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An Optimization Approach to Predict Crude Oil Prices

[1] Mamoon Alameen, [2] Amer Aladad, [3] Reza Taheri, [4] Mohamad Abdul Nibi, [5] Ali Radiy
[1] Assistant Professor, Mathematics Department, Australian College of Kuwait
[2] Ministry of Business and Trade, Qatar
[3,4] Assistant Professor, Department of Petroleum Engineering, Australian College of Kuwait
[5] Behbahani Project, Kuwait

ABSTRACT

The impact of oil price on social, economic, political and many other aspects of human life is quite strong and evident. However, the role playing factors affecting the price are so complex that the price prediction cannot be solely attributed to the simple well known demand-supply relationship. This paper emphasizes on midterm prediction approach rather than short or long term ones, in which a model has been proposed based on a developed algorithm. Prediction of the prices in seasonal or annual basis was performed with highly satisfactory results. Gold and USDX were employed to verify the applicability of the proposed model.

Keywords: *Oil price prediction, algorithm, modeling, simulation, petroleum economy*

1. INTRODUCTION

As an influential parameter, the oil price governs economic relationships in a global level [1]. This will justify the efforts consumed to capture the role playing economic parameters affecting the oil price.

Before illuminating on the purpose of such study, the crude oil is examined for better appreciation of its effect on future economic indicators. It is safe to assume that crude oil prices affect ensuing factors in its own industry such as the supply and demand along with the oil reserve. Once the role playing variables are determined, the enhancement and fine tuning of the variables will assist in potential future predictions. Moreover, the variables are closely interlinked with the economic indicators as a commodity associated with a few adjacent previous years predictions, the effect of which, are sought to be investigated. Such study defines a known market trading proceeding called the futures contract.

1.1 Futures Oil Contract

Having a finite life, futures contract is different from a stock which signifies properties of the company due to stockholders after all claim are liquidated and the stake of the owner is constituted [1]. These contracts have essential role to play in trimming fluctuation and spikes in commodity prices and the risk it holds in changing key indicators of economy [1]. Such trade does not involve cash exchange. A contract is hence formed to take advantage of price movement and to regulate trade of commodity within the proposed time of the contract in the future unless all agreements of the contract are discharged.

The contract will comprise of sections such as; a) the agreement of the buyer to purchase, b) the agreed upon amount of selected commodity at a secure price and c)the timeframe of the expiry of the contract. Such contracts will experience alterations in their price estimates compared with the fixed price of the commodity agreed for purchase when the contract was first produced. In many cases, the contract is satisfied by selling futures contracts to the seller and futures contracts are bought by the buyer.

Ensuing mispricing between cash value and futures contracts is often sought to assist spectators of the international futures market. Large firms take the necessary procedures to facilitate such exchanges (selling of futures contract) for a risk free profit when commodity prices, for instance, are overpriced on a specific duration in a futures contract compared to traditional commodity market and its proposed interest rate. Strategies are developed by those firms to ensure proper prices of future contracts with relation to the market value are available to preserve the corresponding futures contracts.

The future contracts control such values in the future to ensure the appropriate price is preserved and not over spiked. The purpose of this study is to study the future oil prices as a commodity to select the proper fixed price of the futures contract, which in return, will absorb the potential fluctuations in sudden cost estimations by continuous monitoring of oil prices in global market.

1.2 Preliminary Approach toward soil Price Prediction

It must be emphasized that in order to make up the optimized futures oil contract, the oil prices must be considered on its average annual estimates to predict the price in the span of the whole year in the future. Since the oil price fluctuations are ordinary phenomena [2], a series of signal values are generated with the previous oil prices proceeding the year of oil price forecast. Two methods of signal prediction were utilized for such prediction purposes of sample prediction years, which were the neural networks and the wavelet decompositions and coefficients.
First, the Nonlinear Autoregressive neural network (NAR) is considered for the prediction of the oil price of a selected

sample years of algorithm test. This type of network (excluding the exogenous inputs) is a dynamic network model fitted with feedback return signals over a specified number of layers forming inside the network as a time series model.

The equation is the general formula of:

$$y(t) = f\big(y(t-1), y(t-2), \ldots, y(t-d)\big)$$

Where d is the number of delays controlled by the user for manipulation at will for better prediction capabilities. The neural network consists of two layers; the hidden layer and the output layer. Inside the hidden layer, the activation function is chosen to train the neurons to handle the data according to the mentioned function and send the result back to the output layer while tracking the output signal back in a feedback connector. The training function chosen for this network is the Levenberg-Marquardt back propagation optimization [2].This neural network helps in generating the next output value while being regressed on values of the output signal that are previous to the current one in process.

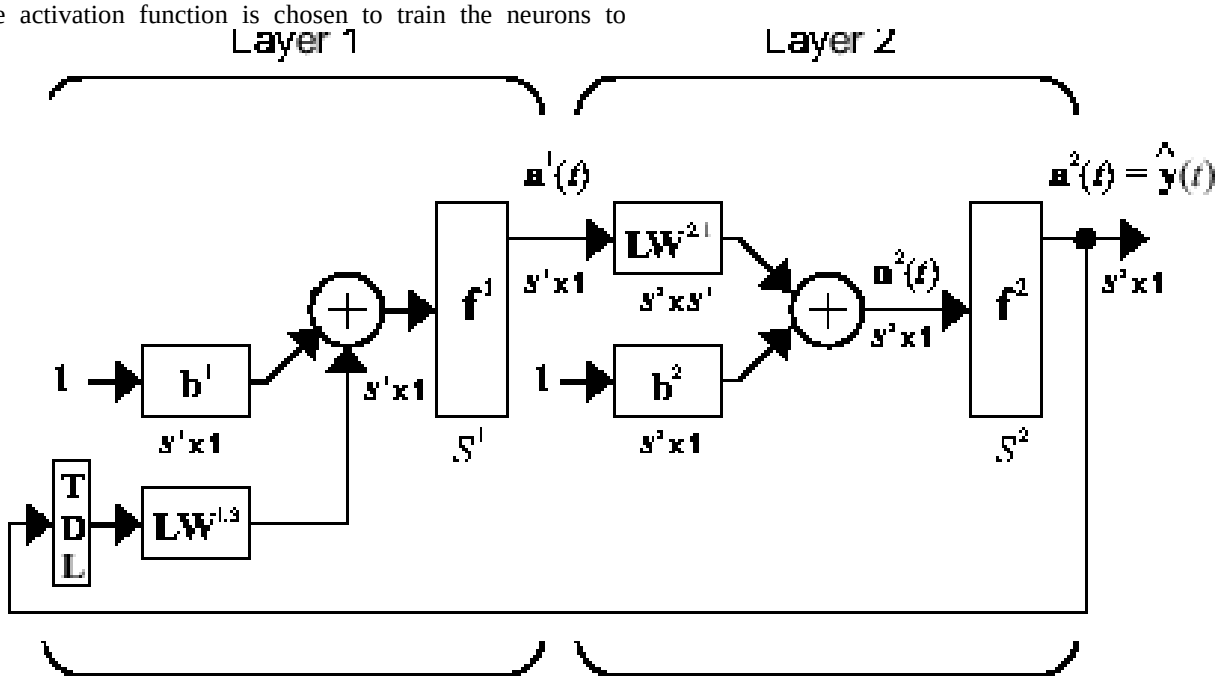

Fig 1: Simple diagram of a neural network

Prior to the suggested method, the method received some noticeable recognition from research journals and conferences. This recognition served as the incentive to research this topic in hopes to be utilized to our purpose in the paper. Such research surely gave us some valuable information about how researcher view the oil price trend in prediction purposes as signal process similar to neural network models [3].

The second method to be considered is the wavelet decomposition and coefficient prediction. A wavelet is a signal that starts at zero and then propagates the field with time with the result of zero regression end value. In this test, the desecrateSymlets wavelet transform with four coefficients associated with the decomposition of the signal is considered for the prediction process of sample collection of prediction years. Three levels of signal decomposition are chosen with two coefficients reconstructing signal. The signal reconstruction is then regressed for [prediction using the ARMA model (Autoregressive Moving average).

Introduction of this new alternative approach, despite the proven capabilities of neural network approach, was to enhance the credibility of price prediction and to minimize the associated risks. The researchers viewed the historical oil prices as signals and processed them accordingly. This provided the researchers with the required motivation to look into alternative methods rather than solely considering the neural network technique. Obviously, neural network model is not the only model that can be

employed to analyze the suggested models such as the oil price signal model[4].

Accuracy of any of the two above-mentioned methods was not as satisfactory as expected and consequently, the urge to introduce an alternative modeling technique and its associated algorithm was vital.

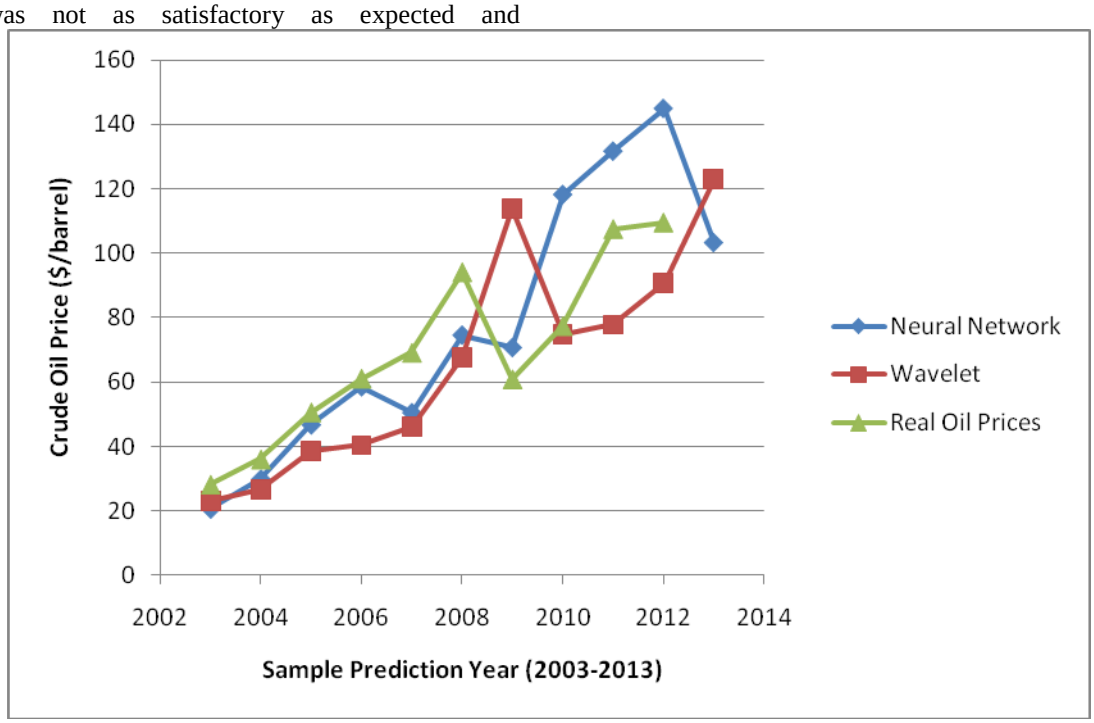

Fig 2: Comparison of Sample Prediction Data

2. OPTIMIZATION APPROACH TO OIL PRICE PREDICTION

Key components of the new proposed algorithm should be discussed prior to discussions about the applications of the algorithm. In this research it was assumed that oil price is affected by economic indicators of similar symbolic power. Oil prices in different countries can be directly attributed to some well-known and widely used economic indicators such as GDP. Oil price and GDP have proven mutual effect on each other [5].

Oil price could also be linked with the prices of two prominent commodities which have strong influence on the global economy and international markets. The first one is Gold and the latter is USDX.

Gold price is a reliable indicator which reflects a general overview of the international economic conditions. It has been set over the years in the global market as a currency rather than a commodity (It behaves more like a currency than a commodity).

On a smaller scale than oil, futures contract are frequently sought for gold prices to ensure such currency would not exceed the spikes that are hazardous in loosing high amounts of revenue along with converting actual cash money into gold for gain. Plotting the prices of oil and gold results in a very important trend recognition in which oil prices follow the gold prices in a very similar pattern with a one year lag time.

The second would be the USDX (U.S. Dollar Index). This index is generated from the bank of currencies, which consists of developed counties with their corresponding share on the influence of this index. Developed countries have significant influence on changes in economic indicators and status in comparison to developing countries. It takes 57.6% of its influence from the Euro currency; a fitting number considering the currency is for the European Union Countries. The Japanese Yen is involved in this index with a percentage of 13.6%. Also, the GBP (Great Britain Pound) influence the factor by 11.9%, while the Canadian dollar holds 9.1% of the index influence. The last two currencies to be part of the bank of currencies are the Swedish Krona and the Swiss Franc, with each holding 4.2% and 3.6% impact on the dollar index power [6]. Figures 3 and 4 show that the oil prices follow a pattern similar to that of the gold within the last year period.

The reliable economic indicators are tested for combinatorial optimization for the crude oil price prediction, keeping in mind the previous data of at least the last two years prior to the year of sample prediction using the proposed algorithm involving the mentioned factors.

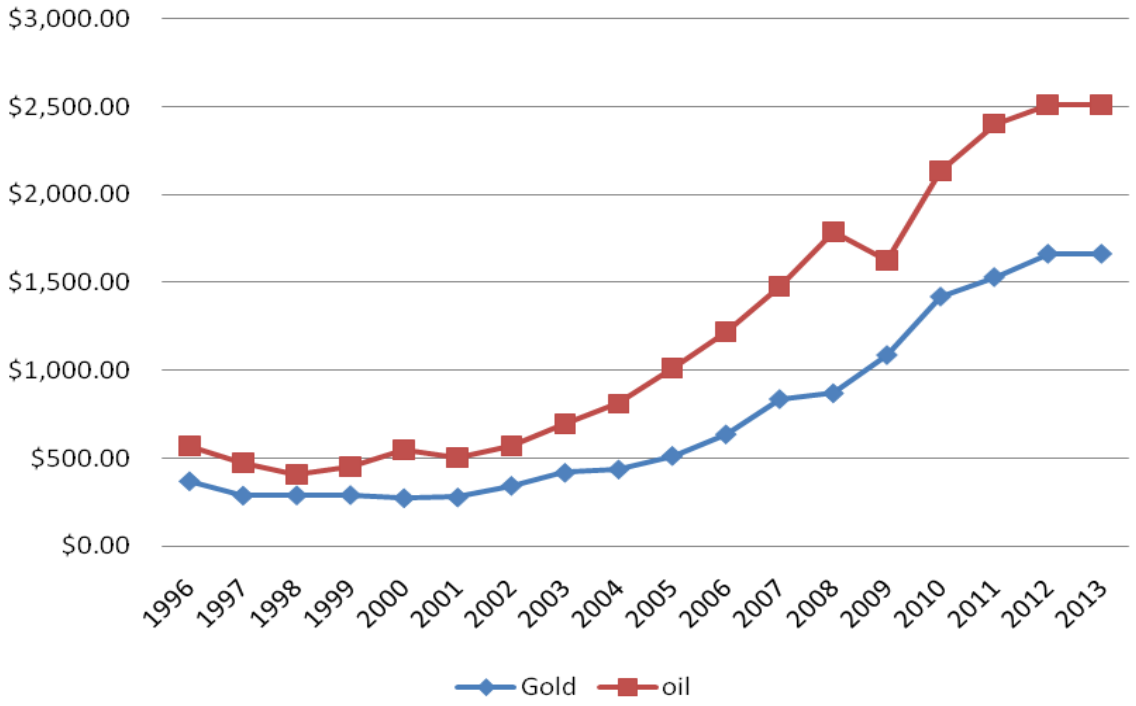

Fig 3: Gold vs Oil Prices

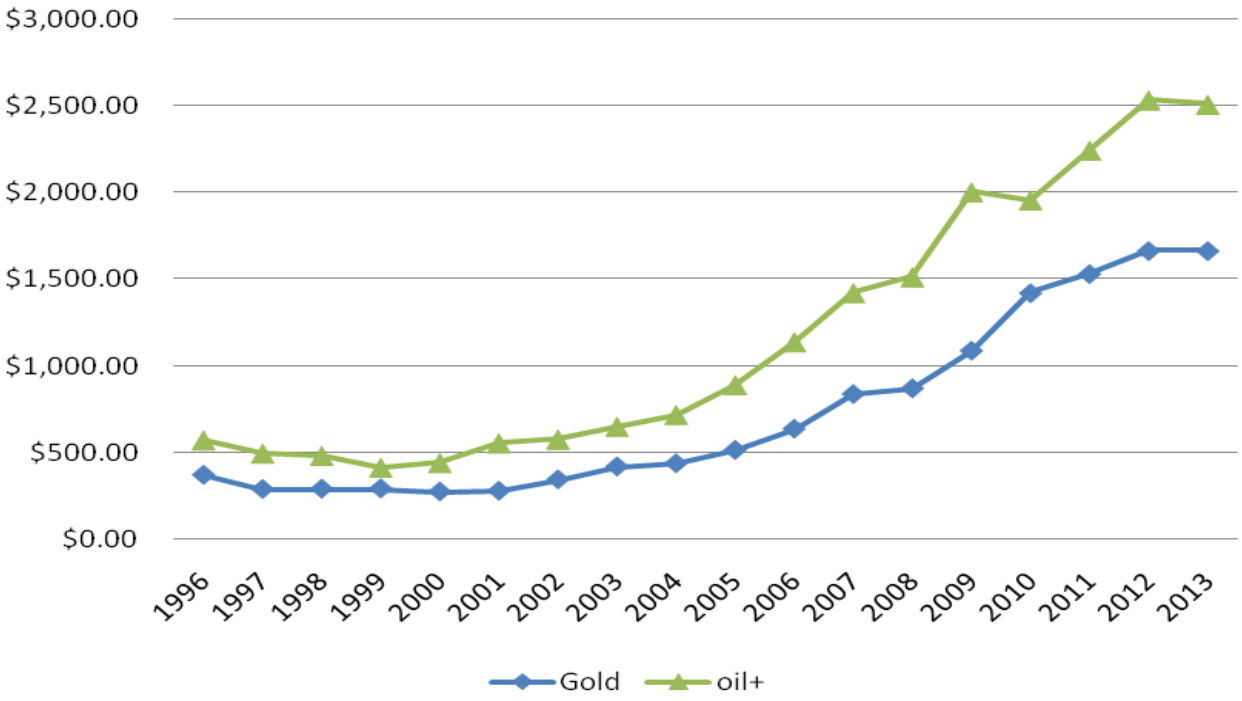

Fig 4: Gold vs Next year Oil Prices

3. PREDICTION ALGORITHM

Assume that P_o is the oil price of the previous year, P_u is the upper limit of the oil price interval, P_L is the lower limit of the oil price interval, GDP_o is the GDP of the previous year, GDP_u is the GDP of the upper limit of the oil price interval, GDP_L is the GDP of the lower limit of the oil price interval and USD_o is the US dollar value of the previous year, USD_u is the US dollar value of the upper limit of the oil price interval and USD_L is the US dollar value of the lower limit of the oil price interval.

a. With the value of P_o, evaluate $P_u = 2P_o$ and $P_L = 0.5P_o$.
b. For P_u and P_L, compare if the prices dropped at the same ratio previously in a period of 1 or 2 years. If not, go to step 6.
c. Compare the changes in ratios between P_o and P_u in order to get GDP_u and USD_u from the years the ratio is consisted of from the data.
d. With the value of GDP_o, compare the change in the ratios of GDP to generate the ratio between GDP_o and GDP_u. With the value of GDP_o, compare the change in the ratios of USD to generate the ratio between USD_o and USD_u.
e. If the change in ratio occurred previously within 1 or 2 years, then assign $x=P_u$ as the upper limit of the oil price and head to step 7. Otherwise, go to step 6.
f. Update the value of P_u to be $P_u= 2P_o -5$ and repeat from step 2.
g. Repeat the steps from 2 to 5 for P_L.
h. If the change in ratio occurred previously within 1 or 2 years, then assign $y=P_L$ as the lower limit of the oil price. Otherwise, head to step 9.
i. Update the value of P_L to be $P_L=0.5P_o+5$ and go to step 3.
j.
$$\alpha = \begin{cases} GP_{n-1} - GP_{n-2}, if\,(GP_{n-1} > GP_{n-2}, DIF_{n-1} < DIFAV) \\ GP_{n-1} \quad if\,(GP_{n-1} > GP_{n-2} \quad DIF_{n-1} \geq DIFAV) \\ GP_{n-1} - GP_{n-2} \quad if\,(GP_{n-1} < GP_{n-2}, DIF_{n-1} < DIFAV) \\ -GP_{n-2} \quad if\,(GP_{n-1} < GP_{n-2}, DIF_{n-1} \geq DIFAV) \end{cases}$$

k.
$$PO_n = \alpha AO_{n-1} + \mathrm{i}\, PO_n$$
$$\mathrm{i} = \begin{cases} \text{Lower if } GP_{n-1} > GP_{n-2} \\ \text{Upper if } GP_{n-1} < GP_{n-2} \end{cases}$$

PO_n : is the predicted oil price for year n

α :is the improvement factor

AO_{n-1} : is the actual oil price for the previous year

GP_{n-1} : is the percentage of gold prices (fluctuations) for the previous year

GP_{n-2} : is the percentage of gold prices (fluctuations) for the last two years.

DIF_{n-1} : is difference in gold prices percentage for the past year and the year before

$DIFAV$: is the average for gold prices percentage differences from year 2002 to 2012.

Step (11) suggests that the predicted oil price is equal to the previous year oil price multiply by the improvement factor α then adding the amount to the Lower or the upper bound of the prediction interval. In addition step (10) decides the value of α . i.e. if gold price percentage increased reasonably (less than the average) then we multiply the difference in gold prices percentages for the past two years by the last year oil price and add it to the lower bound of our prediction. Additionally if gold price percentage increased significantly (more than the average) then we multiply the gold price percentages for the past year only by the last year oil price and add it to the lower bound of our prediction. Moreover if gold price percentage decreased reasonably (less than the average) then we multiply the difference in gold prices percentages for the past two years by the last year oil price and subtract it from the upper bound of our prediction. Finally if gold price percentage decreased significantly (more than the average) then we multiply the gold prices percentage before two years by the last year oil price and subtract it from the upper bound of our prediction.

4. COMPUTATIONAL RESULTS

The analysis is conducted by using the programming software (Mat Lab). The data for the GDP are from reference [7] and the oil prices data are from reference [8].The following Table provides the results obtained by the prediction algorithm.

5. CONCLUSION

The data, logical argument and the obtained results in this paper provided better understanding on how to encounter the prediction problem. Using GDP, USDX and gold prices to predict future crude oil prices provide an excellent algorithm that predict the prices on yearly bases and without requiring too many previous data (like Wavelet or Neural network). The prediction Algorithm in this paper can be a good help for any future pre-sale for crude oil. Above all, the prediction algorithm accuracy is very high and far better than the widely in used wavelet and neural network.

Table 1: Results of the Prediction Algorithm

Year	The Prediction Algorithm	Actual price($/barrel)	Accuracy percentage	Neural Network Accuracy %	Wavelet Accuracy %
2003	28.3	28	1%	2.6	1.8
2004	32.88	36	8 %	16	26
2005	45.5	50	9%	7	23
2006	58.8	58	1.3%	4	35
2007	71	69	2.8 %	27.5	33
2008	87.3	94	7.1%	20.5	28
2009	65.8)	61	7.2%	14	41
2010	70.73	77	8.1%	34.5	2.5
2011	97.8	107	8.6%	19	27
2012	103	109	5.5%	24.5	16.8
2013	99.1	NA	NA	NA	NA

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