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Q1 # Time–frequency featured co-movement between the stock and prices of crude oil and gold

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HIGHLIGHTS

- Time–frequency co-movement among time series is explored in multivariate framework.
- Time, frequency and time–frequency domain analyses are compared.
- Prices of oil and gold correlate with the stock in high and medium frequency bands.
- 2003 is broken point for the relationship between stock and prices of oil and gold.

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ABSTRACT

The nonlinear relationships among variables caused by the hidden frequency information complicate the time series analysis. To shed more light on this nonlinear issue, we examine their relationships in joint time–frequency domain with multivariate framework, and the analyses in the time domain and frequency domain serve as comparisons. The daily Brent oil prices, London gold fixing price and Shanghai Composite index from January 1991 to September 2014 are adopted as example. First, they have long-term cointegration relationship in time domain from holistic perspective. Second, the Granger causality tests in different frequency bands are heterogeneous. Finally, the comparison between results from wavelet coherence and multiple wavelet coherence in the joint time–frequency domain indicates that in the high (1–14 days) and medium frequency (14–128 days) bands, the combination of Brent and gold prices has stronger correlation with the stock. In the low frequency band (256–512 days), year 2003 is the structure broken point before which Brent and oil are ideal choice for hedging the risk of the stock market. Thus, this paper offers more details between the Chinese stock market and the commodities markets of crude oil and gold, which suggests that the decisions for different time and frequencies should consider the corresponding benchmark information.

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1. Introduction

Time series analyses are widely used to explore the nonlinear features of the complex system in multiple disciplines [1–5]. Most of the methods focus on the information of the original time series from the time domain and omit the multiscale

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information from the frequency domain [6,7]. However, this hidden frequency information is the main reason which results in the nonlinearity of the time series [8–10]. The relationships among these time series also behave in a nonlinear way [11,12]. For example, the international asset markets interactions are reputed for their nonlinearity. The assets markets consist of a variety of interacting agents with different term objects, which leads to the time series from these markets being the combination of different components in various frequencies, each components could exert different influence on the whole market [13]. Hence, it is necessary to explore the hidden information in the joint time–frequency domain, which allows us to track the changes belonging to different frequency components of the original time series with the time information and offer deeper insight to understand the interactions among assets markets.

In confront the nonlinear issue caused by the hidden frequency information in the assets markets of which we choose the crude oil, gold and stock as examples; most of the current researches adopted the econometrical models, GARCH, VAR, VEC, etc. [14–16], that are based on the linear regression and mainly focus on the time information from the holistic perspective. With these traditional econometrics models, there are no consensus on the relationship between oil price and stock [14,17–21]. For the Gold–stock nexus, Gold generally is considered as the safe haven for the stock markets [22–24]. In fact, the time series of crude oil and gold prices as well as stock index are the combination of various frequencies components [13,25]. Relevant multiscale empirical researches carried out in the time–frequency domain demonstrate that the oil–stock and gold–stock nexuses both show multiscale features. Specifically, the interaction between variables changes as the time horizon changes [26–28]. Moreover, the joint time–frequency analyses track the relationship of these assets or commodities markets in dynamic way, which show a more detailed observation [29,30]. Hence, exploring their relationship through hidden frequency information could offer more comprehensive understanding in different investment horizons. In addition, most of the researches carried out in frequency domain consider the oil–stock, oil–gold, gold–stock nexuses separately [11,27]. Actually, in the real world, the interactions among the assets markets happen simultaneously and considering their relationships in a separate way only offer a partial picture [29,30]. Hence, unlike the general relationship analysis in the joint time–frequency domain, we distinguish our research by examining the coherence between the stock market and the commodity prices of crude oil and gold with a multiple variable framework in the joint time–frequency domain.

Considering exploring the relationship in the joint time–frequency domain, the wavelet transform is a novel approach, which represents the original time series as a function with two variables, namely, time and frequency [31]. At first, the wavelet transform successfully deal with the nonlinear signal in the field of geosciences, physics and engineering [32–35]. Recently, the economists also find that the wavelet transform also can offer perfect solution to the nonlinear problems of the economical time series [36,37]. The implementation of the wavelet transform enables us to detect the relationship among the assets prices with different time and frequency components [38]. Based on the wavelet transform, the multiple wavelet coherence are developed. The main idea of multiple wavelet coherence is similar to the multiple correlation coefficients. By extending the multiple correlation coefficients to the joint time–frequency domain, the multiple wavelet coherence is effective for exploring the fluctuation characteristics of the relationship from the time and frequency aspects simultaneously [13,30,39].

The main aim of this paper is to explore whether the cross-market linkages vary in different time and frequency domains. We consider their relationship in the time domain, frequency domain and joint time–frequency domain as comparisons. First, we carried out cointegration test in the time domain with traditional econometrics model. Second, combining the discrete wavelet and Granger causality test, we test the relationship between assets markets for different frequency bands. Third, we use multiple wavelet coherence based on the continuous wavelet transform to examine the relationship between the stock market and the international crude oil and gold markets in multivariable framework in time–frequency domain and the pairs wavelet coherence serve as comparison, which could offer more evidence for the coherence evolution of the different frequency components in time.

2. Methodology

2.1. Data description

We take China as an example. On one hand, China has become the largest oil importer since September of 2013,[1] and the dependence on foreign crude oil increased by more than 50%, from 6% in 1993 to 59.6% in 2014 [7]. On the other hand, as the second largest economy in the world, China's stock market also ranks in the top, which indicates that it is closer to the international markets.

The Brent spot oil price (Brent) and London gold fixing price (Gold) have been chosen as the proxy for the international price of crude oil and gold. In addition, the Shanghai Composite index (SH) is adopted for the Chinese stock market. All the variables are sampled in the duration from January 1991 to September 2014 in daily frequency. The Brent oil price is extracted from the US Energy Information Administration (EIA), the London gold fixing price is obtained from the Quandl database, and the Shanghai security index is available from the Wind database.

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[1] US Energy Information Administration, http://www.eia.gov/todayinenergy/detail.cfm?id=15531.