Daily prediction of short-term trends of crude oil prices using neural networks exploiting multimarket dynamics

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Abstract This paper documents a systematic investigation on the predictability of short-term trends of crude oil prices on a daily basis. In stark contrast with longer-term predictions of crude oil prices, short-term prediction with time horizons of 1–3 days posits an important problem that is quite different from what has been studied in the literature. The problem of such short-term predictability is tackled through two aspects. The first is to examine the existence of linear or nonlinear dynamic processes in crude oil prices. This sub-problem is addressed with statistical analysis involving the Brock-Dechert-Scheinkman test for nonlinearity. The second aspect is to test the capability of artificial neural networks (ANN) for modeling the implicit nonlinearity for prediction. Four experimental models are designed and tested with historical data: (1) using only the lagged returns of filtered crude oil prices as input to predict the returns of the next days; this is used as the benchmark, (2) using only the information set of filtered crude oil futures price as input, (3) combining the inputs from the benchmark and second models, and (4) combining the inputs from the benchmark model and the intermarket information. In order to filter out the noise in the original price data, the moving averages of prices are used for all the experiments. The results provided sufficient evidence to the predictability of crude oil prices using ANN with an out-of-sample hit rate of 80%, 70%, and 61% for each of the next three days’ trends.

Keywords crude oil prediction, short-term trend, crude oil futures, heating oil, neural networks, intermarket analysis

1 Introduction

Crude oil is the premier strategic commodity for the modern, engine-driven economies all around the globe. As the total oil resource on the planet is limited, oil demand continues to surge ahead and production continues to decline; it is believed that oil prices will continue to rise to unprecedented levels. Unfortunately, crude oil has proven to be one of the most volatile markets in the world. In addition to daily price fluctuations, oil prices have risen substantially in the last few years. As a reference, in 1999, the price of crude oil hovered around $16 a barrel; but in 2004, the crude oil price was averaging $41 per barrel. By 2008, it had crossed the $100 a barrel mark and fluctuated between $147.96 and $69 (during June–October 2008). The unprecedented increase and the wide swings in crude oil prices have significant impacts on the well-being of the economies of both developed and developing countries. Crude oil price fluctuations and shocks have been a major source of adverse macroeconomic impacts, bringing about economic instability in both oil exporting and oil consuming countries as well as leading to economic crises. Oil price prediction, therefore, is vital to economic agents and policy makers. Consequently, there have been many efforts in developing models to predict oil prices in spot and exchange traded markets.

In stark contrast with many published researches on long-term predictions of crude oil prices, this paper investigates
the possibility of predicting short-term prices and trends of crude oil using any sensible information extracted from the historical and current price time series of the crude oil spot markets, futures markets, as well as markets that are considered to lead the spot markets. This third category of markets are called ‘lead markets’ to the spot markets. In our terms, the so-called ‘short-term’ refers to 1–5 days into the future. Practically, in this study, we limit our scope of study to 1–3 days.

Theoretically, the predictability of crude oil prices and trends in the short term is a scientific problem with two essential aspects—two sub-problems. The first aspect is the properties of the market prices themselves; i.e., whether the prices are solely random walks or exhibit any linear or non-linear dynamics. The second aspect is whether there are any computational models that can capture such linear or nonlinear dynamics, if existent. To address the first sub-problem, we use statistical analysis, in particular, involving using statistical tests to check whether there are nonlinear dynamics in the price time series. To tackle the second sub-problem, we use artificial neural networks (ANN) as computational models for prediction. In particular, we concentrate on using multilayer feedforward neural networks (MFNN), also called multilayer perceptrons, as general approximators to nonlinear mapping from information extracted from historical and current price time series to the prices of the immediate futures—the next three days. The short-term trends of the prices are denoted by the short-term moving averages (MA) of the prices. In this study, we shall limit our scope to the 3-day moving average (3-MA). In this setup, we aim to predict the returns of the filtered spot prices for each of the next three days, which is what we mean by prediction of short-term trends. As a historical background, this study is a further development of a methodology for financial market prediction that has been successfully applied in stock index prediction [1–3]. More general information is provided by [4, 5].

The rest of the paper is organized as follows: Section 2 provides a brief literature review on the related studies for crude oil market analysis and prediction. Section 3 defines the problem of short-term prediction of crude oil prices precisely and presents our methodology for this investigation. Section 4 describes the data sources and their statistical properties as evidence for inherent predictability. Sections 5–8 detail four prediction models separately, of which the differences are in the information sources used for inputs; i.e., (1) the spot prices only, (2) the futures prices only, (3) the spot and futures prices, and (4) the spot and lead market prices. Section 9 shows the results of multi-step prediction. Section 10 concludes the paper.

2 Crude oil market analysis and prediction in the literature

The importance of crude oil to the economy is reflected by the number of studies in this vast area. There is a large and rich literature related to every aspect of crude oil. In particular, there are many published works dedicated to developing fundamental or econometrical models for explaining changes in crude oil prices and for predicting them correctly and accurately in spot and futures markets.

A major characteristic of the crude oil market is significant price fluctuations. This volatility of oil prices could be attributed to three main factors: 1) Increase in demand and supply shortages possibly caused by economic growth or the behaviors of oil producing countries; 2) Exogenous events such as wars, natural disasters, etc.; and 3) Endogenous factors such as speculations in the markets. Moreover, the fact that a significant amount of crude oil comes from the unstable Middle East has contributed to the oil price swings and shocks. However, the fundamental causality analysis of crude oil price fluctuations and shocks are beyond the scope of this paper. We shall limit our discussions to econometrical and computational modeling and the prediction of crude oil price changes and trends.

Early and recent studies in the literature on crude oil market analysis and prediction can be grouped roughly into three clusters: 1) futures as predictors to spot prices, 2) econometrical models for explanation and prediction, and 3) computational intelligence models for prediction.

2.1 Futures as predictor to spot prices

The crude oil futures contract was introduced to NYMEX\textsuperscript{1} in 1983; however, trading in these particular contracts were relatively shallow until 1985, whereas crude oil futures contracts are considered as important financial instruments in the energy market [6]. The relation between futures prices and spot price has been a focus of attention for a number of scholars, and the literature is rich with many studies covering a range of aspects with respect to this relationship. Lead-lag, efficiency, and prediction, among other factors, are the most studied areas in the futures-spot literature.

It is important to note, however, that some economists believe that futures prices are not a predictor for spot prices. For example, Haubrich et al.\textsuperscript{6} argued that crude oil futures prices are not a suitable vehicle to predict spot price, im-