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Oil price forecasting using gene expression programming and artificial neural networks

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ABSTRACT

This study aims to forecast oil prices using evolutionary techniques such as gene expression programming (GEP) and artificial neural network (NN) models to predict oil prices over the period from January 2, 1986 to June 12, 2012. Autoregressive integrated moving average (ARIMA) models are employed to benchmark evolutionary models. The results reveal that the GEP technique outperforms traditional statistical techniques in predicting oil prices. Further, the GEP model outperforms the NN and the ARIMA models in terms of the mean squared error, the root mean squared error and the mean absolute error. Finally, the GEP model also has the highest explanatory power as measured by the R-squared statistic. The results of this study have important implications for both theory and practice.

1. Introduction

Crude oil holds an important and growing role in the world economy as about two thirds of the world's energy demand is met from crude oil (Alvarez-Ramirez et al., 2003). It is documented that crude oil is also the world's largest and most actively traded commodity, accounting for over 10% of total world trade (Verleger, 1993). Crude oil price, like most commodities, is basically determined by supply and demand (Hagen, 1994; Stevens, 1995), it is also affected by many irregular events such as weather, stock levels, GDP growth, political aspects and even people's psychological expectations. Since crude oil takes a considerable time to be shipped from one country to another, oil prices vary in different parts of the world. These factors lead to a strongly fluctuating crude oil market, which has the characteristics of complex nonlinearity, dynamic variation and high irregularity (Watkins and Plourde, 1994). In addition, as sharp oil price movements can disturb aggregate economic activity, crude oil price fluctuations may have a significant impact on a nation's economy. Therefore, volatile oil prices are of considerable interest to many institutions and business practitioners, as well as academic researchers. As such, crude oil price forecasting is a very important topic, albeit an extremely hard one, due to its intrinsic difficulties and high volatility (Wang et al., 2005). Oil price prediction has always proved to be an intractable task due to the intrinsic complexity of oil market mechanisms. In addition, the recent oil shocks and their far-reaching consequences have renewed the debate on understanding the behavior underlying oil prices.

Past studies have demonstrated a relationship between oil price and the GDP growth rate. Hamilton (1983) asserted that this relationship is asymmetric. He argued that the significant impacts on the economy can be observed only through a high increase in the price of oil. Hamilton's results have been confirmed by several subsequent studies. For example, Gisser and Goodwin (1986) indicated for the analyzed period from 1961 to 1982 that the oil price had its potential to predict GNP growth. Moreover, two interesting results concerning the relationship between oil price changes and macroeconomic variables are shown. First, the authors showed that monetary and fiscal policy measures alone cannot explain the effects of oil price shocks on macroeconomy after oil market disruptions. Thus, oil shocks also have an impact on economic output by other means than inflationary cost-push effects. Second, oil price effects on the U.S. economy did not change after 1973 when the OPEC period began. Hooker (1996) confirmed Hamilton's results and demonstrated that the oil price level and its changes do exert influence on GDP growth for the period 1948–1972. The author found that an increase of 10% in oil prices leads to a GDP growth of roughly 0.6 % lower in the third and fourth quarters after the shock. By investigating the relationship between GNP growth and oil price changes and volatility, Hamilton (2003) concluded that there is no doubt about the negative impact of oil price hikes and oil price volatility on economic growth during the last decades.

Narayan et al. (2014) investigated the role of oil price in the prediction of economic growth. The authors analyzed the data of 17 developing countries and 28 developed countries. The findings showed a higher level of predictability in case of developed countries. Driesprong et al. (2008) investigated whether changes in oil price are good predictors of returns in stock market. The authors found

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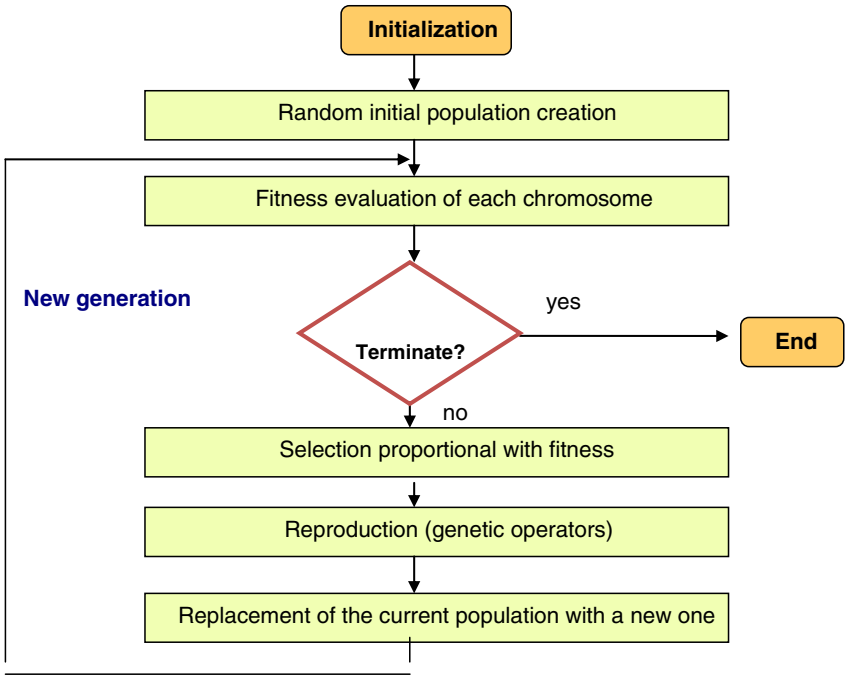

Fig. 1. Gene expression programming (GEP) flowchart.

significant predictability in emerging markets as well as developed markets. The study also found that the introduction of lags of trading days plays a pivotal role in the relationship between oil price changes and stock returns. Pradhan et al. (2015) examined the relationship between economic growth, oil prices, depth in the stock market, real effective exchange rate, inflation rate, and real rate of interest using a panel vector autoregressive model to test Granger causality for the G-20 countries over the period 1961–2012. The results showed a robust long-run economic relationship between economic growth, oil prices, stock market depth, real effective exchange rate, inflation rate, and real rate of interest. While the study found that the empirical evidence of short-run causality is mixed, there was clear evidence that real economic growth responds to various measures of stock market depth, allowing for real oil price movements and changes in the real effective exchange rate, inflation rate, and real rate of interest.

In addition, previous studies have also investigated the link between oil price and firm stock return. Jones and Kaul (1996) belong to the first authors to analyze the reaction of international stock markets to oil shocks by current and future changes in real cash flows and/or changes in expected returns. Their study considered stock markets in the US, Canada, UK and Japan, taking different institutional and regulatory environments into account. Except for the UK, oil prices were able to predict stock returns and output through 1991 in the other three countries. Sadorsky's analysis showed that an oil price shock has a negative and statistically significant initial impact on stock returns. Papapetrou (2001) found that real stock returns are affected negatively. This impact lasts for approximately four months. Ciner (2001) extended existing studies on the relationship between oil prices and the stock market by testing for nonlinear linkages considering recent works on this subject (Hamilton, 1996). Prior studies as the one by Hung et al. (1996) provide evidence for a significant causality between oil futures and stocks of individual companies, but showed no impact on a broad-based index like the S&P 500. Narayan and Sharma (2014) investigated whether the oil price contributes to stock return volatility in 560 firms listed on the NYSE using daily data from January 2000 to 31 December 2008. The study found that oil price is a significant determinant and predictor of firms' returns variance. The study results indicated that investors can make substantial gains in returns by using the oil price in forecasting firms' return variances. Phan et al. (2015a) investigated stock returns in case of oil consumers and oil producers. The findings of the study showed that there are positive effects of oil price fluctuations on stock returns in case of producers of oil. However, the study reported that all sub sectors of consumers of oil are not affected by oil price fluctuations. The study emphasized this asymmetric effect for most of the sub sectors. Using S&P500 indices on daily, weekly, and monthly basis over the period from January 1988 to December 2012, Phan et al. (2015b) used crude oil price to predict stock returns. This pioneering study has three major contributions: i) it focused on out-of-sample forecasting of returns and showed that the ability of oil price to forecast stock returns depends not only on the data frequency used but also on the estimator, ii) that out-of-sample forecasting of returns is sector-dependent, suggesting that oil price is relatively more important for some sectors than others, and iii) it found a strong evidence linking return predictability to certain industry characteristics, such as book-

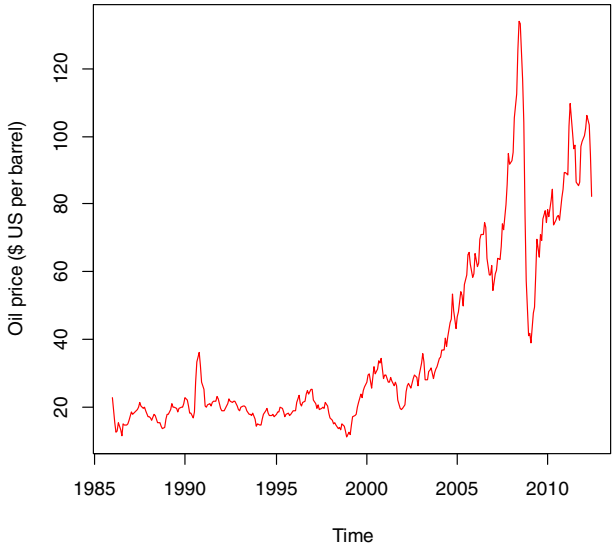

Fig. 2. Oil prices in US$ per barrel (January 2, 1986 to June 12, 2012).