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Asymmetrical long-run dependence between oil price and US dollar exchange rate—Based on structural oil shocks

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HIGHLIGHTS

- The cross-correlations between oil prices and exchange rates are discussed.
- We use four indicators to characterize the asymmetric dependence.
- All the asymmetric cross-correlations are multifractal.
- The results obtained have important implications for market participants.

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ABSTRACT

The multifractal behavior in cross-correlation between oil prices and exchange rates is examined in this paper. We use the multifractal detrended cross-correlation analysis to investigate the general cross-correlations, and further show that these cross-correlations are asymmetric by multifractal asymmetric cross-correlation analysis. We recover the structural oil shocks and then use these indicators to characterize the asymmetries along with oil price trend itself. Our empirical results show that their asymmetric degrees vary significantly. The sign of oil supply shock leads to the most significant asymmetry among them.

1. Introduction

Despite the constant exploration of new sources of energy, oil still takes up a dominating place in the global energy market. The US Dollar, which acts as a predominant quote currency in oil trading, unavoidably has a close relationship with oil price. As a result, a large volume of literature has attempted to investigate this bidirectional linkage. Theoretically, Golub [1] and Krugman [2] argue that the currency of an oil-importing country may depreciate (appreciate) when oil price increases (decreases) and vice versa for the currency of an oil-exporting country. Also, the law of one price serves as an explanation for the effect of USD exchange rate on oil price: an appreciation of USD against other currencies will cause a decline in the oil nominal price (see Ref. [3]).

To be consistent with these theoretical explanations, the historical relationship between oil prices and exchange rates is also well documented in the literature. On the one hand, research provide evidence of the impact of oil price movements on exchange rates (see e.g. Refs. [4–12]). On the other hand, empirical evidence on the causality running from exchange rates

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to oil prices is reported by, e.g. Refs. [13–18]. Other research such as Reboredo [19], Aloui et al. [20], Brahmasrene et al. [21], Bal and Rath [22] find bidirectional causal relationship between oil prices and exchange rates.

The aforementioned research largely analyze the oil price–exchange rate relationship by the means of VAR, cointegration and Granger causality test. The results may show a bidirectional causality, one-way causality or no causality in either short run or long run. So little is known about how the cross-correlation exhibits in a global time–frequency domain. To fill this gap, some researchers employed the wavelet transform to study this relationship, such as Reboredo and Rivera-Castro [23], Tiwari et al. [24], Shahbaz et al. [25]. However, the inner workings of financial markets are very complex. In such a case, wavelet method only accounts for the past relationship, which fails to characterize it systematically.

Fractal market hypothesis (FMH) proposed by Peters [26] provides us a new nonlinear perspective to understand the enigmatic behavior in financial markets. On this theoretical basis, several methods have been proposed to study the fractal nature of financial time series. The rescaled range analysis (R/S) proposed by Hurst [27] is a pioneering approach to study the long memory nature of time series. C.-K. Peng [28] presents a detrended fluctuation analysis (DFA) method to make up for the drawback of R/S in short-term auto-correlation and non-stationary series. Kantelhardt et al. [29] then generalize the DFA method to MF-DFA, which can investigate the multifractal nature. In studying the cross-correlation between two non-stationary time series, Zebende [30] and Zebende et al. [31] propose a long range cross-correlation analysis (DCCA) which can quantify the relationship in a scale domain. Reboredo et al. [32] use this method to investigate the relationship between oil prices and exchange rates. They find that cross-correlations are negative and low, but increased for all the scales after the financial crisis. By combining the MF-DFA and DCCA, Zhou [33] presents a MF-DCCA method to investigate the multifractal cross-correlation.

It is well-known that financial markets may react asymmetrically to news (see e.g. Refs. [34–36]). But the aforementioned methods offer us only general auto-correlation and cross-correlation results. Fortunately, Alvarez-Ramirez et al. [37] provide a new method called A-DFA to investigate the asymmetric auto-correlation in non-stationary time series. Subsequently, by combining the MF-DCCA and A-DFA, Cao et al. [38] propose MF-ADCCA to detect the asymmetric cross-correlation between Chinese stock market and exchange rate markets. This method has been used in studying the relationship between futures and spot markets [39], PM2.5 and meteorological factors [40].

In this paper, we study the cross-correlations between oil prices and exchange rates by using MF-DCCA and MF-ADCCA. But our asymmetric indicator is not confined to the trend of one return series which is provided by the original method and does not make much sense in our case. Instead, we focus on the trend of oil price itself and characterize the asymmetry in this way. Besides that, from the perspective of oil shocks, Kilian [41] introduces a better way to understand oil price, in which oil shocks are disentangled into supply, aggregate demand and oil specific demand shocks. So oil shocks are not treated as exogenous events to the economy. Some researchers follow his approach to study the relationship between structural oil shocks and economic variables, such as Wang et al. [42], Broadstock and Filis [43], Fang and You [44], Atems et al. [36]. They find that economic variables may respond differently to the three kinds of oil shocks. Based on these findings, we are considering whether asymmetries derived from the structural oil shocks will make any difference and which indicator leads to the greatest asymmetric degree. Therefore, we also adopt these structural oil shocks (oil supply shock, aggregate demand shock and oil specific demand shock) to characterize the asymmetries hidden in the cross-correlation between oil prices and exchange rates. Since structural oil shocks are presented in monthly data, it requires us to generalize the MF-ADCCA method first to meet our needs. This will be illustrated in Section 2.2.

The rest of this paper is organized as follows. Section 2 presents the methods of decomposing oil shocks and MF-ADCCA. Section 3 presents data description and descriptive statistics. In Section 4, we present our empirical results on the cross-correlation between oil prices and exchange rates. Section 5 discusses some implications for policy makers and investors. Section 6 draws the conclusions.

2. Methodology

2.1. Decomposing oil shocks

Following Kilian [41], we decompose oil price shocks by using a SVAR model. To avoid the spurious regression problem, we carry out an Augmented Dickey–Fuller test for all the variables to check whether they are stationary. Tests show that the world economic activity index is stationary in levels while others are stationary in log difference. So we use the original world economic activity index data and the log difference of world oil production and oil price in our SVAR model.

Then we specify our SVAR model:

$$A_0 z_t = \alpha + \sum_{i=1}^{24} A_i z_{t-i} + \varepsilon_t \tag{1}$$

where $z_t = (\Delta prod_t, rea_t, \Delta op_t)'$, $\Delta prod_t$ is the log difference of world oil production, rea_t is the world economic activity index, Δop_t is the log difference of oil price. And ε_t denotes the vector of serially and mutually independent structural innovations.