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Interdependence between oil and East Asian stock markets: Evidence from wavelet coherence analysis

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ABSTRACT

This paper examines the interdependence and causality relationship between oil and East Asian stock returns from 1992 to 2015 and provides a fresh perspective on portfolio diversification benefits using wavelet coherence analysis. We find that oil prices and the East Asian stock market move in phase, and oil prices lead to stock returns in the long run. We provide evidence that oil can reduce the risk in the short run, and the degree of risk reduction of oil-stock portfolios decreases over the long term. This study provides information that can guide investors in diversification efforts while investing in oil and East Asian stock markets.

1. Introduction

Crude oil is pertinent for the real economy and financial markets worldwide. Particularly, few economies in the world rely on oil imports to the same extent as East Asia. East Asia includes three of the world's top 10 oil-importing nations – China (China represents the Chinese mainland in our paper), Japan, and South Korea. Each of these three nations, as well as other nations in East Asia, shows an increasing demand for oil. Many studies focus on developed countries while few studies analyze the interdependence between oil and East Asian markets. In fact, this is an important and interesting subject because the East Asian region, which is experiencing rapid economic growth, is the region most likely to increase its demand for oil and become a larger player in global financial markets. Moreover, the majority of East Asian oil imports are from the volatile Middle East, and there has been no regional mechanism in East Asia to stockpile emergency petroleum supplies (Shin and Savage, 2011). This renders East Asia highly susceptible to oil shocks, such as the 2003 Iraq invasion or the 2006 OPEC cut agreement.

In our paper, we investigate the interdependence between oil price and East Asian stock markets because an understanding of volatility and correlation are essential for derivative pricing, portfolio optimization, risk management, and hedging for East Asian financial markets. Despite scarce literature, some authors state that there is a weak or negative link in the sample

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East Asian countries (Basher and Sadorsky, 2006; Zhu et al., 2014). These results are consistent with economic theory because rising oil prices increase production cost, have an adverse effect on cash flows, and reduce stock prices.[1] The study results conclude that oil is an effective diversification tool for East Asian stock markets. This feature is also reflected in international investors' preference to diversify risk. However, the limitations of the previous empirical studies are that they are restricted to one or, at most, two time scales – the short and long term. In fact, international investors should be heterogeneous with respect to their different investment horizons.

We offer two contributions in this paper. First, we employ the wavelet coherence analysis to analyze oil-stock interdependence. Wavelet analysis offers a huge advantage in that it provides a framework to measure the frequency components of dynamic movement without losing time-specific information. Additionally, we employ the recently developed wavelet coherence analysis (Grinsted et al., 2004), which exposes regions in terms of the degree and direction (in phase or out phase) of co-movement and simultaneously reveals the cause-effect relationship in time-frequency space. Second, we measure the oil-stock portfolio diversification benefits that are implied by our model using the appealing framework of Reboredo and Rivera-Castro (2014b). We assess risk reduction by calculating the ratio between the oil-stock mixed portfolio variance and the stock variance in the time-frequency domain and measure the Value at Risk (VaR) and Expected Shortfall (ES) in the oil-stock portfolios.

The remainder of this article is organized as follows. Section 2 explains the methodology, and Section 3 describes the data. Section 4 presents the empirical results. Finally, Section 5 concludes.

2. Methodology

2.1. Wavelet

Wavelet functions are constructed based on location, scale parameters, and a mother wavelet function, $\psi \in L^2(\mathbb{R})$, defined as

$$\psi_{\tau,s}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right),\ s,\tau \in \mathbb{R},\ s\neq 0 \tag{1}$$

where the term $\frac{1}{\sqrt{|s|}}$ denotes a normalization factor ensuring unit variance of the wavelet and $\|\psi_{\tau,s}\|^2 = 1$. s is a scaling factor that controls the width of the wavelet. Scale has an inverse relation to frequency. Accordingly, a higher scale suggests a stretched wavelet that is appropriate for detection of a lower frequency. τ is a translation parameter that controls the location of the wavelet.

There are many types of wavelets with different specifications that are used for different purposes.[2] We use the Morlet wavelet that was first introduced by Goupillaud et al. (1984). Formally, the Morlet wavelet is defined as

$$\psi^M(t) = \frac{1}{\pi^{1/4}}e^{i\omega_0 t}e^{-t^2/2} \tag{2}$$

where $\frac{1}{\pi^{1/4}}$ ensures unity energy of the wavelet. ω_0 is the dimensionless frequency and denotes the central frequency of the wavelet. ω_0 usually equals six in practice because this value can ensure that the Fourier frequency period $(1/f)$ is almost equal to scale (s).[3] $\omega_0 = 6$ is a good choice that satisfies the admissibility condition[4] (Farge, 1992) and enables a balance between time and frequency localizations (Grinsted et al., 2004; Rua and Nunes, 2009) often used in economic applications (Vacha and Barunik, 2012; Yang et al., 2016; Aloui et al., 2016). As noted by Addison (2002), the Morlet wavelet is a complex or analytic wavelet within a Gaussian envelop with good time-frequency localization.

2.2. Continuous wavelets

Given a time series $y(t) \in L^2(\mathbb{R})$, its continuous wavelet (CWT) with respect to the wavelet ψ is a function of two variables, $W_{y;\psi}(\tau,s)$:

$$W_{y;\psi}(\tau,s) = \int_{-\infty}^{\infty} y(t)\frac{1}{\sqrt{|s|}}\psi^*\left(\frac{t-\tau}{s}\right)dt \tag{3}$$

where $*$ denotes the complex conjugate form. The wavelet transform can give us information simultaneously on time-frequency space by mapping the original time series into the function of τ and s. Additionally, because both τ and s are real values and vary continuously, $W_{y;\psi}(\tau,s)$ is named a continuous wavelet transform (Jiang et al., 2015).

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[1] Stock prices can be explained using an equity pricing model in which the price of equity at any point in time is equal to the expected discounted cash flows.

[2] For more details, see Percival and Walden (2000), Addison (2002).

[3] For the particular choice of $\omega_0 = 6$, we can simply use the approximate equation that $f = \frac{\omega_0}{2\pi s} = \frac{6}{2\pi s} \approx 1/s$ implying that broad-scale s corresponds to low Fourier frequency f while fine-scale s corresponds to high Fourier frequency f.

[4] The admissibility condition is defined as $0 < C_\psi = \int_0^\infty \frac{|\Psi(f)|^2}{f}df < \infty$. See Daubechies (1992) for more details.