

# Price Influence and Volatility Risk Transmission of Non-Ferrous Metals Futures: Situation in China

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## Abstract

This paper uses the cointegration correlation theory and the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model method to conduct an empirical study on the price discovery function and influence of non-ferrous metals listed on the Shanghai Futures Exchange, as well as the international pricing power and volatility risk transmission. It is found that the futures prices of six non-ferrous metals in China have a strong price discovery function. Domestic non-ferrous metal futures copper, aluminum, and zinc have strong international pricing influence, while lead, nickel, and tin are weak. There is a significant long-term co-directional change relationship between domestic and foreign non-ferrous metal futures. The long-term price yield of non-ferrous metals (copper, aluminum, zinc, nickel) of London Metal Exchange (LME) futures market is stronger than that of China. There is a long-term cointegration trend between domestic and foreign non-ferrous metal futures prices yields, and there are differences in the risk premium of returns. There are different leverage effects in the domestic and foreign non-ferrous metal futures markets, and the risk in the foreign market is greater than that in the domestic market, and there is a greater risk in cross-market arbitrage. There is a strong mutual influence between the volatility risks of the domestic and foreign non-ferrous metal futures markets, and the risk transmission has obvious asymmetry. There is asymmetry in the spillover effect of domestic and foreign non-ferrous metal futures markets, except for aluminum and lead, the spillover effect of domestic copper, zinc, nickel and tin futures markets to foreign countries is stronger than that of foreign countries to domestic. It is recommended to promote the international development of the domestic non-ferrous metal futures market, enrich the varieties of domestic non-ferrous metal futures and options, establish and improve the basic construction of the

domestic non-ferrous metal futures market, and strengthen the risk supervision of the non-ferrous metal futures market, so as to further promote the high-level development of the domestic non-ferrous metal futures market.

### Keywords

Non-Ferrous Metals, Cointegration Test, Error Correction Model, GARCH Model, Asymmetry

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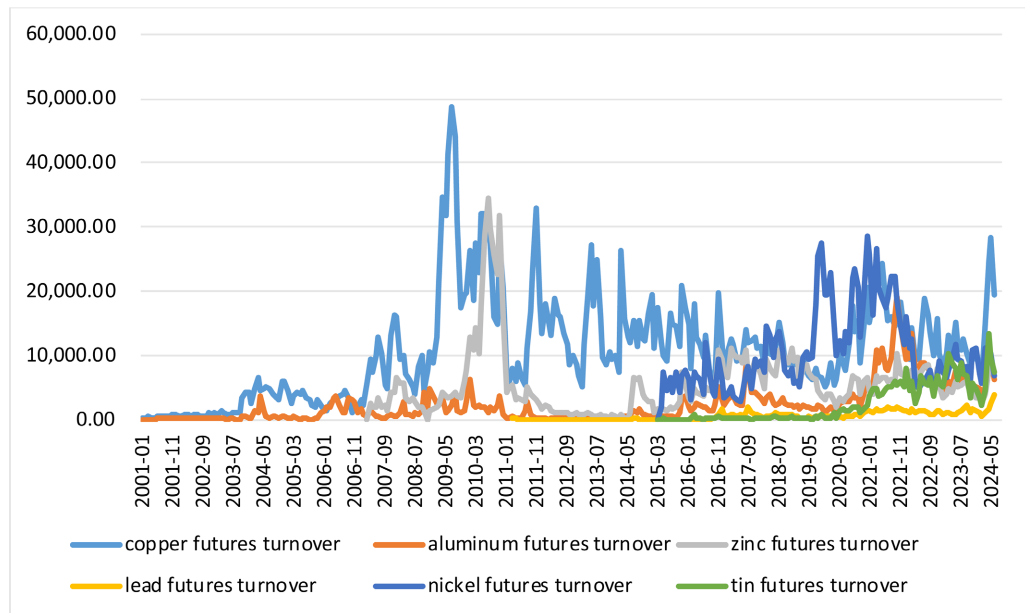
## 1. Introduction

As an important industrial raw material, non-ferrous metals play an important role in the development of the national economy, and in recent decades, the development of the non-ferrous metal industry has strongly promoted the rapid development of China's economy.

With the establishment and development of China's futures market, non-ferrous metal futures have been launched on the Shanghai Futures Exchange (SHFE), and copper and aluminum futures, as the earliest futures varieties of non-ferrous metal futures, were listed and traded on the Shanghai Metal Futures Exchange, the predecessor of the Shanghai Futures Exchange, in 1993. Subsequently, the third non-ferrous metal futures product, zinc futures, was listed on the Shanghai Futures Exchange on March 26, 2007. The fourth non-ferrous metal futures product, lead futures, was listed on the Shanghai Futures Exchange on March 24, 2011. The fifth and sixth varieties of non-ferrous metal futures, nickel and tin futures, were listed and traded on the Shanghai Futures Exchange on March 27, 2015, so far, the Shanghai Futures Exchange has listed six basic futures varieties of non-ferrous metals. With the development of the internationalization of the futures market, the Shanghai International Energy Exchange, a subsidiary of the Shanghai Futures Exchange, launched the first international copper futures variety of domestic non-ferrous metals on November 19, 2020. The Shanghai Futures Exchange has made strict designs for non-ferrous metal futures in terms of trading, delivery and risk control, and has continuously optimized various rules and systems with the development of the market, which has effectively guaranteed the healthy development of the non-ferrous metal futures market.

Since the launch of the non-ferrous metal futures market, the market has been running steadily, and the non-ferrous metal futures varieties have shown different activity, and the following non-ferrous metal futures six varieties of trend chart can be seen that before 2015, the turnover of copper and zinc futures was outstanding, and after 2015, after the launch of nickel futures, the turnover of nickel once exceeded the turnover of copper and zinc, and after 2020, copper, nickel, zinc, aluminum, and tin performed well, and the turnover of lead was at the bottom (**Figure 1**).

After years of development, the non-ferrous metal futures market has become



Source: Shanghai futures exchange website.

**Figure 1.** Trend chart of the turnover of six non-ferrous metal futures varieties.

the most mature futures market in the domestic futures market, and the futures market has achieved remarkable results in serving entity enterprises, and most of the domestic non-ferrous metal enterprises have participated in the hedging of the non-ferrous metal futures market. The price of non-ferrous metal futures has a certain international influence, and the healthy development of the non-ferrous metal industry has laid a solid foundation for the international pricing power of non-ferrous metal futures. Further research on the discovery function of non-ferrous metal futures prices, the influence of international pricing and the transmission of volatility risks, provide theoretical support for the further development of the non-ferrous metal futures market, and provide technical support for market participants, so as to further promote the healthy development of the non-ferrous metal industry.

The article is organized as follows: Part I: Introduction. Part II: Literature Review. Part III: research methods and models; Part IV: Empirical Analysis; Part V: Conclusions.

## 2. Literature Review

There is a lot of research literature on non-ferrous metal futures, and in recent years, there have been many studies on the price discovery, price influence and volatility of the non-ferrous metal futures market in China.

### 2.1. Domestic Literatures on the Relationship between Non-Ferrous Metal Futures and Spot Prices and the Price Discovery Function

For example, Zhang and Liu (2006) found that there is a long-term equilibrium

relationship between aluminum and copper futures prices and spot prices in China. Wang et al. (2011) found that the futures prices of copper, aluminum, and zinc listed on the Shanghai Futures Exchange can guide the spot price, and the futures market is in a dominant position in price discovery and has a stronger ability than the spot market. Xu and Li (2012) found that there is a significant two-way price guidance relationship between China's metal futures and spot market by using the information transfer effect model and the G-S model. Yu (2018) used the Johansen cointegration test and wavelet coherence analysis method to study the correlation between the prices and spot prices of six non-ferrous metal futures traded on the Shanghai Futures Exchange of copper, aluminum, zinc, nickel, lead and tin, and analyzed their leading relationship in the time-frequency domain. The results show that, except for aluminum, there is a cointegration relationship between the futures prices and spot prices of the other five non-ferrous metals. The futures prices of the six non-ferrous metals, including aluminum, can guide the spot prices to a certain extent, but the price discovery efficiency of copper and nickel futures is higher, followed by the price discovery efficiency of lead, tin and zinc futures, and the price discovery efficiency of aluminum futures is significantly lower than that of the other five non-ferrous metals. Li (2018) studied the guiding relationship between the spot prices of copper, aluminum, zinc, lead, nickel and tin in China's non-ferrous metal market through the vector error correction model. The results show that the spot prices of copper, zinc, lead, nickel and tin guide each other, and the price of aluminum futures guides the changes of spot prices in one direction. Song and Xing (2020) used the GARCH family model and the state space model to explore the various functions of the domestic copper futures spot market, and concluded that domestic copper futures have a strong price discovery function, a good hedging function, and a strong volatility spillover to the spot market. Wang and Yu (2021) established the Vector error correction model (VECM) and studied the relationship between domestic copper futures and spot prices, and concluded that there is a long-term cointegration relationship between the two, and the price guidance of futures is more advantageous, but on the whole, the copper price discovery function in China is not efficient. Jiang (2022) studied the linkage relationship between the spot prices of non-ferrous metals in China based on the VAR model, and explored the long-term equilibrium relationship and price guidance relationship between the domestic copper spot, aluminum spot, zinc spot, lead spot, nickel spot, and tin spot prices.

## **2.2. Domestic Literatures on the Relationship between Domestic and Foreign Futures Prices and Volatility Spillover of Non-Ferrous Metals**

For example, Zhou et al. (2012) conducted a study on the copper futures varieties in domestic metal futures trading, analyzed the spillover of domestic aluminum futures and foreign London copper futures on the research object, and found that domestic copper futures are more likely to be affected by London copper futures,

while although there is a two-way spillover between domestic copper futures and aluminum futures, the spillover of copper futures is significantly stronger. Wang and Shao (2012) used the two-state threshold vector error correction model to study the long-term equilibrium relationship and short-term dynamic adjustment mechanism of Chinese and international non-ferrous metal futures prices in different states, and found that there is a significant threshold cointegration relationship between copper and aluminum futures on the London Futures Exchange and the Shanghai Futures Exchange, and the adjustment strength of Chinese and international non-ferrous metal futures prices to the long-term equilibrium state is asymmetrical. Shen and He (2014) used an independent component analysis method to study the risk spillovers of three different futures varieties between domestic and foreign futures markets, and found that there were significant differences in the risk spillover intensity of major futures products at home and abroad before and after the outbreak of the financial crisis. Xu and Wang (2014) constructed the VAR model and G-S model to study the price guidance relationship of the domestic copper futures and spot market and concluded that the domestic copper futures market is weak and effective. And it is believed that the Shanghai copper and London copper futures markets affect each other, but the impact of London copper on the price change of Shanghai copper is more significant. Jiang and Shen (2015) analyzed the correlation between China and the international futures market and the price discovery function by using cointegration theory, VECM and various price discovery models. The study concludes that there is a long-term equilibrium relationship between China and international copper, aluminum and zinc futures prices. The London market has a strong guiding role in the Shanghai market, has a strong impact on the prices of copper, aluminum and zinc in the Shanghai market, and has a weak impact on Shanghai lead. LME has a larger market share, and SHFE has a stronger price discovery function for aluminum and zinc. Liu et al. (2018) examined the degree of spillover between the London copper and Shanghai copper futures markets, and the results showed that there was a positive mutual spillover effect between the London copper and Shanghai copper futures markets. Li (2018) found that there is a long-term equilibrium relationship between the Shanghai and London metal futures markets through the Granger causality test. There will also be cross-influences and transmission effects between different metal futures commodity markets. Liu (2022) starts from the perspective of price discovery function and fluctuation spillover effect, verifies the effectiveness of the domestic pricing center and the influence of international pricing power in China's copper futures market. The model analysis results of the long-term market show that there is an obvious Autoregressive Conditional Heteroskedasticity (ARCH) effect and a strong GARCH effect between the LME and SHFE copper markets, and the price formation process of the two markets is independent, and there are shock spillover effects and fluctuation spillover effects between them, and the overall trend is closely linked. The results of short-term data construction model show that there is only a one-way fluctuation

spillover from SHFE to LME, and there is no fluctuation spillover from LME to SHFE.

### **2.3. Foreign Literatures on the Relationship between Non-Ferrous Metal Futures and Spot Prices, Price Discovery and Volatility Spillover Effects**

For example, [Liu and Wang \(2014\)](#) selected the 3-month contract, 15-month contract and 27-month futures contract of the main non-ferrous metals of copper, aluminum, zinc and nickel in the LME to cross-correlate with their spot prices, and verified the interaction between spot yield and volatility through the VECM model and the binary BEKK-GARCH model. It is concluded that the volatility spillover effect has a significant effect on the nonlinear correlation of spot prices. [Yue et al. \(2015\)](#) used the VAR-DCC-GARCH model to study the relationship between China's non-ferrous metal market price and London metal futures price, and found that there is a linkage between the London futures market price and the Chinese non-ferrous metal market price, and the LME non-ferrous metal price still has a great impact on China's non-ferrous metal price. However, with the exception of lead, the impact of Chinese non-ferrous metal prices on LME non-ferrous metal prices is still weak. [Fernandez \(2016\)](#) studied the correlation between spot and futures prices for aluminium, copper, lead, nickel, tin, and zinc on the London Metal Exchange. Isabel [Figuerola-Ferretti and Gonzalo \(2016\)](#) analyzed the correlation between the spot prices and futures prices of LME copper and other base metals from January 1989 to October 2006, verified the effectiveness of the long-term equilibrium and short-term correction of the futures market through cointegration relationship and nonlinear VECM model, and analyzed the quantitative level of price contribution between the futures and spot prices by using PT decomposition. It is concluded that there is an effective price spillover from the futures market to the spot market, and the effectiveness of the price discovery function is verified. [Kang et al. \(2017\)](#), [Kang & Yoon's \(2019\)](#) study found that LME non-ferrous metal futures have a greater impact on SHFE non-ferrous metal futures. [Shi et al. \(2018\)](#) conducted an in-depth study of the relationship between China's copper and aluminum futures markets by using a volatility decomposition method. [Kang et al. \(2017\)](#) used the weekly data of LME and SHFE copper, aluminum, and zinc varieties to construct a volatility aggregation analysis of time series, and found that the long-term (more than 64 weeks) linkage phenomenon was significant, while the short-term (less than 16 weeks) showed a weak or even negative correlation, arguing that the short-term deviation was caused by short-term investors' diversification in order to reduce risk, and the long-term LME market still dominated. Sang Hoon [Kang and Yoon \(2019\)](#) used the prices of four futures products, including the CSI 300 Index and the Shanghai Futures Exchange Copper from April 2005 to March 2019, and discussed the transmission direction and intensity of yield and volatility spillovers during the global financial crisis and the European debt crisis through the multivariate DECO-GARCH model and the

spillover index model, and concluded that there is a long-term and obvious positive correlation between the CSI 300 Index and commodity futures in the post-financial crisis period, the spillover effects of returns and volatility between markets are more significant.

To sum up, a large number of studies at home and abroad on relationship of non-ferrous metal futures and spot prices, the relationship between domestic and foreign prices and the relationship between fluctuation spillovers are mainly focused on some non-ferrous metal futures and spot varieties, and the price influence of non-ferrous metal futures copper, aluminum, zinc, lead, nickel and tin and the volatility risk transmission of all varieties of non-ferrous metal futures at home and abroad are still relatively lacking. Conduct a comprehensive study on the price discovery and international influence of non-ferrous metal futures and the transmission of volatility risks, hoping to obtain valuable conclusions and provide valuable suggestions for the development of the non-ferrous metal futures market.

### 3. Research Methods and Models

#### 3.1. Cointegration Test and ECM Model of Domestic and Foreign Non-Ferrous Metal Futures Price Yields

If it can be inferred that the logarithmic series of domestic and foreign non-ferrous metal futures prices is a first-order single integer, the possible cointegration relationship between them can be further analyzed. The stable sequence of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures prices and yields is as follows:  $R_{1t}, R_{2t}, R_{3t}, R_{4t}, R_{5t}, R_{6t}, R_{21t}, R_{22t}, R_{23t}, R_{24t}, R_{25t}, R_{26t}$ , The binary error correction model (ECM) can be expressed as:

$$R_{1jt} = \gamma_j (LNP_{1jt-1} - \beta_j LNP_{2jt-1} + C) + \alpha_1 R_{1jt-1} + \alpha_2 R_{1jt-2} + \phi_{j1} R_{2jt-1} + \phi_{j2} R_{2jt-2} + \varepsilon_{jt} \quad (1)$$

$\gamma_j$  is the adjustment parameter for error correction.  $\varepsilon_{jt}$  is the uncorrelated white noise error sequence, where  $J = 1, 2, 3, 4, 5, 6$ . If the above ECM model is true, it shows that the price yield of non-ferrous metal futures at home and abroad is affected by the same error correction process, but with different adjustment speeds, and the return to long-term equilibrium has a common trend component and similar cycle characteristics, which may lead to different short-term fluctuation patterns due to the different error correction coefficients. In ECM, the long-term correction relationship can be expressed as follows:

$$LNP_{1jt} - \beta_j LNP_{2jt} + C = u_{jt} \quad (2)$$

where  $u_{jt}$  is a stationary time series of zero mean,  $j = 1, 2, 3, 4, 5, 6$ . The above relationship represents the cointegration relationship between domestic non-ferrous metal futures prices (copper, aluminum, zinc, lead, nickel, tin) and foreign non-ferrous metal futures prices (copper, aluminum, zinc, lead, nickel, tin), and the standardized cointegration vectors are  $(1, -\beta_j)'$ .

There are many methods for testing and estimating cointegration relations, including the Engle and Granger (1987) two-step method and Johansen (1988) maximum likelihood method (MLE), and the Johansen test is superior to the Engle & Granger method for multivariate cointegration tests. In this paper, the Johansen test is used. According to Engle and Granger (1987) expression theorem, there are three equivalent expressions of cointegration systems: vector autoregressive VAR, moving average MA and ECM, among which ECM can best describe the synthesis of short-term fluctuations and long-term equilibrium, and is the most widely used. Engle and Granger (1987) demonstrated that cointegration sequences can necessarily be represented as error-corrected representations. Therefore, when the variable sequence is cointegrated, an error correction model should be established.

### 3.2. GARCH-M Model of Domestic and Foreign Non-Ferrous Metal Futures Price Returns

The Autoregressive conditional heteroskedasticity model (ARCH) can effectively characterize the volatility of risk and return, and make these volatility and risk measures time-varying in nature, reflecting the dynamic impact of new information acquisition and new shocks. Engle (1982) proposed the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, which can be generalized to allow the conditional variance to have an impact on the rate of return, therefore, the GARCH-M (p, q) model of the futures price yield of non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) at home and abroad is set as follows:

$$R_t = \alpha + \lambda \sigma_t^2 + \sum_{i=1}^m \theta_i R_{t-i} + \sum_{j=1}^n \eta_j \varepsilon_{t-j} \quad (3)$$

Among them,  $R_t$  is the futures price yield of non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) at home and abroad.  $\sigma_t^2$  is the conditional variance,  $\varepsilon$  is the residual, and  $\lambda$ ,  $\theta$ ,  $\eta$  are the parameter. When the risk (volatility) increases, the return level of the domestic and foreign non-ferrous metal futures markets increases, and the coefficient of the corresponding conditional variance in the equation  $\lambda > 0$ . When the risk increases and the return level of the domestic and foreign non-ferrous metal futures markets decreases, the corresponding conditional variance coefficient  $\lambda < 0$ .

### 3.3. Asymmetric Leverage Effect Model of Domestic and Foreign Non-Ferrous Metal Futures Price Returns

The leverage effect reflects the unidirectionality of volatility conduction, or a certain degree of risk attitude difference, and the leverage effect can be achieved by introducing a certain asymmetry into the GARCH model, or it can be achieved through threshold regression, which is called the Threshold Autoregressive Conditional Heteroskedasticity Model (TARCH) model at this time. The TARCH or Threshold ARCH model was independently introduced by Zakoian (1994) and Glosten et al. (1993). The variance equation for the price returns of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, and nickel, tin) futures is set as:

$$\sigma_t^2 = \beta + \sum_{i=1}^q \phi_i \varepsilon_{t-i}^2 + \sum_{j=1}^p \varphi_j \sigma_{t-j}^2 + \omega D_{t-1} \varepsilon_{t-1}^2 \quad (4)$$

$D_{t-1}$  is dummy variable that represents the direction of change in the absolute residuals, if  $\varepsilon_{t-1} < 0$ , then  $D_{t-1} = 1$ . otherwise,  $D_{t-1} = 0$ . In the model, good news ( $\varepsilon_{t-1} > 0$ ) and bad news ( $\varepsilon_{t-1} < 0$ ) have different effects on conditional variance, good news has one  $\sum \phi_i$  shock, the bad news has a  $\sum \phi_i + \omega$  shock. If  $\omega \neq 0$ , the information is asymmetrical, if  $\omega > 0$ , there is a leverage effect, the main effect of the asymmetric effect is to make the fluctuation increase, if  $\omega < 0$ , the main effect of the asymmetric effect is to make the fluctuation decrease.

Due to the asymmetry of market fluctuations and reactions, there are a variety of structural forms and representations, and there are also some generalized forms of GARCH model, such as Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) Model, which are widely used. According to the EGARCH model proposed by Nelson (1991), we set the conditional variance equation for the price return of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures as follows:

$$\ln \sigma_t^2 = \omega + \beta \ln \sigma_{t-1}^2 + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \quad (5)$$

If  $\gamma < 0$ , Bullish and bearish news have different impacts, the bullish news has an  $\alpha - \gamma$  impact on the shock, bearish news has an  $\alpha + \gamma$  impact on the shock, if  $\gamma \neq 0$ , Then there is asymmetry in the shock reaction, then,

$$f\left(\frac{\varepsilon_t}{\sigma_t}\right) = \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \quad (6)$$

$f(\bullet)$  is the information impact curve.

### 3.4. Volatility Spillover Effect Model of Domestic and Foreign Non-Ferrous Metal Futures Prices Yields

When there is a large fluctuation in the foreign (domestic) non-ferrous metal futures market, it will cause investors to change their investment behavior in the domestic (foreign) non-ferrous metal futures market, and transmit this fluctuation to other futures markets, that is, the “spillover effect” of the non-ferrous metal futures market. In order to describe the correlation between the volatility of domestic and foreign non-ferrous metal futures markets, we use the volatility spillover model proposed by Hamao et al. (1990) to analyze the short-term dependence and interaction between the volatility of domestic and foreign non-ferrous metal futures markets, then,

$$\sigma_{A_t}^2 = \beta + \sum_{i=1}^q \phi_i \varepsilon_{A_t-i}^2 + \sum_{j=1}^p \varphi_j \sigma_{A_t-j}^2 + \sum_{l=1}^r \zeta_l \varepsilon_{B_{t-l}}^2 \quad (7)$$

$\varepsilon_{B_{t-l}}^2$  means that the yield shock or disturbance in market B in the previous L period is the absolute volatility degree that has been realized in reality, and if the coefficient of these perturbation terms is statistically significantly positive, it

indicates that there is a significant spillover effect.

## 4. Empirical Analysis

### 4.1. Variable and Data

#### 4.1.1. Variable Selection

At present, the main varieties of non-ferrous metal commodity futures listed in China are copper, aluminum, zinc, lead, nickel, tin, alumina and international copper, etc., according to the needs of research, we select the basic varieties of non-ferrous metal futures copper, aluminum, zinc, lead, nickel, tin futures, therefore, we select the domestic and foreign basic non-ferrous metal futures prices and the domestic spot prices of the corresponding varieties as research variables.

The domestic non-ferrous metal commodity futures prices are selected as the research targets of copper, aluminum, zinc, lead, nickel and tin futures listed on the Shanghai Futures Exchange. The futures prices of foreign non-ferrous metal commodities are selected as the research targets of copper, aluminum, zinc, lead, nickel and tin futures prices with 3-month expiring's on the LME in London, United Kingdom. The spot prices of domestic non-ferrous metals are selected as the average spot prices of copper, aluminum, zinc, lead, nickel and tin in the domestic non-ferrous metals market as the research objects.

#### 4.1.2. Data

Due to the existence of different holidays at home and abroad, such as "May Day", "Eleventh", Spring Festival and other holidays in China, and Christmas and other holidays abroad, the data does not match part of the time, and the mismatched data will be deleted in the specific processing process. In addition, the moving average method is used to make up for the missing data.

In order to eliminate the possibility of heteroskedasticity in the data, we use a logarithmic processing method for the selected data. Data source: Shanghai Futures Exchange website, Wind information terminal.

We define the non-ferrous metal futures price yield  $R_t$  as the first-order difference of the logarithm of the non-ferrous metal futures price, then

$$R_t = LNP_t - LNP_{t-1} \quad (8)$$

$P_t$  is the price of non-ferrous metal futures. When the price fluctuation of non-ferrous metal futures is not very drastic, it is approximately equal to the daily rate of change of non-ferrous metal futures price, corresponding to the overall income level of the non-ferrous metal futures market.

Since there is no unified qualitative conclusion on the statistical nature of the non-ferrous metal futures price yield series, there are still different views on whether the non-ferrous metal futures price yield is strong, weakly effective, or invalid, therefore, we investigate the changes in the daily rate of return series  $R_t$ , absolute daily rate of return series  $|R_t|$  and daily average square rate of return series  $R_t^2$  of non-ferrous metal futures prices. When the sample size is relatively

large, according to the large number theorem and the weak effective market, it can be seen that the average price return of the overall non-ferrous metal futures in the sample interval is as follows:

$$\bar{R}_t = \frac{1}{T} \sum_{t=1}^T R_t \approx 0 \quad (9)$$

where  $T$  is the sample size. Assuming that the deviation of the daily return of the non-ferrous metal futures price from the sample mean is described as  $\varepsilon_t$ , then,

$$\varepsilon_t = R_t - \bar{R}_t \approx R_t \quad (10)$$

$$|\varepsilon_t| = |R_t - \bar{R}_t| \approx |R_t| \quad (11)$$

$$\varepsilon_t^2 = (R_t - \bar{R}_t)^2 \approx R_t^2 \quad (12)$$

Therefore, the daily yield  $R_t$ , daily absolute yield  $|R_t|$ , and daily average square yield  $R_t^2$  of non-ferrous metal futures prices respectively indicate the two-way movement, absolute change, and mean square fluctuation of non-ferrous metal futures prices around the mean, and the fluctuations they reflect are gradually increasing. In particular, the mean square rate of return actually represents the variance of the current fluctuation of the daily return series of non-ferrous metal futures prices, which is a measure of current risk.

#### 4.1.3. Descriptive Statistical Analysis

The following is a descriptive statistics on the futures and spot prices of various non-ferrous metal, and the specific results are shown in **Table 1** & **Table 2** below.

**Table 1.** Descriptive statistics of futures and spot prices of copper, aluminum, and zinc at home and abroad.

	LNFP1	LNL1	LN1	LNFP2	LNL2	LN2	LNFP3	LNL3	LN3
Mean	10.819	8.743	10.829	9.666	7.643	9.664	9.808	7.743	9.834
Median	10.854	8.832	10.858	9.658	7.623	9.650	9.812	7.745	9.831
Maximum	11.381	9.302	11.378	10.114	8.256	10.097	10.263	8.415	10.268
Minimum	9.773	7.458	9.763	9.181	7.160	9.179	9.065	6.975	9.117
Std. Dev.	0.299	0.355	0.290	0.172	0.189	0.172	0.217	0.235	0.212
Skewness	-0.998	-1.294	-1.006	-0.034	0.225	0.021	-0.365	-0.315	-0.320
Kurtosis	3.779	4.478	3.995	2.368	2.570	2.389	2.902	3.625	2.796
Jarque-Bera	932.485	1801.913	1022.866	77.560	74.343	72.143	88.720	128.755	73.721
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sum	52678.92	42568.16	52725.92	44579.98	35248.34	44572.10	38478.50	30374.47	38577.79
Sum Sq. Dev.	435.887	612.340	408.141	136.549	164.937	136.877	184.586	217.365	176.358
Observations	4869	4869	4869	4612	4612	4612	3923	3923	3923

Note: FP1 represents the Shanghai copper futures price, LP1 represents the LME copper futures price, SP1 represents the domestic copper spot price, FP2 represents the Shanghai aluminum futures price, LP2 represents the LME aluminum futures price, SP2 represents the domestic aluminum spot price, FP3 represents the Shanghai zinc futures price, LP3 represents the LME zinc futures price, SP3 represents the domestic Shanghai zinc spot price, and LN represents the logarithm.

**Table 2.** Descriptive statistics of futures and spot prices of lead, nickel and tin at home and abroad.

	LNFP4	LNLP4	LNSP4	LNFP5	LNLP5	LNSP5	LNFP6	LNLP6	LNSP6
Mean	9.648	7.640	9.650	11.648	9.595	11.659	11.987	9.974	11.992
Median	9.635	7.644	9.638	11.602	9.539	11.610	11.895	9.913	11.890
Maximum	10.014	7.955	9.995	12.497	10.781	12.738	12.877	10.7924	12.817
Minimum	9.380	7.359	9.419	11.082	9.001	11.074	11.305	9.492	11.336
Std. Dev.	0.118	0.107	0.115	0.312	0.338	0.325	0.302	0.272	0.303
Skewness	0.449	-0.109	0.506	0.324	0.438	0.332	0.523	0.803	0.581
Kurtosis	2.802	2.832	2.887	2.312	2.683	2.320	2.866	3.083	2.908
Jarque-Bera	109.828	9.894	134.691	80.922	78.754	81.889	100.383	233.489	123.007
Probability	0.000	0.007	0.000	0.000	0.0000	0.000	0.000	0.000	0.000
Sum	30093.14	23828.94	30098.48	25347.20	20878.29	25370.99	25999.57	21634.51	26010.18
Sum Sq. Dev.	43.349	35.658	41.302	211.446	248.571	229.634	197.423	160.920	199.541
Observations	3119	3119	3119	2176	2176	2176	2169	2169	2169

Note: FP4 represents the Shanghai lead futures price, LP4 represents the LME lead futures price, SP4 represents the domestic lead spot price, FP5 represents the Shanghai nickel futures price, LP5 represents the LME nickel futures price, SP5 represents the domestic nickel spot price, FP6 represents the Shanghai tin futures price, LP6 represents the LME tin futures price, SP6 represents the domestic Shanghai tin spot price, and LN represents the logarithm.

#### 4.1.4. Non-Ferrous Metals Domestic and Foreign Futures and Spot Price Chart

The following is a time series chart of non-ferrous metal futures and spot prices, as follows:

As can be seen in the above **Figure 2**, the futures and spot price series of non-ferrous metal futures at home and abroad are all non-stationary series.

#### 4.1.5. Domestic and Foreign Non-Ferrous Metal Futures Price Yield Chart

In the following, we make a time series chart of each time series of domestic and foreign non-ferrous metal futures and spots, and make a basic judgment on the price yield and volatility of domestic and foreign non-ferrous metal futures.

It can be seen from **Figures 3-20** that there are multiple abnormal peaks in the futures and spot price yield series of non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) at home and abroad, and the fluctuations show obvious volatility clustering phenomenon, indicating that the daily fluctuation of the price yield series of non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures and spot markets at home and abroad is sudden and significant, and the volatility has the phenomenon of conditional heteroskedasticity. It can be speculated that the disturbance in the sequence of futures and spot prices yields in the domestic and foreign markets of non-ferrous metals is not a white noise process.

From the comparison of various yield series of domestic and foreign non-ferrous metal futures and spot prices, it is found that there are similar fluctuation



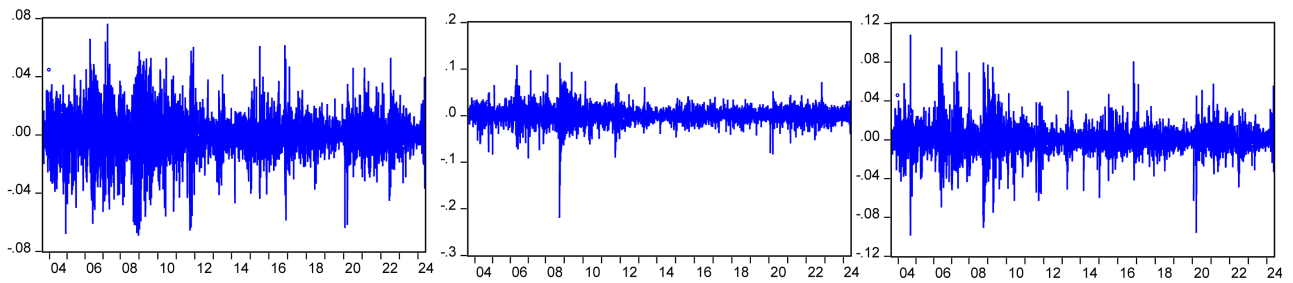


Figure 3. Futures and Spot price daily yield of copper at home and abroad.

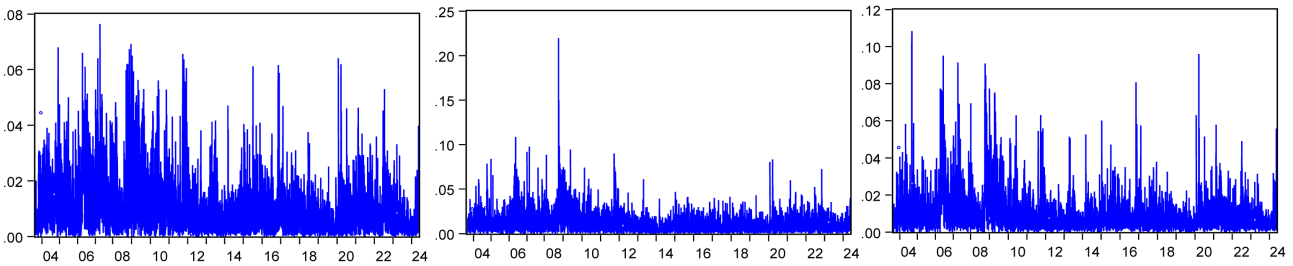


Figure 4. The daily absolute yield chart of copper futures and spot prices at home and abroad.

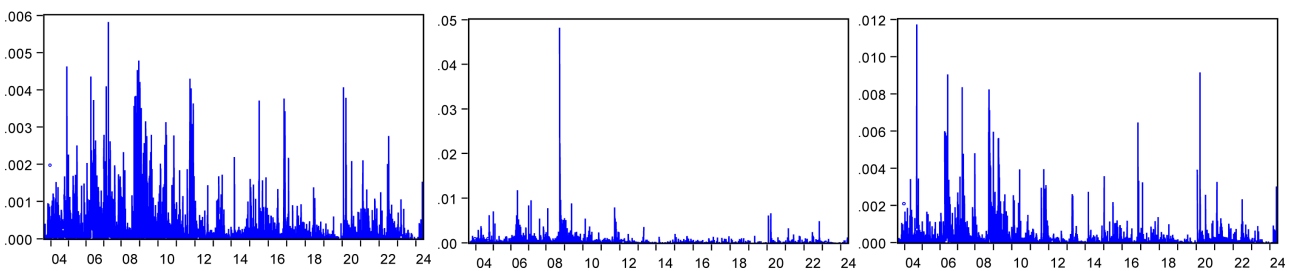


Figure 5. The daily average square yield chart of copper futures and spot prices at home and abroad.

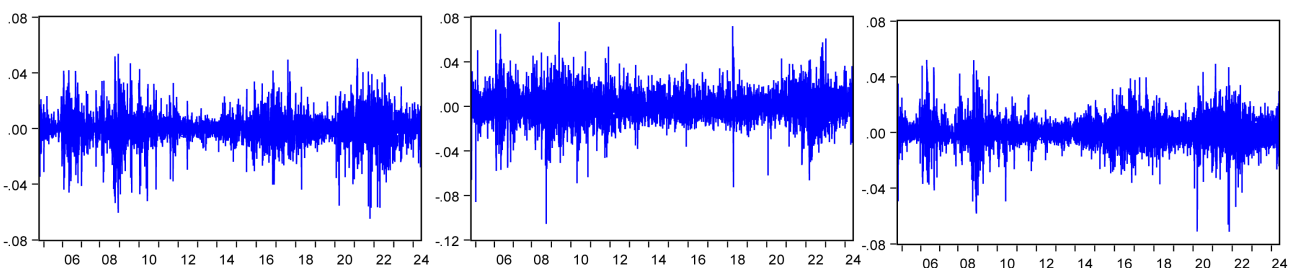


Figure 6. The daily yield chart of aluminum futures and spot prices at home and abroad.

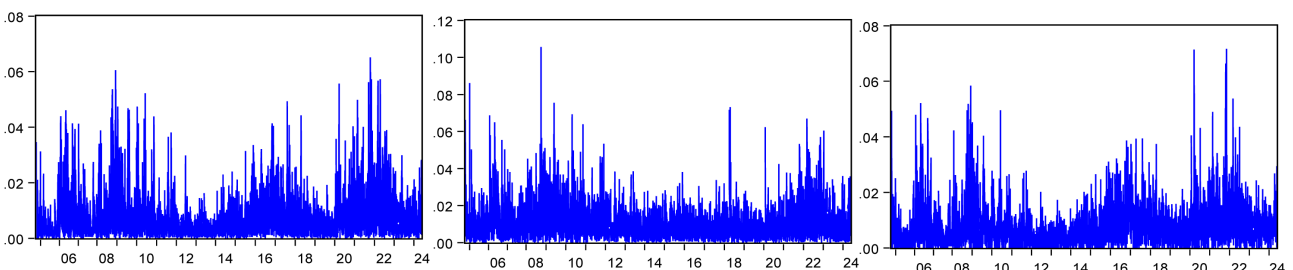
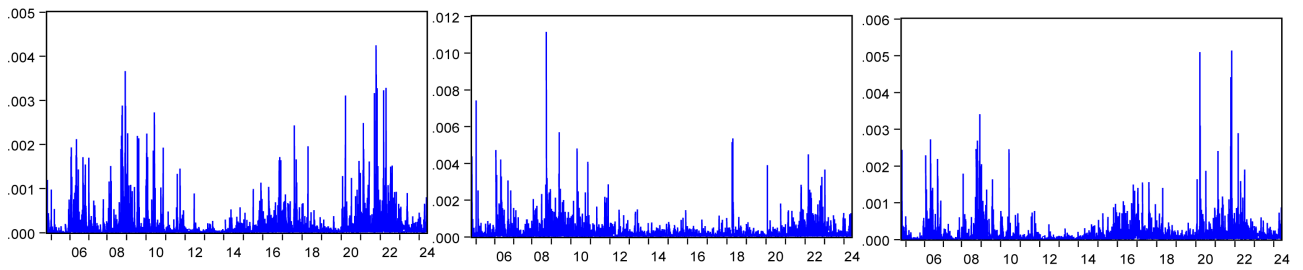
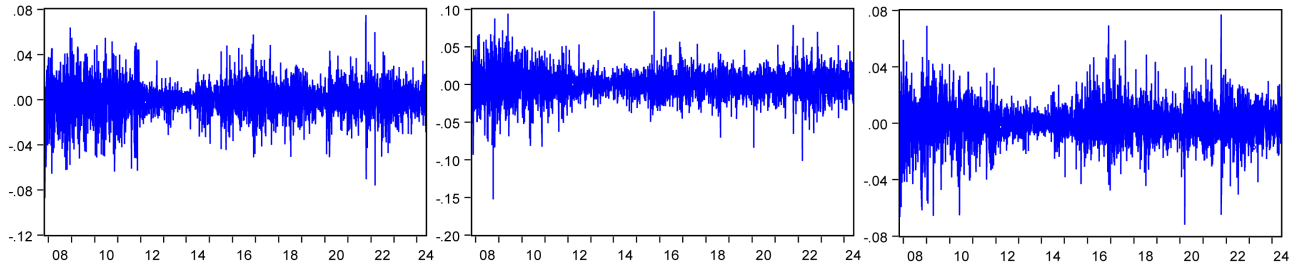


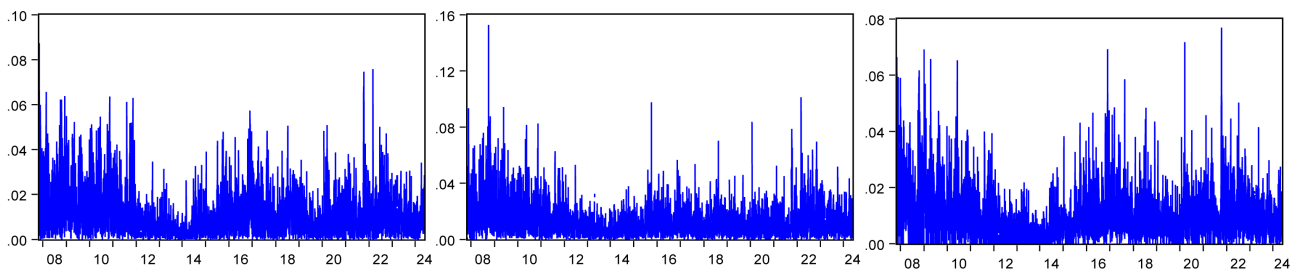
Figure 7. The daily absolute rate of return chart of aluminum futures and spot prices at home and abroad.



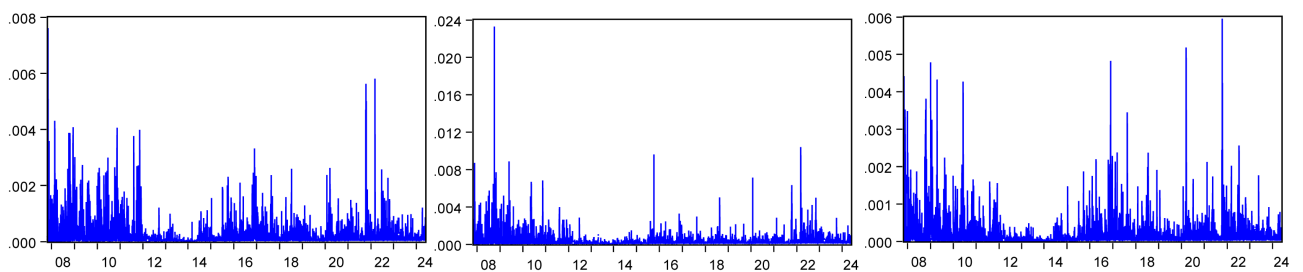
**Figure 8.** The daily average square yield chart of aluminum futures and spot prices at home and abroad.



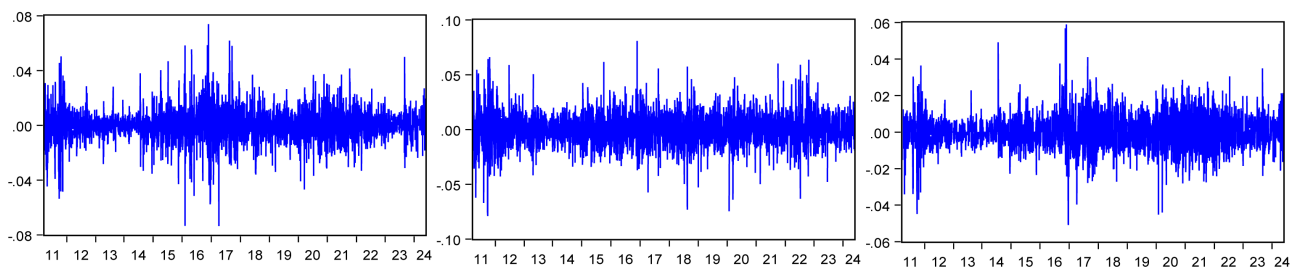
**Figure 9.** The Daily yield chart of zinc futures and spot prices at home and abroad.



**Figure 10.** The Daily absolute yield chart of zinc futures and spot prices at home and abroad.



**Figure 11.** The daily average square yield chart of zinc futures and spot prices at home and abroad.



**Figure 12.** The daily yield chart of the futures and spot price of lead at home and abroad.

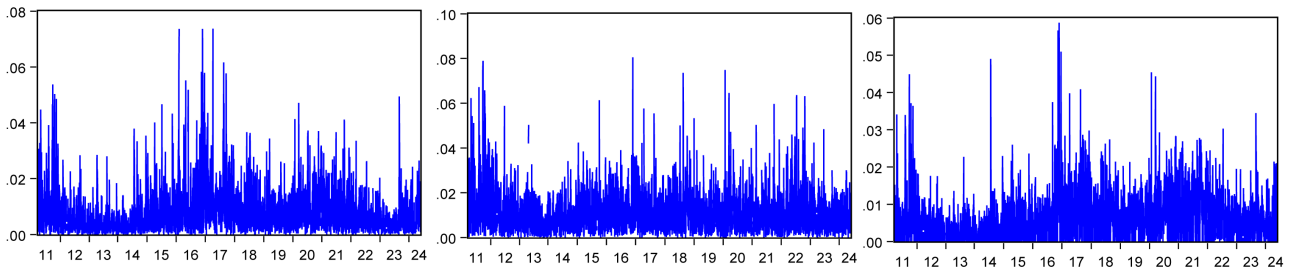


Figure 13. The daily absolute yield chart of the futures and spot price of lead at home and abroad.

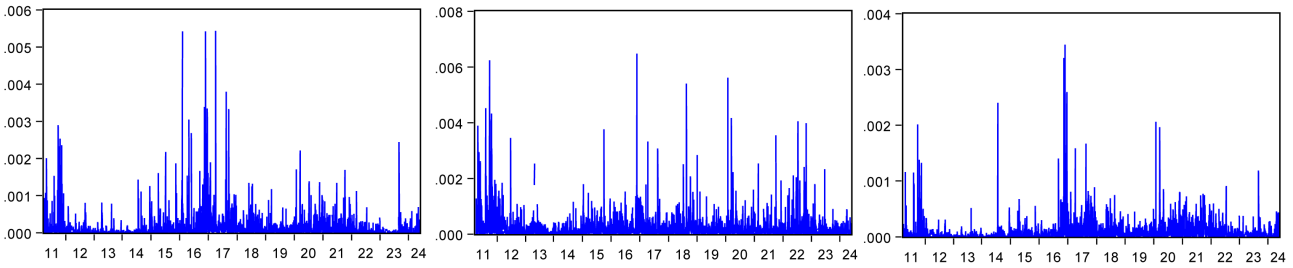


Figure 14. The daily mean square yield chart of lead futures and spot prices at home and abroad.

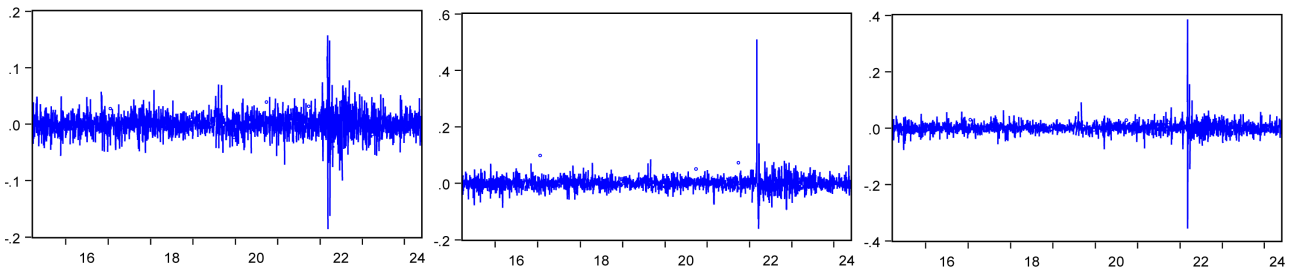


Figure 15. The Daily yield chart of nickel futures and spot prices at home and abroad.

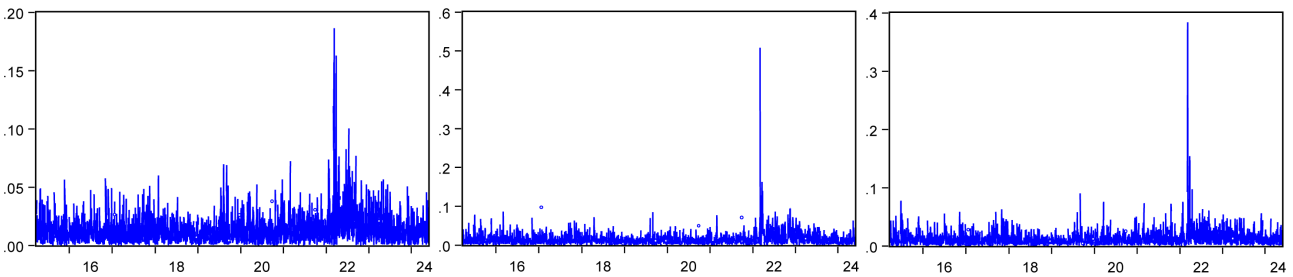


Figure 16. The Absolute daily yield chart of nickel futures and spot prices at home and abroad.

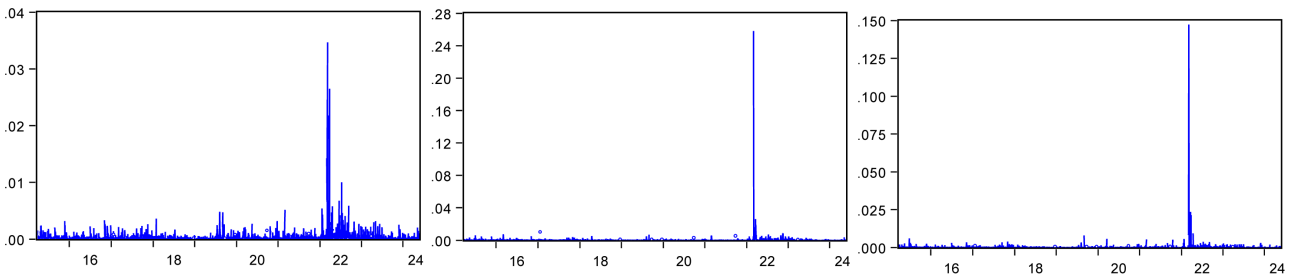


Figure 17. The Daily average square yield chart of nickel futures and spot prices at home and abroad.

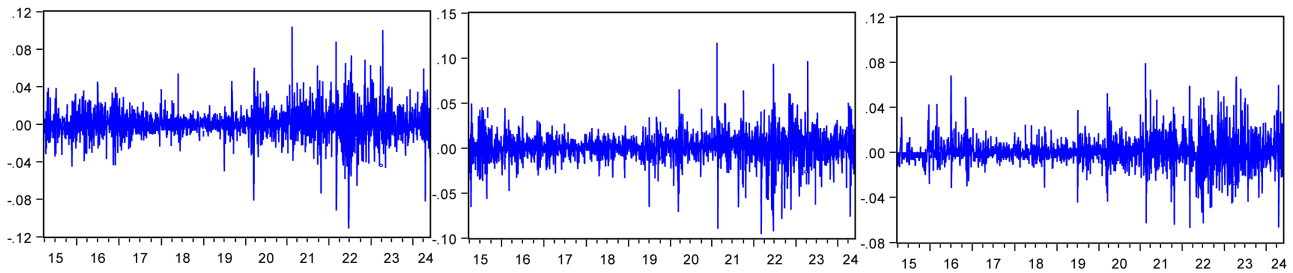


Figure 18. The Daily yield chart of futures and spot price of tin at home and abroad.

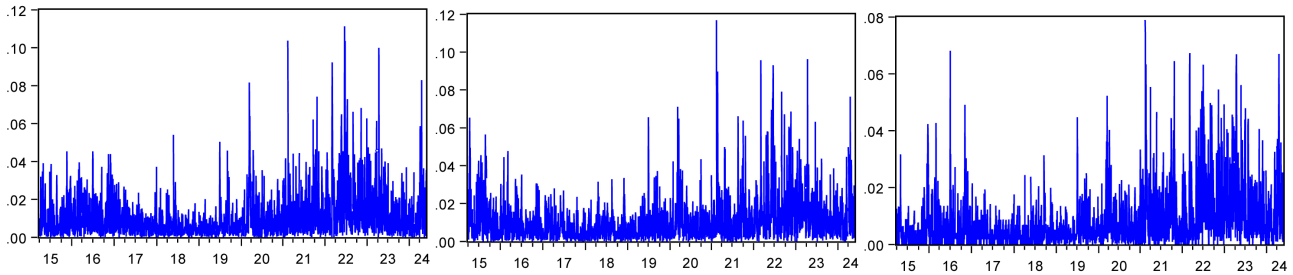


Figure 19. The daily absolute yield chart of tin futures and spot prices at home and abroad.

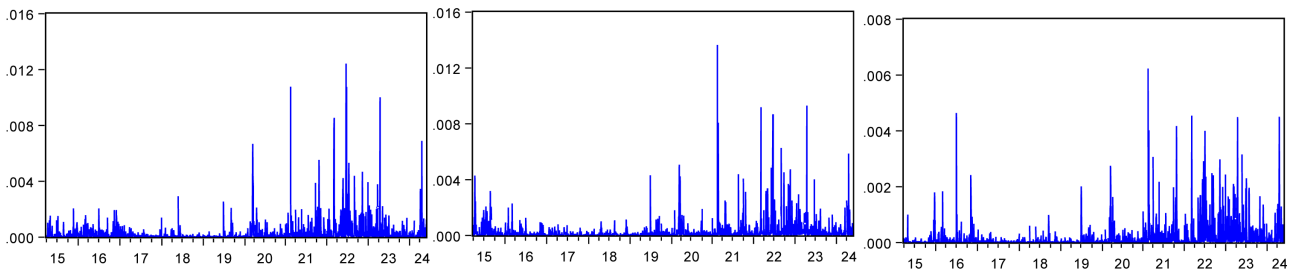


Figure 20. The daily average square yield chart of nickel futures and spot prices at home and abroad.

## 4.2. Non-Ferrous Metal Futures Cointegration Correlation Test and ECM Model Empirical Analysis

### Data Stationarity Test

There are many methods for unit root testing, generally including DF, ADF testing and PP testing. The most commonly used ADF test is used here. On the premise of ensuring that the residual terms are not correlated in the test, we use the AIC criterion and the SC criterion to determine that the hysteresis order is the best lag order when both values are the minimum. The specific test results are as follows **Table 3**.

Table 3. ADF unit root test results.

Variable	Augmented Dickey-Fuller test statistic	Test type (c, t, n)	1% level	5% level	10% level	Durbin-Watson stat	whether or not stable
lnfp1	-3.039	(c, t, 2)	-3.960	-3.411	-3.127	2.004	No
lnlp1	-3.179	(c, t, 1)	-3.960	-3.411	-3.127	2.000	No*
lnsp1	-3.376	(c, t, 22)	-3.960	-3.411	-3.127	1.999	No*

## Continued

Lnfp2	-1.924	(c, t, 10)	-3.960	-3.411	-3.127	1.999	No
Lnlp2	-2.446	(c, t, 2)	-3.960	-3.411	-3.127	1.997	No
Lnsfp2	-1.828	(c, t, 29)	-3.960	-3.411	-3.127	1.998	No
Lnfp3	-0.034	(0, 0, 2)	-2.566	-1.941	-1.617	2.004	No
Lnlp3	-2.206	(c, 0, 18)	-3.432	-2.862	-2.567	2.001	No
Lnsfp3	-2.109	(c, 0, 1)	-3.432	-2.862	-2.567	1.991	No
Lnfp4	-2.318	(c, 0, 21)	-3.432	-2.862	-2.567	1.998	No
Lnlp4	-0.274	(0, 0, 4)	-2.566	-1.941	-1.617	1.998	No
Lnsfp4	-2.108	(c, 0, 1)	-3.432	-2.862	-2.567	1.999	No
Lnfp5	-1.183	(c, 0, 9)	-3.433	-2.863	-2.567	1.998	No
Lnlp5	-1.359	(c, 0, 13)	-3.433	-2.863	-2.567	1.998	No
Lnsfp5	-1.115	(c, 0, 12)	-3.433	-2.863	-2.567	2.003	No
Lnfp6	-1.110	(c, 0, 18)	-3.433	-2.863	-2.567	1.997	No
Lnlp6	-1.298	(c, 0, 8)	-3.433	-2.863	-2.567	1.999	No
Lnsfp6	-1.824	(c, t, 0)	-3.962	-3.412	-3.128	1.955	No
D (lnfp1)	-10.990	(0, 0, 31)	-2.565	-1.941	-1.617	2.001	Yes
D (lnlp1)	-11.920	(0, 0, 26)	-2.565	-1.941	-1.617	1.998	Yes
D (lnsp1)	-14.546	(0, 0, 21)	-2.565	-1.941	-1.617	1.999	Yes
D (lnfp2)	-70.730	(0, 0, 0)	-2.565	-1.941	-1.617	1.998	Yes
D (lnlp2)	-47.443	(0, 0, 1)	-2.565	-1.941	-1.617	1.997	Yes
D (lnsp2)	-13.205	(0, 0, 28)	-2.565	-1.941	-1.617	1.998	Yes
D (lnfp3)	-43.371	(0, 0, 1)	-2.566	-1.941	-1.617	2.004	Yes
D (lnlp3)	-15.133	(0, 0, 17)	-2.566	-1.941	-1.617	2.001	Yes
D (lnsp3)	-63.829	(0, 0, 0)	-2.566	-1.941	-1.617	1.991	Yes
D (lnfp4)	-12.574	(0, 0, 23)	-2.566	-1.941	-1.617	2.005	Yes
D (lnlp4)	-27.714	(0, 0, 3)	-2.566	-1.941	-1.617	1.998	Yes
D (lnsp4)	-54.440	(0, 0, 0)	-2.566	-1.941	-1.617	1.999	Yes
D (lnfp5)	-17.144	(0, 0, 8)	-2.566	-1.941	-1.617	1.998	Yes
D (lnlp5)	-14.098	(0, 0, 12)	-2.566	-1.941	-1.617	1.998	Yes
D (lnsp5)	-13.849	(0, 0, 11)	-2.566	-1.941	-1.617	2.003	Yes
D (lnfp6)	-9.468	(0, 0, 17)	-2.566	-1.941	-1.617	1.997	Yes
D (lnlp6)	-15.859	(0, 0, 7)	-2.566	-1.941	-1.617	1.999	Yes
D (lnsp6)	-45.530	(0, 0, 0)	-2.566	-1.941	-1.617	1.999	Yes

Note: D denotes the first-order difference. C is the intercept, t is the temporal trend, n is the lag order, and \* is significant at the significance level of 1% and 5%.

From the above unit root test results, it can be seen that the logarithm of domestic and foreign non-ferrous metal futures and spot prices is non-stationary at the significance levels of 1%, 5% and 10%, except for the LME copper futures price and the domestic copper spot price, which are non-stationary at the significance level of 1%, 5% and 5%. The first-order difference of each variable is stationary at the significance levels of 1%, 5%, and 10%.

### 4.3. Causality Test Analysis

#### 4.3.1. Causality Test of Domestic Non-Ferrous Metal Futures and Spot Prices

We conduct a Granger causality test on the futures and spot prices of domestic non-ferrous metal, and study the guidance of domestic non-ferrous metal futures prices on domestic non-ferrous metal spot price variables. Since the causality test is sensitive to the lag order, in the actual test, according to the AIC and SC criteria, the best lag order is when the two values are the smallest. The specific test results are as follows **Table 4**.

**Table 4.** Granger causality test results for each variable.

Null Hypothesis	Sample	F-Statistic	Prob.
LNSP1 does not Granger Cause LNFP1	4868	5.173	0.023
LNFP1 does not Granger Cause LNSP1		118.717	2.E-27
LNSP2 does not Granger Cause LNFP2	4602	2.066	0.024
LNFP2 does not Granger Cause LNSP2		89.063	2E-168
LNSP3 does not Granger Cause LNFP3	3915	2.215	0.019
LNFP3 does not Granger Cause LNSP3		89.800	2E-152
LNSP4 does not Granger Cause LNFP4	3110	2.264	0.016
LNFP4 does not Granger Cause LNSP4		57.925	4.E-98
LNSP5 does not Granger Cause LNFP5	2174	21.537	4.E-06
LNFP5 does not Granger Cause LNSP5		150.810	1.E-33
LNSP6 does not Granger Cause LNFP6	2167	7.350	0.001
LNFP6 does not Granger Cause LNSP6		173.374	1.E-70

From the above test results, it can be seen that at the significance level of 1%, the domestic non-ferrous metal copper, aluminum, zinc, lead, nickel and tin futures prices are the Granger reasons for their spot prices. At the significance level of 5%, the spot prices of domestic non-ferrous metals copper, aluminum, zinc, lead, nickel and tin are the Granger reasons for their futures prices. The domestic non-ferrous metal copper, aluminum, zinc, lead, nickel and tin futures prices have a stronger guiding effect on their spot prices than the spot prices on their futures prices.

### 4.3.2. Causality Test between Domestic and Foreign Non-Ferrous Metal Futures Prices

We conduct a Granger causality test on domestic and foreign non-ferrous metal futures prices, and study the guidance of foreign non-ferrous metal futures prices on domestic non-ferrous metal futures price variables. Since the causality test is sensitive to the lag order, in the actual test, according to the AIC and SC criteria, the best lag order is when the two values are the smallest. The specific test results are as follows **Table 5**.

**Table 5.** Causality test results of domestic and foreign non-ferrous metal futures prices

Null Hypothesis	Sample	F-Statistic	Prob.
LNLP1 does not Granger Cause LNFP1	4868	35.419	3.E-09
LNFP1 does not Granger Cause LNLP1		8.918	0.003
LNLP2 does not Granger Cause LNFP2	4603	113.310	1E-192
LNFP2 does not Granger Cause LNLP2		3.003	0.001
LNLP3 does not Granger Cause LNFP3	3907	197.966	9E-282
LNFP3 does not Granger Cause LNLP3		1.905	0.055
LNLP4 does not Granger Cause LNFP4	3116	247.295	7E-144
LNFP4 does not Granger Cause LNLP4		1.178	0.317
LNLP5 does not Granger Cause LNFP5	2174	166.492	9.E-37
LNFP5 does not Granger Cause LNLP5		1.479	0.224
LNLP6 does not Granger Cause LNFP6	2165	106.595	6.E-83
LNFP6 does not Granger Cause LNLP6		0.296	0.881

From the above causality test, it can be seen that at the significance level of 1%, there is a two-way Granger causal relationship between the domestic Shanghai copper and aluminum futures prices and LME copper and aluminum futures prices. At the significance level of 5%, there is a two-way Granger causal relationship between domestic Shanghai zinc and LME zinc futures prices. At the significance levels of 1%, 5% and 10%, the LME lead, nickel and tin futures prices are the one-way Granger causality of domestic Shanghai lead, Shanghai nickel and Shanghai tin. Therefore, the futures prices of copper, aluminum and zinc in domestic non-ferrous metal futures have a strong guiding effect on LME copper, aluminum and zinc futures prices, while the lead, nickel and tin futures prices in domestic non-ferrous metal futures have no obvious guiding effect on LME lead, nickel and tin futures prices. So in domestic non-ferrous metal futures, copper, aluminum, and zinc have strong international pricing influence, while lead, nickel, and tin have weak international pricing influence.

### 4.4. Long-Term Cointegration Relationship Test Analysis

We make Johansen's maximum likelihood estimation test for domestic non-

ferrous metal (copper, aluminum, zinc, lead, nickel, tin) futures prices and foreign (copper, aluminum, zinc, lead, nickel, tin) futures prices. In the test, the case containing constants is considered, and the equation form of the optimal lag order is determined according to the SC criterion and the AIC criterion, and the lag order is selected 4 except for the lead 1, and the results are as follows **Table 6**.

**Table 6.** Johanson cointegration test results between domestic and foreign non-ferrous metal futures prices.

Cointegration relation	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.	The number of cointegration relationships
Domestic Shanghai copper futures prices and LME copper futures prices	0.004	26.172	15.495	0.001	None*
	0.002	8.970	3.841	0.003	At most 1*
Domestic Shanghai aluminum futures price and LME aluminum futures price	0.006	31.623	15.495	0.000	None*
	0.001	5.186	3.841	0.023	At most 1*
Domestic Shanghai zinc futures prices and LME zinc futures prices	0.006	26.497	15.495	0.001	None*
	0.001	4.564	3.841	0.033	At most 1*
Domestic Shanghai lead futures price and LME lead futures price	0.006	24.226	15.495	0.002	None*
	0.001	4.625	3.841	0.032	At most 1
Domestic Shanghai nickel futures prices and LME nickel futures prices	0.024	53.993	15.495	0.000	None*
	0.001	1.755	3.841	0.185	At most 1
Domestic Shanghai nickel futures prices and LME nickel futures prices	0.011	28.705	25.872	0.022	None*
	0.002	4.763	12.518	0.631	At most 1

Note: “\*” indicates rejection of the null hypothesis at the 5% significance level.

The cointegration test results show that there is a cointegration relationship, so the cointegration relationship between the domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures prices and the LME non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures prices is estimated as follows:

$$\mu_{1t} = LNP_{11t} - 0.965LNP_{21t} - 2.285 \quad (13)$$

$$u_{2t} = LNP_{12t} - 0.986LNP_{22t} - 2.128 \quad (14)$$

$$u_{3t} = LNP_{13t} - 0.959LNP_{23t} - 2.383 \quad (15)$$

$$u_{4t} = LNP_{14t} - 3.510LNP_{24t} + 17.164 \quad (16)$$

$$u_{5t} = LNP_{15t} - 0.934LNP_{25t} - 2.691 \quad (17)$$

$$u_{6t} = LNP_{16t} - 0.854LNP_{26t} - 0.0001 @ \text{TREND} - 3.312 \quad (18)$$

Then the cointegration equations corresponding to the maximized eigenroots are as follows (the values in parentheses are the standard deviations, and the following are similar)

$$LNP_{11t} = 0.965LNP_{21t} + 2.285 \quad (19)$$

(0.059)

$$LNP_{12t} = 0.986LNP_{22t} + 2.128 \quad (20)$$

(0.084)

$$LLNP_{13t} = 0.959LNP_{23t} + 2.383 \quad (21)$$

(0.046)

$$LNP_{14t} = 3.510LNP_{24t} - 17.164 \quad (22)$$

(0.660)

$$LNP_{15t} = 0.934LNP_{25t} + 2.691 \quad (23)$$

(0.017)

$$LNP_{16t} = 0.854LNP_{26t} + 0.0001@TREND + 3.312 \quad (24)$$

(0.055)      (2.4E-05)

From the cointegration equation, we can see that there is a significant long-term co-directional change relationship between domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures and LME non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures market, except for lead, there is little difference in the range of changes of copper, aluminum, zinc and nickel (0.965, 0.986, 0.959, 0.934, 0.854), and the lead futures in the domestic and LME markets have the strongest co-directional change relationship (2.765).

#### 4.5. ECM Model Estimation of Non-Ferrous Metals Futures Price Yield at Home and Abroad

From the above cointegration test, it can be seen that there is a cointegration relationship between domestic and foreign non-ferrous metal (copper, aluminum, zinc, lead, nickel, tin) futures prices. Therefore, we establish an ECM between the price yield of domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures and the price yield of LME (copper, aluminum, zinc, lead, nickel and tin) futures and the results are shown in **Table 7** below.

**Table 7.** Error correction model estimation results.

ECM	R11	R21	R12	R22	R13	R23
EC	-0.0002 (0.002)	0.010 (0.003)	0.001 (0.002)	0.013 (0.003)	-0.008 (0.004)	0.016 (0.006)
R11 (-1)	-0.459 (0.016)	0.095 (0.023)	R12 (-1) -0.211 (0.015)	0.017 (0.022)	R13 (-1) -0.406 (0.019)	0.038 (0.027)
R11 (-2)	-0.206 (0.018)	0.041 (0.026)	R12 (-2) -0.044 (0.016)	0.024 (0.023)	R13 (-2) -0.173 (0.020)	-0.012 (0.029)
R11 (-3)	-0.095 (0.017)	-0.008 (0.024)	R12 (-3) -0.023 (0.016)	0.026 (0.023)	R13 (-3) -0.094 (0.019)	0.007 (0.028)
R11 (-4)	-0.022 (0.013)	-0.031 (0.018)	R1 (-4) -0.009 (0.014)	-0.013 (0.020)	R13 (-4) -0.055 (0.015)	-0.066 (0.022)

## Continued

R21 (-1)	0.592	-0.104	R22 (-1)	0.347	-0.023	R23 (-1)	0.495	-0.037
	(0.012)	(0.016)		(0.011)	(0.016)		(0.013)	(0.019)
R21 (-2)	0.349	-0.058	R22 (-2)	0.072	0.012	R23 (-2)	0.243	0.014
	(0.015)	(0.022)		(0.012)	(0.017)		(0.016)	(0.023)
R21 (-3)	0.186	-0.012	R22 (-3)	0.003	-0.028	R23 (-3)	0.118	-0.004
	(0.016)	(0.023)		(0.012)	(0.018)		(0.016)	(0.025)
R21 (-4)	0.110	0.065	R22 (-4)	0.033	0.005	R23 (-4)	0.068	0.062
	(0.014)	(0.020)		(0.012)	(0.017)		(0.015)	(0.022)
C	0.0001	0.0004		3.49E-05	8.84E-05	C	2.25E-06	9.95E-06
	(0.0002)	(0.0003)		(0.0002)	(0.0002)		(0.0002)	(0.0003)
$R^2$	0.363	0.016		0.181	0.008		0.289	0.009
R-squared	0.361	0.015		0.180	0.006		0.287	0.007
Adjusted R-squared	0.698	1.432		0.450	0.915		0.623	1.3179
S.E. of regression	0.012	0.017		0.010	0.014		0.013	0.0184
Sum squared resid	306.749	9.005		113.168	4.135		176.248	4.091
Log likelihood	14620.59	12872.46		14732.03	13099.34		11557.95	10091.94
Durbin-Watson stat	-6.008	-5.289		-6.391	-5.682		-5.902	-5.153
Mean dependent var	-5.9948	-5.276		-6.377	-5.668		-5.886	-5.137
S.D. dependent var	0.0004	0.0004		6.15E-05	8.80E-05		1.14E-05	1.11E-05
Akaike info criterion	0.0158	0.017		0.011	0.014		0.015	0.018
ECM	R14	R24		R15	R25		R16	R26
EC	0.001	0.004		-0.043	0.032		-0.027	-0.006
	(0.001)	(0.001)		(0.009)	(0.012)		(0.006)	(0.007)
R14 (-1)	-0.213	0.022	R15 (-1)	-0.310	-0.085	R16 (-1)	-0.280	0.008
	(0.019)	(0.027)		(0.024)	(0.034)		(0.025)	(0.028)
R14 (-2)	-0.033	0.049	R15 (-2)	-0.183	0.002	R16 (-2)	-0.101	0.014
	(0.019)	(0.027)		(0.025)	(0.035)		(0.026)	(0.029)
R14 (-3)	-0.017	0.044	R15 (-3)	-0.063	-0.0133	R16 (-3)	-0.024	0.020
	(0.019)	(0.027)		(0.024)	(0.035)		(0.026)	(0.028)
R14 (-4)	0.011	0.021	R15 (-4)	-0.023	-0.003	R16 (-4)	-0.039	-0.007
	(0.017)	(0.024)		(0.021)	(0.029)		(0.023)	(0.025)
R24 (-1))	0.357	-0.006	R25 (-1)	0.442	0.104	R26 (-1)	0.438	0.023
	(0.013)	(0.019)		(0.018)	(0.026)		(0.023)	(0.025)
R24 (-2))	0.060	-0.022	R25 (-2)	0.193	0.011	R26 (-2)	0.104	0.020
	(0.015)	(0.021)		(0.021)	(0.029)		(0.025)	(0.028)

## Continued

R24 (-3))	-0.004 (0.015)	-0.055 (0.021)	R25 (-3)	0.071 (0.021)	0.011 (0.029)	R26 (-3)	0.063 (0.025)	0.007 (0.028)
R24 (-4))	0.012 (0.015)	0.027 (0.021)	R25 (-4)	-0.059 (0.020)	-0.006 (0.028)	R26 (-4)	-0.025 (0.024)	0.004 (0.027)
C	2.46E-05 (0.0002)	-5.96E-05 (0.0003)		0.0002 (0.0004)	0.0002 (0.0005)		0.0004 (0.0003)	0.0003 (0.0004)
R-squared	0.198	0.011		0.295	0.0106		0.176	0.003
Adjusted R-squared	0.196	0.008		0.291	0.005		0.172	-0.001
S.E. of regression	0.334	0.676		0.623	1.246		0.453	0.557
Sum squared resid	0.010	0.015		0.017	0.024		0.015	0.016
Log likelihood	85.136	3.947		99.543	2.318		51.062	0.720
Durbin-Watson stat	9811.563	8715.066		5757.849	5006.400		6095.057	5872.893
Mean dependent var	-6.295	-5.591		-5.307	-4.613		-5.624	-5.419
S.D. dependent var	-6.276	-5.572		-5.281	-4.587		-5.598	-5.392
Akaike info criterion	-6.0E-07	-5.67E-05		0.0002	0.0002		0.0004	0.0003
Schwarz criterion	0.012	0.015		0.020	0.024		0.016	0.016

Note: Among them, R11, R21, R12, R22, R13, R23, R14, R24, R15, R25, R16 and R26 respectively represent the price yield of Shanghai copper, LME copper, Shanghai aluminum, LME aluminum, Shanghai zinc, LME zinc, Shanghai lead, LME lead, Shanghai nickel, LME nickel, Shanghai tin, LME tin futures respectively, where a positive number in parentheses indicates the standard deviation and a negative number indicates the lag order. EC stands for Error Correction Item, which is similar to the following.

According to the above error correction equation calculation, solving the unconditional mathematical expectation of the yield series, the long-term equilibrium futures price return levels of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures markets can be obtained as follows:  
 $\overline{R}_{11} = 0.03\%$ ,  $\overline{R}_{21} = 0.04\%$ ,  $\overline{R}_{12} = 0.004\%$ ,  $\overline{R}_{22} = 0.007\%$ ,  $\overline{R}_{13} = -0.002\%$ ,  
 $\overline{R}_{23} = 0.00\%$ ,  $\overline{R}_{14} = 0.00\%$ ,  $\overline{R}_{24} = 0.00\%$ ,  $\overline{R}_{15} = 0.00\%$ ,  $\overline{R}_{25} = 0.02\%$ ,  
 $\overline{R}_{16} = 0.04\%$ ,  $\overline{R}_{26} = 0.03\%$ .

According to the calculation results, there is no significant difference between the long-term price yield of domestic non-ferrous metals (copper, lead, nickel, tin) and LME non-ferrous metals (copper, lead, nickel, tin) futures, and there is a significant difference between the long-term futures price yield of the domestic non-ferrous metals (aluminum, zinc) futures market and the LME non-ferrous metals (aluminum, zinc) futures market, and the long-term price yield of the LME non-ferrous metals (copper, aluminum, zinc, nickel) futures market is stronger than that of the domestic non-ferrous metals (copper, aluminum, zinc, nickel) futures market. Only the domestic tin futures price yield is stronger than that of the LME tin futures, except for the domestic Shanghai zinc futures price yield is negative, the other domestic non-ferrous metal futures price yields are positive. The price

yield of non-ferrous metal futures at home and abroad is affected by the long-term equilibrium relationship, and the correction item is a negative marginal contribution to the price yield of Shanghai copper, Shanghai zinc, Shanghai nickel, Shanghai tin and LME tin, and a positive marginal contribution to the price yield of other domestic and foreign non-ferrous metal futures. In the ECM model, due to the partial and insignificant hysteresis coefficients, it indicates that there is an interaction between the corresponding futures price returns of domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) and LME (copper, aluminum, zinc, lead, nickel, tin) and short-term fluctuations. Therefore, the ECM model shows that although there are different short-term fluctuation patterns between the corresponding futures price returns of domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) and LME (copper, aluminum, zinc, lead, nickel, tin), there is also a long-term cointegration trend.

#### **4.6. The GARCH Model Family Analysis of Domestic and Foreign Non-Ferrous Metal Futures Markets**

We use the GARCH model to test the conditional heteroscedasticity of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, and nickel, tin) futures price return series. First, the partial autocorrelation function (PACF) and the autocorrelation function (ACF) are used to determine the order of the AR process and the MA process in the mean equation, and then according to the characteristics of the absolute residual sequence, the order of the ARCH term and the GARCH term in the variance equation is determined, and the domestic non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) are finally determined after analysis and comparison. The mean equation for the futures price return series is ARMA (1, 1), ARMA (1, 1), ARMA (4, 4), ARMA (2, 2), ARMA (2, 2), ARMA (5, 5), and the variance equation is GARCH (1, 1). The mean equations of the foreign LME non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures price return series are ARMA (8, 8), ARMA (9, 9), ARMA (10, 10), ARMA (8, 8), ARMA (14, 14), ARMA (4, 4), and the variance equation are all GARCH (1, 1). Due to space limitations, the overall estimate and significance results are omitted. The GARCH-M model, leverage effect model and spillover effect model for estimating the price returns of non-ferrous metal futures at home and abroad are as follows:

##### **4.6.1. GARCH-M Model Estimation of the Price Yield of Non-Ferrous Metal Futures at Home and Abroad**

Our empirical estimates of the GARCH-M model of futures prices returns for domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) are shown in **Table 8** below (the estimates of non-major parameters are omitted, and the values in parentheses are standard deviations, which are similar as follows):

From the above estimation results, it can be seen that the coefficient estimates of the conditional variance term GARCH of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures price returns are 0.022,

**Table 8.** GARCH-M estimation results.

variable	R11	R21	R12	R22	R13	R23	R14	R24	R15	R25	R16	R26
@SQRT (GARCH)	0.022 (0.131)	0.034* (0.017)	-0.008 (0.583)	0.006 (0.677)	0.003 (0.842)	0.008 (0.590)	-0.009 (0.427)	0.005 (0.741)	0.0001 (0.990)	0.008 (0.625)	0.030* (0.091)	0.024 (0.272)
AR (1)	-0.615 (0.002)		-0.582 (0.001)									
AR (2)							0.946 (0.000)		-0.677 (0.000)			
AR (4)					0.649 (0.000)							0.928 (0.000)
AR (5)											0.852 (0.000)	
AR (8)		-0.992 (0.000)						0.76 (0.000)				
AR (9)				0.878 (0.000)								
AR (10)						0.644 (0.000)						
AR (14)										0.964 (0.000)		
MA (1)	0.577 (0.006)		0.531 (0.002)									
MA (2)							-0.967 (0.000)		0.674 (0.002)			
MA (4)					-0.651 (0.000)							-0.934 (0.000)
MA (5)											-0.880 (0.000)	
MA (8)		0.994 (0.000)						-0.810 (0.000)				
MA (9)				-0.876 (0.000)								
MA (10)						-0.651 (0.000)						
MA (14)										-0.978 (0.000)		
R-squared	0.002	0.005	0.001	0.001	0.003	0.008	0.003	0.011	0.002	0.012	0.012	0.003
Adjusted R-squared	0.001	0.004	0.001	0.0007	0.003	0.007	0.002	0.0101	0.001	0.011	0.011	0.002
S.E. of regression	0.015	0.017	0.011	0.014	0.015	0.018	0.012	0.015	0.020	0.024	0.024	0.016
Sum squared resid	1.093	1.448	0.552	0.920	0.874	1.318	0.416	0.675	0.884	1.243	1.243	0.557
Log likelihood	14263.93	13508.61	15103.35	13384.82	11357.63	10462.99	9843.369	8805.539	5636.302	5314.661	5314.661	6147.480
Durbin-Watson stat	1.972	2.142	1.981	2.046	2.056	2.071	2.138	2.020	1.962	1.883	1.883	1.938

**Continued**

Mean dependent var	0.0003	0.0004	4.1E-05	8.7E-05	8.0E-06	1.2E-05	2.1E-06	-7.5E-05	0.0002	0.0002	0.0002	0.0003
S.D. dependent var	0.015	0.017	0.011	0.014	0.015	0.018	0.012	0.015	0.020	0.024	0.024	0.016
Akaike info criterion	-5.859	-5.557	-6.550	-5.810	-5.793	-5.345	-6.314	-5.659	-5.177	-4.913	-4.913	-5.676
Schwarz criterion	-5.851	-5.549	-6.541	-5.806	-5.784	-5.335	-6.302	-5.647	-5.164	-4.897	-4.897	-5.660
Hannan-Quinn criter.	-5.856	-5.554	-6.547	-5.811	-5.790	-5.341	-6.310	-5.655	-5.174	-4.907	-4.907	-5.670

0.034, -0.008, 0.003, 0.008, -0.009, 0.005, 0.0001, 0.008, 0.030 and 0.024, respectively. The conditional variance coefficient of non-ferrous metal futures price yield at home and abroad is significant for London copper and Shanghai nickel, while the others are not significant. The conditional variance coefficient of domestic and foreign non-ferrous metal futures price yields is positive except for Shanghai Aluminum and Shanghai Lead, which reflects the negative correlation between the returns and risks of Shanghai Aluminum and Shanghai Lead futures markets, and the negative risk premium of returns.

There is a positive correlation between the returns and risks of the domestic copper, zinc, nickel and tin futures markets and LME copper, aluminum, zinc, lead, nickel and tin futures markets. There is a positive risk premium for returns, there is a certain risk reward in the market, and volatility increases the current rate of return. In addition to the Shanghai nickel futures market, the risk premium of the LME copper, aluminum, zinc, lead and tin futures markets is higher than that of the domestic futures market, indicating that foreign non-ferrous metal market investors have a stronger risk appetite than domestic investors, and the risk appetite of domestic and foreign nickel futures market investors is relatively strong, and the risk appetite of domestic investors is slightly stronger than that of foreign investors. Therefore, there is a difference in the risk premium of returns between the domestic non-ferrous metal futures market and the LME metal futures market, so there are theoretical arbitrage opportunities in the domestic and foreign metal futures markets.

#### 4.6.2. EGARCH Model Estimation of Domestic and Foreign Non-Ferrous Metal Futures Price Yields

The following estimates the EGARCH model of the price yield of non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures at home and abroad, and the estimation models are EGARCH (2, 2), EGARCH (1, 1), EGARCH (2, 2), EGARCH (2, 2), EGARCH (2, 2), EGARCH (2, 1), EGARCH (2, 1), EGARCH (2, 2), EGARCH (1, 1), EGARCH (2, 2), EGARCH (2, 2), and the results of the variance equation for specific estimates are shown in **Table 9**.

From the above estimation results, it can be seen that the estimated value of the asymmetric term coefficient is not equal to zero, indicating that the impact of the

**Table 9.** EGARCH model estimation results.

variable	$\ln \sigma_1^2$	$\ln \sigma_2^2$	$\ln \sigma_3^2$	$\ln \sigma_4^2$	$\ln \sigma_5^2$	$\ln \sigma_6^2$	$\ln \sigma_7^2$	$\ln \sigma_8^2$	$\ln \sigma_9^2$	$\ln \sigma_{10}^2$	$\ln \sigma_{11}^2$	$\ln \sigma_{12}^2$
C	-0.654 (0.000)	-0.260 (0.000)	-0.811 (0.000)	-0.040 (0.000)	-0.504 (0.000)	-0.139 (0.000)	-0.340 (0.000)	-0.135 (0.000)	-0.019 (0.040)	-0.950 (0.000)	-0.630 (0.000)	-1.173 (0.000)
$ \varepsilon_i(-1)/\sigma_i(-1) $	0.217 (0.000)	0.157 (0.000)	0.274 (0.000)	0.220 (0.000)	0.169 (0.000)	0.172 (0.000)	0.296 (0.000)	0.199 (0.000)	0.190 (0.000)	0.359 (0.000)	0.219 (0.000)	0.297 (0.000)
$ \varepsilon_i(-2)/\sigma_i(-2) $	0.167 (0.000)		0.237 (0.000)	-0.192 (0.000)	0.172 (0.000)	-0.067 (0.000)	-0.104 (0.000)	-0.134 (0.000)	-0.177 (0.000)		0.187 (0.000)	0.255 (0.000)
$\varepsilon_i(-1)/\sigma_i(-1)$	-0.023 (0.000)	-0.030 (0.000)	0.038 (0.000)	0.005 (0.006)	-0.005 (0.030)	0.006 (0.002)	0.022 (0.001)	-0.023 (0.000)	0.008 (0.004)	0.074 (0.000)	0.042 (0.000)	-0.041 (0.000)
$\ln \sigma_i^2(-1)$	0.052 (0.163)	0.983 (0.000)	0.046 (0.010)	1.592 (0.000)	-0.015 (0.000)	0.993 (0.000)	0.978 (0.000)	0.990 (0.000)	1.785 (0.000)	0.911 (0.000)	0.027 (0.050)	-0.018 (0.143)
$\ln \sigma_i^2(-2)$	0.905 (0.000)		0.907 (0.000)	-0.594 (0.000)	0.986 (0.000)				-0.786 (0.000)		0.933 (0.000)	0.926 (0.000)
R-squared	0.002	0.001	0.001	0.001	0.003	0.007	0.003	0.005	0.002	0.0002	0.001	0.005
Adjusted R-squared	0.001	0.001	0.001	0.001	0.003	0.007	0.002	0.005	0.001	-0.001	-0.0003	0.004
S.E. of regression	0.015	0.017	0.011	0.0141	0.015	0.018	0.012	0.015	0.020	0.024	0.016	0.016
Sum squared resid	1.093	1.454	0.552	0.921	0.874	1.318	0.416	0.679	0.884	1.258	0.550	0.555
Log likelihood	14257.07	13508.28	15110.12	13385.79	11360.98	10465.38	9854.916	8818.152	5637.689	5295.307	6213.473	6167.578
Durbin-Watson stat	1.978	2.148	1.985	2.048	2.056	2.071	2.139	2.017	1.962	1.887	2.082	1.933
Mean dependent var	0.0003	0.0004	4.1E-05	8.7E-05	8.0E-06	1.2E-05	2.1E-06	-7.5E-05	0.0002	0.0002	0.0004	0.0003
S.D. dependent var	0.015	0.017	0.011	0.014	0.015	0.018	0.012	0.015	0.020	0.024	0.016	0.0160
Akaike info criterion	-5.855	-5.556	-6.551	-5.813	-5.793	-5.345	-6.320	-5.666	-5.178	-4.894	-5.737	-5.692
Schwarz criterion	-5.843	-5.547	-6.539	-5.801	-5.779	-5.332	-6.305	-5.650	-5.155	-4.876	-5.713	-5.668
Hannan-Quinn criter.	-5.851	-5.553	-6.547	-5.810	-5.788	-5.340	-6.315	-5.660	-5.170	-4.888	-5.728	-5.683

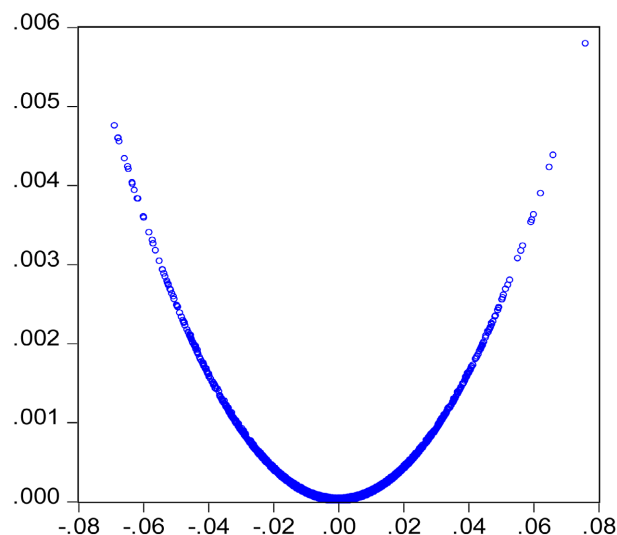
Note:  $\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2, \sigma_5^2, \sigma_6^2, \sigma_7^2, \sigma_8^2, \sigma_9^2, \sigma_{10}^2, \sigma_{11}^2, \sigma_{12}^2$  represent the variance of Shanghai copper, London copper, Shanghai aluminum, London aluminum, Shanghai zinc, London zinc, Shanghai lead, London lead, Shanghai nickel, London nickel, Shanghai tin, and London tin futures.  $\varepsilon_i$  represent residuals,  $\sigma_i$  stands for standard deviation. The negative number in parentheses is the lag order, t = 1.2--12.

news shock is asymmetrical, and the asymmetric coefficient in the variance equation of the price return of Shanghai copper, London copper, Shanghai zinc, London lead, and London tin futures is negative and significant, indicating that there is asymmetry and leverage effect in the Shanghai copper, London copper, Shanghai zinc, London lead, and London tin futures markets, and when the impact of bullish news, the Shanghai copper, London copper, Shanghai zinc, London lead, and London tin futures markets are 0.361, 0.127, and 0.336, 0.042, 0.511 times the shock impact respectively.

When the negative news hits, it will have an impact of 0.407, 0.187, 0.346, 0.088

and 0.593 times on the Shanghai copper, London copper, Shanghai zinc, London lead and London tin futures markets respectively. The impact of negative news is greater than the impact of bullish news, among which the leverage effect of LME tin is the strongest, and the leverage effect of Shanghai Zinc is the weakest. The asymmetry coefficient in the variance equation of other non-ferrous metals Shanghai aluminum, London aluminum, London zinc, Shanghai lead, Shanghai nickel, London nickel and Shanghai tin price yield is positive, indicating that the impact of bullish in these markets is greater than the impact of bearishness, when the impact of bullish news, Shanghai aluminum, London aluminum, London zinc, Shanghai lead, Shanghai nickel, London nickel, Shanghai tin market has a 0.549, 0.033, 0.111, 0.214, 0.021, 0.433, 0.448 times shock impact, when the impact of negative news, Shanghai aluminum, The London aluminum, London zinc, Shanghai lead, Shanghai nickel, London nickel and Shanghai tin markets had an impact of 0.473, 0.023, 0.099, 0.170, 0.005, 0.285 and 0.364 times. The following is the shock response curve of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures market information as follows:

From **Figures 21-32** below, we can see the asymmetric impact of market news on volatility, the impact of negative news in Shanghai copper and London copper futures markets is greater than the impact of bullish news, but the impact of negative news in London copper market is greater than that of Shanghai copper negative news. The impact of the bullish news in the Shanghai aluminum and London aluminum markets is slightly greater than the impact of the negative news, and the impact of the bullish and negative news on the two markets is relatively close. There are obvious differences in the negative and bullish impact of the Shanghai zinc and London zinc futures markets, the impact of the bullish news in the Shanghai zinc market is greater than the impact of the bearish news, and the impact of the negative news in the London zinc futures market is significantly greater than the impact of the bullish news. There are also obvious differences



**Figure 21.** The information shock curve of Shanghai copper futures markets.

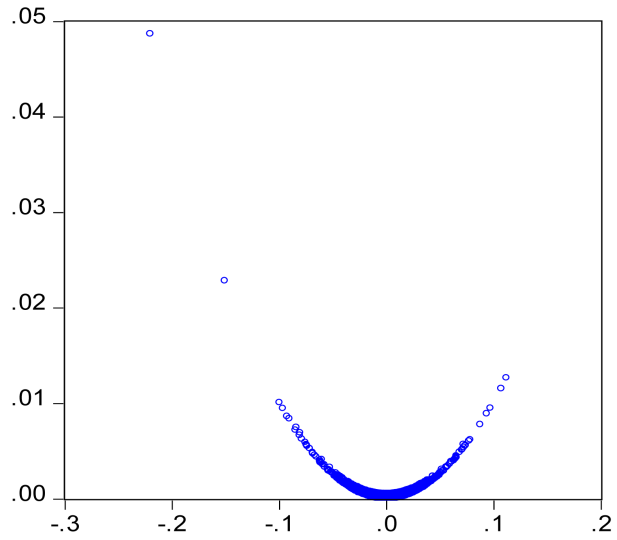


Figure 22. The information shock curve of London copper futures markets.

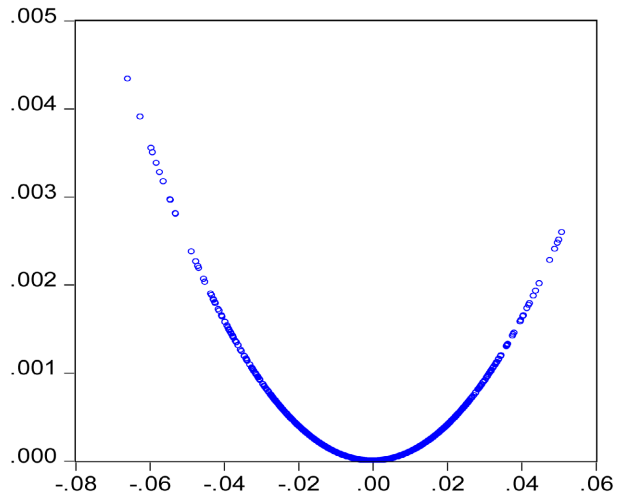


Figure 23. The information shock curve of Shanghai aluminum futures markets.

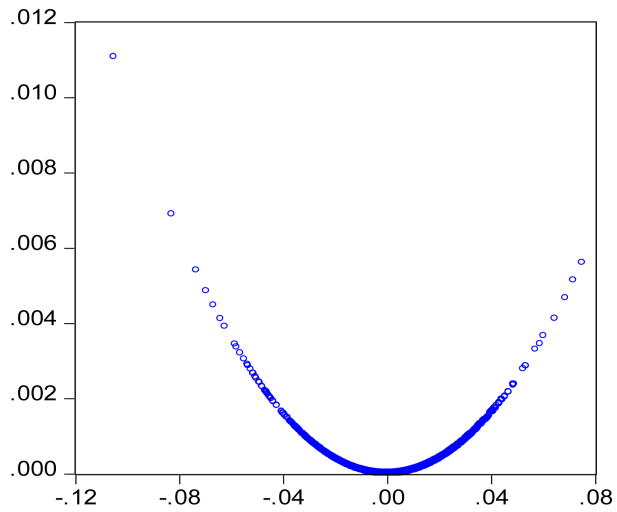
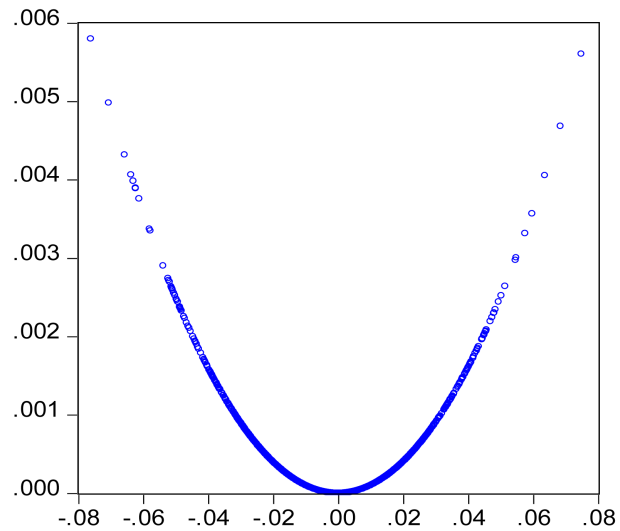
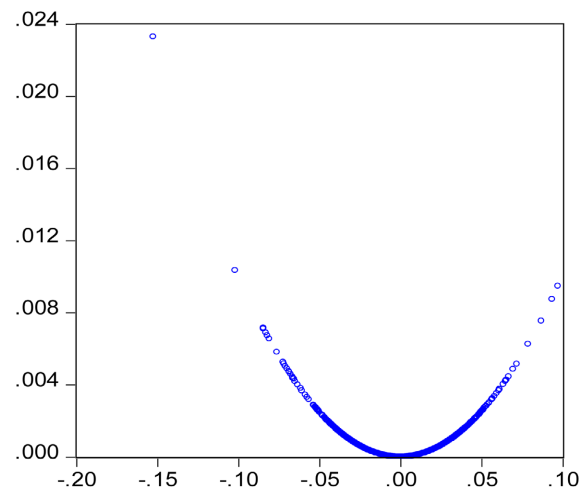


Figure 24. The information shock curve of London aluminum futures markets.



**Figure 25.** The information shock curve of Shanghai zinc futures markets.



**Figure 26.** The information shock curve of London zinc futures markets.



**Figure 27.** The information shock curve of Shanghai lead futures markets.

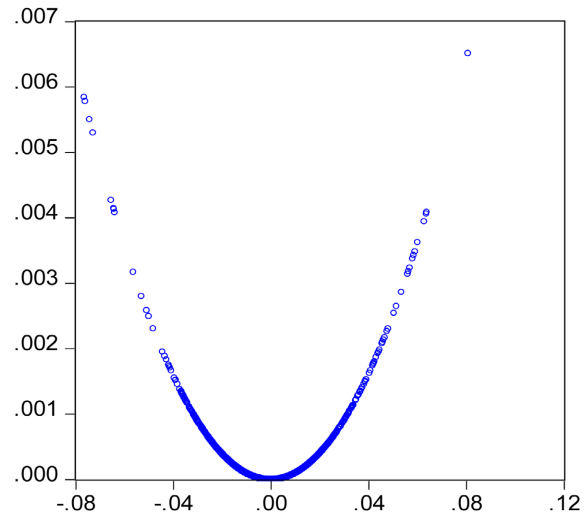


Figure 28. The information shock curve of London lead futures markets.

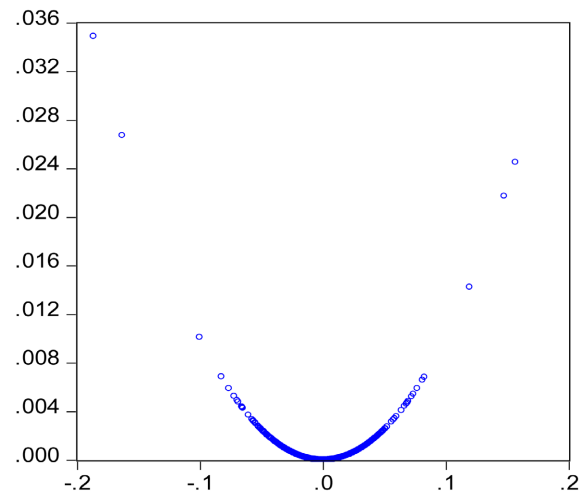


Figure 29. The information shock curve of Shanghai nickel futures markets.

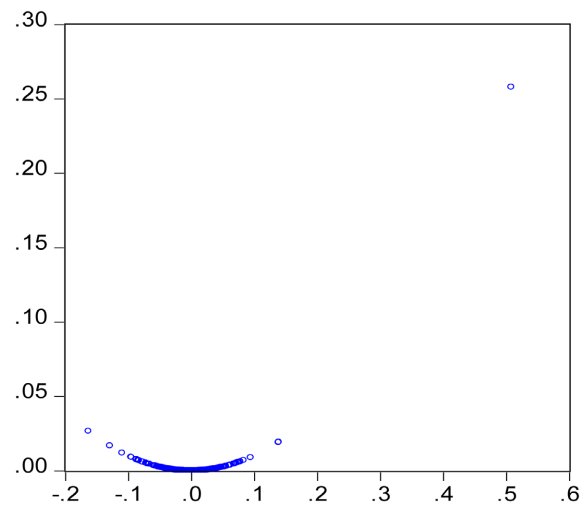
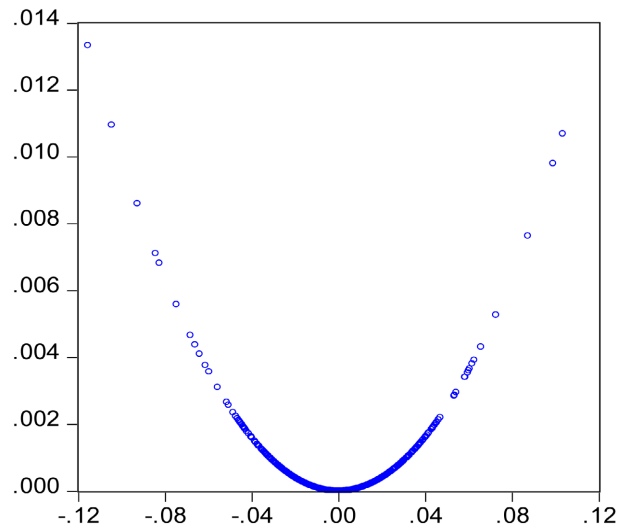
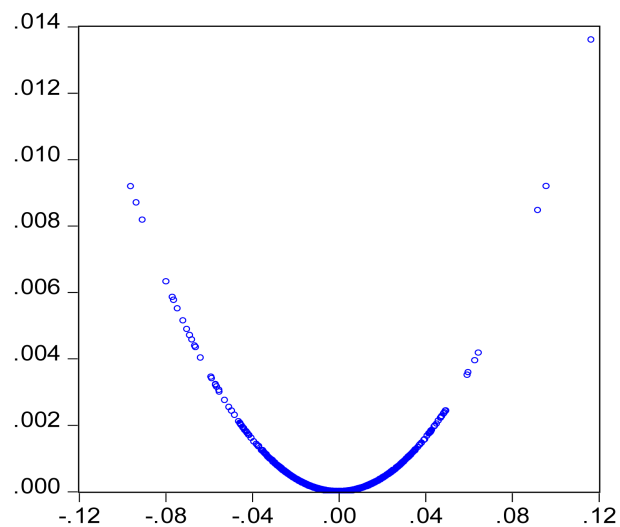


Figure 30. The information shock curve of London nickel futures markets.



**Figure 31.** The information shock curve of Shanghai tin futures markets.



**Figure 32.** The information shock curve of London tin futures markets.

in the impact of negative news in the Shanghai lead and London lead futures markets, the impact of the positive news in the Shanghai lead futures market is greater than the impact of the negative news, and the negative news in the London lead futures market is slightly greater than the impact of the positive news. The impact of bullish news is greater than that of bearish news in the Shanghai nickel futures market, but the impact of bullish news is greater than that of bearish news in the London nickel futures market than that of the Shanghai nickel market. There are obvious differences in the impact of negative news in the Shanghai tin and London tin futures markets, the impact of the positive news in the Shanghai tin futures market is slightly greater than the impact of the negative news, and the impact of the negative news in the London tin futures market is greater than the impact of the positive news.

The enlightenment from the gap in the impact of the news of the non-ferrous

metal futures market at home and abroad is that in addition to the domestic and foreign aluminum futures, from the comparison of the domestic and foreign futures markets of copper, zinc, lead, nickel and tin, the risk of the foreign market is greater than the risk of the domestic market. For investors, arbitrage is carried out in accordance with the normal domestic and foreign futures price comparison relationship, due to the different degrees of influence of bullish and negative news at home and abroad, the normal price comparison relationship is often distorted, therefore, there is a greater risk of cross-market arbitrage through the copper, zinc, lead, nickel and tin futures markets.

#### 4.6.3. Spillover Effect Model Estimation of Domestic and Foreign Non-Ferrous Metal Futures Price Yields

Firstly, the conditional variance of the GARCH-M model of domestic and foreign non-ferrous metal futures price returns is tested for the Granger causality test, and the best lag order is selected, and the test results are shown in **Table 10** & **Table 11** below.

**Table 10.** The Granger causality test results of conditional variance of domestic and foreign non-ferrous metal futures prices yields.

Null Hypothesis	Sample	F-Statistic	Prob.
H2 does not Granger Cause H1	4858	153.149	3.E-65
H1 does not Granger Cause H2		2.575	0.076
H4 does not Granger Cause H3	4600	15.446	2.E-07
H3 does not Granger Cause H4		123.631	5.E-53
H6 does not Granger Cause H5	3911	22.482	2.E-10
H5 does not Granger Cause H6		142.257	2.E-60
H8 does not Granger Cause H7	3108	30.766	6.E-14
H7 does not Granger Cause H8		96.619	2.E-41
H10 does not Granger Cause H9	2153	2.450	0.012
H9 does not Granger Cause H10		213.809	3E-266
H12 does not Granger Cause H11	2161	2.193	0.112
H11 does not Granger Cause H12		44.502	1.E-19

Note: Among them, H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, and H12 are the conditional variances of the Garch-M model of Shanghai copper, London copper, Shanghai aluminum, London aluminum, Shanghai zinc, London zinc, Shanghai lead, London lead, Shanghai nickel, London nickel, Shanghai tin, and London tin futures price returns.

From the results of the above Granger causality test, it can be seen that at the significance level of 10%, the volatility of Shanghai copper and London copper futures price returns is causal with each other, and at the significance level of 1% and 5%, London copper has a one-way guiding relationship with Shanghai copper, indicating that the influence of London copper on Shanghai copper is greater than

that of Shanghai copper on London copper. At the significance levels of 1%, 5% and 10%, there is a two-way guiding relationship between the price return volatility of Shanghai Aluminum and London Aluminum, Shanghai Zinc and London Zinc, and Shanghai Lead and London Lead futures. At the 1% significance level, Shanghai Nickel has a one-way guiding relationship with the price return volatility of London nickel futures, and at the 5% and 10% significance levels, there is a two-way guiding relationship between the price return volatility of Shanghai Nickel and London Nickel futures, indicating that the impact of Shanghai Nickel on London Nickel is greater than that of London Nickel on Shanghai Nickel. At the significance levels of 1%, 5% and 10%, there is a one-way guiding relationship Shanghai tin futures price returns volatility on London tin futures price returns volatility, and there is no guidance relationship London tin futures price returns volatility on Shanghai tin futures price returns volatility, indicating that the impact of Shanghai tin on London tin is significantly greater than that of London tin on Shanghai tin.

In short, the price return volatility of London copper, Shanghai nickel and Shanghai tin futures has a stronger guiding effect on the price return volatility of Shanghai copper, London nickel and London tin than the price yield fluctuation of Shanghai copper, London nickel and London tin futures on the price return volatility of London copper, Shanghai nickel and Shanghai tin futures. There is a strong mutual guiding effect between the price yields fluctuations of aluminum, zinc and lead futures of domestic non-ferrous metal futures and the price yields fluctuations of foreign aluminum, zinc and lead futures, and there is little difference in mutual guidance.

It shows that the risks of domestic and foreign non-ferrous metal futures markets have strong mutual influences, and the impact of the London copper, Shanghai nickel and Shanghai tin futures market on the Shanghai copper, London nickel and Shanghai tin futures markets is stronger than that of the Shanghai copper, London nickel and Shanghai tin futures markets on London copper, Shanghai nickel and Shanghai tin futures market. Therefore, the risk transmission of copper, nickel and tin futures prices at home and abroad has obvious asymmetry.

The following are the specific estimates of the spillover effect models of domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel, tin) futures markets, as shown in **Table 11** below.

The above conditional variance model shows that the early absolute disturbance of the yield of the London copper futures price has a negative impact on the fluctuation of the current yield of the Shanghai copper futures price, and the absolute disturbance of the early absolute disturbance of the Shanghai copper futures price yield has a positive impact on the fluctuation of the current yield of the London copper futures price. The early absolute disturbance of the price yield of London aluminum futures has a positive impact on the fluctuation of the current yield of Shanghai aluminum futures price, and the early absolute disturbance of the price yield of Shanghai aluminum futures has a negative impact on

**Table 11.** Estimation results of spillover effect model in domestic and foreign non-ferrous metal futures markets.

variable	$\sigma_1^2$	$\sigma_2^2$	$\sigma_3^2$	$\sigma_4^2$	$\sigma_5^2$	$\sigma_6^2$	$\sigma_7^2$	$\sigma_8^2$	$\sigma_9^2$	$\sigma_{10}^2$	$\sigma_{11}^2$	$\sigma_{12}^2$
$\sigma_7^2(-1)$	0.912 (0.000)	0.928 (0.000)	0.877 (0.000)	0.937 (0.000)	0.933 (0.000)	0.954 (0.000)	0.902 (0.000)	0.965 (0.000)	0.927 (0.000)	0.542 (0.000)	0.915 (0.000)	0.900 (0.000)
$\varepsilon_1^2(-1)$	0.085 (0.000)	0.001 (0.000)										
$\varepsilon_2^2(-1)$	-1.96E-05 (0.441)	0.066 (0.000)										
$\varepsilon_3^2(-1)$			0.126 (0.000)	-0.0002 (0.000)								
$\varepsilon_4^2(-1)$			0.0004 (0.000)	0.058 (0.123)								
$\varepsilon_5^2(-1)$					0.067 (0.000)	0.0001 (0.000)						
$\varepsilon_6^2(-1)$					2.48E-05 (0.083)	0.044 (0.005)						
$\varepsilon_7^2(-1)$							0.096 (0.000)	6.75E-05 (0.222)				
$\varepsilon_8^2(-1)$							0.0005 (0.000)	0.033 (0.000)				
$\varepsilon_9^2(-1)$									0.059 (0.000)	0.013 (0.000)		
$\varepsilon_{10}^2(-1)$									3.04E-05 (0.233)	0.289 (0.000)		
$\varepsilon_{11}^2(-1)$											0.084 (0.000)	0.065 (0.000)
$\varepsilon_{12}^2(-1)$											6.04E-05 (0.332)	0.009 (0.000)
R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.997	0.999	0.917
Adjusted R-squared	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.999	0.997	0.999	0.917
S.E. of regression	1.74E-06	2.57E-06	8.75E-07	1.86E-06	6.69E-07	1.19E-06	1.13E-06	1.05E-06	6.53E-06	9.72E-05	2.02E-06	8.32E-05
Sum squared resid	1.46E-08	3.21E-08	3.52E-09	1.60E-08	1.75E-09	5.58E-09	3.95E-09	3.42E-09	9.19E-08	2.04E-05	8.77E-09	1.50E-05
Log likelihood	57558.55	55650.25	57650.70	54173.47	50069.66	47800.04	38170.51	38392.65	22737.19	16892.72	25287.26	17243.54
Durbin-Watson stat	0.012	0.034	0.073	0.025	0.011	0.013	0.086	0.023	0.023	0.078	0.016	1.974
Mean dependent var	0.0002	0.0003	0.0001	0.0002	0.0002	0.0003	0.0001	0.0002	0.0004	0.0006	0.0003	0.0003
S.D. dependent var	0.0002	0.0004	0.0001	0.0001	0.0001	0.0003	0.0001	9.22E-05	0.0004	0.002	0.0003	0.0003
Akaike info criterion	-23.690	-22.905	-25.059	-23.547	-25.596	-24.436	-24.553	-24.696	-21.040	-15.639	-23.390	-15.949

## Continued

Schwarz criterion	-23.686	-22.901	-25.055	-23.543	-25.591	-24.431	-24.547	-24.690	-21.032	-15.631	-23.382	-15.941
Hannan-Quinn criter.	-23.689	-22.903	-25.057	-23.546	-25.595	-24.434	-24.551	-24.694	-21.038	-15.631	-23.387	-15.946

Note:  $\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2, \sigma_5^2, \sigma_6^2, \sigma_7^2, \sigma_8^2, \sigma_9^2, \sigma_{10}^2, \sigma_{11}^2, \sigma_{12}^2$  is the conditional variance of the price yield of Shanghai copper, London copper, Shanghai aluminum, London aluminum, Shanghai zinc, London zinc, Shanghai lead, London lead, Shanghai nickel, London nickel, Shanghai tin, and London tin futures,  $\sigma_t^2, t=1,2,3,4,5,6,7,8,9,10,11,12$  They are Shanghai copper, London copper, Shanghai aluminum, London aluminum, Shanghai zinc, London zinc, Shanghai lead, London lead, Shanghai nickel, London nickel, Shanghai tin, London tin and London tin futures price yield disturbances, the positive data in parentheses are the standard deviation, and the negative values are the lag order.

the fluctuation of the current yield of London aluminum futures price. The absolute disturbance of the early stage of the price yield of London zinc and Shanghai zinc futures has a positive impact on the current yield fluctuation of Shanghai zinc and London zinc futures prices, respectively, and the impact of Shanghai zinc on the London zinc market is more significant. The absolute disturbance of the early stage of the price yield of London lead and Shanghai lead futures has a positive impact on the fluctuation of the current yield of Shanghai lead and Shanghai lead futures, respectively, and the impact of London lead on the Shanghai lead market is more significant. The absolute disturbance of the early stage of the price yield of London nickel and Shanghai nickel futures has a positive impact on the fluctuation of the current yield of Shanghai nickel and London nickel futures respectively, and the impact of Shanghai nickel on the London nickel market is more significant. The absolute disturbance of the yield of London and Shanghai tin futures prices in the early stage has a positive impact on the fluctuation of the current yield of Shanghai tin and London tin futures prices, respectively, and the impact of Shanghai tin on the London tin market is more significant.

This shows that there are spillover effects between domestic and foreign non-ferrous metals (copper, aluminum, zinc, lead, nickel and tin) futures markets, and the spillover effects of domestic copper, zinc, nickel and tin futures markets on foreign copper, zinc, nickel and tin futures markets are stronger than those of foreign copper, zinc, nickel and tin futures markets on domestic copper, zinc, nickel and tin futures markets. The spillover effect of foreign aluminum and lead futures markets on the domestic aluminum and lead futures markets is stronger than that of the domestic aluminum and lead futures markets on foreign aluminum and lead futures markets. The asymmetry of the spillover effect between the domestic and foreign non-ferrous metal futures markets shows that there is a mutual influence on the volatility transmission of the domestic and foreign non-ferrous metal futures markets. The above shows that after years of development, China's non-ferrous metal futures market has a strong demonstration role in the global market in terms of yield level and volatility, especially the international pricing power and influence of copper, zinc, nickel and tin have been significantly improved.

## 5. Conclusion

In this paper, we use the cointegration correlation theory and GARCH model method to conduct an empirical study on the price discovery function and influence of non-ferrous metals copper, aluminum, zinc, lead, nickel and tin futures listed on the Shanghai Futures Exchange, as well as the international pricing power and volatility risk transmission.

It is found that the domestic non-ferrous metal copper, aluminum, zinc, lead, nickel and tin futures prices have a strong price discovery function, and the domestic non-ferrous metal futures have a strong international pricing influence of copper, aluminum and zinc, while the international pricing influence of lead, nickel and tin is weak. There is a significant long-term co-directional movement relationship between domestic non-ferrous metal futures and LME non-ferrous metal futures market, and the lead futures in China and LME market have the strongest co-directional change relationship. There is an interaction between domestic non-ferrous metal futures and LME metal futures price yields and short-term fluctuations, and although there are different short-term fluctuation patterns between futures price yields, there is also a long-term cointegration trend. In addition to the Shanghai nickel futures market, the risk premium of the Shanghai nickel futures market is higher than that of the LME nickel futures market, and the risk premium of the other copper, aluminum, zinc, lead and tin futures markets is higher than that of the domestic futures market, and there are theoretical arbitrage opportunities in the domestic and foreign metal futures markets. In addition to aluminum, from the copper, zinc, lead, nickel, tin domestic and foreign futures market comparison, the risk of the foreign market is greater than the risk of the domestic market, due to the degree of influence of the bullish news at home and abroad, the normal price relationship is often distorted, therefore, through the copper, zinc, lead, nickel, tin futures market cross-market arbitrage there is a greater risk. The risks of domestic and foreign non-ferrous metal futures markets have strong mutual influences, and the risk transmission of copper, nickel and tin futures prices at home and abroad has obvious asymmetry. There is asymmetry in the spillover effect between domestic and foreign non-ferrous metal futures markets, and there is mutual influence on the volatility transmission of domestic and foreign non-ferrous metal futures markets. After years of development, China's non-ferrous metal futures market has a strong demonstration role in the global market in terms of yield level and volatility, especially the international pricing power and influence of copper, zinc, nickel and tin have been significantly improved.

In short, China's non-ferrous metal futures have a strong price discovery function, have a certain international influence, international pricing power, at that time the domestic non-ferrous metal futures market and the foreign LME market still have a certain gap, therefore, the following suggestions are put forward for the development of the domestic non-ferrous metal futures market:

First, further promote the international development of the domestic non-

ferrous metal futures market. Promote the internationalization of existing non-ferrous futures varieties as soon as possible. Docking with the international futures market and improving the trading rules of the international futures market. Strengthening cooperation with international futures exchanges. Continuously enhance the price guiding role of domestic non-ferrous metal futures on foreign non-ferrous metal futures. On the basis of allowing QFIIs and RQFIIs to participate in the trading of specific domestic products, we will widely introduce international industrial and institutional customers, enrich the trader structure of the non-ferrous metal futures market, and further enhance the level of internationalization.

Second, further enrich the varieties of domestic non-ferrous metal futures and options to meet the needs of different traders. On the basis of the existing non-ferrous metal futures and options, more subdivided varieties of non-ferrous metal futures will be launched according to different market needs, and the research and development of non-ferrous metal intermediate products will be actively carried out, especially the development of some minor metal futures varieties, so as to meet the diversified needs of international investors. In addition, on the basis of the existing futures varieties, we can consider the optimization of contracts and launch mini contracts to meet the needs of some investment customers. Enhance the international competitiveness of domestic non-ferrous metal futures through variety development and contract optimization.

Third, further establish and improve the basic construction of the domestic non-ferrous metal futures market. Explore the construction of overseas non-ferrous metal futures delivery warehouses to meet the delivery needs of international institutional investors. Promote the improvement of the development of the non-ferrous metal OTC commodity trading market, and optimize the logistics and warehousing service system. Regulate the business of futures companies, promote the rapid development of futures business, create a good futures business environment, and promote the international development of the non-ferrous metal futures market.

Fourth, within the framework of the Futures Law, strengthen the risk supervision of the non-ferrous metal futures market. In the face of the complex international political and economic environment, the continuous outbreak of political and economic risks, the international market of non-ferrous metals soars and plummets from time to time, and the transaction risks of domestic and foreign markets continue to gather. Therefore, both market trading entities and regulatory authorities should do a good job in risk prevention and control. In response to abnormal trading behaviors in the market, the regulatory authorities should supervise them in a timely manner to prevent further expansion of risks and maintain the normal operation of the market.

### **Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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