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Evolution of world crude oil market integration and diversification: A wavelet-based complex network perspective ☆

Xiaoliang Jia, Haizhong An *, Xiaoqi Sun, Xuan Huang, Lijun Wang

School of Humanities and Economic Management, China University of Geosciences, Beijing, China
Key Laboratory of Carrying Capacity Assessment for Resource and Environment, Beijing, China
Lab of Resources and Environmental Management, China University of Geosciences, Beijing, China

HIGHLIGHTS

- Evolution of world crude oil market integration and diversification is investigated.
- Forty-two wavelet-based complex network models are constructed.
- The leading role of regional market is found.
- Two large stable homogeneous groups of regional markets are found.

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ABSTRACT

Previous research on the crude oil market has focused on the constant degree of the market integration or diversification, ignoring the time-varying market integration and diversification during different typical stages of the global oil price volatility. This paper proposes a novel wavelet-based complex network method to investigate the evolution feature of the world crude oil market integration and diversification from the perspective of the interdependent structural relationship of global oil prices, so that two critical reference indexes, namely the reference decision-making cycle and the target regional market, will be proposed for decision makers to better adjust their strategies. The results show that the dominant evolution cycle of the market integration from the stable stage to the high shock stage is time-varying, featuring the weekly → weekly → short yearly → short quarterly → short monthly cycle, and the dominant evolution cycle of the market diversification is also time-varying, characterized by the short monthly → weekly → long yearly → weekly → weekly cycle. These findings provide a clearer reference decision-making cycle for decision makers to create a more efficient period-oriented strategy. Two larger stable homogeneous groups of regional oil markets and the dominant regional markets in the process of the market evolution are discovered, providing more details regarding the target monitoring regional market for the oil-related early warning strategy and hedging strategies.

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1. Introduction

As an indispensable part of the global economic system, the crude oil market has aroused great concern on the international level [1–3]. Crude oil price is the ultimate embodiment of the trading result in the global market. It has been influenced by a variety of factors, such as the diversity of oil producing areas, different oil quality in supply and demand, the interaction of energy policies, geopolitics, and the hedging or arbitrage of the investment market. Therefore, crude oil price is prone to violent volatility, which makes it difficult to predict the nonlinear characteristics. Additionally, the volatility of the oil price exerts special influence on other international commodity prices and the domestic economy of countries that depend on oil import and export, and may even be used for political purposes. Currently, influenced by the globalization and regionalization of trade development, the co-movement of various oil prices exhibits a dynamic interdependent relationship. Although the global oil prices present a convergence development trend, the variety of trade regionalization results in different oil

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* Corresponding author at: School of Humanities and Economic Management, China University of Geosciences, Beijing, China. Tel.: +86 10 82323783.
E-mail address: ahz369@163.com (H. An).

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trading prices. With the interdependence and interaction of various oil prices, the co-movement of oil prices has created complex hidden relations with the same tendency. This indicates a potential integration or diversification of the world crude oil market. And the crude oil market tends to boom or crash in response to the same exogenous shocks, such as financial crises, wars and extreme weather [4]. Therefore, the world crude oil market has been characterized with different phases due to the oil price volatility. Previous research on the crude oil market has mainly focused on the constant degree of the market integration or diversification [5–12], ignoring the time-varying market integration and diversification during different typical stages of the global oil price volatility, which can provide more effective decision-making reference. For market investors and policy makers, it is more helpful to have a clear sense of the fluctuating relation of global oil prices and the evolution law of the world crude oil market integration and diversification, as it helps to determine the development characteristics of the market environment in which they exist, and discovering the key role of regional crude oil market as a strategy-target reference is more beneficial for creating a target-oriented investment strategy or energy policy.

The aim of this paper is to propose a novel empirical method, namely wavelet-based complex network model, to describe and analyze the evolution feature of the world crude oil market integration and diversification based on the interdependent structural relationship of global oil prices. Additionally, the changes of the local market conditions often result in the changes of the world oil market, such as the Libyan war, the conflict in Syria and the 2011 Egyptian revolution [4]. Therefore, an investigation of the time-varying market integration and diversification, with a focus on the specific regional characteristics, has important economic implications. Two main issues are dealt with in this paper. The first is how the integration and diversification of the world crude oil market evolve during different typical stages, which can provide an overall understanding of the rapidly changing market environment for decision makers. The second is which crude oil price of the regional market plays a key role in the evolution of the world crude oil market during the corresponding decision-making cycle, which can provide two critical reference indexes for decision makers to improve the strategy adjustment, namely the reference decision-making cycle and the target regional market. This study contributes to an understanding of the time-varying structural characteristics of the dynamic relationships between crude oil prices and provides insight into the world crude oil market rules, with important policy implications for state energy policy and investment reference for market investors.

The remainder of this paper is divided into four sections. Section 2 provides a review of the relevant literature. Section 3 describes the empirical data and methodologies. In particular, a wavelet-based complex network model is proposed and described in detail. Section 4 addresses the empirical results and provides a discussion. Section 5 presents the conclusions.

2. Literature review

Regarding the previous research on the oil market, most studies focused on two perspectives of globalization and regionalization. Adelman [5] proposed a whole study perspective, "one great pool", to discover the convergence development trend. Weiner [7] described the globalization of the oil market by investigating the transmission mechanism between various oil prices. Then, Gülen [13] proposed a study perspective of regionalization to describe the relation between different oil markets. Bhar et al. [14] suggested that more than two sets of oil prices should be employed to explore the regional volatility characteristics of the global oil market. In the following studies, considering both the globalization and regionalization of the global oil market, a single-variable oil price was employed to study the characteristics of the tendency. The bivariate ones were employed to discover the fluctuation relation. However, there is still controversy surrounding the integration and diversification of the world crude oil market. For instance, Kleit [8] used the improved arbitrage technique to verify the integration of the regional crude oil market. AlMadi and Zhang [9] validated that there is a long-term market integration more significant than diversification by exploring the co-integrated relationship between four different crude oil prices. Narayan et al. [15] found the clustering feature of various oil future prices to discover the market inefficiency. Liu et al. [10] and Li and Leung [11] verified the integration of the world crude oil market from the perspective of China's crude oil market. Giulietti et al. [16] validated that the leading role of the oil price exhibits a long-term stability. Ji and Fan [12] employed the graph theory to verify that the world crude oil market integration is becoming entrenched. Charles and Darne [17] validated the weak-form efficient market hypothesis from the perspective of the regional crude oil market. Zhang and Zhang [18] verified the inconsistent relationship between the regional crude oil markets. In brief, the world crude oil market did not always exhibit constant integration or diversification because the sudden unexpected oil-related events have increased the uncertainty and complexity of the worldwide oil market. [19]. Therefore, an investigation of the world crude oil market based on dynamic evolution can provide more valuable information to decision-making.

Additionally, econometric and financial models were widely used to investigate the volatility of the bivariate relation [20–23]. However, the complex relation of various oil price co-movements remains incompletely described by the study of a few oil prices and their volatile characteristics. The complex network model provides an innovative perspective to explore and analyze the complex systematic phenomena and structural characteristics based on a many-to-many node-edge relation; this is employed to describe and investigate the network evolution of the global oil price co-movement with the oil market's double development of globalization and regionalization. The previous studies using the complex network model mainly focused on the global feature, the collectivization, the special role of nodes and edges and the key spreading analysis of the network structure [24–29]. These provide more evidence for better exploiting the information hidden in the co-movement of global oil prices.

In particular, this paper used the average grey relation degree (AGRD) to define the edge of the complex network model, and calculated the value of AGRD as the interdependent degree of nodes (oil prices) in the network structure. In contrast to the econometric and financial models of previous research, the AGRD originates the grey relation analysis (GRA) proposed by Deng [30]. This method is focused on the measurement of the relative influence of the compared series on the reference series, which is based on the better description of the geometric shape similarity of different time series data in relational space. Additionally, there is no process of parameter estimation that avoids several common statistical errors [31–33]. The previous study using the GRA suggested that GRA can characterize the interaction between a bivariate time series [34–36]; the AGRD is particularly more suitable for revealing the interdependent relation between bivariate oil price fluctuations [37].

Regarding the network evolution analysis, the previous research generally focused on the evolution analysis of the yearly period, ignoring the unique periodic characteristics of the evolution analysis object [26–28]. This paper considered the obvious stage volatile characteristics of the crude oil price, dividing the original sample period into five continuous stages: the stable period, low shock, sharp increase, sharp decline and high shock. These five

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