Predicting Crude Oil Price Trends Using Artificial Neural Network Modeling Approach

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Outline

- Introduction
- Methodology
- Data and Sources of Data
- Calculations and Results
- Conclusion
Introduction

WHAT DICTATES CURRENT TRENDS IN WORLD CRUDE OIL PRICES?

- 1) TECHNICAL (Exploration & Production Activity)?
  - Plenty of activity worldwide therefore no effect?
- 2) MARKET FUNDAMENTALS (Supply & Demand)?
  - No shortages foreseen in the near future, so little effect?
- 3) SEASONAL (Warm & Cold Climates)?
  - Warm weather for the near future but still little effect?
- 4) PSYCHOLOGICAL (Rumors & False Reports)?
  - Plenty of rumors and false reporting and very large effect?
    - Speculative buying
    - Commercial traders raising prices
Introduction

- Accurate estimation of crude oil price trends can optimize production strategies.
- Accurate estimation of crude price trends is likely to lead to some stability in the world oil market.
- Prices are certainly affected by supply and demand in addition to other factors.
Introduction

- Several authors have used ANN to model complex non-linear system, Moshiri and Fooutan (2004).
- Agbon and Araque (2003) used time series analysis and Chaos-Theory to add some complexity to ANN modeling framework.
- The main objective of this study is to model price trends using ANN with supply and demand levels as input variables.
Methodology

- Generalized Regression Neural Network (GRNN) model is used in this study.
- GRNN is a universal approximation for a smooth function.
- GRNN has two layers:
  - Radial basis transfer function.
  - Purelin transfer function
A = \text{radbas}(\| w - p \| b)

Where...

- \( R \) = number of elements in input vector
- \( s_1 \) = number of neurons in layer 1
- \( s_2 \) = number of neurons in layer 2

\( a_j = \text{radbas}(\| IW_{1,j} - p \| b_j) \)

\( a^2 = \text{purelin}(LW_{2:1} a^1 + b^2) \)

\( a_j \) is the \( j \)th element of \( a \) where \( IW_{1,j} \) is a vector made of the \( j \)th row of \( IW_{1:1} \).
Methodology

- Radial basis function has a maximum of 1 when its input is 0. As the distance between w and p decreases, the output increases. Thus, a radial basis neuron acts as a detector that produces 1 whenever the input p is identical to its weight vector w.

- The bias b allows the sensitivity of the radbas neuron to be adjusted. For example, if a neuron had a bias of 0.1 it would output 0.5 for any input vector p at vector distance of 8.326 (0.8326/b) from its weight vector w.
Methodology

![Graph showing the relationship between Radial Basis Function Spread Constant and Sum Of Squares Error. The graph includes a table with the following data:

<table>
<thead>
<tr>
<th>Spread</th>
<th>R2</th>
<th>SSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.93</td>
<td>0.8666</td>
<td>516.6035</td>
</tr>
</tbody>
</table>

The graph illustrates how the Sum Of Squares Error changes with different values of the Radial Basis Function Spread Constant. The data point with Spread 0.93 has the lowest Sum Of Squares Error of 516.6035.]
Methodology

- GRNN predictive power depends on input variables and how these variables can be grouped / normalized.
- Several models were considered in this study.
- The best model was chosen based on the following statistical indicators
  - correlation coefficients ($R^2$)
  - Sum of Squares Error (SSE)
  - Standard Deviation (St. Dev.)
Data and Sources of Data

- Input Variables
  - OPEC Production
  - World Demand
  - US Domestic Supply
  - OPEC Reserves
  - OECD Demand
  - OECD Consumption
  - OECD Refinery Capacity
  - OECD Refinery Throughput

- Target Predictor: WTI Spot Price ($/bbl)
Data and Sources of Data

- Data were collected from different sources:
  - Energy Information Administration website (EIA).
  - The Annual Statistical Bulletin of OPEC Website.
Data Definitions

\[
\text{Res./ Prod} = \frac{\text{OPEC Proved Reserves}}{\text{OPEC Production}}
\]

\[
\text{OECD\_INDEX} = \frac{\text{Average(Demand, Consumption, Ref. C., Ref. T.)}}{\text{OPEC Production}}
\]

\[
\text{WORLD\_INDEX} = \frac{\text{Total World Demand}}{\text{OPEC Production}}
\]

\[
\text{US\_INDEX} = \frac{\text{US Total Demestic Supply}}{\text{OPEC Production}}
\]
Data Trends

![Graph showing data trends for different variables such as Refinery Capacity (MBOPD), Refinery throughputs (MBOPD), Average Demand (MBOPD), Consumption (MBOPD), and WTI Price ($/bbl).](image)
Data Trends

WTI Price
Res/Prod.
OECD_INDEX
World_INDEX
US_INDEX

Date

Index

WTI Price ($/bbl), Res/Prod., OECD_INDEX, World_INDEX, US_INDEX
OLS Estimation and Results

R² = 0.796
SSE = 5747.07
St.Dev. = 6.6764
Model Estimation and Results

- OLS predictor target can be better enhanced using GRNN.
GNNN Estimation & Results

Training Dataset Correlation

Actual Price ($/bbl)

GRNN Calculated Price ($/bbl)
Testing Dataset Correlation

Actual Price ($/bbl)

GRNN Calculated Price ($/bbl)
## GRNN Estimation & Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Training</th>
<th>Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.8976</td>
<td>0.8666</td>
</tr>
<tr>
<td>SSE</td>
<td>2678.2807</td>
<td>516.6035</td>
</tr>
<tr>
<td>St.Dev.</td>
<td>3.3168</td>
<td>3.4659</td>
</tr>
</tbody>
</table>
Training Error = WTI_Price - WTI_Calc

Year:
- 1980
- 1981
- 1982
- 1983
- 1984
- 1985
- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003

Training Error ($/bbl):
- $20
- $15
- $10
- $5
- 0
- $5
- $10
- $15
- $20

GNNN Estimation & Results
GNNN Estimation & Results

Testing Error = WTI_Price - WTI_Calc

Year

Testing Error ($/bbl)
Conclusion

- GRNN can predict crude oil prices with a reasonable degree of accuracy, taking into account different supply and demand levels in OECD Europe, WORLD and North America.
- The network captured with a better accuracy the correct behavior in comparison to the regular regression analysis. Although the data plots show good correlation between the input parameters and price data.
- Price driven indices were used in this study to show the effect of different factors on the behavior of crude prices.