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The influence of global benchmark oil prices on the regional oil spot market in multi-period evolution

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ABSTRACT

Crude benchmark oil prices play a crucial role in energy policy and investment management. Previous research confined itself to studying the static, uncertain, short- or long-term relationship between global benchmark oil prices, ignoring the time-varying, quantitative, dynamic nature of the relationship during various stages of oil price volatility. This paper proposes a novel approach combining grey relation analysis, optimization wavelet analysis, and Bayesian network modeling to explore the multi-period evolution of the dynamic relationship between global benchmark oil prices and regional oil spot price. We analyze the evolution of the most significant decision-making risk periods, as well as the combined strategy-making reference oil prices and the corresponding periods during various stages of volatility. Furthermore, we determine that the network evolution of the quantitative lead/lag relationship between different influences of global benchmark oil prices shows a multi-period evolution phenomenon. For policy makers and market investors, our combined model can provide decision-making periods with the lowest expected risk and decision-making target reference oil prices and corresponding weights for strategy adjustment and market arbitrage. This study provides further information regarding period weights of target reference oil prices, facilitating efforts to perform multi-agent energy policy and intertemporal market arbitrage.

1. Introduction

The global crude oil market is influenced by various factors, such as the diversity of oil producing areas, mismatches between supply and demand for a given level of oil quality, the interaction of energy policies and geopolitics, and hedging or arbitrage in the investment market and stock market [1,2]. Therefore, the oil price remains the ultimate indicator of value for trading in the global market. As crude oil is a globally traded commodity, the volatility of oil prices can provide information regarding market risk to producers and industrial consumers and affect their investments in the oil market [3–5]. The higher the volatility of crude oil prices is, the more uncertainty it creates, leading to economic instability for both oil export and import dependent countries [6]. Under this background, studying the behavior of volatility is not only essential for profit-maximizing investors to carry out derivative valuations, make hedging decisions, and to determine whether to invest in physical capital, but also is of keen interest to governments in terms of policy making [7–9]. There are, however, numerous global crude oil trading streams coming out of different oil production fields [10], leading to a multiplicity of oil prices globally. Furthermore, the nonlinearity and unpredictability of oil prices make it difficult for policy makers and investors to optimize their strategies [5,11,12]. In particular, determining a reference target for decision making and a benchmark period for strategy is of urgent concern to many actors, including oil import dependent countries who try to implement early warning mechanisms regarding oil price variation, oil export dependent countries who seek to develop their oil export pricing strategy, and market investors who seek to define their portfolio management and arbitrage strategies.

Many existing studies provided valuable insights into global oil prices based strategy adjustment, focusing primarily on the variations among global representative benchmark oil prices [13–15]. Because global representative benchmark oil prices are the main pricing references for different regional oil markets, investigating

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these benchmark prices is the most effective way to identify trends in the global oil market. These studies primarily used econometric and financial models to investigate the variability among global oil prices. For instance, Mehmet, Hasan and Shawkat [16] used MS-VEC model to study the time-varying causality between spot and futures crude oil prices. Chan and Woo [17] employed the M-TAR model to investigate the dynamic relationship between international and domestic crude oil prices in China. Reboredo [18] used the copula approach to investigate the co-movement characteristics between different representative oil prices in the global oil market. Kisswani and Nusair [19] used an improved STAR model to reveal the nonlinearities in the dynamics of oil prices. Trifonova [20] employed an improved M-TAR model to examine the variability between the prices of oils of different quality. Recent studies indicated that signal analysis such as wavelet transform methods is widely used to investigate the synchronism and lead/lag effect between different oil prices [21–23]. Most studies about the relationships between economic and financial variables demonstrated that wavelet analysis is an effective tool to investigate bivariate relationships in economic and financial time series [24–26].

Previous studies mostly assumed that the variability between different oil prices remains steady for a given long-term interval. However, many uncertainties exist in the process of determining a given level of variability and the corresponding long-term interval, which limits the usefulness of these results in terms of improving strategy adjustment to some extent. In reality, the level of variability between different oil prices often fluctuates. In particular, the degree of influence of different oil prices on each other usually exhibits time-varying nonlinearity and unpredictability because other factors outside the global oil market also come into play. By investigating the dynamic relationship between different oil prices and the co-movement of correlations of global oil prices, we aim to provide more valid and accurate market information to improve target oriented strategy [27]. Due to the interaction among various crude oil prices, the combination pricing strategy can avoid risks effectively. The research method using the single model have its limitation for providing the combination pricing strategy, especially determining the reference targets and weights for portfolio strategy for the regional oil price setting.

Based on these premises, our major aim is to explore the periodic evolution characteristics of the dynamic influence of global representative benchmark oil prices on the regional oil spot market, including intensity of volatility, synchronization, and lead/lag effects, to provide more valuable information regarding decision-making reference targets and periods to help improve national energy policy and market investment management. Because of the diversity of these purposes, we use the different methods to solve different purposes. To describe the dynamic relationship between different crude oil prices, grey relation analysis provides a good solution [28]. To choose the decision-making periods with the lowest expected risk based on the evolution of the relationship between different crude oil prices during different periods, we use the optimization wavelet analysis which can extract the multi-period feature from time series and the wavelet variance analysis which can define the volatile intensity [29]. To find the decision-making reference targets and the corresponding weights, we use the Bayesian network models which can determine the dominant lead/lag relationship between different crude oil prices from the overall structure and the wavelet cross-correlation analysis which can determine the dominant lead/lag periods [30].

Thus, we propose a novel empirical approach combining grey relation analysis (GRA), various wavelet methods, and Bayesian network analysis (BNA) to study the fluctuation intensity, synchronization, and lead/lag effects of the relationship between the benchmark oil prices and the regional oil spot prices. By considering the characteristics of the various phases in the fluctuation of global oil prices, we demonstrate the multi-period evolution phenomenon which can provide valuable information in terms of determining a strategy-making risk period, as well as reference targets and weights for portfolio strategy and improve the strategic adjustment process, especially as regards oil price variation early warning mechanisms and arbitrage strategies, allowing governments and investors to develop more effective target oriented strategies.

The remainder of this paper is divided into three sections. Section 2 describes the empirical data and methods. Section 3 describes the empirical results. Section 4 presents the discussion and conclusions.

2. Data and methodology

2.1. Data

Based on previous studies [27], we assume three main factors influencing global oil prices to be Middle East oil prices, the Asia Pacific oil market, and representative oil future prices. We select the Dubai and Oman oil spot prices to represent Middle East oil prices, the Minas, Cinta and Widuri oil spot prices to represent the Asian oil market, the Tapis oil spot price to represent the Southeast Asian oil market, and the WTI (West Texas Intermediate) and Brent oil future prices to represent global oil future prices. The China-Daqing oil spot price is used as the comparison point to represent the Chinese regional oil spot market.

We use daily price points from 25 November 2002 to 31 July 2015, for a total of 3027 days, obtained from the websites of International Energy [31] and the Energy Information Administration [32]. All prices are expressed in US dollars per barrel.

To explore the multi-period evolution phenomenon, the full sample period is divided into seven sub-sample sets representing different phases of volatility, including relative stability, low shock, sharp increase, sharp decline, shock increase, high shock, and another sharp decline (see Table 1). These phases provide a more valuable reference to predict the volatility of global oil prices. The descriptive statistics are shown in Table 1. Compared with the full period, the seven sub-stages exhibit remarkably different volatility characteristics, which suggests that there is more to be discovered regarding the volatility of global oil prices than indicated using only the entire period.

2.2. A combined empirical approach

In contrast to the research methods used in previous studies on relationships between oil prices, we propose a novel combined empirical approach that takes into account the advantages of methods used in various fields, combining GRA (used in the systematics field), various wavelet transform methods (used in the signal analysis field), and BNA (used in the probability and statistics field). To investigate the multi-period evolution of the influence of global benchmark oil prices on the regional oil spot market, our empirical analysis includes six steps (see Fig. 1).

2.2.1. Using GRA to describe the dynamic influence relationship

GRA is an important method in the study of grey systems. It is used to explore system behavior and evolution by means of modeling based on partially known information [28,33]. In particular, the grey relation degree is based on the calculation of the dynamic geometric similarity between time series, which is widely employed to measure the relative degree of influence of one economic time series on another [27,34]. In this paper, we calculate the