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A novel method based on numerical fitting for oil price trend forecasting☆

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HIGHLIGHTS

- We innovative definition of time series trends based on numerical fitting methods.
- The Vector Trend Forecasting Method (VTFM) is developed to oil price forecasting.
- Exponential and linear functions are better than periodic function in VTFM.
- VTFM can deduce the trend directly and avoid randomness in oil price forecasting.
- We forecast mid and long term oil price trends such as monthly, quarterly or semi-annual.

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ABSTRACT

Crude oil plays an important role in various production processes throughout the world. Changes in oil prices affect economic development, social stability and the residents in a country. Based on a full consideration of the fluctuations in oil prices and discovering the future dynamic trend of oil prices from historical trend features, a vector trend forecasting method that defines the vector trend over a specified length of time and predicts future price trends of crude oil based on the vector trend series of historical crude oil prices is proposed. The core idea behind vector trend forecasting method is to construct the vector trend by using the parameters of a fitting function within a specified interval. Based on the previous linear regression, a variety of non-linear morphological features were selected for numerical fitting, avoiding unity in the price trend and stochastic factors that are difficult to solve in forecast price trends. Combined with an econometric model composed of simultaneous equations, making full use of the characteristic information of the historical vector trend makes the definition of the trend more reasonable and the prediction more accurate. The empirical results show that the percentage error of the fitted real oil price in the vector trend is less than 4%. At the same time, it is found that the numerical fitting result using exponential and quadratic functions are better than that with general linear regression. The forecasting error of the trend is no more than 5%, which is lower than the traditional forecasting accuracy of econometrics and statistical learning models. This study can provide suggestions for oil market investors to understand trends in oil prices and for their investment decision-making, and provide reference for policy makers to stabilize economic markets and people's life.

1. Introduction

Crude oil plays an important role in global industrial production. Crude oil is likely to be the most prominent source of energy for decades to come even under the most optimistic scenario for alternative energy development [1–3]. Crude oil price fluctuations have an important impact on economic growth, stock reporting rates, bond markets, and national security [4–6]. At the same time, crude oil has obvious political and financial attributes. Some strong impact events, the dollar exchange rate and market speculation will also lead to fluctuations in crude oil prices [7,8]. Investor mentality changes as the price of crude oil increases or decreases, so features such as chase selling are obvious [9]. In 2017, China's oil dependence on foreign countries reached 68.7%, which means the Chinese oil industry is greatly affected by the global oil price changes [10]. Many studies show that the impact of oil prices often leads to economic recession and inflation. The impact of oil price shocks has different effects on the short-term and long-term economic output [11]. In addition, some scholars report that the effects

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of oil price changes on different economies are different [12]. In other areas of energy, fluctuations in oil prices have a significant impact on the production of fossil fuels such as natural gas [13,14]. If we can get a more accurate grasp of the trends in oil price changes, it will be significant for reducing the complexity of crude oil price on economic growth, policy making, bond markets, and national security [15,16].

At present, the theory of studying the changing trend of price series entails the use of many forms and systems for different research subjects and different financial products. For example, the typical "Dow Theory", proposed by Charles Dow for stock market price movements, was based on the mutual validation that the same market trend can be drawn in at least two ways to reach the purpose of mutual confirmation. However, there is a certain delay in this method. Only after the trend is unfolded can it be truly identified [17]. "Wave Theory", which is based on the study of stock price patterns and can predict the time by which the trend is just established, is one of the best existing forecasting tools except for being too subjective and lacking objective criteria, leading to a high risk when forecasting market volatility [18]. In addition, based on time series analysis, there is also a popular trend analysis theory dominated by the moving average method [19]. However, because its forecasting value always stays at the previous level, it is unable to forecast higher or lower fluctuations in the future [20,21]. Although the aforementioned theories have a wide range of applications in the fields of biomedicine, finance, and weather forecasting, they have limitations as well.

Whether in the financial market, or in the energy market, the accurate judgement of the historical trend and the prediction of future trends play a great role in investment and policy-making. Trend forecasting usually refers to the trend towards a certain interval, and predicts the trend of future trends. In terms of trend characterization, Gorawski et al. [22] proposed a TUBE algorithm for time series trend detection and data cleaning to detect the time series trend of early fuel leakage data, whose detection probability was 98.84%. Aljawarneh et al. [23] propose an improved G-SPAMINE method to discover time trends in temporal data in the Internet of Things by studying temporal schema, whose effect was better than the traditional SPAMINE method. Wu and Duan [24], using fractal theory to analyse price volatility, helped investors analyse the price trend of the gold in the futures market. Noguera [25] validated the existence of oil price stochasticity by analysing multiple structural changes in the actual oil price. Ahrens and Sharma [26] used the unit root test flow to show the trend in an economic time series. Zhang and Zhang [27] used the Markov system transformation model, with dynamic autoregressive coefficients, to discuss the price form of Brent and WTI after the financial crisis, and analysed the causes of the abnormal fluctuations in two benchmark crude oil price: Brent crude and WTI crude price returns under three sets of key conditions. Gao et al. [28] proposed an integrated approach to detect short-term oil price volatility. A sliding time window was used to divide the time series of crude oil price into several parts and an autoregressive model was defined based on the regression model. Under different cyclic time series, the statistical characteristics of various autoregressive models are significantly different, providing decision makers with valuable information on time series from different periods. Therefore, it is clear that trend forecasting is mainly concerned with identifying time series trends, volatility change, and structural change. Trend description for crude oil prices should incorporate a reasonable description of the aforementioned characteristics, so as to lay a foundation for further prediction of future trends.

In recent years, there has been much research into future trends in the energy, financial, economic, and other fields. Tsai et al. [29] compared the effect of three grey models (GM, NGBM, and Verhulst) in predicting the future growth trend of renewable energy consumption in China. Naccarato et al. [30] first predicted youth unemployment rates in Italy through the use of an ARIMA model combined with data about official youth unemployment rates. The innovation therein lay in the combination of official data with Google trend information, and they predicted the trend in unemployment rate by using a VAR model. Das et al. [31] combined empirical mode decomposition (EMD) and the fast reduced kernel Extreme Learning Machine (KELM), transforming complex series into smooth linear series to predict the trend of currency exchange rate movements. The trend prediction in different fields is essentially the prediction of the future trend of a time series, and provides many methods for use in trend discovery from crude oil price time series.

In view of the core role of crude oil in various industries, the future trend of crude oil prices has become a fashionable topic for academic research; however, the prediction of crude oil price trends remains difficult. The time interval selection, the frequency of sample data, and the sudden changes in sample structure all affect predictions of crude oil price trends [32]. In the research into future trend development in crude oil price series, scholars have combined traditional time series methods and machine learning algorithms to improve predictions of oil prices, for example, Naser [32] used dynamic model averaging (DMA) to test the 28-day monthly data set of WTI crude oil prices. The results showed that the DMA method could predict the spot price trend better than the futures price. Miao et al. [33] considered six factors that influence the forecast of crude oil prices (supply, demand, financial market, commodity market, speculation, and geo-politics), using LASSO regression to find that the prediction of eight forward steps can significantly reduce the mean square prediction error. Edmundo et al. [34] studied the feasibility of the Hidden Markov Model for predicting the future price of crude oil. By predicting the probability distribution of time cumulative price returns in the future, it provided possible to infer future price trends and provide effective decision support for agents involved in the oil market. Shin et al. [35] used a semi-supervised learning method to predict changes in oil price, which achieved good effects for a prediction of one-month-further sample. Fan et al. [36] proposed the use of independent component analysis to analyse oil price, and then predicted the price of crude oil based on support vector machine regression (SVR). E [37] predicted the future price by using the autoregressive moving average method through analysing the factors influencing crude oil prices. Zhang et al. [16] proposed a new hybrid approach that uses the predicted crude oil price for each component as the final forecast of a crude oil price. In the context of big data, some scholars have proposed the use of news reports as data and natural language processing methods to predict the trend in crude oil prices [38]. Others have also applied deep learning-based models to the prediction of crude oil price trends to capture the complex non-linear characteristics of crude oil price movements [8]; however, the aforementioned methods all predict crude oil prices through a model, and then use the price value to construct the trend over a specified interval. Price fluctuations will have serious consequences in the forecasting process.

The oil price trend is an important reference when trying to understand the market direction and in investment decision-making. Many studies have shown that oil has certain financial attributes. It is feasible to apply the features of financial markets to the oil market, however, most current research into trend forecasting only focuses on the prediction of the oil price itself and its fluctuations, few provide a clear definition of oil price trends, or make use of historical trend characteristics to forecast future trends in oil prices. Therefore, reasonable definition of oil price trends, and the prediction of the oil price trend combined with the information and characteristics of the trend itself, is innovative. A vector trend forecasting method that defines the vector trends over a specified length of time window, and predicts future price trends of crude oil based on historical crude oil price vector trend series is presented. It mainly constructs the vector trend using the parameters of the fitted function in a specified interval, avoiding those stochastic factors that are difficult to solve in the forecast price, making the definition of the trend more reasonable and the forecast more accurate.