Study on the Price Spillover Effect between China Iron ore Futures Import Price and International Dry Bulk Freight and Crude Oil Market

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Abstract. This paper takes the international dry bulk freight, international crude oil market and China iron ore futures import price from January 2010 to March 2023 as the research objects, and verifies and studies the relationship among them from the perspective of price spillover and fluctuation spillover. The results show that significant price spillover effects exist between the international dry bulk freight market and the import price of iron ore futures in China, and between the international crude oil market and the international dry bulk freight market. This study first uses the VAR model, and draws the conclusion that the import price of China iron ore futures is directly affected by the price spillover effect of the international dry bulk freight market, while the international dry bulk freight is directly affected by the price spillover effect of the international crude oil market. Secondly, with the help of BEKK-MGARCH model, it is concluded that from the perspective of volatility risk spillover effect, the fluctuation of each variable is mainly impacted by its own changes, and there is a significant linkage between the international dry bulk freight market and the import price of iron ore futures in China, but this linkage relationship is not found among the other variables, but there is GARCH or ARCH effect.

Keywords: shipping market, iron ore futures, price spillover effect, VAR model, BEKK-MGARCH model

1 INTRODUCTION

In recent years, in the process of social development, the demand and import of iron ore in China have increased year by year. As a dry bulk, iron ore accounts for one third of the total international transportation trade. On the other hand, crude oil is the basic energy and fuel raw material of modern industry, and its price has an important influence on the development of global shipping and transportation [1].

Previous studies have shown that the price spillover effect can be quantitatively studied, but it is mainly inferred from the previous data values[2]. Previous studies have analyzed the impact of variables on their own early fluctuations in the future, and some studies have also analyzed the spillover effect of early fluctuations of external factors

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on future fluctuations of a variable[11]. Andrei Coplos et al. (2014) chose the VAR model to study the spillover effect from the perspective of the Group of Seven (the United States, Britain, France, Germany, Japan, Italy and Canada). The conclusion of the analysis is that during the financial turmoil in 2008, there was no significant liquidity among the seven countries. Most of the research focuses on the market research in a single financial field. Based on the VEC model, Zhang Jinlin et al. (2012) first confirmed that there is a co-integration relationship among the following four markets, namely, futures market, stock market, price market and bond market. Through the analysis of the results, it shows that the more obvious direction of spillover effect is only in one case, that is, when the stock market faces the other three markets, it shows obvious price spillover effect. On the contrary, the results are different, and the other three markets are little affected by external factors. Therefore, it is pointed out that China's financial market price system still needs to be continuously improved.

When the futures price of any country initially meets the demand at home and does not participate in international trade activities, the price fluctuation is mainly regulated by supply and demand within the country. Later, more suppliers and demanders participated in the trade, and the trading parties expanded from domestic to international, and the factors that caused the fluctuation of the import price of iron ore futures in this country also expanded to some international markets and prices, which may increase the uncertainty of spillover effects among variables[3][4] (for example, China joined the International Trade Organization in 2001 and became a major importer). This logic can be used to study the spillover effect of China iron ore futures import price, international dry bulk freight and international crude oil market. Because of the certain interaction of international trade, the import price of China iron ore futures will also reflect a similar slow growth when international dry bulk freight and international crude oil market trade develop smoothly. If the international dry bulk freight rate and the international crude oil market suddenly change positively or negatively, the import price of iron ore futures in China will also change similarly. Therefore, we can assume that the fluctuation of international dry bulk freight and international crude oil market leads to the fluctuation of China iron ore futures import price. We have studied the dynamic relationship between the monthly import price of iron ore futures in China, international dry bulk freight and international crude oil price in recent 13 years. The purpose of this study is to determine whether the latter two variables have a significant impact on the import price of iron ore futures in China, as well as the intensity and direction of this trend. The rest of this paper is organized as follows. The second part reviews the related literature. The third part discusses the research methods. The fourth section describes the data attributes and empirical results. The fifth section makes a conclusion analysis.

2 LITERATURE REVIEW

Some research focuses on the spillover effect between spot markets linked by supply and demand. In order to consider the factors in shipping cost more comprehensively, scholars such as 5. Dimitris A. Tsouknidis (2016) pay attention to the spillover effect between shipping freight rate and marine fuel price. Through verification and analysis,

it is found that the fluctuation of marine fuel price has obvious influence on shipping freight rate. On the other hand, the research focuses on the spillover effect between the spot and futures markets within the shipping market[5]. Visvikis et al. (2014) analyzed the lag-lead relationship between shipping futures agreement (FFA) and spot shipping rate based on the charter lines (namely, charter line P1 and charter line P2) and time charter line (spot charter line P1A and time charter line P2A) of Panamanian ship routes[6]. It is concluded that there is a price spillover effect relationship between FFA and spot freight rate, and it is bidirectional, and the price of shipping futures agreement can reflect new dynamic signals with faster response speed than spot freight rate[7]. Some studied the unbalanced effect in the freight market and the macroeconomic impact on the freight fluctuation in the tanker market and the dry bulk freight market, and used the GARCH family model[8][9]. Shen Qian et al. (2014) studied and analyzed the price linkage effect between the spot markets in China. By collecting price data and establishing a VECM model, they found that in the short term, the spot market prices in have two-way spillover effects with different intensities, but in the long run, the China futures market will dominate the price response in the spot market[10].

3 METHODOLOGY

In the economic field, there are many models in which the response variable is influenced by itself and other variables. We try to clarify the interaction between the import price of iron ore futures in China and the price fluctuation between the international dry bulk freight and the international oil market. This study combines the statistical characteristics of abnormal distribution of data to establish a VAR model to study the price spillover relationship among them.

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \varepsilon_t (t = 1, 2, \cdots, T) \tag{1}$$

Among them, the y representing endogenous variables, the x representing exogenous variables, p is the lag order, T represents the number of samples, and ε is the error column vector, which is the same dimension with y but related to the the right side of the equation. Equation (1) is usually called a non-limiting vector autoregressive model. In this analysis, the VAR model does not contain the exogenous variable x, and is expressed by Equation (2):

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t (t = 1, 2, \cdots, T) \tag{2}$$

In addition, in order to determine the fluctuation risk effect among China iron ore futures import price, international dry bulk freight and international crude oil market, the BEKK-MGARCH model is established to study the fluctuation spillover effect of China iron ore futures import price, international dry bulk freight and international crude oil market, and to judge the correlation and direction of fluctuation transmission among them. The matrix expression of the mean equation of this model is as follows.

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_k \end{pmatrix} = \begin{pmatrix} x_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & x_k \end{pmatrix} \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \vdots \\ \gamma_k \end{pmatrix} + \begin{pmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_k \end{pmatrix} \tag{3}$$

y is the observation vector of the i-th equation, x is the explanatory variable matrix of the i-th equation, μ is the perturbation term vector of the i-th equation, and k is the number of endogenous variables. If there is a constant term, the first column of is all 1, indicating the number of explanatory variables of the i-th equation and the coefficient vector of the i-th equation, i = 1, 2, …, k.

According to the basis of multiple variables in this study, the diagonal BEKK-GARCH model is established to simplify the parameter estimation. A large number of studies at home and abroad show that BEKK-MGARCH has a good description of the time-varying conditional variance by using the first-order lag form, but it has no obvious effect by using the higher-order model, and the estimation parameters are greatly increased. In this paper, the BEKK-MGARCH model is adopted. Taking the ternary diagonal model as an example, the expression is as follows (4):

$$H_{t+1} = C^T C + A^T \mu_t \cdot \mu_t^T A + B^T H_t B \tag{4}$$

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix}, \quad C = \begin{bmatrix} c_1 & c_2 & c_3 \\ 0 & c_4 & c_5 \\ 0 & 0 & c_6 \end{bmatrix}$$

$$A = \begin{bmatrix} a_1 & 0 & 0 \\ 0 & a_2 & 0 \\ 0 & 0 & a_3 \end{bmatrix}, \quad B = \begin{bmatrix} b_1 & 0 & 0 \\ 0 & b_2 & 0 \\ 0 & 0 & b_3 \end{bmatrix}$$

Assume that the current period is t period, where T is the number of sample observations and H is the conditional variance covariance matrix of μ in t-period, and the influence of the residual term of the lag period (t-1 period) on the fluctuation of the current period is represented by the elements of diagonal matrix A, indicating the influence of new information generated by the lag period on the current market fluctuation, that is, ARCH effect (time-varying characteristics); The elements of matrix B represent the influence of fluctuations in t-1 period on current fluctuations, that is, GARCH effect (persistent characteristics). In order to clearly show the description of the fluctuation characteristics of the model, the expansion of (4) is given, in which the constant term does not have much influence on the results, and to simplify the expression, it is expressed as C:

$$h_{ii,t+1} = C_1 + a_i^2 \mu_i t^2 + b_1^2 h_{ii,t} \tag{5}$$

$$h_{ij,t+1} = C_2 + a_i a_j \mu_{i,t} \mu_{j,t} + b_i b_j h_{ij,t} \quad (6)$$

4 DATA DESCRIPTION AND EMPIRICAL RESULTS

4.1 Data Description

This analysis selects the period from January 2010 to March 2023, and selects the monthly China CFR iron ore futures import price (PUSG_B), the monthly Baltic freight index (BDI) and the monthly Baltic Cape of Good Hope dry bulk freight index (BCI) to represent the international dry bulk freight and the international crude oil market benchmark price (WTI). Finally, we get 159 valid data for each variable, all of which are from Clarkson sin (Clarkson Shipping Intelligence Network).

The ADF unit root test shows that the above four time series are not stable. After logarithm of the original series, the yields are obtained, and the monthly China CFR iron ore futures import price yield (RPUSG_B), monthly Baltic freight index yield (RBDI), monthly Baltic Cape of Good Hope dry bulk freight index yield (RBCI) and international crude oil market benchmark price yield (RTCI) are obtained respectively. The processed data are all stable processes.

Sample data are described in the following table 1. It can be judged by Skewness, Kurtosis and J-B that the sequences of the four variables all show the characteristics of sharp peaks and thick tails, and all deny the assumption of normal distribution, and the results of ADF test are all stable.

Table 1. Descriptive statistical analysis results.

	Mean	Median	SD	Skewness	Kurtosis	J-B	ADF
RBDI	-0.0004	0.0058	0.2082	0.3800	9.2253	258.9380	-8.7072**
RBCI	0.0087	-0.0025	0.3300	0.4597	6.5490	30.8023	-8.1098*
RCIT	0.0000	0.0148	0.1094	-1.0500	10.6974	413.7344	-9.6765*
RPUSG_B	0.0006	0.0155	0.0929	-1.2652	7.9951	205.1092	-8.8700**

Note: "*", "* *" and "* * *" mean rejecting the original hypothesis at 10%, 5% and 1% significance levels respectively.

4.2 Empirical Results

Price Spillover Effect

(1) VAR model modeling

In order to ensure that the VAR model can accurately reflect the dynamic characteristics between variables, this study should choose an appropriate lag order when

analyzing the VAR model. The optimal lag order of different standards is shown in Table 2.

In this analysis, variance decomposition is used to study the dynamic relationship of variables in the system, so a VAR model is established. Combined with FPE, AIC, SC, HQ criteria, choose lag order 1 to establish the model.

Table 2. Test results of lag order of VAR model.

Lags	LL	LR	FPE	AIC	SC	HQ
0	279.5264	NA	3.06e-07	-3.6494	-3.5694*	-3.6169
1	295.9536	31.7670	3.04e-07*	-3.6550*	-3.2554	-3.4927*
2	320.6071	46.3682*	2.71e-07	-3.7696	-3.0503	-3.4774
3	342.5565	21.6077	3.11e-07	-3.6365	-2.2777	-3.0845

Note: * indicates the optimal lag order selected according to specific criteria at the level of 10% significance.

(2) Granger causality test and variance decomposition

The original hypothesis of Granger causality test, H0: variable X can't cause Granger to change variable Y; The alternative hypothesis is that H1: the variable X can cause the change of the variable Y by Granger. Figure 1 below shows the interaction of China iron ore futures import price yield, Baltic dry bulk freight index yield, Baltic Cape dry bulk freight index yield, and international crude oil price yield. The arrow in the figure shows that the change of one variable that lags behind the first period has an impact on the other yield, and 10% and 1% respectively indicate different significance levels.

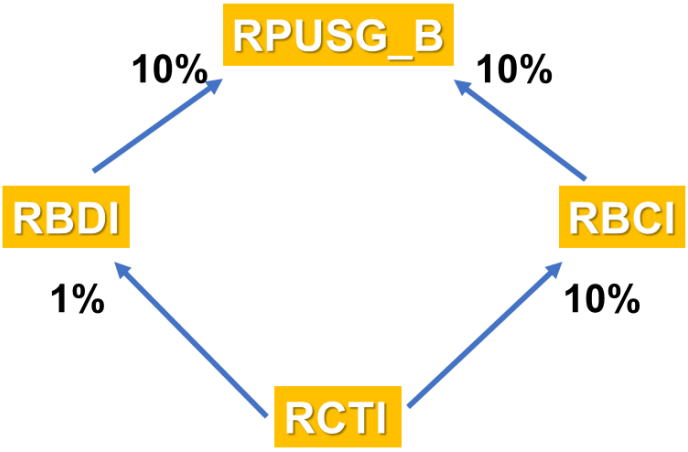

Fig. 1. Granger causality test results.

The following tables 3, 4, 5 and 6 give the variance decomposition results between the above four variables in the system respectively. Due to space, only the results with a lag of 3 orders are given here.

Variance decomposition indicates the contribution of other variables in the system to the change of a variable, that is, the degree of influence. Based on Granger causality test and variance decomposition results, we have the following conclusions:

(1) For the four return variables in this study, the changes in this period are mainly impacted by their own changes.

(2) The Baltic dry bulk freight index yield and the Baltic Cape dry bulk freight index yield represent the international dry bulk freight, so the international dry bulk freight is positively impacted by the international oil price in one direction, and this impact did not immediately cause the change of the international dry bulk freight. On the contrary, the impact of international dry bulk freight has not caused significant changes in international oil prices.

(3) The Baltic dry bulk freight rate and the Baltic dry bulk freight rate have a one-way positive impact on the import price of iron ore futures in China, that is to say, the international dry bulk freight rate has a one-way positive impact on the import price of iron ore futures in China. Moreover, this impact will immediately cause a slight change in the import price of iron ore futures in China, and then the impact of the lag period will be strengthened, and then it will remain at a certain level. On the contrary, the change of China iron ore futures import price has no significant impact on international dry bulk freight.

Table 3. Contribution of other variables in the system to the change of Baltic dry bulk freight index yield.

Variance Decomposition of RBDI					
Period	S.E.	RBDI	RBCI	RCTI	RPUSG_B
one	0.2333	100.0000	0.0000	0.0000	0.0000
2	0.2390	95.4531	0.0705	4.3926	0.0838
three	0.2396	94.9900	0.0906	4.8358	0.0836

Table 4. Contribution of other variables in the system to the change of the yield of Baltic Cape dry bulk freight index.

Variance Decomposition of RBCI					
Period	S.E.	RBDI	RBCI	RCTI	RPUSG_B
one	0.6031	72.3153	27.6847	0.0000	0.0000
2	0.6130	70.0040	27.7394	1.7257	0.5310
three	0.6135	69.8907	27.6904	1.8878	0.5311

Table 5. Contribution of other variables in the system to the change of international crude oil price yield.

Variance Decomposition of RCTI					
Period	S.E.	RBDI	RBCI	RCTI	RPUSG_B
1	0.1058	0.0011	8.2252	91.7737	0.0000
2	0.1106	0.2484	7.5602	92.1393	0.0521
3	0.1111	0.2632	7.5067	92.1784	0.0517

Table 6. Contribution of other variables in the system to the change of import price yield of iron ore futures in China.

Variance Decomposition of RPUSG_B					
Period	S.E.	RBDI	RBCI	RCTI	RPUSG_B
1	0.0673	0.1797	0.2550	0.0972	99.4682
2	0.0685	0.2852	2.1813	1.0125	96.5210
3	0.0685	0.2910	2.2039	1.0298	96.4753

Fluctuation Spillover Effect. Fluctuation spillover effect between variables is another indirect form of interaction between different variables. With the development of international trade, the fluctuation of international market or price may cause the fluctuation of a country's commodity import price. The fluctuation of international or national economic variables then affects its own fluctuation, so it is necessary to analyze the actual impact of this fluctuation from the fluctuation spillover effect between different variables.

(1) China iron ore futures import price and international dry bulk freight and international oil price fluctuation spillover effect

Table 7. Estimation results of BEKK-MGARCH model parameters of China iron ore futures import price, international dry bulk freight and international oil price.

	parameter	a1	a2	a3
ARCH	estimated value	0.243991	0.184564	0.190415
	Z statistics	3.290159	1.79983	2.375289
	P value	***	***	*
	parameter	b1	b2	a3
GARCH	estimated value	0.243991	0.184564	0.190415
	Z statistics	3.290159	1.79983	2.375289
	P value	***	***	*

Note: where 1, 2 and 3 respectively represent Baltic dry bulk freight index, Baltic Cape dry bulk freight index and international oil price.

Table 7 shows that the fluctuation of China iron ore futures import price and international oil price are influenced by the new information generated by their own changes, that is, there is ARCH effect; At the same time, the fluctuation of Baltic dry bulk freight index, Baltic dry bulk freight index and China iron ore futures import price are all affected by previous fluctuations, that is, there is GARCH effect.

Besides, table 7 also presents that there is a significant GARCH effect in the linkage between the Baltic Cape dry bulk freight index and other variables except the international oil price, but there is no ARCH effect. The linkage between the international oil price and other variables except the Baltic Cape dry bulk freight index has GARCH effect, but there is no ARCH effect. There are significant ARCH effects and GARCH

effects in the linkage between the import price of iron ore futures in China and the Baltic dry bulk freight index.

5 CONCLUSION

(1) Price spillover effect. In the research interval, the international crude oil price has a significant positive price spillover effect on the international dry bulk freight, and the international dry bulk freight also has a significant positive price spillover effect on the China iron ore futures import price.

(2) Fluctuation spillover effect. In the system of this study, only the international dry bulk freight and the import price of China iron ore futures have significant linkage. On the one hand, it shows that the impact of the fluctuation of international dry bulk freight and China iron ore futures import price will impact each other in the early period, which will further affect their prices in the early period; On the other hand, the fluctuation of international dry bulk freight and China iron ore futures import price will have an impact on the changes of the next two series, thus affecting their price changes in the future.

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