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A study of correlations between crude oil spot and futures markets: A rolling sample test

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ABSTRACT

In this article, we investigate the asymmetries of exceedance correlations and cross-correlations between West Texas Intermediate (WTI) spot and futures markets. First, employing the test statistic proposed by Hong et al. [Asymmetries in stock returns: statistical tests and economic evaluation, Review of Financial Studies 20 (2007) 1547–1581], we find that the exceedance correlations were overall symmetric. However, the results from rolling windows show that some occasional events could induce the significant asymmetries of the exceedance correlations. Second, employing the test statistic proposed by Podobnik et al. [Quantifying cross-correlations using local and global detrending approaches, European Physics Journal B 71 (2009) 243–250], we find that the cross-correlations were significant even for large lagged orders. Using the detrended cross-correlation analysis proposed by Podobnik and Stanley [Detrended cross-correlation analysis: a new method for analyzing two nonstationary time series, Physics Review Letters 100 (2008) 084102], we find that the cross-correlations were weakly persistent and were stronger between spot and futures contract with larger maturity. Our results from rolling sample test also show the apparent effects of the exogenous events. Additionally, we have some relevant discussions on the obtained evidence.

1. Introduction

The futures markets have two important functions. The first one is to hedge and reduce the potential risk for investors and practitioners. The other is the mechanism of price discovery. These two functions are based on the theory that the futures prices can reflect the expectation of investors which is one of the important determinants of price mechanism. Theoretically, the futures prices are equal to the spot prices in the future. However, it is always not consistent with the reality because of the transaction cost and market noise. Thus, it is worth having an examination of correlations between spot and futures markets. Especially, for crude oil markets, the relationship between spot and futures market has been investigated extensively. For example, Quan [1], Schwarz and Szakmary [2], and Gulen [3] detected the correlations between oil spot and futures markets using the methods of cointegration proposed by Engle and Granger [4] and Johansen [5]. However, the above cointegration methods do not consider the shock on the correlations caused by the structural break and do not imply that the cointegrating vectors have the property of time invariance. Similar studies can also be found in Serletis and Banack [6], Cologni and Manera [7], and Chen and Lin [8]. As argued in Bekiros and Diks [9], the recent empirical evidence on the relationship between spot and futures markets is invariably based on the Granger test [10]. Although it requires the linearity assumption, this approach is appealing. In fact, the nonlinear structure has been a "stylized fact" in financial

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markets. For this consideration, Bekiros and Diks [9] investigated the linear and nonlinear causal linkages between daily spot and futures prices for maturities of one, two, three and four months of WTI crude oil. Besides the conventional Granger test, Bekiros and Diks [9] detected the nonlinear causal relationship not only between raw data series using a nonparametric test for nonlinear causality, but also between VECM and GARCH-BEKK residual series. Their results showed that WTI crude oil spot and futures markets displayed asymmetric GARCH effects and/or statistically significant higher order conditional moments. Huang et al. [11] investigated the dynamics of a nonlinear relationship between crude oil spot and futures prices and found that the nonlinear model was clearly superior to that of the linear model. Different from previous works, in this paper, we investigate the relationships between crude oil spot and futures markets in the perspective of cross-correlation and exceedance correlation.

As the presence of auto-correlations in crude oil markets which has been extensively investigated in the existing literature [12–18] implies the predictability and market inefficiency, the cross-correlations also have some implications and have been studied in some of the previous works [19–32]. First, it implies that the predictability of spot (futures) prices can be improved based on the analysis of the history data of futures (spot) prices. Second, it also implies the market inefficiency because under the efficient market hypothesis, the dynamics of prices are dominated by randomness and cannot be predicted technically.

Motivated by the fact that many physical and financial systems display power-law correlations together with an asymmetry in the probability distribution [33][1], we investigate the exceedance correlations between crude oil spot and futures returns, asymmetry property between upside moves and downside moves in financial markets [34–36]. Obviously, the presence of asymmetric correlations can cause problems in hedging effectiveness. Then, if all of the other assets tend to fall together as one kind of asset falls, the traditional investment theory which suggests the diversification in optimal portfolio allocation is also questionable.

As far as we know, there are very few investigations on the exceedance correlations or cross-correlations between crude oil spot and futures prices. The only exception is the work of Wang et al. [37]. Their results indicates that the spot and futures prices and volatilities are long-range cross-correlated. However, Wang et al. [37] study cross-correlations between crude oil spot price series and 1 month futures price series only, not between spot price and futures prices with other maturities. Moreover, Wang et al. [37] only analyze the cross-correlations between two whole series. Their overall analysis cannot show the evolutions of correlations over time. Third, Wang et al. [37] do not analyze the asymmetry property of correlations between upside moves and downside moves.

Comparing to the work in Wang et al. [37], our contributions are as follows: (1) We investigate the exceedance correlations between WTI crude oil spot and four futures price series and test for the asymmetries using the method proposed by Hong et al. [36]. (2) *Qualitatively*, we investigate the cross-correlations using the statistic introduced by Podobnik et al. [21]. *Quantitatively*, we also study the cross-correlations using the detrended cross-correlation analysis proposed by Podobnik and Stanley [19]. (3) Employing the rolling sample test, we study the evolution of local asymmetric correlations and cross-correlations, and find the apparent influence of some exogenous events on the two kinds of correlations. Some economic implications of our results are also discussed.

This paper is organized as follows: the next section provides the methodology description. We show the data description and preliminary analysis in Section 3. We get the empirical results in Section 4 and some relevant discussions in Section 5. Then, we conclude the article in the last section.

2. Methodology

2.1. Asymmetries of exceedance correlations

Following Longin and Solnik [34], Ang and Chen [35] and Hong et al. [36], we consider the exceedance between two series. The correlation at exceedance level c is defined as the correlation between two variables when both of them exceed c standard deviations away from their means, respectively,

$$\rho^{+}(c) = corr(R_{1t}, R_{2t} | R_{1t} > c, R_{2t} > c), \tag{1}$$

$$\rho^{-}(c) = corr(R_{1t}, R_{2t} | R_{1t} < -c, R_{2t} < -c), \tag{2}$$

where, following Ang and Chen [35] and Hong et al. [36], the returns are always standardized to be zero mean and unity variance. The null hypothesis of symmetric correlations is

$$H_0 : \rho^{+}(c) = \rho^{-}(c), \quad \text{for all } c \geq 0. \tag{3}$$

If the null hypothesis is rejected, there must be the asymmetric correlations. The alternative hypothesis is

$$H_1 : \rho^{+}(c) \neq \rho^{-}(c), \quad \text{for some } c \geq 0. \tag{4}$$

[1] In Ref. [33], a stochastic process was proposed that can model both properties.