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Do oil spot and futures prices move together?

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ABSTRACT

This paper investigates the time-varying correlation and the causal relationship between crude oil spot and futures prices using a newly developed approach — wavelet coherency analysis in time–frequency domain. First, we find evidence of a long-run cointegration relationship between oil spot and futures prices. Moreover, the short-run causality is more significant in shorter maturity pairs versus longer maturity pairs in the vector error correction framework. Second, the results from wavelet coherency analysis show significant dynamic correlations between variables in the time–frequency domain. Third, the illustration of the phase-difference series around zero suggests that spot and futures prices contribute to the dynamics of the long-run equilibrium. Fourth and finally, we provide reasons for the structural changes in oil prices and also recommend investment strategies corresponding to risk diversification. Future studies focusing on the behavior of oil prices should consider the characteristics of the time–frequency space and lead–lag dynamic relationships.

1. Introduction

The relationship between crude oil spot and futures prices has attracted substantial attention within the energy economics literature in the past several decades. There are two objectives for investigating this issue: one is the price discovery mechanism in oil spot and futures markets (Yousefi et al., 2005), and the other is an investigation of oil markets' efficiency, especially examining the spread between spot and futures prices (Bekiros and Diks, 2008; Lee and Zeng, 2011). Similarly, in order to study the long-run cointegration relationship between spot and futures prices, the literature has extensively evaluated these issues using two approaches: a simple (linear) cointegration analysis (see, for example, Bekiros and Diks, 2008; Quan, 1992) and advanced investigations, such as threshold models (see, for example, Mamatzakis and Remoundos, 2011).[1] Zakaria and Shamsuddin (2012) note that, while spot and futures prices are cointegrated, there does exist a long-run relationship between the two, and the direction of their causality can be determined using causality tests.

While early studies have focused on oil spot and futures prices, they rarely allow for bidirectional causality or cointegration tests (see, for example, Silvapulle and Moosa, 1999; Wang and Wu, 2013; Westgaard et al., 2011; Zakaria and Shamsuddin, 2012). Some recent studies, such as Noguera (2013) and Chen et al. (2014), consider structural changes in the empirical analysis. However, while these studies have addressed the issues from the viewpoints of linearity versus nonlinearity, symmetry versus asymmetry, or cointegration versus causality, the current evidence is less clear since these studies have been conducted strictly in the time-domain. They are therefore uninformative about the frequencies with respect to the relationship between oil spot and futures prices.

The reason why researchers should consider the frequency domain is because clearer evidence can be offered. For example, using Morgan Stanley Capital International (MSCI) Index for the World, Naccache (2011) indicates that the relationships among oil price and macroeconomic variables may exist at different frequencies: oil prices may act like a supply shock at high and medium frequencies, and the relative short-run relation can affect industrial production, whereas in the long run (i.e., at the lower frequencies), industrial production affects oil prices. For this reason, Aguiar-Conraria and Soares (2011) address similar issue of oil prices and macroeconomic variables for the U.S. economy by utilizing the wavelet coherency of continuous wavelet approach. Putting all such information together, this may be the

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[1] Briefly, the existence of cointegrating relationships among spot and futures prices prevents the distance between the two from increasing (Kawamoto and Hamori, 2011).

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plausible explanation for why Tiwari (2013) argues that the techniques employed by Aguiar-Conraria and Soares (2011) are relatively superior than those studies using traditional time-domain methods; hence, since the relationships between oil prices and macroeconomic variables may exist at different frequencies, the problem of "frequency-varying" cannot be avoided when investigating the behavior of oil prices.

This paper utilizes a novel wavelet analysis technique to explore the relationship between West Texas Intermediate (WTI) oil spot and the New York Mercantile Exchange (NYMEX) futures prices in the time and frequency domains. Wavelet analysis possesses more significant advantages than the conventional time-domain methods. It expands the underlying time series into a time–frequency space whereby researches can visualize both time- and frequency-varying information of the series in a highly intuitive way. Wavelet coherency assesses how the comovement between spot and futures prices varies across various frequencies, and phase analysis is a non-linear technique that allows us to study the synchronization and delays between two time series across different frequencies. In this way, we can observe high-frequency (short-term) and low-frequency (long-term) relationships between the crude oil prices as well as possible structural changes and time-variations. This methodology therefore enables us to analyze the spot–futures relation in energy markets from a new perspective.

Ignoring the non-linearity problem of energy prices may invalidate any empirical results to be wrongly accepted (Beckmann et al., 2014). This is the main reason why the non-linearity of oil prices has been accounted in recent empirical literature through conventional time-domain methods, such as the threshold autoregressive estimation (Mamatzakis and Remoundos, 2011), the neural networks approach (Ghaffari and Zare, 2009), and the Markov switching model (Janczura and Weron, 2010). However, fully understanding the price dynamics has become a fundamental concern, because energy commodity prices commonly tend to have more extreme statistical properties that combine both time- and frequency-varying features than the prices of other financial assets (Vacha and Barunik, 2012).

Wavelet analysis simultaneously considers such relationships using time- and frequency-varying features that provide important practical implications for energy commodity management. Chang et al. (2013) propose that time-varying comovement presents investment strategies to investors in how to take the actions of risk exposure and diversification benefits of commodities over time. Frequency-varying comovement suggests that investors can more effectively consider the comovement formed by a combination of different investment horizons at different frequencies (Vacha and Barunik, 2012). The time- and frequency-varying features in a causality also significantly affect the accuracy of price prediction and the decision-making process. Clearly, traditional non-linear econometric methods do not explore the frequency-variation of relationships since they generally consider the frequency and time components separately.

A simple example may help bring home why it is important to use wavelet coherence in measuring the association in the time–frequency domain, rather than simply using the frequency or the time domains separately. Rua and Nunes (2009) adopt such a technique to analyze stock markets' comovement and to study the distinction between short-term and long-term investors, in which a higher strength of the comovements of stock returns at lower frequencies suggests greater benefits from international diversification in the short term, in comparison to the long term (Aguiar-Conraria et al., 2012). This encourages us to use wavelet coherence to investigate the relationship between oil spot and futures prices with different maturities. In general, short-term investors, such as arbitragers or speculators, are more concerned about the comovement of crude oil spot prices, aiming at higher frequency data (variation) and short-term futures contracts; contrarily, long-term investors (e.g., oil producers or policymakers) mostly focus on the comovement of crude oil futures prices, targeting at lower frequency data and longer-term futures contracts. We believe that the analysis herein can bring differentiated investment strategies for those investors.

Aguiar-Conraria et al. (2012) point out that the characteristic of a wavelet approach is advantageous to quantify the degree of different time series in the dynamic time–frequency domain, and it measures the comovement of two time series under the consideration of time and frequency simultaneously. More importantly, wavelet analysis enables us to detect multi-scale relationships between variables, in contrast to the traditional methodologies that only distinguish two time scales (i.e., short-run and long-run scales). This technique not only demonstrates the relationships between high-frequency (i.e., short-term fluctuations) and low-frequency (i.e., long-term fluctuations) series, but also illustrates possible time-variations in such relationships (Rua, 2010).[2] Vacha and Barunik (2012) adopt it to analyze the dynamic correlations among prices of crude oil, gasoline, heating oil, and natural gas.[3] The technique's main advantage is the ability to decompose the time-varying comovements into different investment horizons; one can thus provide beneficial investment strategies to various investors with different investment horizons (Graham et al., 2012).

Vacha and Barunik (2012) discover that the dynamic properties of energy commodities have become important to financial analysis. It may be especially interesting to observe how the correlations adjust with time, once the time span of samples is very long. Moreover, it may be helpful for assessing whether the dependencies vary across different frequencies in oil spot and futures prices. We can utilize any additional information in the decision-making process, no matter for shorter or longer investment horizons. Therefore, the wavelet coherence approach is a suitable tool that allows researchers to study the dependence in the time and frequency domains.

Our empirical procedure initially tests the spot and futures price series for unit roots and cointegration; given the presence of cointegration, the series are filtered through an appropriate vector error correction (VEC) model in sequential steps; and we can then discover the short-run and long-run causalities between oil spot and futures prices. Next, we employ wavelet coherency analysis to review the dynamic comovement between crude oil spot and futures prices, with the phase-difference technique therefore deriving the time-varying leads-and-lags, the casual relationships, and the positive/negative correlations between the two-pattern time series. Using these techniques, we provide suitable investment strategies in accordance with our findings.

Given that "cointegration" implies "comovement", wavelet coherence is interpreted as the degree of comovement that varies over time and is combined with providing the degree of comovement between the series over a sample period (Rua, 2010). Compared with Vacha and Barunik (2012), who focus on general wavelet coherence, this paper distinguishes the role of the price discovery mechanism for oil spot and futures prices when the wavelet model we utilize is representative of the standard methods of time-varying comovement. We contribute to the issue of oil markets' comovement by studying the dynamics of spot and futures prices in the time–frequency domain with four different maturity contracts. More specifically, the main question of our analysis is whether such comovement changes significantly when one considers the changes in terms of data frequency, the length of maturity, and short-run and long-run causalities in empirical models.

The remainder of this paper is organized as follows. Section 2 briefly reviews the recent literature discussing the relationship between spot and futures prices for different energy commodities, especially crude oil. Section 3 illustrates the adopted methodological framework. Section 4 presents our empirical results. Section 5 concludes and

[2] According to Ozdemir et al. (2013), while plotting the time series of Brent crude oil spot and futures prices, several structural breaks are found in the series. They thus suggest that the probable structural breaks have to be incorporated into the analysis to capture the properties of the time series.

[3] There are also several published papers in the nexus between energy commodities and wavelet analysis: Davidson et al. (1997) study commodity price behavior; Yousefi et al. (2005) look at the prediction of oil prices; Connor and Rossiter (2005) estimate the price correlations of commodity markets; and Naccache (2011) analyzes the dynamic correlation analysis of oil prices and economic activity.