctuations. Features are very consistent. Using the GARCH model to study the volatility characteristics of the dry bulk shipping market can better characterize the heteroscedasticity of the error term, which makes the estimation of the mean equation more effective. On the basis of comprehensive consideration of the specific characteristics of the dry bulk shipping market and reference to the research results of other scholars, this paper selects the BEKK model in the multivariable GARCH model to study the volatility spillover effect between dry shipping markets of different ship types.

3.4 Model Selection

Through the above usability analysis, the BEKK model in the multivariable GARCH model can better analyze the volatility spillover effect between different markets. Because this paper analyzes the volatility spillover effect among the cargo markets and shipping markets of dry bulk shipping market, the volatility spillover model in this paper chooses the binary GARCH-BEKK model.

3.4.1 Mean value equation of binary GARCH-BEKK model

The expression of the mean equation of the ternary GARCH-BEKK (1, 1) model of the volatility of the dry bulk shipping market is:

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} + \sum_{j=1}^{k} \begin{bmatrix} a_{11,j} & a_{12,j} \\ a_{21,j} & a_{22,j} \end{bmatrix} \begin{bmatrix} Y_{1t-j} \\ Y_{2t-j} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} | I_{t-1} \sim N(0, H_t) \quad (3\text{-}18)$$

In the model, Y_{it} represents the price index sequence of cargo markets and shipping markets in dry bulk markets. u_{it} is unconditional mean of Y_{it}, $\mathrm{i} = 1,2$; ε_{it} is white noise, and $\varepsilon_{it}|I_{i,t-1} \sim N(0, H_{it})$, $I_{i,t-1}$ is i type price index's information set at time $\mathrm{t}-1$. H_{it} is the variance-covariance matrix of the conditional residuals of the price index series at period t.

3.4.2 Variance equation of binary GARCH-BEKK model

To study the volatility spillover effect between the cargo markets and shipping markets in dry bulk shipping market, this paper establishes a binary BEKK (1, 1) variance model, whose expression is:

$$H_t = C^T C + A^T \varepsilon_{t-1}^T \varepsilon_{t-1} A + B^T H_{t-1} B \quad (3\text{-}7)$$

Among them, H_t is the 2×2 order variance-covariance matrix of the conditional residual at time t. Both A and B are 2×2 order parameter matrices to be estimated, where A is the ARCH term and B is the GARCH term. The diagonal elements a_{ii} and b_{ii} in A and B represent the sequence's residual squared lag period to the current fluctuation band. a_{ij} and b_{ij} $(i \neq j)$ reflect the change and overflow of the conditional fluctuations of one variable in the past due to the abnormal shock of another variable in the past. C is a 2×2 order constant triangular matrix to be estimated. The specific expression of BEKK (1, 1) variance model is:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}^T \cdot \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \end{bmatrix}^T \cdot \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^T + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \cdot \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \cdot \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^T$$

(3-19)

In the model, $h_{11,t}$ and $h_{22,t}$ represent the conditional variance of cargo markets' price index sequence and Baltic dry bulk index sequence at time t. $h_{12,t}$ and $h_{21,t}$ represent the conditional covariance of cargo markets' price index sequence and Baltic dry bulk index sequence. For instance, when analyzing the volatility spillover effect between the cargo price index series and the BDI series, if $a_{12} = b_{12} = 0$, it means that there is no volatility spillover effect on the BDI series

by the goods price index series; similarly, when $b_{21} = a_{21} = 0$, it shows that the BDI series has no volatility spillover effect on the cargo price index series. Therefore, by examining whether a_{12}, b_{12}, a_{21} and b_{21} is significantly 0 in the model to examine whether there is a volatility spillover effect between the cargo market and the shipping market.

Chapter 4 Empirical studies of spillover effect between cargo market and shipping market

4.1 Data source processing

This article selects the dry bulk freight price index data published on the Clarkson website as the sample data of the shipping market. The Platts iron ore index, the Australian BJ coal index and the United Nations cereal price index were selected as sample data of the cargo markets. Graph the three main dry bulk cargoes. It can be seen from the trend that the BDI, iron ore and grain indexes fluctuate greatly, which is a non-stationary process. The prerequisite for the application of the multivariable GARCH model is that the data series under study are stationary series. Therefore, the logarithmic difference processing is performed on the price indices of the three dry bulk cargoes, that is, the logarithmic rate of return series of the three dry bulk cargoes.

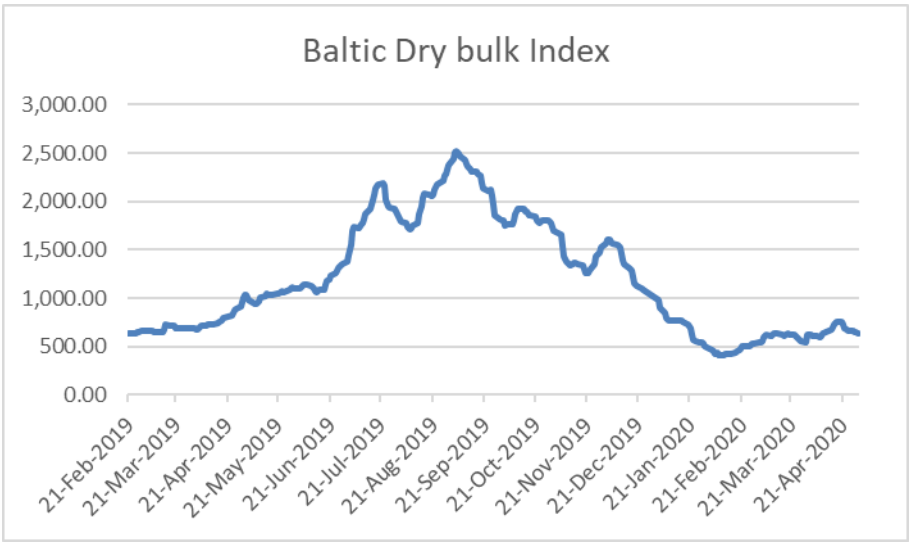


Figure 4.1

Resource: Clarksons Research

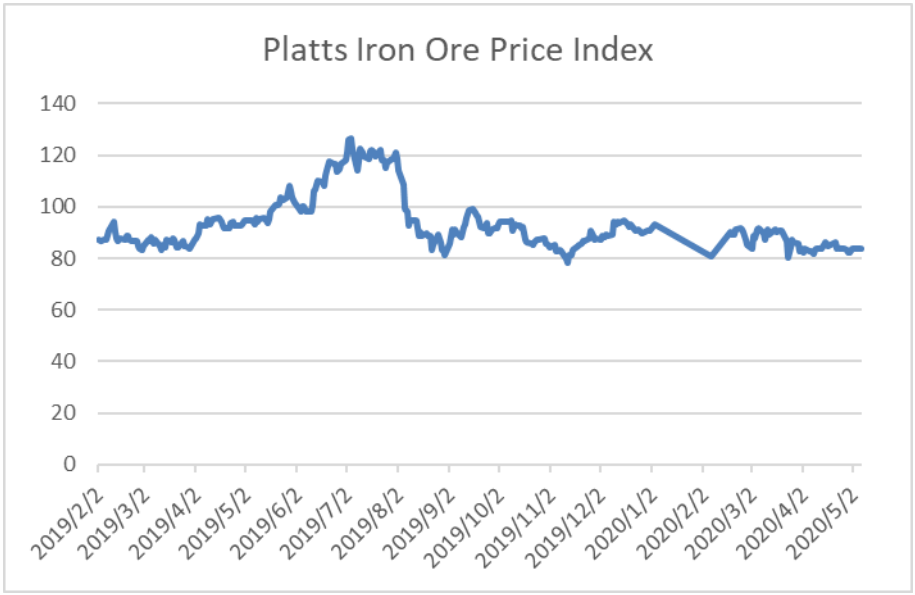


Figure 4.2

Resource: Clarksons Research

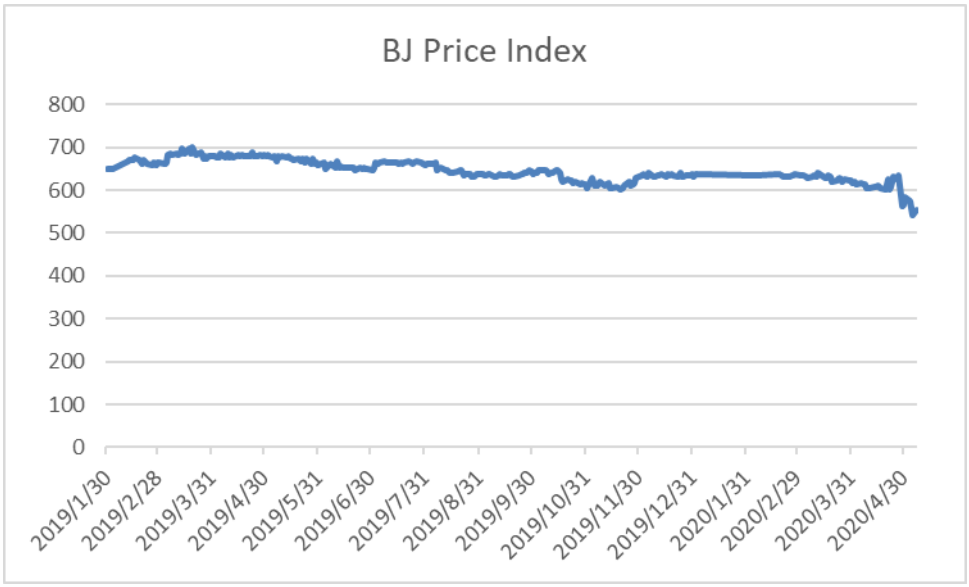


Figure 4.3

Resource: Clarksons Research

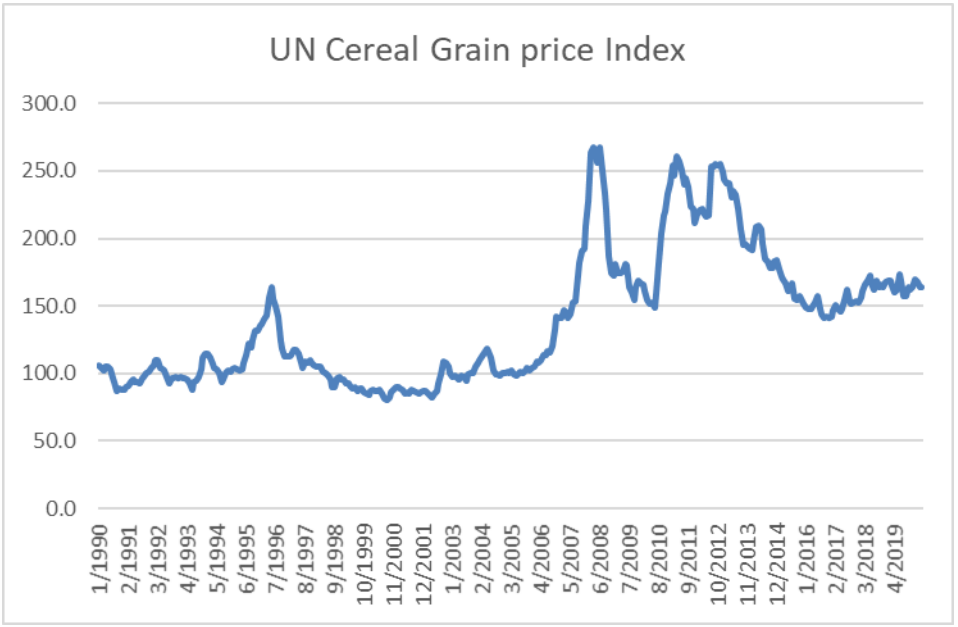


Figure 4.4

Resource: Food and Agriculture Organization of the United Nations

Let the rate of return after the difference be Rt, the freight index be P, and the logarithmic rate of return of the three ship types be expressed as RBDI, RIOI, RCI

and RCGI. The logarithmic difference formula is:

$$R_t = \ln P_t - \ln P_{t-1} \tag{4-1}$$

It can be seen from the trend chart of the logarithmic return rate series of the three goods prices that after the logarithmic difference, the RBDI, RIOI, RCI and RCGI logarithmic return series have their tendency to return to the average level, after the logarithmic difference. The logarithmic return series is stable. Large fluctuations are followed by large fluctuations, and small fluctuations are followed by small fluctuations, that is, the "clustering" characteristic of the heteroscedastic model. The traditional econometric model is not suitable for studying the fluctuation characteristics of RBDI, RIOI, RCI and RCGI. Therefore, it can be preliminarily judged that the logarithmic rate of return of iron ore, coal and grain after the logarithmic difference is stable, and the multivariable GARCH model is suitable for analyzing and studying the volatility spillover effect of the goods market and the shipping market. The following is a basic feature analysis and various tests to specifically verify whether the logarithmic return series of the goods market and the shipping market are stable and whether they have heteroscedasticity characteristics, and whether the GARCH model is suitable for the study of the volatility spillover effect of the goods market and the shipping market.

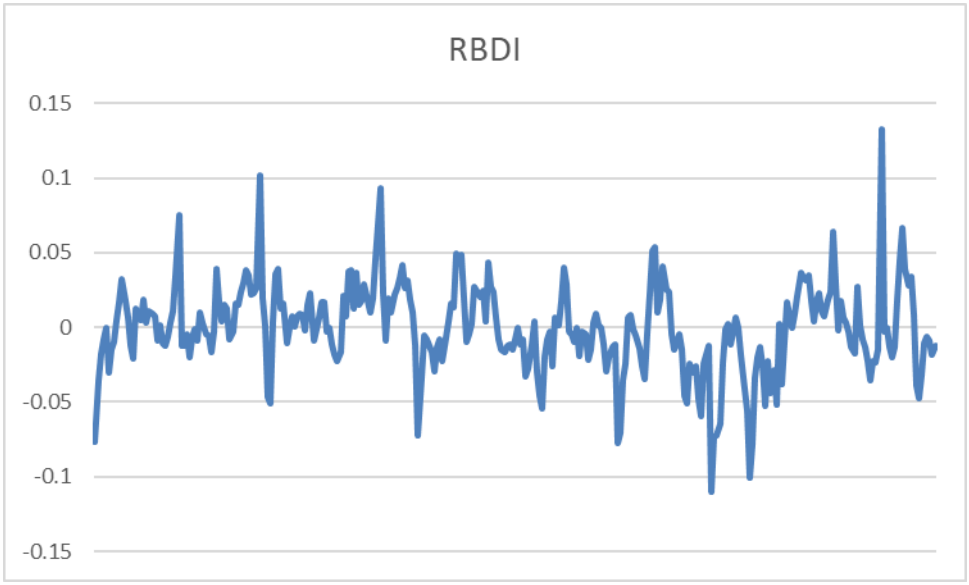


Figure 4.5

Source: Own Composition

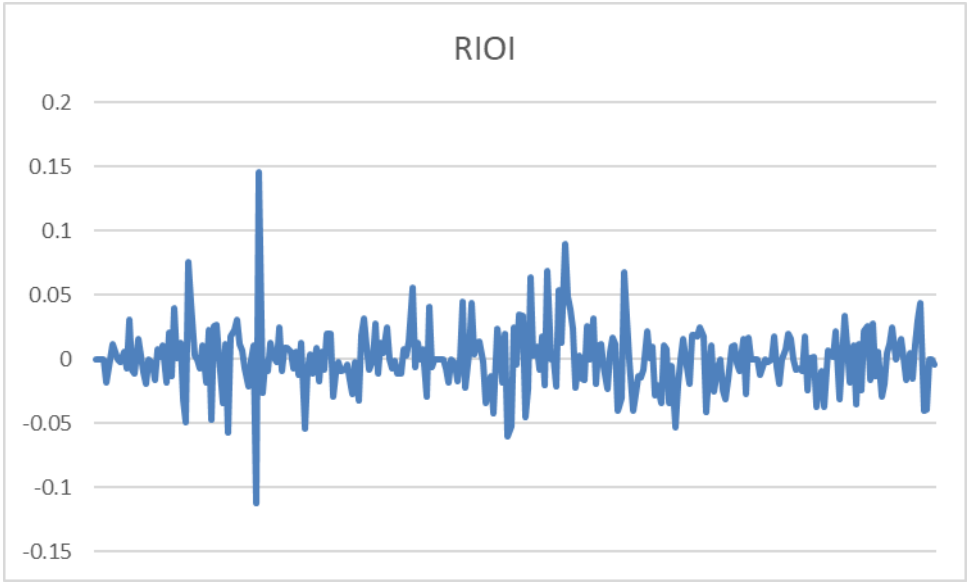


Figure 4.6

Source: Own Composition

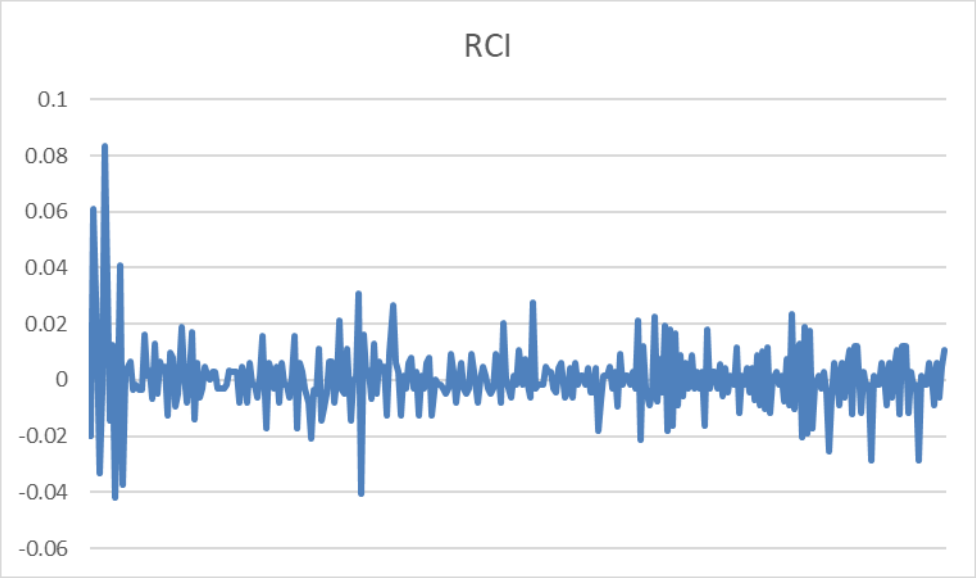


Figure 4.7

Source: Own Composition

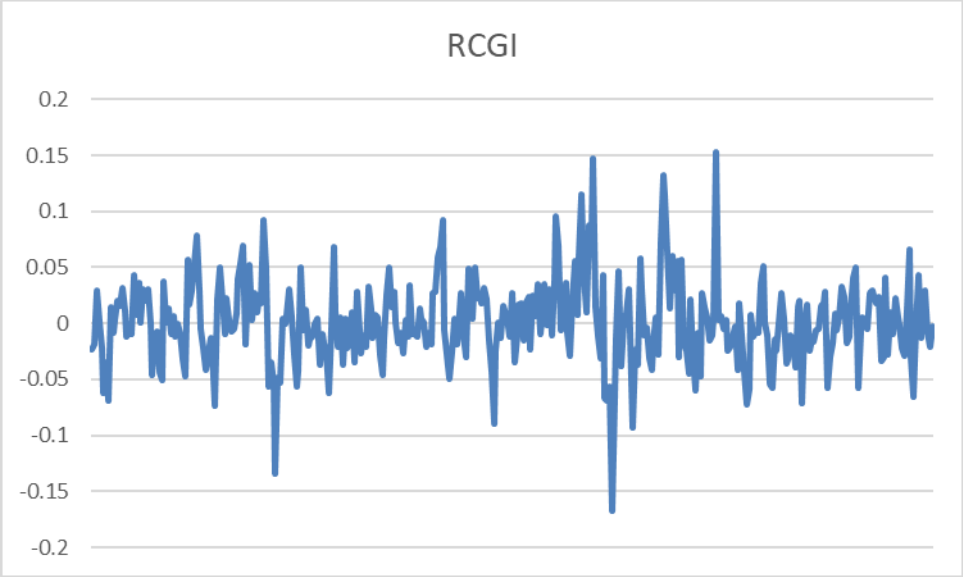


Figure 4.8

Source: Own Composition

4.2 Analysis of Basic statistics character

4.2.1 Basic statistics

The purpose of the basic statistical feature analysis is to investigate whether the RIOI, RCI and RCGI sequences have the peak-to-tail feature of heteroscedasticity. The basic statistics examined include 5 values of sample mean, variance, skewness, kurtosis and Jarque-Bera statistics.

4.2.1.1 Mean

The sample mean of the logarithmic rate of return is $\mathrm{E}(\mathrm{Y})$, which refers to the average value of the rate of return sample during the observation period, and the calculation formula is:

$$\mathrm{E}(\mathrm{Y}) = \frac{1}{T}\sum_t Y_t \tag{4-2}$$

Y is the logarithmic rate of return time series, and T is the number of statistical days in the sample interval. The sample average describes the average volatility of the rate of return within the sample interval. The larger the value, the greater the sample average fluctuation.

4.2.1.2 Variance

The sample variance σ^2 of the daily logarithmic rate of return reflects the degree of deviation of the rate of return from the sample mean. The larger the value, the greater the degree of deviation. The calculation formula is:

$$\sigma^2 = \frac{1}{T}\big(Y - E(Y)\big)^2 \tag{4-3}$$

4.2.1.3 Skewness

The value of the sample skewness S reflects the degree of skew, and the positive and negative reflect the direction of skew. When the skewness is greater than zero, the sequence distribution is right or positive; when the skewness is less than zero, the sequence distribution is left or negative; the larger the absolute value of the skewness, the greater level the skewness. The calculation formula of sample skewness S is as follows:

$$\mathrm{S} = \frac{\frac{1}{T}\sum_t \big(Y_t - E(Y)\big)^3}{\sigma^3} \tag{4-4}$$

4.2.1.4 Kurtosis

The sample kurtosis K of the return rate of financial assets is used to determine the shape of the income distribution. Generally, the kurtosis value of the normal distribution is used as the benchmark (the kurtosis value of the normal distribution is 3). When the kurtosis is greater than 3, it indicates that the distribution is thicker than the normal distribution; when the kurtosis is less than 3, it indicates that the distribution is thinner than the normal distribution. The formula for calculating the kurtosis is:

$$\mathrm{K} = \frac{\frac{1}{T-1}\sum_t \big(Y_t - E(Y)\big)^4}{\sigma^4} \tag{4-5}$$

4.2.1.5 Jarque-Bera statistics

Jarque-Bera statistic is mainly used to test whether the sequence is normally distributed, and its calculation formula is:

$$\mathrm{JB} = \frac{T-K}{6}\left(S^2 + \frac{1}{4}(K-3)\right)^2 \tag{4-6}$$

In the formula, S and K represent skewness and kurtosis.

4.2.2 Basic statistics analyze

According to the formulas above, the basic sequence diagrams of RBDI, RIOI, RCI and RCGI are showed as follows:

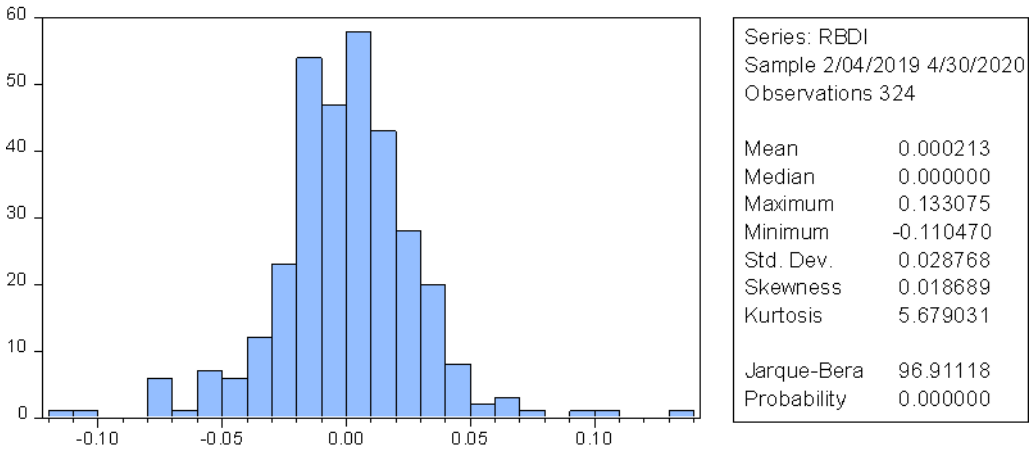


Figure 4.9 Descriptive Statistics of RBDI

Source: Own Composition

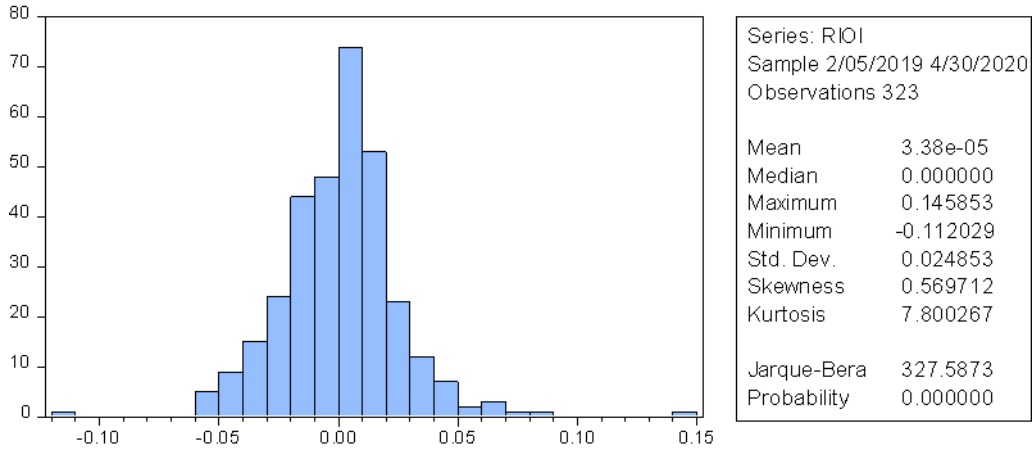


Figure 4.10 Descriptive Statistics of RIOI

Source: Own Composition

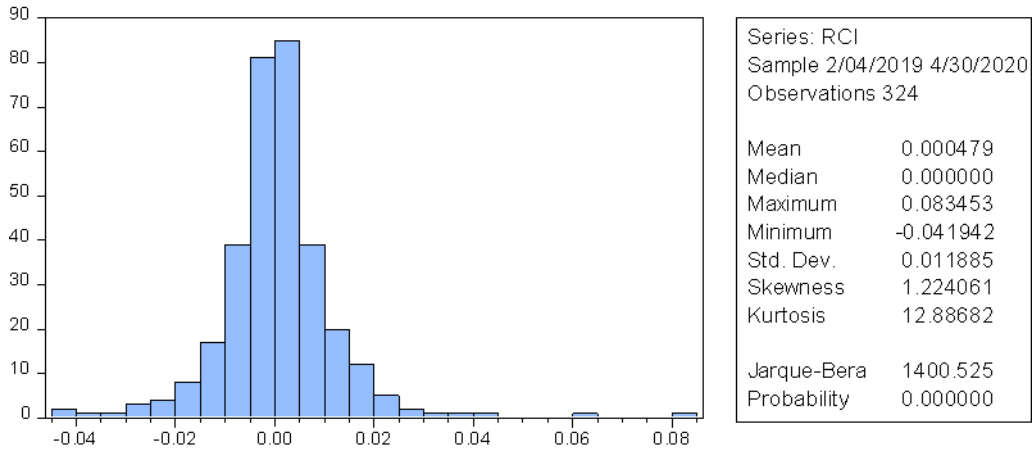


Figure 4.11 Descriptive Statistics of RCI

Source: Own Composition

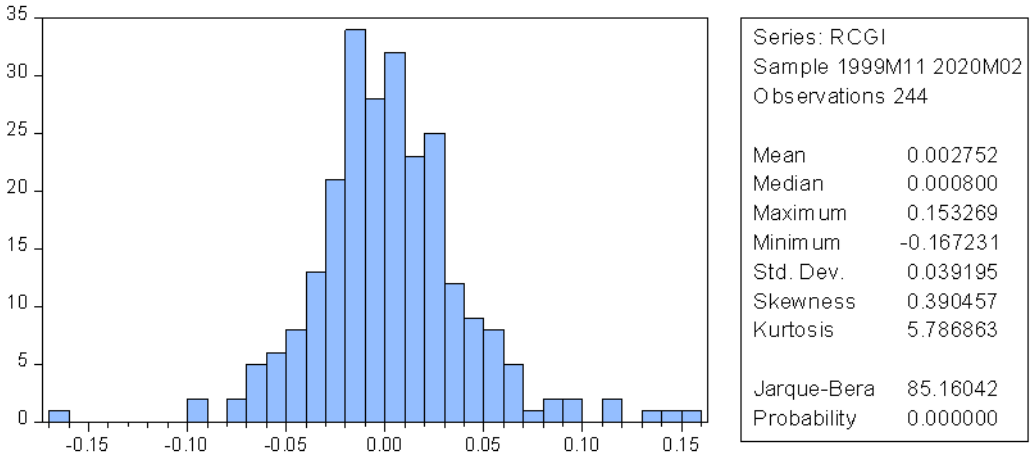


Figure 4.12 Descriptive Statistics of RCGI

Source: Own Composition

As can be seen from the above Figures 4.8 to 4.12, , the dry bulk shipping market, the iron ore market, the coal market and the grain market are all profitable; analyzing the four markets from the perspective of variance, The variance of the RCGI sequence is the largest, the variance of the RBDI and RIOI sequences is second, and the variance of the RCI sequence is the smallest, indicating that the RCGI sequence has the largest deviation from the average value, and the RCI sequence value is relatively small from the average value; In terms of skewness value, RIOI and RCGI belong to the right-biased type, and the statistical value of less than the average rate of return is more. There is a thick tail dragging to the right. The RBDI and RCI series are left-biased. The thicker tail drags to the left; in terms of kurtosis, relative to the normal distribution, the kurtosis values of the four sequences of RBDI, RIOI, RCI and RCHI are all greater than 3, indicating that the distribution

of the three sequences is thicker than the normal distribution. In addition, the accompanying probability of JB statistics is 0, rejecting the null hypothesis of normal distribution. The summary table of the basic statistical characteristics of the three series is shown in Table 4.1.

From the basic statistical characteristic data in Table 4.1, it can be seen that the daily returns of each index are non-normal distribution, which is consistent with the characteristics of sharp peaks and thick tails.

Table 4.1 The summary of descriptive statistics

	RBDI	RIOI	RCI	RCGI
Mean	0.000213	0.000034	0.000479	0.002752
Std. Dev.	0.028768	0.024853	0.011885	0.039195
Skewness	0.018689	0.569712	1.224061	0.390457
Kurtosis	5.679081	7.800267	12.88682	5.786863
Jarque-Bera	96.91118	327.5873	1400.525	85.16042
Probability	0.00000	0.00000	0.00000	0.00000

4.3 Parameter estimation of spillover effect

Before estimating the parameters of the volatility spillover effect model, it is necessary to analyze whether the selected sample data is suitable for the selected model from three aspects. First, check whether the selected sample data is stationary, that is, to perform a stationarity test. Second, investigate whether the selected sample

data is censored or tailed, and whether the correlation coefficient is significantly different from 0. Third, it is necessary to check whether the selected sample data has ARCH effect, and only the sequence with ARCH effect can use the GARCH model for volatility analysis.

4.3.1 Stationary test

The primary condition for using the GARCH model to analyze the volatility spillover effect is that the selected sample data should be stable. Therefore, the stationary test is the premise of the analysis of the volatility spillover effect in this paper. There are many methods of stationarity test. In this paper, the unit root test is selected to investigate the stationarity of the daily logarithmic return series of the three ship types. Since the ADF test is a unit root test method for checking the stationarity of the series in Eviews. Therefore, ADF test is selected to test the stationarity of RBDI, RIOI, RCI and RCGI. The statistical table of ADF test of four sequences is shown in Table 4.2.

Table 4.2 Examination of ADF test

	RBDI	RIOI	RCI	RCGI
ADF test value	-8.459119	-19.58269	-23.69183	-10.23551
1% level	-2.572163	-2.572163	-2.572163	-2.574513
5% level	-1.941811	-1.941811	-1.941811	-1.942136
10% level	-1.616040	-1.616040	-1.616040	-1.615828

According to the data in Table 4.2, according to the selection criterion of Schwartz Criterion lag period, when the maximum lag period is 16, the ADF test values of the three sequences of RBDI, RIOI, RCI and RCGI are all less than 1%, 5%, 10%. The critical value of means that at the test level of 1%, 5%, and 10%, the four sequences RBDI, RIOI, RCI, and RCGI reject the null hypothesis. Therefore, the four sequences RBDI, RIOI, RCI and RCGI meet the stability requirements of the GARCH model.

4.3.2 Autocorrelation test

The autocorrelation test mainly examines whether the data series are tailed or censored, and whether the correlation of the data is 0. The ultimate goal is to investigate whether the sample data is suitable for establishing an autoregressive model. In this paper, autocorrelation (ACF) and partial autocorrelation function graph (PACF) are selected to examine the autocorrelation of four sequences: RBDI, RIOI, RCI and RCGI.

It can be seen from the autocorrelation and partial autocorrelation function graphs of the four sequences of RBDI, RIOI, RCI and RCGI that the autocorrelation functions of the three show significant tailing characteristics, while the partial autocorrelation function graphs show significant truncation. Therefore, the logarithmic returns of dry bulk market, iron ore market, coal market and grain market satisfy the low-order autoregressive model.

The Q-Stat statistic is analyzed below. At a significant level with a critical value of 5%, the critical values of the Q statistic are $Q(1) = 0.004$, $Q(5) = 1.145$, $Q(10) = 3.940$, $Q(20) = 10.851$, $Q(30) = 18.493$, the Q statistic values of the four sequences of RBDI, RIOI, RCI and RCGI when the degrees of freedom are 1 to 30 are greater than the corresponding critical value, that is, at the 5% significance level The above rejects the null hypothesis of no autocorrelation, and the four logarithmic sequence has obvious sequence autocorrelation. Therefore, the index of return rate fluctuation is transitive, that is, the level of the rate of return in a certain period is related to the level of the rate of return in the previous period. The existence of autocorrelation is the fundamental reason why the sequence exhibits the characteristics of "clustering", so that the three graphs have the characteristics of large fluctuations followed by large fluctuations and small fluctuations followed by small fluctuations.

4.3.3 ARCH effect test

The ARCH effect test refers to whether the time series has autoregressive conditional heteroscedasticity. The most commonly used methods of ARCH effect test are the Lagrange multiplier (LM) test and BDS test proposed by Engle in 1984.

In this paper, the LM method is used to carry out the ARCH test on the logarithmic returns of four markets. According to the LM test method, the test statistic is $LM = obs * R^2$, where obs is the number of samples. The statistic LM

gradually follows the X^2 with degree of freedom q. Using the EWIEVS software, the ARCH test is performed on the logarithmic return series of the four markets. The ARCH effect test of the four markets is shown in the Appendix.

When the lag period is 2, the test results are summarized as shown in Table 4.3. It can be seen from the table that the F statistics of the four markets are all greater than the value under the condition of 5%, and $obs * R^2 > X^2_{0.05}$. Therefore, RBDI, RIOI, RCI and RCGI sequences have conditional heteroscedasticity.

Table.4.3 Examination results of ARCH test of residual

	RBDI	RIOI	RCI	RCGI
F	21.37587	45.73557	17.43741	11.25827
$obs * R^2$	20.16616	40.28131	31.75117	10.84508

In summary, the analysis of the basic statistical characteristics of the data shows that the logarithmic return sequence after the first-order difference meets the spiked and thick-tailed characteristics of the conditional heteroscedastic model. The ADF test shows that the data of the daily logarithmic return rate series is stable, and the ARCH test shows that. The RBDI, RIOI, RCI and RCGI sequences have conditional heteroscedasticity, so the BEKK model is suitable for the study of the volatility spillover effects of the four selected market price indices.

4.3.4 Variance equation parameter estimation

Through the above various tests, we know that the binary BEKK model is

suitable for analyzing the volatility spillover effect between two markets. In order to analyze the volatility spillover effect between the goods market and the shipping market, this paper establishes a binary BEKK (1, 1) variance model, whose expression is:

$$H_t = C^T C + A^T \varepsilon_{t-1}^T \varepsilon_{t-1} A + B^T H_{t-1} \tag{3-7}$$

Among them, H_t is the 2×2 order variance-covariance matrix of the conditional residual at time t. Both A and B are 2×2 order parameter matrices to be estimated, where A is the ARCH term and B is the GARCH term. The diagonal elements a_{ii} and b_{ii} in A and B represent the sequence's residual squared lag period to the current fluctuation band. a_{ij} and b_{ij} $(i \neq j)$ reflect the change and overflow of the conditional fluctuations of one variable in the past due to the abnormal shock of another variable in the past. C is a 2×2 order constant triangular matrix to be estimated.

The specific expression of BEKK (1, 1) variance model is:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix}^T \cdot \begin{bmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \end{bmatrix}^T \cdot \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}^T + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \cdot \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix} \cdot \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}^T$$

(3-19)

In the model, $h_{11,t}$ and $h_{22,t}$ represent the conditional variance of cargo markets' price index sequence and Baltic dry bulk index sequence at time t. $h_{12,t}$ and

$h_{21,t}$ represent the conditional covariance of cargo markets' price index sequence and Baltic dry bulk index sequence.

According to the BEKK variance model, the estimated results of the BEKK variance equation of the return rate series of the goods market and the shipping market are shown in the following tables.

Table 4.4 Variance equation estimation results of BEKK between RBDI and RIOI

Variable	Coeff	Std.Error	T-Stat	Signif
1.Mean(1)	0.000366136	0.001521395	0.24066	0.80982008
2.Mean(2)	-0.00043792	0.001224345	-0.35768	0.72058353
3. c_{11}	0.011636856	0.005075831	2.2926	0.02187099
4. c_{21}	0.020062288	0.004059191	4.94244	0.00000077
5. c_{22}	0.00000004	0.055948398	7.13E-07	0.99999943
6. a_{11}	0.876445602	0.108075106	8.1096	0
7. a_{12}	-0.06156771	0.062468035	-0.98559	0.32433559
8. a_{21}	0.241828673	0.078941456	3.06339	0.00218843
9. a_{22}	0.26054689	0.099929905	2.6073	0.00912603
10. b_{11}	-0.03401868	0.143870845	-0.23645	0.81308125
11. b_{12}	0.045866508	0.105405131	0.43514	0.66345723
12. b_{21}	-0.60579567	0.181137826	-3.34439	0.00082464
13. b_{22}	0.490459832	0.259501024	1.89001	0.05875647
14.Shape	5.503836938	1.032570312	5.33023	0.0000001

Table 4.5 Variance equation estimation results of BEKK between RBDI and RCI

Variable	Coeff	Std.Error	T-Stat	Signif
1.Mean(1)	0.001667637	0.001697714	0.98228	0.32596023
2.Mean(2)	0.000328432	0.000356706	0.92074	0.35718872
3. c_{11}	0.018423564	0.002288959	8.04888	0
4. c_{21}	0.000943317	0.001079259	0.87404	0.38209601
5. c_{22}	0.006527221	0.001030189	6.33595	0
6. a_{11}	0.907268437	0.098017515	9.25619	0
7. a_{12}	-0.01440943	0.023143702	-0.62261	0.53354283
8. a_{21}	0.27107188	0.185049362	1.46486	0.14295842
9. a_{22}	-0.71983354	0.122816908	-5.86103	0
10. b_{11}	0.183202566	0.195173774	0.93866	0.34790336
11. b_{12}	0.018870228	0.041343851	0.45642	0.64808682
12. b_{21}	0.138349648	0.221147568	0.6256	0.53157814
13. b_{22}	0.472060381	0.165654373	2.84967	0.00437645
14.Shape	5.201356379	0.92683503	5.61195	0.00000002

Table 4.6 Variance equation estimation results of BEKK between RBDI and RCGI

Variable	Coeff	Std.Error	T-Stat	Signif
1.Mean(1)	0.016625125	0.01019566	1.63061	0.10297306
2.Mean(2)	0.001206966	0.002147327	0.56208	0.5740627
3. c_{11}	-0.04064373	0.017528284	-2.31875	0.02040852
4. c_{21}	-0.00442831	0.022729975	-0.19482	0.84553178
5. c_{22}	0.028669285	0.005682321	5.04535	0.00000045
6. a_{11}	0.512915865	0.116399191	4.40652	0.0000105
7. a_{12}	0.011532861	0.016944301	0.68063	0.49610333
8. a_{21}	0.18369822	0.464646065	0.39535	0.69258397
9. a_{22}	0.733272828	0.133201379	5.50499	0.00000004
10. b_{11}	0.856871552	0.073113945	11.71967	0
11. b_{12}	-0.02862781	0.023061935	-1.24134	0.21447845
12. b_{21}	-0.46304633	1.188730682	-0.38953	0.69688408
13. b_{22}	-0.15187983	0.174048251	-0.87263	0.38286446
14.Shape	5.689063098	1.330670589	4.27534	0.00001908

4.3.5 Wald effect test

In order to prove the validity of the above BEKK model parameters, the validity of the parameters needs to be tested.

This paper chooses Wald effect test to analyze the validity of each parameter. The results of the Wald effect test are shown in Table 4.7 to Table 4.9.

Table 4.7 Wald test result of spillover effect between RBDI and RIOI

Null hypothesis	Wald test statistics	conclusion
RBDI has no spillover effect on RIOI	0.978163	Reject
RIOI has no spillover effect on RBDI	21.104342	Reject

Table 4.8 Wald test result of spillover effect between RBDI and RCI

Null hypothesis	Wald test statistics	conclusion
RBDI has no spillover effect on RCI	0.472993	Reject
RCI has no spillover effect on RBDI	2.257542	Reject

Table 4.9 Wald test result of spillover effect between RBDI and RCGI

Null hypothesis	Wald test statistics	conclusion
RBDI has no spillover effect on RCGI	1.882791	Reject
RCGI has no spillover effect on RBDI	0.197189	Reject

4.3.6 ARCH test of residuals

To ensure the accuracy and reliability, this article also did ARCH test of residuals of BEKK equations. Using e-views to get the results, the tables are as follows:

Table 4.10 ARCH test result of BEKK equation between RBDI and RIOI

Heteroskedasticity Test: ARCH			
F-statistic	2.057186	Prob. F(10,303)	0.6277
Obs*R-squared	19.96331	Prob. Chi-Square(10)	0.5296

Table 4.11 ARCH test result of BEKK equation between RBDI and RCI

Heteroskedasticity Test: ARCH			
F-statistic	2.111821	Prob. F(10,303)	0.7234
Obs*R-squared	20.45895	Prob. Chi-Square(10)	0.6252

Table 4.12 ARCH test result of BEKK equation between RBDI and RCGI

Heteroskedasticity Test: ARCH			
F-statistic	3.225552	Prob. F(15,213)	0.6401
Obs*R-squared	42.38898	Prob. Chi-Square(15)	0.5120

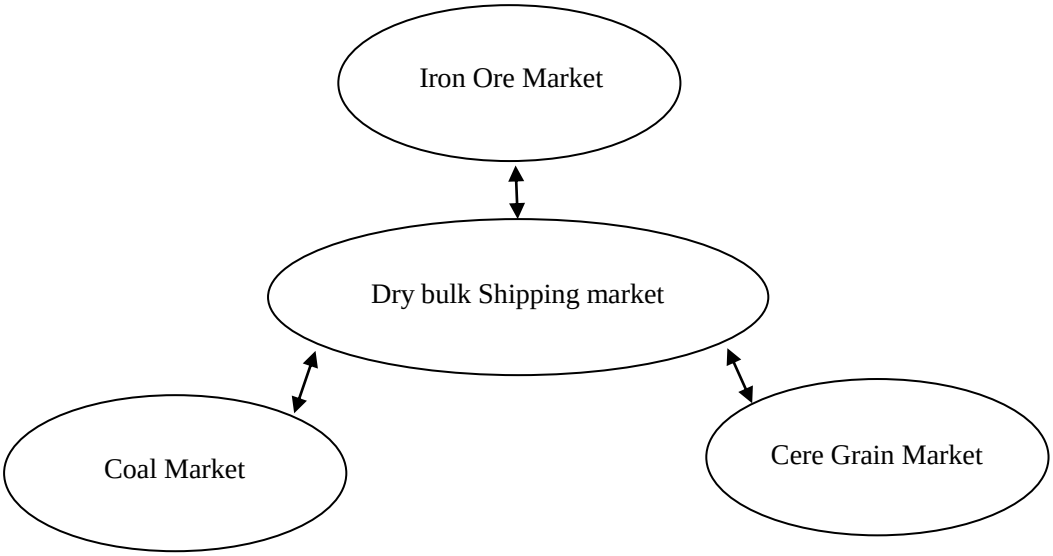
It can be seen in these tables that the P value are all greater than 0.5, which means that ARCH effect does not exist in the residuals.

4.4 Analysis of results

It can be seen from Tables 4.4 to 4.6 that at a significant level of 5%, among the three binary BEKK equations, a_{11}, b_{11}, a_{22}, and b_{22} are significant, indicating that there are ARCH effects between the three goods markets and the shipping market, as well GARCH effect. a_{11} and a_{22} reflects the degree of impact of external shocks on the dry bulk shipping market, that is, the sensitivity of the market to fluctuations. From the numerical value, in the BEKK equations of RBDI and RIOI, a_{11} is greater than a_{22}, indicating that in these two markets, the volatility sensitivity

of the dry bulk shipping market is stronger than that of the iron ore market. In the BEKK equations of RBDI and RCI, a_{11} is less than a_{22}, indicating that the volatility sensitivity of the coal market is stronger than that of the dry bulk shipping market. In the BEKK equations of RBDI and RCGI, a_{11} is less than a_{22}, indicating that the fluctuation sensitivity of the grain market is stronger than that of the dry bulk shipping market. b_{11} and b_{22} reflect the market's memory of volatility. The larger the value, the stronger the continuity of the volatility. In terms of numerical values, in the BEKK equations of RBDI and RIOI, b_{22} is greater than b_{11}, indicating that the fluctuation duration of the iron ore market is longer than that of the dry bulk shipping market. In the BEKK equations of RBDI and RCI, b_{22} is greater than b_{11}, indicating that in both markets, the volatility duration of the coal market is longer than that of the dry bulk shipping market. In the BEKK equations of RBDI and RCGI, b_{22} is smaller than b_{11}, indicating that the fluctuation duration of the dry bulk shipping market is longer than the fluctuation duration of the grain market.

Table 4.4 to Table 4.9 shows that the transmission mechanism of volatility spillover between the three types of dry bulk shipping market is shown in Figure 4.13.



Sources: Own Composition

Figure 4.13 The conduction mechanism of volatility spillover effect

Analysis of Figure 4.13 shows that there is a two-way volatility spillover effect between the dry bulk shipping market and the iron ore market, coal market and grain market, that is, there is a risk transmission between the two markets. When one market fluctuates, this kind of market volatility will spread to another market.

By analyzing the above results and combining the relevant information of the dry bulk shipping market, we believe that there are mainly the following reasons for the volatility spillover effect in the dry bulk shipping market and the cargo market: First, the dry bulk shipping market basically belongs to a free market, and there is a certain connection between markets, so that there is an intersection of information flow, business flow, capital flow and logistics between the markets. Second, started from

spreading to most people, there are errors and interruptions in the spread process, which are not evenly and steadily transmitted. Third, the direct causes of the fluctuation and overflow between different markets when the behavior of participants in the dry bulk market. The behavior of the dry bulk shipping market and the participants in the cargo market, especially the behavior of investors, is manifested as a herd effect. Investors 'behavior is often affected by other investors and has certain irrational, this leads to the volatility spillover effect between the dry bulk shipping market and the cargo market. Fourth, the dry bulk shipping market is part of the global trade market, and the demand for the dry bulk shipping market is a derivative demand of global trade. Therefore, the development of the global economy is closely related to the market situation of the dry bulk shipping market. When the economic conditions of the cargo market are great, the dry bulk shipping market will also be good, the supply of goods is sufficient, and the demand for ships will be great, and when the global economic is in a downturn, the dry bulk shipping market will also be down relatively.

Chapter 5 Countermeasures to avoid risks

5.1 More government support for companies

5.1.1 Establish and improve the management system of dry bulk shipping industry

In order to ensure the efficient and stable operation of the dry bulk shipping

industry, relevant government departments need to formulate a well-organized, flexible, efficient and unified dry bulk shipping industry management system, and at the same time formulate a legally effective dry bulk shipping industry policy. The system should include different functional departments, different departments have a clear division of labor, and there are special departments responsible for risk assessment and early warning analysis of the dry bulk shipping industry, which can detect problems in the dry bulk shipping industry earlier. Based on this, corresponding countermeasures are proposed to avoid large market fluctuations in the dry bulk shipping industry. When a market crisis occurs in the dry bulk shipping industry, relevant departments can quickly set up a team of experts to respond to the crisis, formulate effective solutions to the crisis, and make full use of various resources, so that dry bulk shipping companies are exposed to minimal loss.

5.1.2 Establish and improve the information system of dry bulk shipping industry

The unevenness of information in the transmission process is the root cause of the volatility spillover effect between dry bulk cargo markets and shipping markets. When the information between shipping companies is transparent to each other, there will be no unevenness and diffusion of information. Therefore, establishing and improving the information system in the dry bulk shipping industry plays an important role in reducing market fluctuations in the dry bulk shipping industry. A

good information communication mechanism can ensure that cargo owners, shipowners and investors in the dry bulk shipping industry fully understand the information in the market and make corresponding adjustment strategies in a timely manner. At the same time, the perfect information system also has a great effect on the relevant government functional departments. When a crisis occurs in the market, the relevant departments can realize the timely communication of information and the coordinated operation of the entire social resources through the established information system. When the government establishes an information system, it should be noted that the established information platform is highly transparent and unobstructed, and all enterprises, individuals, and groups related to the dry bulk shipping industry can use the system without barriers, which hinder the transmission of information.

5.1.3 Provide financing support for small and medium dry bulk companies

Participants in dry bulk shipping companies, especially ship owners, because of high cost of ship construction and operation, the capital operation is often tight when they first enter dry bulk shipping companies. Meanwhile, there are also some groups or individuals of shipping companies who intend to enter dry bulk shipping, however, cannot enter the dry bulk shipping industry due to lack of funds.

The government should provide certain financial support to enterprises suitable for development in the dry bulk shipping industry to help enterprises develop in the

dry bulk industry. In 2008, the global financial crisis triggered by the US subprime mortgage crisis had a great impact on the dry bulk shipping industry, and many small and medium-sized dry bulk companies were forced to close. They were forced to close due to lack of funds and poor liquidity. Governments at all levels provide financial support to social dry bulk companies that have a market and potential to help them survive the crisis when the financial crisis occurs in the dry bulk shipping industry. At the same time, state-owned banks should also increase support for small and medium-sized shipping companies, and provide convenient and high-quality services to small and medium-sized shipping companies that meet the relevant national policies and have development potential and provide preferential policies for their loans. In response to the special needs of some enterprises, banks should provide special and customized financial services to meet the development needs of enterprises.

5.2 Shipping enterprises strengthen the ability to against risks

5.2.1 Improve operating mechanism

First of all, dry bulk shipping companies can improve their own advantages through organization or alliances, to overcome their own shortcomings in certain aspects, so as to be able to expand the business scope of the company, provide customers with better quality services, and improve the company's market. In terms of competitiveness, both companies of the alliance can achieve a win-win goal. For

some large shipping companies, their own competitive advantages are greater, but their competitive advantages on a certain route may be relatively weak. At this time, the alliance can strengthen their competitiveness on a single route. For small and medium-sized shipping companies, alliances can enable enterprises to obtain the scale of transportation economy, thereby reducing costs, and can strengthen their competitiveness in the market, which is of great benefit to enterprises.

Secondly, companies can also use a variety of charter methods to avoid market risks. Put a part of the ship into the liner transportation and time charter market to ensure that the enterprise has a part of fixed income. At the same time, a certain percentage of ships will be put into the spot market, through voyage charter or route charter and other different operating methods, with the help of price fluctuations in the market, higher profits will be obtained at the peak.

Thirdly, shipping companies can cooperate with other transportation modes such as land transportation and air transportation to provide customers with modern transportation services such as multimodal transportation. Multimodal transport can combine two or more different transport modes to provide customers with "one-stop" and "door-to-door" services. In addition, multi-modal transport has become a more competitive mode of transportation because it can avoid more loading and unloading processes and reduce the loss of goods. Shipping companies can provide one-stop services for customers by combining with railway, highway or aviation companies,

and provide customers with more convenient services, which can enhance their competitiveness in the market.

5.2.2 Improve the ability to collect information

Information spillover is the root cause of market fluctuations of dry bulk shipping companies. The unevenness of information diffusion makes dry bulk shipping companies unable to fully understand the market of dry bulk cargoes. In addition, due to inadequate information and the influence of the "herding effect", dry bulk shipping companies will make irrational decision-making behaviors when making decisions. Therefore, improving the ability to collect information is of great significance to dry bulk shipping companies. In order to improve the ability to collect information, in addition to the government and other related information systems that cannot be provided, dry bulk shipping companies themselves must also establish corresponding information systems to timely collect information on the dry bulk shipping market and arrange corresponding experts. Analyze the collected information and discover the abnormal fluctuations in the dry bulk shipping market as early as possible. You can also make predictions about the future market of the dry bulk market based on the collected information. When making predictions, you need to consider the volatility linkage between different markets. In addition, when the shipping market of a certain ship type is found to fluctuate abnormally, the volatility of the dry bulk shipping market of different ship types obtained in this paper is used

to predict the volatility of other ship types.

5.2.3 Avoid risks with freight derivatives

Recently, with the strengthening of freight rate fluctuations in the dry bulk shipping market, the shipping futures market was born to control the risks brought by freight rate fluctuations. Among them, marine derivatives provide great protection against shipping risk.

Freight derivatives mainly include Baltic Freight Index Futures (BIFFEX), Forward Freight Agreement (FFA) and freight options. The freight index futures have ceased operation in 2002. So far, the FFA forward freight agreement has played an important role in avoiding freight risk. FFA is a forward freight agreement between the buyer and the seller. The agreement specifies the specific route, price, quantity, etc., and the two parties agree to collect or pay the freight based on the Baltic official freight index price and the contracted price at a certain point in the future. Shipping companies use freight derivatives transactions to effectively lock in profits to avoid risks and obtain stable cash flow; at the same time, in terms of cost control, FFA effectively controls the rental level of chartered ships. Some shipping companies with a higher proportion of own ships can obtain stable income and maintain control of assets by participating in derivatives transactions; while some shipping companies with a lower proportion of own ships can be obtained by purchasing derivatives contracts. Great management flexibility. The forward price discovery function of

freight charges is also extremely important for shipping companies to plan and allocate capacity in advance.

5.2.4 Establish a scientific management system

First, adjust the ship structure and establish a professional and modern fleet. As the competition in the shipping market intensifies, the quality of cargo services provided by cargo owners is getting higher and higher. Shipowners should fully analyze the market needs, establish a professional fleet for transportation, and meet the special requirements of customers. While improving to meet the needs of specialization, shipowners order the development and development of modern ships with good technical performance and energy saving to reduce transportation costs.

Secondly, shipping companies should improve service awareness and provide a full range of transportation services. The transportation industry is a category of the tertiary industry. As a special service industry, shipowners should have the service awareness of other service providers. While providing high-quality transportation, other reasonable requirements for customers should be met as much as possible. Creating a good transport enterprise image and providing special services that satisfy customers according to the special service needs in the market make the company itself have unparalleled advantages compared with other companies and stand out among many aerospace companies.

Third, cultivate corporate culture and attract excellent shipping talents.

Corporate culture is the soul of an enterprise and the foundation of its long-term development. The most fundamental thing for customers to recognize an enterprise is to recognize its culture. Therefore, corporate culture is of great significance to all companies, including shipping companies. In addition, the most valuable asset of an enterprise should be talents, and shipping companies are no exception. If shipping companies want to have high level technology and services, they can only rely on the talents in the enterprise.

Chapter 6 Conclusion

The dry bulk shipping market is significant to the international shipping market. With the complication of the international market, the freight rates of the dry bulk shipping market fluctuate more and more drastically. The fluctuation of the freight index of the dry bulk shipping market has attracted the attention of scholars, and has conducted a lot of research on it from different angles. Based on other researchers, this paper analyzes the influence between the dry bulk shipping market and the cargo market. Then, focus the research on the volatility spillover effect between them. The main work of this article includes the following parts:

Doing Qualitatively analysis of global dry bulk shipping market. Detailed analysis of the demand and supply of the dry bulk shipping market; introduction of the Baltic Dry Bulk Freight Price Index, Platts Iron Ore Index, BJ Coal Index and the United Nations Grain Index factor.

Introduced the commonly used volatility spillover effect model. The univariate GARCH model, the multivariable GARCH model，the SV model and Copula are analyzed, the differences between the three models are compared, and the BEKK model suitable for analyzing the volatility spillover analysis between dry bulk shipping markets is selected, and analyze applicability of it.

Before using the binary GARCH-BEKK model to analyze the volatility spillover effect between the dry bulk shipping market and cargo market, the basic characteristics of the selected sample data are first analyzed, and it is found that the dry bulk freight price index does not have stability. The daily logarithmic rate of return sequence after logarithmic difference meets the stability requirement and has the "clustering" required by the GARCH model. By analyzing the basic statistics, it is found that the returns of each index are non-normal distribution, which is in line with the characteristics of sharp peaks and thick tails.

Binary GARCH-BEKK was used to analyze the volatility spillover effect between the dry bulk shipping market and the cargo market. Firstly, after testing the stationarity, autocorrelation and ARCH effect, it is found that the logarithmic return series of the four markets can be studied using the GARCH-BEKK model. Research indicates. The volatility sensitivity of the coal market is stronger than that of the dry bulk shipping market between these two markets. The fluctuation sensitivity of the grain market is stronger than that of the dry bulk shipping market between these two

markets. By analyzing the market's memory of volatility, the fluctuation duration of the iron ore market is longer than that of the dry bulk shipping market. The volatility duration of the coal market is longer than that of the dry bulk shipping market. The fluctuation duration of the dry bulk shipping market is longer than the fluctuation duration of the grain market. There is a two-way volatility spillover effect between the dry bulk shipping market and the iron ore market, coal market and grain market, that is, there is a risk transmission between the two markets. When one market fluctuates, this kind of market volatility will spread to another market.

Studying the volatility spillover effect of the dry bulk shipping market, countermeasures are proposed to avoid risks in the dry bulk shipping market. On the one hand, the government needs to strengthen support for the dry bulk shipping market. On the other hand, shipping companies must strengthen their ability to resist risks by themselves.

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