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The global interdependence among oil-equity nexuses

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ABSTRACT

We propose a global network model to investigate the interdependence among the oil-equity nexuses from different countries in various time horizons based on wavelet coherence and gray correlation. The stock indexes from 28 countries and crude oil prices of WTI (West Texas Intermediate price) and Brent are the sample. We obtain the following primary results: Oil-equity nexuses throughout the world are well-integrated across time scales; Ireland, the Netherlands, Norway, Singapore, Demark, Germany and the Czech Republic for Brent-stock nexuses and Ireland, the Netherlands, Netherlands, Singapore, Japan, Germany and Malaysia for WTI-stock nexuses, successively corresponding to the frequency bands of 4 days–256 days, can be treated as a benchmark and can spread their fluctuations to other nexuses easily and rapidly. By contrast, China is more isolated in most time horizons and could be the ideal risk-hedging choice. Next, the global interdependence among oil-stock nexuses is characterized by the clustering effect, by which geographical factors and the oil production-consumption profile can exert their influence in most time horizons. In contrast, the speculation deals as well as energy policy and stagey are primarily influential in certain frequency bands. Thus, the decision-making for different time horizons could consider corresponding references.

1. Introduction

Crude oil, as a crucial raw material and fuel, drives the world's economies, and the stock market immediately and sensitively reflects changes in the economy. Due to the various economical and energy production-consumption structures, the effects of the oil price on the stock markets differ across countries. There is strong and sufficient evidence that the relationships between the oil price and stock markets could be positive [1,2], negative [1,3–7] or insignificant [2,8–12]; recently, a strand of studies also found that the oil-stock nexuses are changeable in terms of time, frequency or other nonlinear factors [13–18]. Furthermore, the integration within global crude oil [19–22] and stock markets [23–25] is becoming increasingly closer, thereby strengthening the interactions among the heterogeneous or homogenous oil-stock linkages in different countries, which complicates the overall energy and the asset markets interdependence. Therefore, exploring the interactions among the relations of the oil price and stock markets from different countries in a dynamic and compressive manner could be helpful to understand the fluctuations and interactions of energy and stock markets.

The research of previous research on oil-equity nexuses show the diversity of effects of the oil price on the stock markets, as mentioned above. However, such studies primarily choose bivariate models to explore the oil-stock nexuses of specific countries, and they lack a quantitative assessment of the dynamic interactions among the oil-stock nexuses. Meanwhile, most studies that focus on the integration of the global energy and stock markets explore this issue through separating the oil price and stock markets individually. Studying oil markets, Ji and Fan verify the integration of the international oil prices with a geographical and organizational structure [26]; Fattouh shows that the oil price market behaves as a great pool but is not always fully integrated [27], and other

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empirical works also contribute to this point of view [22,28,29]. For the stock markets, Forbes and Rigobon argue for the interdependence of stock markets throughout their entire data sample [23]. Horvath and Petrovski examine the co-movement among stock markets in the European area [25]. Obviously, studies on the interaction between the oil price and the stock market sample only certain countries, while the integration research on oil and stock markets separate these two markets. There is scarce literature that considers the interdependence among the oil-equity nexuses from a global point of view. For a more proper and comprehensive understanding, considering the oil-equity nexuses from different countries interacting with each other in multiple variable frameworks could offer a picture distinguished from the previous research. Concerning the multivariate issue, the network analysis offers an effective tool that simulates a complex system as a network of nodes and edges. Recent research shows that a network analysis could characterize the commodity and financial markets through identifying their structure features [26,33].

Moreover, there is another significant issue that should be addressed. The diversity and complexity of the oil-equity nexuses may be caused by multiscale information [15,30,31,34]. More specifically, there are a variety of stakeholders in the oil and stock markets with objects from different time horizons, and all of these factors work together to make the entire market more complex [13,35–37]. The oil-equity nexuses are shown to change as the time scale changes [7,38]. Hence, exploring the interdependence among the oil-equity nexuses in a multiscale perspective could offer explicit observations that are helpful not only for policy-making but also for portfolio designing. Wavelets could effectively solve the multiscale problem in the financial research [13,39]. The main idea of such research is to use different resolutions to observe the original time series and to track the details with a trend of a given time series in the time and frequency domains simultaneously [40,41].

Therefore, to explore the interdependence among oil-equity nexuses from a multivariate and multiscale perspective, we integrate the wavelet coherence with the gray correlation and network analyses. First, we implement the wavelet coherence to different oil price and stock index pairs to attain a multiscale correlation, which can track the correlation between given variables with the changes in time and frequency. Then, the gray correlation is conducted to detect the interdependence of oil-equity correlations for different time scales. Taking the oil-equity nexuses as nodes and the gray correlation between two oil-equity nexuses as edges, we can construct a global interdependence network for the oil-equity nexuses from different countries for various time scales and characterize these interdependence networks though structure analyses.

2. Methodology

2.1. Research framework

To understand the interdependence among oil-equity coherence of different counties across multiple time horizons, we propose a research combining the wavelet coherence, gray correlation and networks analyses. The procedures are described in Fig. 1 and each step, especially the componential figures, will be associated with more detail in following sections.

First, we implement the wavelet coherence to each stock index and oil price. The wavelet coherence extends the traditional correlation into the joint time-frequency, which enables us to observe the correlation between two given time series with the changes of time and frequencies ((a) and (b) in Fig. 1). Second, we discretize the continuous frequency band of the wavelet results and choose seven main bands to characterize the entire one (Fig. 1(c)).

Third, we construct a global interdependence model for the oil-equity correlations based on the gray correlations evaluate the similarity among these correlations. Specifically, calculating the integrated gray correlation coefficients of pairwise oil-equity coherences for each frequency band; thus, we obtain seven gray correlation matrixes for main frequency bands (Fig. 1 (d), one of the gray correlation coefficients matrixes could be seen in Appendix due to its big size). Then, in each frequency band, oil-equity coherence for each country could be considered as one agent, and the gray correlation coefficients are used to determine whether there is the interdependence between the agents. Hence, we transform the gray correlation matrix into the global interdependence network of the oil-equity coherence (Fig. 1(e)).

2.2. Wavelet coherence

2.2.1. Continuous wavelet transform

Wavelet coherence is capable of tracking the nonlinear correlation between two time series in the joint time-frequency domain and is based on the continuous wavelet transform [41–43]. A wavelet is a small wave with real-value and zero mean as well as could be represented as a square integrable function of time and frequency. We use two parameters, location (u) and scale (s) to illustrate the time and frequency information. The location parameters decide the position of the wavelet in time through its shift, whereas the scale parameter u is used to stretch or dilate the wavelet to localize different frequencies. Therefore, with the location and scale parameters, the original time series could be observed in time and frequency simultaneously and the wavelet could be defined as following,

$$\psi_{u,s} = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right) \tag{1}$$

The wavelet has good time resolution in high-frequency domain and fine scale resolution in low-frequency domain. Hence, there is always a trade-off between the localization of the time and scale. For the features' extraction purpose, the Morlet wavelet with ω_0=6 (Equation (2)) is a suitable choice because it provides a suitable balance between time and frequency localizations [44].

$$\psi_0(\eta) = \pi^{-\frac{1}{4}}e^{iw_0\eta}e^{-\frac{1}{2}\eta^2} \tag{2}$$

When project an original time series to a certain wavelet function with specific location and scale parameters, we attain the continuous wavelet transform of given time series, which could be represented as the following equation,

$$W_X(u,s) = \int_{-\infty}^{\infty} \frac{1}{\sqrt{s}}\overline{\psi\left(\frac{t-u}{s}\right)}dt \tag{3}$$

Based on the continuous wavelet transform, we obtain the wavelet power of given time series by the square of the amplitude $|W_X|^2$, which indicates that the energy distribution of different frequency components of the original time series evolves in time, with a large variance corresponding to a large power.

2.2.2. Wavelet coherence

The wavelet coherence combines the linear correlation with the cross spectrum technology and distinguishes itself by demonstrating the correlation of two time series in the joint time-frequency domain. The calculation of the wavelet coherence is