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Price linkage between Chinese and international nonferrous metals commodity markets based on VAR-DCC-GARCH models

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Abstract: Using VAR-DCC-GARCH model, the literature on commodity price was extended by exploring the co-movement between Chinese nonferrous metal prices and global nonferrous metal prices represented by the nonferrous metal prices from London Metal Exchange (LME). The results show that LME nonferrous metals prices still have a greater impact on Chinese nonferrous metals prices. However, the impact of Chinese nonferrous metals prices on LME nonferrous metals prices is still weak except for lead price. The co-movement of nonferrous metal prices between LME and China presents hysteretic nature, and it lasts for 7−8 trading days. Furthermore, the co-movement between LME nonferrous metals prices and Chinese nonferrous metals prices has the characteristics of time-varying, and the correlation of lead prices between LME and China is the more stable than all other nonferrous metals prices.

Key words: price linkage; nonferrous metals commodity prices; Chinese metals commodity market; LME; co-movement; VAR model; DCC-GARCH model

1 Introduction

Accompanying the advent of urbanization and heavy industrialization, there is a rapid growth in the demand for metal resources in China. As a result, the international trade volume of metals increases largely in China. According to statistics, China accounts for 40% of the global consumption in copper in 2011. However, 71% of copper in China comes from abroad. The heavy demand for metal resources makes China play a more and more important role in global metal commodity markets, thus Chinese factors have become the major cause which can affect the change in global metal commodity markets [1].

With the economic globalization nowadays, the metal prices are fluctuating more violently than before, in turn, the risk of Chinese market is much larger as well. However, China does not have an enough loud voice in global metal markets. As a result, the metal prices in China fluctuate passively with the global metal prices change. Therefore, we cannot help but ask: Does the changes of metal prices in China can play an important role in the volatility of global metal prices? How do the global metal prices affect Chinese metal commodity market?

An increasing number of studies attempt to explore the relationship between the prices of different commodity markets. CASHIN et al [2] used monthly IMF data on primary commodities to examine the persistence of shocks to world commodity prices, they found that shocks to commodity prices are typically long-lasting and the variability of the persistence of price shocks is quite wide. They also showed that if price shocks are long-lived, then the cost of stabilization schemes will likely exceed any associated smoothing benefits. JOSEPH et al [3] used nonstationary panel methods to document a statistically significant degree of co-movement due to a common factor, which confirmed what CASHIN et al [2] found. In other words, these works suggested that the co-movement of prices is always seen between interrelated commodities, which reflect the degree of interplay between different commodities' prices. Some researchers, however, held

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the opposite view. Studying on the long-run relationship between gold and silver of Tokyo Commodity Exchange, CINER [4] found that the stable long-run relationship between the two precious metals broke down suddenly in the 1990s. He believed that the reason may be that gold and silver have different economic use at that time, in turn, form separate markets. LUCEY and TULLY [5] re-examined the results of CINER [4], they showed that using a longer run of data, for both cash and futures, CINER's finding may be unwarranted. The findings are that while there are periods when the relationship is weak, overall a stable relationship prevails. Additionally, the short-run relationships among different commodities' prices have been studied. LESCAROUX [6] considered monthly data of 51 commodities from 1980 to 2008 to confirm that raw resources exhibit co-movement at high frequencies. SARIA et al [7] examined the co-movements and information transmission among the spot prices of four precious metals (gold, silver, platinum, and palladium), oil price and the US dollar/Euro exchange rate, they found the evidence of a weak long-run equilibrium relationship but strong feedbacks in the short run. Furthermore, some studies explored the influence of international market factors on the change of commodity's prices. MOLLICK et al [8] examined the impact of globalization on commodities terms of trade and the global prices on American commodities' prices. JAIN and GHOSH [9] investigated the cointegration and Granger causality among global oil prices, precious metal (gold, platinum and silver) prices and Indian Rupee-US Dollar exchange rate using daily data spanning from 2nd January 2009 to 30th December 2011. Chinese scholars have done some related studies in recent years as well [10−15], however, there are still few studies focusing on the price linkage between Chinese and international nonferrous metals commodity markets.

According to the above discussion, we find that the majority of the previous studies focus on the relationship or co-movement between different commodities' prices in the same market. However, few of them study the co-movement between the commodities from different markets. Therefore, using VAR model and DCC-GARCH model, the relationship between the global metal prices, which are represented by the metals prices of LME, and Chinese metal prices, which are represented by the prices provided by China Yangtze River Nonferrous Metals Market (YRNMM), was analyzed.

2 Research method and data

2.1 Research method

2.1.1 VAR model

The measurement of return and volatility spillovers is based on vector autoregression (VAR) models, and focuses on the impact from intensity and duration of prices between LME spot market and YRNMM. The VAR(p) model used in this work is given by

$$\boldsymbol{Y}_t = \boldsymbol{A}_0 + \sum_{i=1}^{p} \boldsymbol{A}_i \boldsymbol{Y}_{t-i} + \boldsymbol{\varepsilon}_t \tag{1}$$

$$\boldsymbol{Y}_t = [\ln(l_t/l_{t-1}), \ln(c_t/c_{t-1})]' \tag{2}$$

where l_t is the price of LME nonferrous metals spots in the period of t, c_t is the price of YRNMM nonferrous metals spots in the period of t, $\boldsymbol{A}_n$ is 2×2 parameter matrix of lagged variables, $\boldsymbol{\varepsilon}_t=[\varepsilon_{1,t}, \varepsilon_{2,t}]'$, $E(\varepsilon_t)=0$, $E(\varepsilon_t\varepsilon'_t)=\sigma^2$, $E(\varepsilon_t\varepsilon'_t)=0$, $t\neq s$.

As an efficient causal analysis method, impulse response function can be used to analyze the relationship between variables. Residual in VAR model reflects the impact from external system on system variables, hence, the coefficient matrix in the moving average form, is also impulse response coefficient matrix, that is

$$\boldsymbol{F}_t = C_0 + B_0\boldsymbol{\varepsilon}'_t + B_1\boldsymbol{\varepsilon}'_{t-1} + \cdots + B_n\boldsymbol{\varepsilon}'_{t-n} + \cdots \tag{3}$$

where $\boldsymbol{F}_t=[f_{1,t}, f_{2,t}]'$ and $\boldsymbol{B}_n=[b_{ij,n}]$ are 2×2 coefficient matrixes, $b_{ij,n}$ reflects the impact of $f_{i,t-n}$ on $f_{j,t}$ during the period of $t-n$. Therefore, the accumulative response of $f_{j,t}$ to $f_{j,t}$ can be written as $\sum_{t=0}^{m} b_{ij,t}$.

2.1.2 DCC-GARCH model

DCC-GARCH model suggested by ENGLE [16] has outstanding effect on describing dynamic mechanism of action between financial variables. By calculating dynamic conditional coefficient, it can reflect the influence between variables efficiently. In order to analyze the influence between LME nonferrous metals prices and YRNMM nonferrous metals prices, we adopt DCC-GARCH model to measure the interaction effect of prices between these two markets. Assuming all the nonferrous metals prices follow multivariate normal distribution, we have $r'_{i,t} \left| I_{t-1} \sim N(0, H_t)\right.$. The DCC-GARCH model used in this work is given by

$$\begin{cases} \boldsymbol{H}_t = \boldsymbol{D}_t\boldsymbol{R}_t\boldsymbol{D}_t \\ \boldsymbol{R}_t = \mathrm{diag}(\sqrt{q_{i,j,t}})\boldsymbol{Q}_t\mathrm{diag}(\sqrt{q_{i,j,t}}) \\ \boldsymbol{Q}_t = [q_{i,j,t}] = \boldsymbol{S}(1-\alpha-\beta) + \alpha(\boldsymbol{\varepsilon}_{t-1}\boldsymbol{\varepsilon}'_{t-1}) + \beta\boldsymbol{Q}_{t-1} \\ \rho_{i,j,t} = q_{i,j,t}\Big/\sqrt{q_{i,i,t}q_{j,j,t}} \end{cases} \tag{4}$$

where $\rho_{i,j,t}$ is the dynamic correlation coefficient in DCC-GARCH model, $\boldsymbol{R}_t$ is the dynamic correlation matrix, $\boldsymbol{D}_t = \mathrm{diag}\{\sqrt{h_{i,t}}\}$ is the symmetric matrix of dynamic correlation matrix, $\boldsymbol{Q}_t$ is 2×2 positive definite matrix, $\boldsymbol{S}$ is 2×2 covariance matrix, α and β are the coefficients of DCC-GARCH model.

We can estimate by using two-step method as follows. In the first step, we estimate the coefficient of univariate GARCH model. In the second step, we use the conditional variances standardized residuals obtained from the first step to estimate the coefficient of the dynamic correlation matrix. We use maximum likehood estimate in the second step, and the log likelihood is

$$L=-\frac{1}{2}\sum_{t=1}^{T}(n\lg(2\pi)+2\lg|\boldsymbol{D}_t|+ \lg|\boldsymbol{R}_t|+\boldsymbol{\varepsilon}'_{t-1}\boldsymbol{R}_t^{-1}\boldsymbol{\varepsilon}_{t-1}), n=2 \tag{5}$$

2.2 Data selection, stationarity and ARCH effect

Copper price, lead price and zinc price were chosen as research objects. Sample range is between 4th January, 2007 and 31st May, 2013, getting rid of the inconsistent dates because of traditional holidays, and using three steps Hemite polynomial method to polish individual missing data.

Since the purpose of this work is to analyze the interaction between Chinese nonferrous metal prices and global nonferrous metal prices, all nonferrous metals prices were handled using $r_t=\ln(p_t/p_{t-1})\times 100$. Table 1 gives the ADF inspection results of the six groups of time series, which shows that all time series are stationary series. Table 2 presents the results of ARCH-LM test, F statistic and TR^2 statistic, which indicates that all time series have ARCH effect, meanwhile, Ljung-Box statistic is also different from zero, so it is suitable for building GARCH model.

Table 1 ADF test results of nonferrous metals prices

Variate	t-statistic	1% level	Stationarity
LME copper (CuL)	−37.014	−3.434	Stable
LME lead (PbL)	−35.624	−3.434	Stable
LME zinc (ZnL)	−34.975	−3.434	Stable
Chinese copper (CuC)	−16.523	−3.434	Stable
Chinese lead (PbC)	−18.929	−3.434	Stable
Chinese zinc (ZnC)	−33.534	−3.434	Stable

3 Empirical results

3.1 Granger causality test and impulse response analysis of co-movement between Chinese and global metals prices

On the basis of lag order test of VAR model, VAR (7) model of copper prices, VAR (7) model of lead prices, and VAR (5) model of zinc prices were built. Additionally, Granger causality test and impulse response analysis were used to study the co-movement between Chinese and global metals prices.

3.1.1 Granger causality test

First, Granger causality test was carried out to the VAR model of copper, lead, and zinc prices, respectively. Table 3 shows the results of the test. The metal prices of LME have a much bigger impact on Chinese metals prices. Particularly, with respect to copper, although the impact from the price of LME on Chinese price is bigger, there also have some effect of Chinese price on LME's price; with respect to lead, the degree of the interrelationship between Chinese price and LME's price are almost the same; the zinc price of LME has a significant impact on Chinese zinc price, however, Chinese zinc price has no influence on LME's zinc price. Therefore, the results suggest that the prices of LME can still play a more significant role in global metal commodity market than that of China.

3.1.2 Impulse response analysis

Impulse response analysis is a causal analysis method to study the structural relation between variables. This method can be used to analyze the causality between variables by the response on the impulse from other variables, and it also can be used to study the dynamic effect from external shock to the system. This work discusses the dynamic relationship between the metal prices of LME and China to evaluate the effect and duration of the impulse by VAR model, thereby, analyzing the interactive relationship between the prices of LME and China.

The impulse response function results are plotted in Figs. 1−3. The full line and dotted line give the result of impulse response analysis and the confidence interval, respectively. Figure 1 reveals the impacts of LME's copper price on Chinese copper price as well as the impacts of Chinese copper price on LME's copper price. The results show that given a positively and significantly initial impact of CuL on CuC, CuC has a strong and positive response in the first two horizons (days).

Table 2 ARCH-LM test result of nonferrous metals prices

Variate	F-statistic	TR^2-statistic	$Q(6)$	$Q(12)$	$Q^2(6)$	$Q^2(12)$
CuL	15.942***	15.926***	21.520***	37.246***	21.656***	37.498***
PbL	142.941***	130.826***	152.01***	152.26***	147.65***	147.93***
ZnL	22.443***	22.146***	26.100***	39.974***	26.147***	40.117***
CuC	16.360***	16.207***	43.674***	71.450***	43.939***	71.845***
PbC	363.566***	293.777***	418.56***	455.81***	418.99***	456.17***
ZnC	42.362***	41.268***	41.895***	65.099***	42.049***	65.305***

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level. () is z-statistics.

Table 3 Results of Granger causality test

H0	Lags	χ^2 statistics	*P* value
CuL is not the Granger causality of CuC	7	614.634	0.000
CuC is not the Granger causality of Cul	7	19.250	0.007
PbL is not the Granger causality of PbC	7	99.629	0.000
PbC is not the Granger causality of PbL	7	65.808	0.000
ZnL is not the Granger causality of ZnC	5	502.038	0.000
ZnC is not the Granger causality of ZnL	5	4.392	0.495

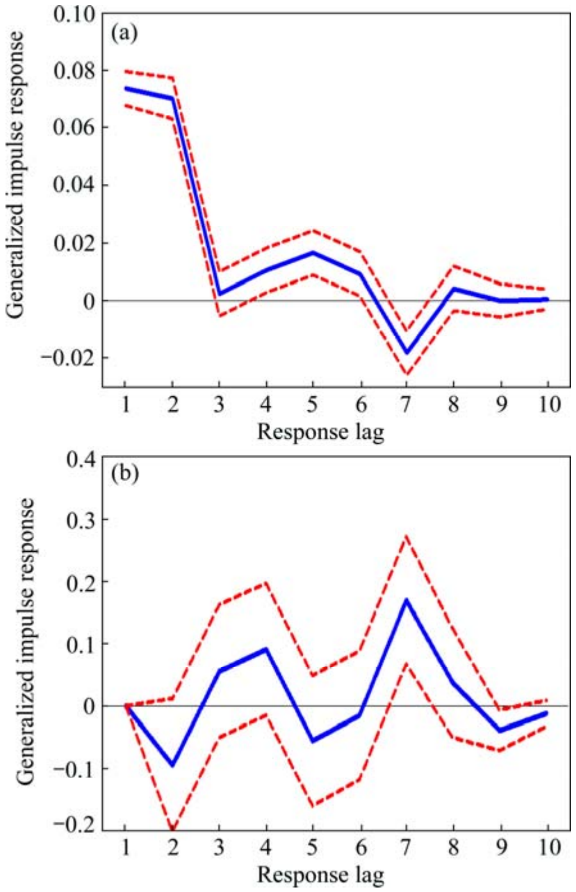

Fig. 1 Generalized impulse response between Chinese and LME copper prices: (a) Response of CuC to Cholesky one S.D. CuL innovations; (b) Response of CuL to Cholesky one S.D. CuC innovations

However, these impacts die out temporarily in the third horizon, then float down and up around 0 from the forth horizon to ninth horizon. While given a positively and significantly initial impact of CuC on CuL, CuL responses to CuC negatively and significantly in the second horizon. Then, the impacts are positive and the degree equals the impact of the first horizon in the third and forth horizons. However, in the fifth and sixth horizons, the impacts are negative and weaker than the first horizon. In particular, the impact is the greatest and positive in the seventh horizon, then, the impacts die out gradually in the next horizons. As the following figures indicate, the volatility of copper prices of LME and China can affect each other, however, the impact of LME's copper price on Chinese copper price is still bigger than the opposite.

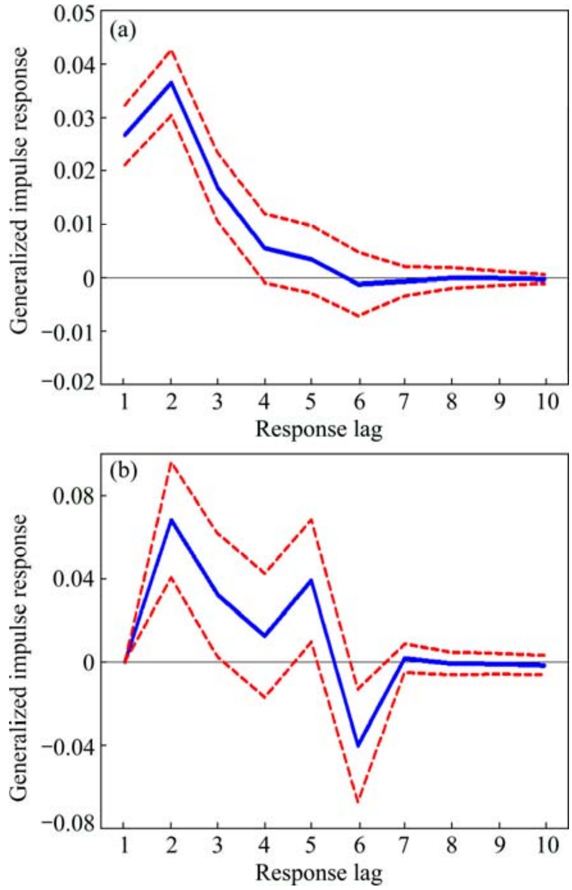

Fig. 2 Generalized impulse response between Chinese and LME lead prices: (a) Response of PbC to Cholesky one S.D. PbL innovations; (b) Response of PbL to Cholesky one S.D. PbL innovations

Figure 2 shows the impacts of LME's lead price on Chinese lead price as well as the impacts of Chinese lead price on LME's lead price. Given a positively initial impact of PbL on PbC, the responses of PbC to PbL are positive, and the second greatest and the greatest in the first and second horizon, respectively. The positive impacts are growing weaker gradually from the forth horizon, and become negative in the seventh horizon, then die out quickly. While given a positive initial impact of PbC on PbL, the response of PbL reaches the greatest and positive in the second horizon, and it becomes weaker but still positive in the third and forth horizons. After it gets the second greatest and positive in the fifth

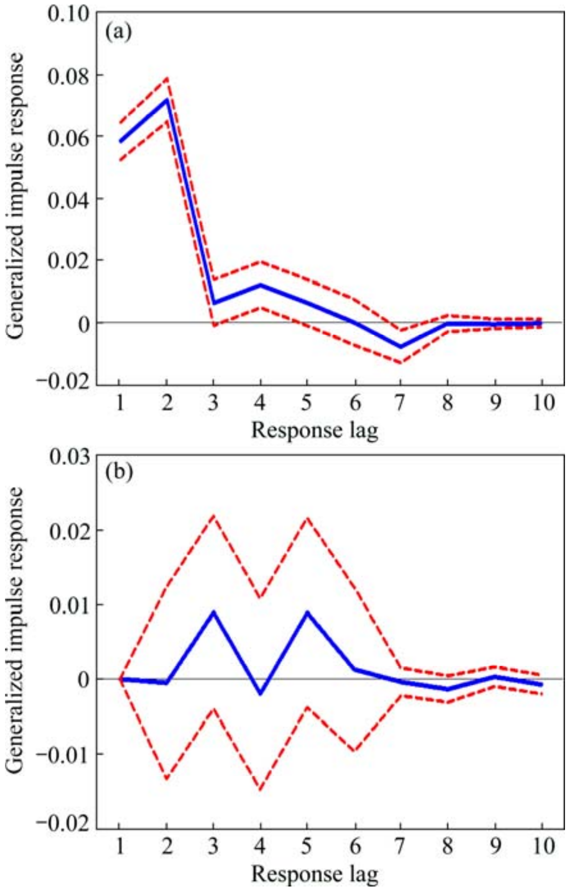

Fig. 3 Generalized impulse response between Chinese and LME zinc prices: (a) Response of ZnC to Cholesky one S.D. ZnL innovations; (b) Response of ZnL to Cholesky one S.D. ZnC innovations

horizon, the impacts become negative in the sixth and seventh horizons. However, the impact dies out gradually. These results suggest that the lead prices of LME and China can affect each other.

The responses of zinc prices are plotted in Fig. 3. Given a positively initial impact of ZnL on ZnC, the responses of ZnC are positive and significant in the first and second horizon which reaches the highest in the second horizon, after that it decreases in the third horizon. However, in the forth horizon, the response slightly increases and then gradually dies out. The impact is negative in the seventh horizon and gradually dies out then. Additionally, given a positively initial impact of ZnC on ZnL, the impacts of ZnL on ZnC are weak but negative in the third and fifth horizons, then die out almost instantly. Figure 3 indicates that the zinc price of LME has a great influence on Chinese zinc price, however, the impact of Chinese zinc price on LME's zinc price is still very weak.

In summary, we draw the conclusion that the metals prices of LME have significant influence on Chinese metals prices, however, the impacts of Chinese metals prices on LME's are still weak except for lead. The finding suggests that although Chinese factors have become the main influencing factors in global commodity market, Chinese commodity's price still cannot guide the global commodity's price except for lead commodity market. In particular, Chinese zinc price has very weak impact on the global zinc price. Furthermore, the impacts of Chinese metals prices on LME's are all positive, which suggests that Chinese metals price change with LME's metals price change. Additionally, we also find that both Chinese market and LME market's responses to the market shocks last for seven to eight horizons, which indicate that it needs an adjustment period of seven to eight trading days when there has an impact of external price shocks on metal commodity prices.

3.2 DCC-GARCH model of co-movement between Chinese and global metals prices

Using DCC-GARCH model, this work studies the dynamic process of the co-movement between the metal prices of LME and China. The process is as follows. First, the parameter of univariate GARCH model is estimated, and the results are shown in Table 4. Second, the parameter of DCC-GARCH is estimated by the variance series calculated in the first step. The results are present in Table 5. Third, the dynamic correlation coefficient is estimated by model 4 and the parameter of DCC-GARCH model.

As can be seen from Table 5, all ARCH coefficients

Table 4 Results of parameter estimation of univariate GARCH model

Parameter	CuL	PbL	ZnL	CuC	PbC	ZnC
ω	$3.9\times10^{-8***}$ (3.3826)	$2.9\times10^{-7***}$ (4.382)	$2.6\times10^{-8**}$ (2.162)	$2.1\times10^{-8***}$ (5.831)	$4.6\times10^{-8***}$ (5.632)	$2.9\times10^{-8***}$ (6.734)
α	0.077^{***} (6.778)	0.312^{***} (20.879)	0.044^{***} (6.778)	0.115^{***} (12.183)	0.313^{***} (12.659)	0.130^{***} (12.655)
β	0.918^{***} (78.112)	0.693^{***} (57.873)	0.918^{***} (78.112)	0.882^{***} (100.93)	0.698^{***} (39.969)	0.869^{***} (118.75)
$\alpha+\beta$	0.995	1.004	0.962	0.997	1.011	0.999

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level, () is z-statistics

Table 5 Results of parameter estimation of DCC-GARCH model

Parameter	Cu	Pb	Zn
ω_L	0.003* (1.901)	0.004*** (4.840)	0.002 (1.588)
α_L	0.041** (2.205)	0.289*** (7.508)	0.040*** (3.246)
β_L	0.941*** (46.337)	0.646*** (20.707)	0.953*** (51.210)
$\alpha_L+\beta_L$	0.982	0.935	0.993
ω_C	0.004 (1.289)	0.005 (1.130)	0.005 (0.525)
α_C	0.155*** (106.079)	0.273*** (263.058)	0.131*** (82.186)
β_C	0.842*** (44.328)	0.685*** (22.322)	0.857*** (48.703)
$\alpha_C+\beta_C$	0.997	0.958	0.988
α_{DCC}	0.010*** (73.562)	0.002*** (21.388)	0.010*** (68.779)
β_{DCC}	0.981*** (328.758)	0.996*** (336.84)	0.977*** (240.790)
$\alpha_{DCC}+\beta_{DCC}$	0.991	0.998	0.987

* Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level; () is z-statistics

and GARCH coefficients are significant in 1% level. This shows that DCC-GARCH model can receive external information efficiently, and the impact from external information is highly persistent. When $\alpha+\beta<1$, all the DCC-GARCH models are mean back. In all DCC-GARCH models, the estimated parameter α is more less than β, which means that the price linkage has lags.

Figures 4−6 show the dynamic correlation coefficients between LME and Chinese nonferrous metals prices. There are some abnormal values in the volatility of dynamic correlation coefficient, which

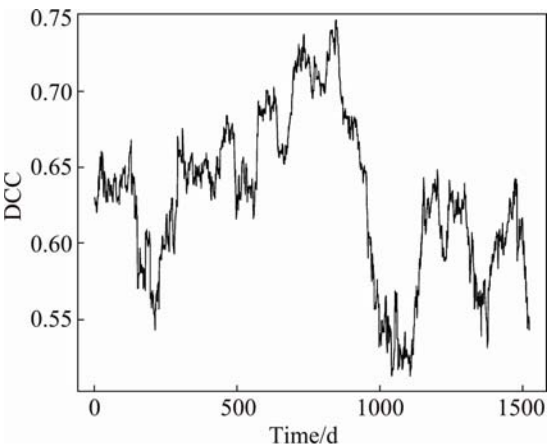

Fig. 4 Dynamic correlation coefficient of LME copper price and Chinese copper price

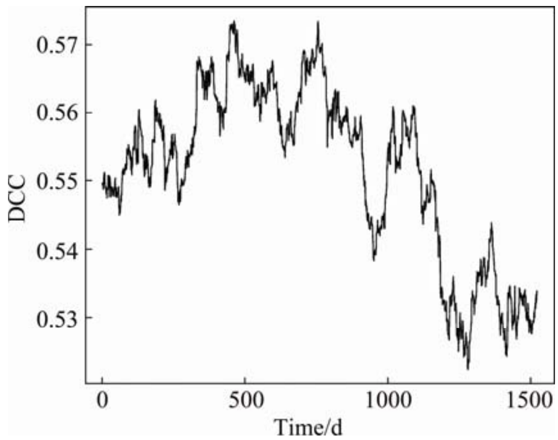

Fig. 5 Dynamic correlation coefficient of LME lead price and Chinese lead price

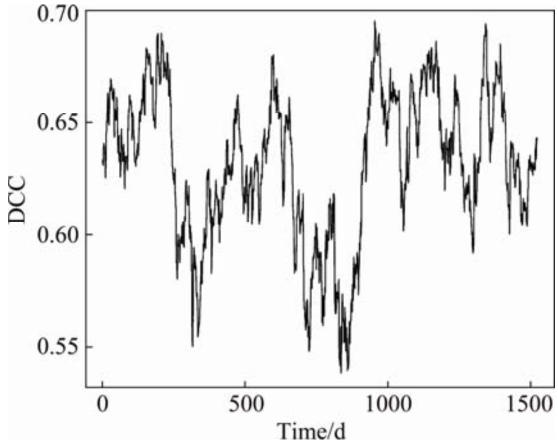

Fig. 6 Dynamic correlation coefficient of LME zinc price and Chinese zinc price

means that correlation volatility has volatility cluster. According to the volatility of dynamic correlation coefficient, we find that the co-movement between LME prices and Chinese prices is time-dependent nature, in which the change scope of zinc price’s dynamic correlation coefficient is minimum. Thus, the relationship between LME and Chinese zinc prices is the most stable, and the relationships between LME and Chinese copper prices and lead prices are not stable enough.

4 Conclusions

1) LME nonferrous metals prices still have a greater impact on Chinese nonferrous metals prices, however, the impact of Chinese nonferrous metals prices on LME nonferrous metals prices is still weak except for lead price.

2) Co-movement of copper prices, lead prices and zinc prices between LME and China is positive.

3) Co-movement of nonferrous metals prices

between LME and China presents hysteretic nature, and lasts for 7−8 trading days.

4) Co-movement between LME nonferrous metals prices and Chinese nonferrous metals prices has the characteristics of time-varying, and the correlation of lead price between LME and China is more stable than all other metal prices.

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基于 VAR-DCC-GARCH 模型的
国内外有色金属商品价格联动分析

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摘 要：运用 VAR-DCC-GARCH 模型，研究 LME 金属价格与中国金属价格间的联动效应及其动态相关性。结果表明：LME 金属价格依然对中国金属价格有着较大的影响，而中国除了铅价外，其余金属价格对 LME 金属价格的影响还很微弱；中国铜、铅、锌价格与 LME 价格间均存在正向的联动性；LME 金属价格与中国金属价格之间的联动性在反应时间上存在滞后性，滞后期在 7 到 8 个交易日左右；LME 金属价格和中国金属价格间的互动影响关系存在时变性，其中，LME 铅价与中国铅价间的相互关联最稳定。

关键词：价格联系；有色金属商品价格；中国金属商品市场；伦敦金属交易所；联动性；VAR 模型；DCC-GARCH 模型

(Edited by Yun-bin HE)