Co-movement of coherence between oil prices and the stock market from the joint time-frequency perspective

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HIGHLIGHTS

- The co-movement of oil-stock nexuses' coherence is investigated.
- A multivariate research framework is established involving time and frequency information.
- The coherence of oil-stock nexuses is tremendously different in short time scale.
- Coherence of Brent-stock and OPEC-stock has low correlation during 80% of the sample period.
- Investment in oil prices of Brent and OPEC as well as Chinese stock market could reduce the risk.

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ABSTRACT

Interactions between oil prices and the stock market are complex both in the time and frequency domain. Unlike previous studies mainly focus on the dynamic correlation of specific oil-stock nexus with bivariate model; we explore the co-movement among coherence of oil-stock nexuses from a multivariate perspective with an integrated research framework composed by the wavelet coherence and the complex network. Multiple oil prices of Brent, Dubai, Minas and OPEC (Organization of the Petroleum Exporting Countries) as well as Shanghai Composite index are chosen as data sample. In term of the frequency, coherence of multiple oil prices with the stock market measured via the wavelet coherence is tremendously different in the short time scale, even though integral trends of multiple oil prices in the holistic time domain are highly similar, which means that the multiple oil portfolio could reduce the risk in the short term. Concerning changes over the time, co-movement matrix is defined to reflect that coherence of multiple oil-stock nexuses move in different or similar manner at each time point. We find that the coherence of the stock market with Brent and OPEC move diversely during 80% of the sample period, which indicates that portfolio involving Brent, OPEC and Chinese stock index could improve the diversification. Co-movement matrixes with high betweenness centrality could be considered as clues of unusual market fluctuations. This study offers more information for investors focusing on hedging strategies when investing in Chinese stock market and international crude oil markets.

1. Introduction

Crude oil is reputed as the driver of the modern industrial development and could exert extraordinary influences on the real economy and financial markets. Comparing to the significant negative effect of the crude oil price on the real economy [1,2], the effect of the oil price on the stock market is still far away from reaching a consensus among economists. According to the results, existing studies could be categorized into three kinds. First, some studies find insignificant linkage between the oil price and the stock market [3–5]. On contrary, a thread of literature supports that there is significant positive effect of the oil price on the stock market [6–9]. In addition, some literature shows that the oil price could exert negative influence on the stock market [10–12].

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All above literature explores the interaction between the oil price and stock markets in the holistic time scale with linear or nonlinear models. However, the interaction between the oil price and stock market may behave differently within various time scales [13]. Practically, both in oil markets and stock markets, there are multiple stakeholders who activate with different objectives rooting in different time horizons [14,15]. Such as, policy-makers focus on the long-term equilibrium [16], while speculators tend to trade in short term. Therefore, the oil market and the stock market as well as their interactions could be different in various time scales. Theoretically, the oil price could influence the stock market through three channels. One is information transmission between efficiency finance markets [17,18]; the future cash flow of listed firms and the cash flow discounted factors, such as interest rate and monetary policy [19]. And different channels are related with different time horizons. Therefore, the linkages between oil prices and stock markets may vary according to time scale [20,21], which is supported by empirical studies [22,23]. Moreover, the interaction between the oil price and the stock market is not only full of changes across time scales, but also varies over time [24]. With the wavelet based research framework, dynamic interaction of oil-stock nexus is uncovered. Reboredo et al. find that the coherence between the oil price and renewable energy stock indices varies over time and across frequencies [25]. Jammazi finds that the holistic correlations between Brent/WTI oil prices and stock indices from developed countries are various in different time scales [26]. Then Jammazi et al. extend the examination of oil-stock nexuses into a time varying perspective involving frequency information [27]. Cai et al. offer evidence show that correlations between the oil price and East Asian stock markets change with respect to time and frequency [28].

However, existing studies mainly focus on the correlations between the oil price and the stock market based on a bivariate framework and ignore the co-movement of correlations of multiple oil-stock nexuses. Why is the co-movement of oil-stock nexuses' correlations important? For example, China is the biggest oil importer in the world since 2015 following by U.S. And the oil product prices are setting by three major crude oil prices from the global oil market, which means that the economy and the stock market in China are very sensitive to multiple oil markets. Understanding how correlation of multiple oil-stock nexuses co-move over time and across time scales could be helpful for the policy-maker to understand influences of international oil markets on China's economy. For investors, such co-movements could be useful to find time and frequency reference for portfolio management.

How could we explore the co-movement of multiple oil-stock nexuses' correlations with consideration of the time and frequency (time scale) information simultaneously? The first issue is to fully identify coherence between multiple oil prices and the stock market in the time and frequency domain. We implement the wavelet transform, especially wavelet coherence, to explore the coherence between the oil price and the stock index in joint time-frequency domain. Wavelet coherence extends the traditional correlation conception in both time and frequency perspectives and offers us sufficient information to identify the differences hidden among time scales and over time [29,30]. Then for each time point, we could obtain a sequence of coherence values rather than one single value for a pairwise oil-stock nexus from the wavelet coherence results. We define the co-movement matrix through comparing the coherence sequences at each time point for difference oil-stock nexuses, to reflect whether or not the coherence among oil-stock nexuses move in the same manner. Then explore the evolution of co-movement matrixes over time quantitatively with the complex network analysis. Complex network is a novel and effective approach to analysis the evolution of the complex system with time [31]. Unlike general time series analysis approach, the complex network could deal with evolution of matrixes or modes containing more information than a single value [32,33]. By doing so, our main contributions to the existing literature could be summarized in two points, one is exploring the oil-stock nexuses from a dynamic perspective associating with

multivariate co-movement; and the other is offering a more detailed time and frequency reference for the financial risk hedging.

The rest of the paper is laid out as follows, Section 2 introduces the wavelet based network model and the data used in our study. Section 3 describes the results and their application as well as Section 4 concludes the paper.

2. Methods and data

2.1. Data description

For the stock market, the Shanghai composite index (SHCI) is used as the proxy, and the SHCI is composed of the listed stock exchanged in the Shanghai stock exchange, which could comprehensively reflect the fluctuations of the Chinese stock market. Concerning the crude oil price, Brent, Dubai, Minas and OPEC crude oil prices are chosen. In China, Brent, Minas and Dubai oil prices are used for the oil product pricing, hence these three oil price could influence Chinese market more directly [34]. Then 57% of the imported oil of China is from OPEC[1] and the OPEC organization could influence the world oil market significantly, therefore we also add OPEC oil price into our data sample. The sample period is from January 2003 to December 2015, and there are 2962 data points in total because we keep the shared common data points among four oil prices and one stock index. All of the data sets are in daily frequency. The original series of oil prices and the stock index is shown in Fig. 1.

2.2. Methods

Aiming to understand the co-movement of coherence of multiple oil prices with the Chinese stock market, we proposed an integrated research framework (Fig. 2) involving wavelet coherence and complex network model that could uncover this issue with multiscale information over time dynamically.

To be more specific, we firstly implement the wavelet coherence for each oil price and the stock market index to find out coherence between oil prices and Chinese stock market from joint time-frequency aspect. With the coherence information from the joint time-frequency aspect, it is easy to identify the correlation extent between the oil price and the stock market at any specific time point and frequency (time horizon). The wavelet coherence results could be illustrated by the matrix, in which each column is composed by coherence values for each frequency at the same time point between the oil price and the stock market. Third, through evaluation of the correlations coefficients of pairwise coherence columns we could clarify the co-movement situation among oil-stock nexuses at each time point. Then, the network model is introduced for the evolution of the co-movement of correlations.

2.2.1. Coherence in the joint time-frequency domain

First, we use the wavelet coherence to acquire the correlation between crude oil prices and the stock index in different frequencies corresponding to various time horizons. Wavelet coherence extends the traditional correlation both in time and frequency perspectives through the combination of the wavelet transform and cross spectrum technology [35]. To be more specific, the traditional correlation coefficients merely used one single value to describe the correlative extent between two time series, whereas the wavelet coherence could offer accurate correlation coefficients for each time point and frequency band [36]. Wavelet coherence explores the correlation between two time series with a matrix instead of one single value. Therefore, it is possible to identify the differences among the coherence between oil prices on the

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[1] U.S Energy Information administration: https://www.eia.gov/beta/international/analysis.cfm?iso=CHN.