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# A multiple adaptive wavelet recurrent neural network model to analyze crude oil prices

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### ABSTRACT

International crude oil prices are an important part of the economy, and trends in changing oil prices have an effect on financial markets. Traditional hybrid analysis methods for international crude oil prices, such as wavelet transform and back propagation neural network (BPNN), seek synergy effects by sequentially filtering data through different models. However, these estimation methods cause loss of information through the introduction of biases in each filtering step, which are aggregated throughout the process when model assumptions are violated, and the traditional BPNN model does not have forecasting ability. In this study, we constructed a multiple wavelet recurrent neural network (MWRNN) simulation model, in which trend and random components of crude oil and gold prices were considered. The wavelet analysis was utilized to capture multiscale data characteristics, while a real neural network (RNN) was utilized to forecast crude oil prices at different scales. Finally, a standard BPNN was added to combine these independent forecasts from different scales into an optimal prediction of crude oil prices. The simulation results showed that the model has high prediction accuracy. The designed neural network is able to predict oil prices with an average error of 4.06% for testing and 3.88% for training data. This forecasting model would be able to predict the world crude oil prices with any commercial energy source prices instead of the gold prices.

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## 1. Introduction

The global economy has not improved since the American financial crisis in October 2008. International oil prices have been in a recession given the serious lack of market confidence. Oil plays an important role in the economy, and the broad consensus is that higher oil prices affect gold prices and financial markets (Brown & Yucel, 2002; Jones, Leiby, & Paik, 2004). The main methods for predicting oil prices are quantitative, such as an econometric model or a stochastic model. Most methods assume that a crude oil price series implies a linear relationship. In fact, crude oil prices are a very complex nonlinear time series and show very complex characteristics. Crude oil prices are influenced by objective economic laws as well as politics and pricing systems. Therefore, establishing an effective prediction model based on general time series analysis is difficult.

Generally, economic and market factors are considered to be the main causes of surging and falling global oil prices. By considering different economic factors, many researchers have attempted to describe and even predict changes in oil prices. Barone-Adesi, Bourgoignie, and Giannopoulos (1998) used semi-empirical equations to forecast oil prices. Noel (2000) investigated the impact of oil prices on the production of crude oil and gas, while Yasander (1983) studied the relationship between oil prices and economic stability. Gulen (1998) used the continuity principle to predict prices of West Texas Intermediate (WTI) crude oil. The GARCH model was used by Morana (2001) to forecast short-term oil prices. Mirmirani and Li (2004) forecasted oil prices in the American market using neural networks and genetic algorithms. Lanza, Manera, and Giovannin (2005) used error correction models to predict oil prices. Abramson and Finizza (1991) attempted to predict oil prices using neural network models. Xie, Yu, Xu, and Wang (2006) used a support vector machine method to forecast oil prices. Azadeh, Arab, and Behfard (2010) modeled long-term oil prices with an adaptive intelligent algorithm. Gori, Ludovisi, and Cerritelli (2007) forecasted oil prices and consumption using three different scenarios. Tabak and Feitosa (2009, 2010) devoted proactive knowledge to developing new predictive models, including for nonlinear and chaotic behavior of a time series. In recent years, practitioners have emphasized decomposition methods to capture drifts or spikes relative to major economic aggregations. He, Xie, Chen, and Lai (2009) employed three wavelet variants to estimate the risk value in the oil market. Silva, Legey, and Silva (2010) used a wavelet decomposition to forecast oil price trends. Tsung, Hsiao, and Yeh (2011) used wavelet transformation to decompose original data and a simple RNN with a three-layer architecture to forecast stock market movements by sending all wavelet coefficients to the input layer of only one RNN, which cannot analyze trends and forecast crude oil prices on multiple scales. Jammazi and Aloui (2011) developed a crude oil price forecasting model, and a smoothed signal after wavelet decomposition was used as training data to construct the back propagation neural network (BPNN). To determine synergy effects, sequential filtering data were assumed in the traditional hybrid models. However, this estimation method led to information loss because biases were introduced in each filtering step when model assumptions were violated. Therefore, the traditional BPNN model does not have forecasting ability. All of these researchers ignored the real dynamical relationship between crude oil and gold prices.

In this paper, a new, real dynamical model to predict crude oil prices was established by considering gold prices. The dynamic properties of recurrent neural network (RNN) were combined with wavelet decomposition to analyze and forecast a series of international crude oil prices, and finally, a standard BPNN was added to combine these independent forecasts from different scales into an optimal prediction of crude oil prices. Wavelet analysis was used to capture multiscale data characteristics, and RNN was used to simulate crude oil prices. This model will be useful in determining policies on international crude oil price estimations.

The structure of this paper is as follows. A brief overview on wavelet transform is presented in Section 2. Section 3 describes the MWRNN. The data used and the exploratory analysis carried out on the data are explained in Section 4. Finally, Section 5 describes the model estimation and provides a comparison of density forecasting accuracy.

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