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Cross-correlations between spot and futures markets of nonferrous metals

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HIGHLIGHTS

- Cross-correlations between nonferrous metal spot and futures markets are investigated.
- Return cross-correlations are significant for longer lag lengths.
- Volatility cross-correlations are highly significant for all lag lengths.
- DCCA-based Cross-correlation coefficients are very high and decrease with the futures maturity increases.
- Volatility spillover contributes major to cross-correlations and mean spillover contributes very minor.

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ABSTRACT

In this paper, we investigate cross-correlations between nonferrous metal spot and futures markets using detrended cross-correlation analysis (DCCA). We find the existence of significant cross-correlations for both return and volatility series. The DCCA-based cross-correlation coefficients are very high and decrease with the futures maturity increases. Using the multifractal extension of DCCA, the multifractality in cross-correlations is revealed. We also detect the source of cross-correlations between spot and futures markets. We use the vector error correction model and bivariate BEKK–GARCH to model the interactions between returns and volatilities of spot and futures, respectively. Our findings indicate that the volatility spillover between spot and futures markets contributes major to nonlinear cross-correlation while the contribution of mean spillover is very minor.

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1. Introduction

Since the seminal work of Podobnik and Stanley [1], cross-correlation in financial markets has been investigated in a vast number of recent studies based on their proposed detrended cross-correlation analysis (DCCA). The reason is that long-range cross-correlations are related to multivariate fractional Gaussian noise [2–4] which is more realistic than the classical assumption of multivariate Gaussian distribution in financial modeling. For example, Podobnik et al. [5] investigate the cross-correlations between price changes and volume changes of Standard Poor's (S&P) 500 index over the period of about 60 years and the persistent cross-correlations are revealed. Sequeira Jr. et al. [6] find that cross-correlations in Brazilian stock and commodity markets are stronger than what would be expected from the simple combinations of auto-correlations in individual series. Wang et al. [7] analyze cross-correlations between Chinese A-share and B-share markets. They find significant cross-correlations between both returns and volatilities of two stock markets. The return cross-correlations gradually became weaker and weaker over time but the volatility cross-correlations are still very high. More recently, He

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and Chen [8] use DCCA to analyze price–volume cross-correlations in Chinese commodity markets. Wang et al. [9] employ DCCA and its multifractal extension [10] to investigate cross-correlations in West Texas Intermediate crude oil markets. Wang et al. [11] study price–volume relationships in CSI300 market. Additionally, DCCA method is also used to detect cross-correlations between stock and exchange rate markets [12,13], cross-correlations in world agricultural futures markets [14], cross-correlations in international exchange rate markets [15] and those in international stock markets [16].

The DCCA method is also extended in several perspectives. For example, Horvatic et al. [17] propose a new technique of DCCA with time-varying order of polynomial and use it to quantify power-law cross-correlations between different simultaneously recorded time series in the presence of highly non-stationary sinusoidal and polynomial overlying trends. One of the most important brands of DCCA extensions is the multifractal form of it. Zhou [10] proposes a multifractal DCCA in analogy to MF-DFA [18] to investigate the multifractality in cross-correlations. Jiang et al. [19] introduce a multifractal cross-correlation detrending moving average analysis (MF-X-DMA). As DCCA removes the local trend using polynomial fitting, MF-X-DMA is based on the algorithm of DMA [20–23] which removes the local trend in time series by subtracting the local means. Additionally, Kristoufek proposes the multifractal height cross-correlation to investigate the multifractal cross-correlations [24].

In this paper, we will study cross-correlations between spot and futures markets of nonferrous metals. Our contributions to this literature are three-folds. First, very few existing studies focus on the cross-correlation between commodity spot and futures markets except for the notable works of Wang et al. [9] and Liu and Wan [25]. Furthermore, previous researches do not pay attention to nonferrous metal market. We will fill this gap by analyzing cross-correlations between returns and volatilities of nonferrous metal spot and futures using DCCA. Second, we investigate futures with different contracts. Because the resolution of uncertainty or the information flow into the underlying market is greater as the delivery date approaches [26], futures prices are always less volatile as the maturity increases according to the "Samuelson effect" [27–29]. Thus, we can expect that the cross-correlations between prices of spot and futures with different maturities are not consistent. However, existing studies do not show any evidence about this time-to-maturity effect. Third, we detect what is the source of cross-correlation in nonferrous commodity markets. We consider two possible sources of cross-correlation which is widely existed between the commodity spot and futures markets, named "mean spillover" and "volatility spillover" [30–33]. The source of multifractal auto-correlations has been widely investigated in existing studies [34–40]. However, the source of cross-correlations has not been studied in the area of econophysics. To the best of our knowledge, this is the first time that the origins of cross-correlations in financial markets are investigated.

Our main findings can be summarized as follows: first, using a statistical test proposed by Podobnik et al. [41], we find that the cross-correlations between spot and futures returns are significant at 10% level for larger lag lengths and the cross-correlations between their volatilities are highly significant for all the lag lengths. Second, based on DCCA, we find that spot and futures price returns of two commodities (aluminum and copper) are persistently cross-correlated while cross-correlations between spot and futures volatilities of all commodities are highly persistent. The cross-correlation coefficients of returns and volatilities are always larger than 0.8 implying the strong correlated behavior. Furthermore, the cross-correlations become weaker with the futures maturity increases. Third, we use vector autoregressive model (VECM) and BEKK–GARCH to model "mean spillover" and "volatility spillover", respectively. Then, we compare the cross-correlations of model filtered residuals and those of the original returns. Our evidence indicates that VECM-filtered residuals are still highly cross-correlated whereas after BEKK filtering, the cross-correlations become much lower. That is, the major source of cross-correlations between nonferrous metal spot and futures markets is volatility spillover while the mean spillover contributes very minor. Finally, we use the multifractal extension of DCCA and find that the cross-correlations of returns and volatilities are both multifractal, further reinforcing the findings in the literature.

The remainder of this paper is organized as follows: Section 2 describes the methodology of DCCA. Section 3 presents the data description. Section 4 shows the main empirical results, including the findings about cross-correlation test, DCCA analysis, the detection of the source of cross-correlation and the multifractal analysis. The last section concludes the paper.

2. Methodology

In earlier years, cross-correlation function was always used to analyze the dynamics of natural system. However, this method can be only applied to the stationary time series. As an important stylized fact, financial time series are always long-range auto-correlated and nonstationary, and have strong trends. Researchers always need to remove the possible trend which is widely existed in financial time series. The detrended cross-correlation analysis (DCCA) proposed by Podobnik and Stanley [1] can well solve these problems and is a robust method of detecting cross-correlations between two time series. This is also an outstanding advantage of DCCA over conventional methods such as random matrix [42,43]. DCCA method can be described as follows:

Step 1: consider the spot and futures return series used in this paper, $\{x_t, t = 1, \ldots, N\}$ and $\{y_t, t = 1, \ldots, N\}$, where N is the equal length of these two series. Then, we describe the "profile" of each series and get two new series, $xx_k = \sum_{t=1}^{k}(x_t - \bar{x})$ and $yy_k = \sum_{t=1}^{k}(y_t - \bar{y})$, $k = 1, \ldots, N$.

Step 2: divide the both profiles $\{xx_k\}$ and $\{yy_k\}$ into $N_s = \mathrm{int}(N/s)$ nonoverlapping segments of equal length s. Since the length N of the series is often not a multiple of the considered time scale s, a short part at the end of each profile may

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