Exploring Crude Oil Impacts to Oil Stocks through Graphical Computational Correlation Analysis

Anthony Lai, Lei Song, Yiming Peng, Peter Zhang, Qili Wang, and Shaoning Pang

Department of Computing, Unitec Institute of Technology, Private Bag 92025, New Zealand
alai@unitec.ac.nz

Abstract. This paper presented the relationship between the world price of crude oil and oil related stocks over 2011:4-2011:6 is analysed by using a graphical computational correlation analysis method. The Operation Neptune Spear happened in 2011:5 may change nature of the price connection between oil and stock, we evaluate and rank the impact of crude oil for the period before and after the event respectively. Over the statistical results, we find that graphic correlation is superior to typical point-to-point distance calculation for correlation analysis; and we discover stock market interesting knowledge on crude-oil to stock correlations.

Keywords: Crude oil to stock correlation, Graphical computational correlation analysis, Economical event impact analysis.

1 Introduction

The price of crude oil is often dynamic but it is considered one of the major factors for understanding fluctuations of related stock prices. In principle, the production of crude oil is subjected to "supply and demand" activities. The marketplace forces of supply and demand determine the price of crude oil. If demand grows or if a disruption in supply occurs, there will be an upward pressure on prices. On the other hand, if demand falls or there is an oversupply of crude oil in the market, there will be a downward pressure on prices.

Some researches show that the natural disaster may cause the crude oil to rise dramatically. Hurricane Katrina caused oil price to rise $3 a barrel, and gas price to reach $5 a gallon in 2005. Katrina affected 19% of the nation's oil production. It had destroyed 113 offshore oil and gas platforms, and 457 oil and gas pipelines were damaged [17]. Similarly, the Mississippi River flooding in May 2011 caused gas price growing to $3.98 a gallon [19]. Traders' concern lies at that, the flooding would damage oil refineries and the supply cannot accommodate the demand.

Also, economic events cause crude oil price change. For example, US's most recent military activities in the Middle East region have stirred up the political

T. Huang et al. (Eds.): ICONIP 2012, Part V, LNCS 7667, pp. 309–317, 2012.

unstable in the respective regions. These military actions will continue affecting crude oil price in short and long term, as the unstable political situation will cause a certain detrimental effect on the crude oil production from Middle-East countries. As seen in Figure 1, the WTI crude oil price fluctuates because Osama Bin Laden was killed in the Operation Neptune Spear on 02/05/2011.

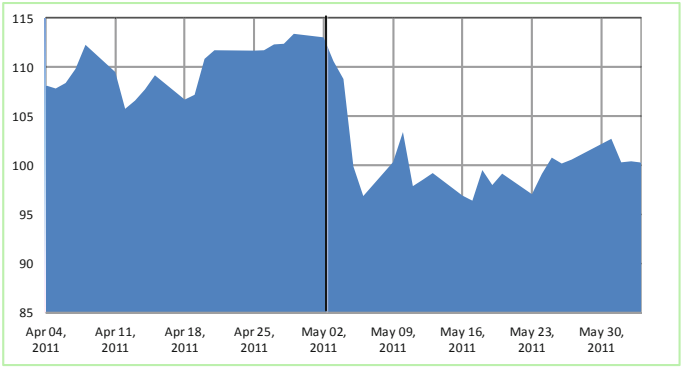


Fig. 1. The WTI crude oil price variation for the period of 03/04/2011 to 02/06/2011

There is a possible factor that the majority inventory oil producers and consumers build a storage capacity to store crude oil for immediate future needs. They also build some inventories to speculate on the price expectations and sale/arbitrage opportunities in case of any unexpected changes in supply chain. Any change in these inventory levels triggers volatilities in crude oil's prices which in turn creates ripples in the stock markets.

Another significant factor, which impacts on crude oil price, is the Organization of Petroleum Exporting Countries. A large part of the world's crude oil share is produced by OPEC (Organization of Petroleum Exporting Countries) nations. Apparently, they have the power in controlling the crude oil prices. Any decisions, made by OPEC countries to raise the prices or reduce production, would immediately lead to crude oil price shock in the global commodity market.

Importantly, the crude oil price is a major driver on its related stock market prices. Clearly, the crude oil is one of the most influencing evidences on macro-variables economic and commodity market, which implies that oil price variation is associated with most economic activities. This paper investigates in-depth the relationship between crude oil price and 6 oil-related stocks. A graphical computational correlation analysis method is introduced to discover those associations.

2 Related Work

2.1 Previous Oil Prices Impact Investigations

In literature, a number of previous researches have been conducted to investigate the effect of oil prices on stock market returns [3,5,4,1,7]. Jones research [5] indicated that oil price rises have a negative impact on stock market returns for all sectors except mining, oil and gas industries. Similarly supported by Robert[2] found that crude oil has significant positive correlation to the oil and gas and diversified resources industries. Nevertheless, he also found negative oil price correlation in the paper and packaging as well as transport industries. Kling[6] summarized that the increases in crude oil price may have been followed months later to see the impact of declining the stock prices. Isaac[4] used co-integrated vector error correction model to analyze the long run relationship between crude oil and international stock market which showed stock market respond negatively to increases in the oil price long run. However, Lutz[1] found the aggregate stock returns may differ greatly depending on whether the increase in the price of crude oil is driven by demand or supply shocks in the crude oil market. Huang[7] examined the lead-lag correlations between daily returns of oil futures contracts and stock returns. He found out there is no correlation between oil futures returns and the returns of various stock indexes. In the case of specific oil stocks, there is existing correlation on one day lead of oil futures returns. Both Perry and Huang used similar methods to evaluate the correlation.

2.2 Existing Correlation Analysis Methods

In recent years, correlation analysis methods have been with extensive and productive efforts. The research has been expanding from simple to more advanced techniques both in depth and in breadth. The computational correlation analysis is normally based on two variables (e.g., crude oil price and a stock price).

Point-to-point distance similarity is a straightforward correlation measurement. Given two variables X and Y, their correlation can be defined as their Euclidean mean distance,

$$d_s = \frac{\sum_{t=1}^{T} |y_t - x_t|}{T}, \tag{1}$$

where t is the dimensionality of variable X and Y.

The dot product is another simple approach to computational correlation analysis. It measures the angle between two vectors/variables that have the same initial point as,

$$cos(\theta) = \frac{X.Y}{\|X\| \, \|Y\|}, \tag{2}$$

where $cos(\theta)$ identifies the trend closeness of two vectors/variables.

Pearson's Correlation is the first formal correlation measure and it is still the most widely used measure of relationship[8]. It is a statistical measure of

two variables movement relationship, which can be calculated as correlation coefficient $\rho_{X,Y}$,

$$\rho_{X,Y} = \frac{cov_{(X,Y)}}{\sigma_X \sigma_Y} = \frac{E((X - \mu_X)(Y - \mu_Y))}{\sigma_X \sigma_Y}, \tag{3}$$

where cov is the covariance; σ_X and σ_Y are standard deviations; μ_X and μ_Y are the expected value; and E is the expected value operator. Practically, except $\rho_{X,Y}$ returns a probability p-value. The advantage of using Pearson's correlation is that more accurate prediction can be made when a strong correlation exists amongst variables.

3 Graphical Computational Correlation Analysis

In this research, a graphical computational correlation analysis method is adopted which is called channel method [18] is used to model a concrete arc for graphically estimating the trend of the target stock price. Figure.2 shows 4 typical trend patterns: fast growing, slowly increasing, fast dropping and slowly decreasing. It is straightforward to describe each of the trend pattern by an arc which can be formulated to a sub-circle shown as in Figure 2. The 4 trend patterns can be obtained by the following equations respectively:

$$(x - x_0)^2 + (y - y_0)^2 = R^2 \left| \begin{array}{l} x_0 = 0, y_0 = R \\ x \in [0, sin\alpha \cdot R\sqrt{2(1 - cos2\alpha)}] \end{array} \right. \tag{4}$$

$$(x - x_0)^2 + (y - y_0)^2 = R^2 \left| \begin{array}{l} x_0 = R, y_0 = 0 \\ x \in [0, sin\alpha \cdot R\sqrt{2(1 - cos(\pi - 2\alpha))}] \end{array} \right. \tag{5}$$

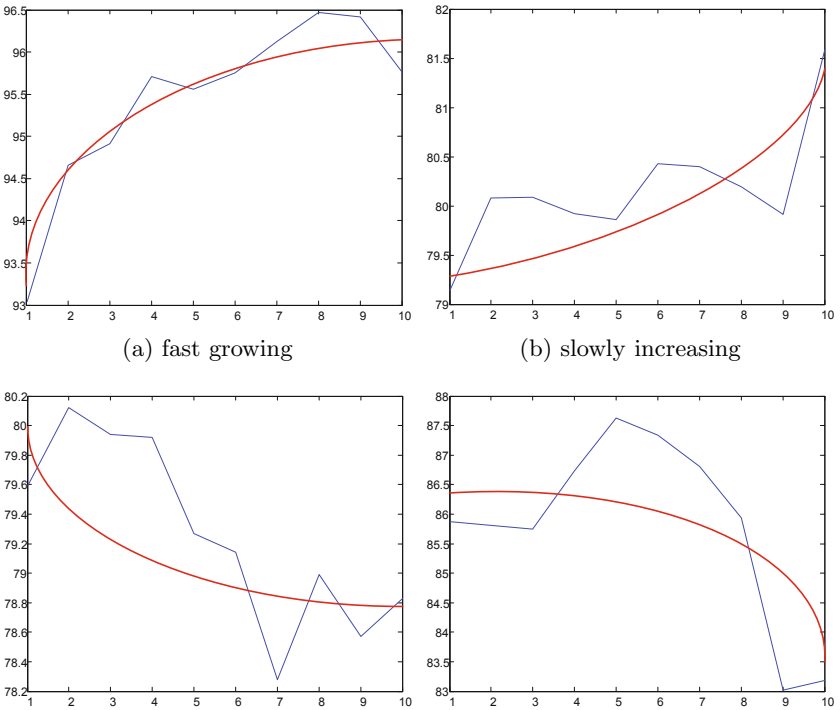
$$(x - x_0)^2 + (y - y_0)^2 = R^2 \left| \begin{array}{l} x_0 = 0, y_0 = 0 \\ x \in [0, (1 - cos\alpha) \cdot R\sqrt{2(1 - cos(\pi - 2\alpha))}] \end{array} \right. \tag{6}$$

$$(x - x_0)^2 + (y - y_0)^2 = R^2 \left| \begin{array}{l} x_0 = R, y_0 = R \\ x \in [0, (1 - cos\alpha) \cdot R\sqrt{2(1 - cos2\alpha)}] \end{array} \right. \tag{7}$$

where $\alpha \in (0, \pi/4)$, $\angle\alpha$ is used to measure the speed of increasing and decreasing trend, and the radius R determines the length of the trend pattern corresponding to the time period of observation. In practice, a discrete arc can be obtained according to the length of time series for channel approximation.

Given the observation (i.e, a stock closing price) X within a time frame T, applying Eq.(4) - Eq.(7) to X, respectively, one of 4 types arc (i.e. functions) called 'channel pattern' is selected with its parameter α tuned to best suit the time series under observation,

$$p = \arg \min_{\alpha, i \in [1,4]} \frac{\sum_{t=1}^{T} \|p_t^i - x_t\|}{T}. \tag{8}$$



(a) fast growing (b) slowly increasing

(c) fast dropping (d) slowly decreasing

Fig. 2. Four trend patterns used for channel approximation

In addition, based on the extracted 'channel pattern' p, the channel distance of an observation X to the reference Y(i.e, WTI Crude Oil) can be defined as below:

$$d_c = \frac{\sum_{t=1}^{T-1} ((p_{t+1}^y - p_t^y) + (p_{t+1}^x - p_t^x))}{T-1}. \tag{9}$$

4 Computational Evaluations and Results

4.1 Data

In the research, the historical time frame 03/04/2011 to 02/06/2011 is selected as the study period. It is noticeable that within the period, the WTI crude oil price has a big fluctuation due to the Operation Neptune Spear event which led to the killing of Osama Bin Laden on 2 May 2011. WTI crude oil price data is collected from the oil-price.net. Within the same time frame, 6 crude oil related stocks price data is also collected from Google Finance. This includes ExxonMobil Cooperation (XO), Royal Dutch Shell Group (ZX), BP United Kingdom (BP), Total S.A. (TT), Chevron (CV) and Conoco Philips (CP). The 6 companies is

ranked by respective net income reported in their 2011 annual report and the ranking is used as the fundamental truth of the crude oil impact analysis. Table 1 summarizes the information of the data collection.

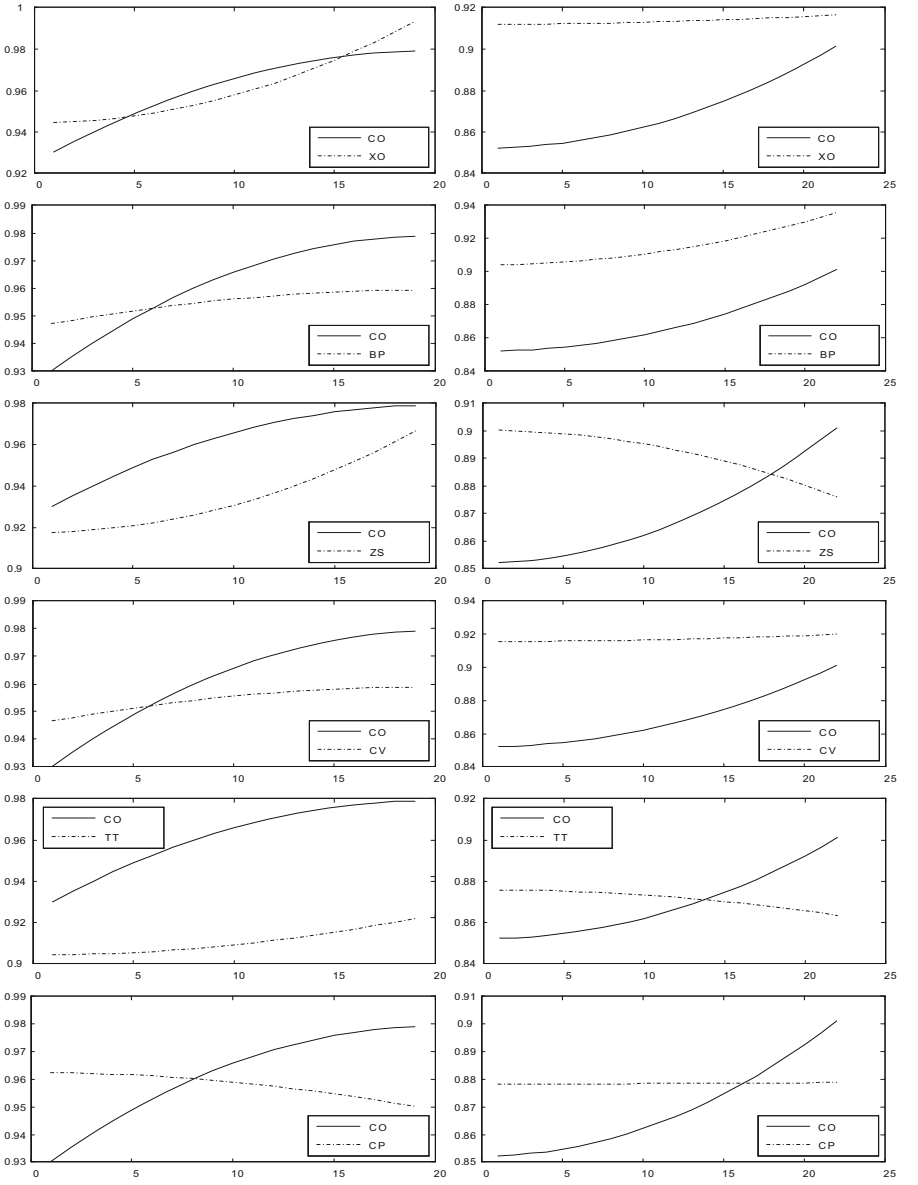


Fig. 3. Stock to crude oil correlation illustration by graphical channels. (left) before event, and (right) after event.

Table 1. The description of 6 crude oil related stocks and their ranks

Rank	Stock Name	Net Income ($ million)
1	Exxon Mobil Corporation (XO)	41,060 [14]
2	BP(BP)	38,463 [9]
3	Royal Dutch Shell(ZS)	31,185 [11]
4	Chervon(CV)	26,895 [10]
5	Total S.A.(TT)	15,902 [12]
6	Conoco Phillips (CP)	12,436 [13]

4.2 Results

In the crude oil impact analysis, the influence of the Operation Neptune Spear event is considered and the study period 03/04/2011-02/06/2011 are divided into two sub-periods, which are before event period 03/04/2011-01/05/2011, and after event period 02/05/2011-02/06/2011. As a preprocessing step, all prices are normalised into $[0, 1]$ to ensure correlation calculation is comparable among different stocks. Then, the correlation of each stock is evaluated to the crude oil by the distance similarity (i.e., Eq.(1)) and channel similarity (i.e., Eq.(9)) calculation, respectively.

As a result, Figure 3 gives a stock to crude oil correlation illustration by the graphical channel method, where the *left* and *right* columns illustrate respectively the correlation for each stock before and after the Operation Neptune Spear event. Table 2 (a) and (b) present the results of crude oil to stock relevance evaluation and ranking by distance and channel similarity, respectively.

As seen from the tables, the overall rank by channel similarity is found consistent to the fundamental truth rank that were defined by the 2011 stock company net income comparison given in Table 1. In contrast, rank by distance similarity gives the result that could not be explained. This implies that the graphical channel approach is able to perceive the market better than the traditional point-to-point distance calculation. This can be on the other hand demonstrated by Figure 3, in which 4 graphical patterns are extracted as: 1) parallel pattern (e.g., BP *right*, XO *right*, and CV *right*); 2) double intersections, which includes actual crossing (e.g., XO *left*) or trend crossing (e.g., ZS *left*); 3) single intersection in same direction (e.g., CV *left*); and 4) single intersection in two reverse directions (e.g., CP *left*, TT *right*). This identifies 4 types of stock to crude oil correlation may occur at different period of the time. The strength of correlation decreases from pattern 1 (strongest positive correlation) to pattern 4 (strongest negative correlation), please find the statistical evidences in Table 2.

5 Impacts Discussion

As known from literature, oil price rises often cause a negative impact on all stock returns except mining, oil and gas industries [5,15,16]. This implies that crude oil to oil-related stocks is on a positive correlation (i.e., stock follows crude

Table 2. Stock to crude oil relevance evaluation and ranking by (a) distance similarity calculation, and (b)channel similarity calculation

Before event		After event		Overall	
Rank	S_d**(Stock)**	**Rank**	S_d**(Stock)**	**Rank**	S_d**(Stock)**
4	0.99870(CV)	5	0.99770(TT)	5	0.99530(TT)
1	0.99820(XO)	6	0.98790(CP)	3	0.96870(ZS)
5	0.99760(TT)	3	0.97780(ZS)	6	0.95070(CP)
2	0.99480(BP)	1	0.94630(XO)	1	0.94450(XO)
3	0.99090(ZS)	4	0.94410(CV)	4	0.94280(CV)
6	0.96280(CP)	2	0.91300(BP)	2	0.90780(BP)

(a)

Before event		After event		Overall	
Rank	S_c**(Stock)**	**Rank**	S_c**(Stock)**	**Rank**	S_c**(Stock)**
3	0.00542(ZS)	2	0.00380(BP)	**1**	0.00792(XO)
1	0.00542(XO)	1	0.00250(XO)	**2**	0.00719(BP)
5	0.00369(TT)	4	0.00250(CV)	**3**	0.00662(ZS)
2	0.00339(BP)	6	0.00230(CP)	**4**	0.00589(CV)
4	0.00339(CV)	5	0.00170(TT)	**5**	0.00539(TT)
6	0.00202(CP)	3	0.00120(ZS)	**6**	0.00432(CP)

(b)

oil on its price variation) As seen from the experimental results, for 5 of total 6 petroleum companies under discussion, the stock price variation matches well the above statement. The exception exits because the stock has been influenced by the Operation Neptune Spear event. It is worth to note that the event takes significant effect on the correlations of crude oil to oil-related stocks. For example, the correlation nature of the stock Shell has changed from positive to negative after the event occurs, meanwhile its correlation strength also drops from the top to the bottom. Among the 6 stocks, Exxon Mobil, BP and Shell are widely recognized as the top 3 largest petroleum companies. They are sensitive to crude oil shocks because they have a higher degree of internationalization, higher outputs of oil production and higher revenues per year as compared to Chevron, Total S.A. and ConocoPhilips. The strongest correlation to oil appears to be Exxon Mobil. The company dominate the market of 5 continents. In 2011, it produced 2.3 million barrels of oil per day and gained 486400 million dollars (US) revenue. On the other hand, ConocoPhilips shows the weakest correlation to crude oil. The company registers to the American market. Its oil production is only 0.7 million barrels per day and its revenue is just 12,436 million dollars (US).

6 Conclusions

The crude oil price has been widely sought has impact on stock market variation. It is practically very difficult for traditional technical and fundamental analysis approaches to discover the correlation of crude oil to an observed stock.

A graphical computational correlation analysis method is proposed for crude oil impact analysis. The comparison results demonstrate the significance of the proposed method against the traditional point-to-point distance calculation. More significantly, it helps discover and characterize the positive impacts to oil-related stocks.

References

1. Lutz, K., Cheolbeom, P.: The Impact of Oil price Shocks on the US Stock Market. International Economic Review 50(4), 1267–1287 (2009)
2. Faff, R.W., Brailsford, T.J.: Oil Price Risk and the Australian Stock Market. Journal of Energy Finance and Development 4, 69–87 (1999)
3. Sadorsky, P.: Oil Price Shocks and Stock Market Activity. Energy Economics, 449–469 (1999)
4. Miller, I.J., Ratti, R.A.: Crude Oil and Stock Markets: Stability, Instability and Bubbles. Energy Economics 31, 559–568 (2009)
5. Jones, C., Kaul, G.: Oil and the Stock Markets. Journal of Finance 51, 463–491 (1996)
6. Kling, J.L.: Oil Price Shocks and Stock Market Behaviour. Journal of Portfolio Management 12, 34–39 (1985)
7. Huang, R.D., Masulis, R.W., Stoll, H.R.: Energy Shocks and Financial Markets. Journal of Futures Markets 16, 1–27 (1996)
8. Pearson, K.: Mathematical Contributions to the Theory of Evolution. On a Form of Spurious Correlation Which Arise When Indices Are Used in the Measurement of Organs. Proceedings of the Royal Society of London 60, 489–498 (1896)
9. BP p.l.c., Summary Review 2011 (2012)
10. Chevron Corporation, 2011 Annual Report (2012)
11. Royal Dutch Shell p.l.c., Royal Dutch Shell plc Annual Review and Summary Financial Statements 2011 (2012)
12. TOTAL S.A. 2011 Annual Report (2012)
13. ConocoPhilips, 2011 Summary Annual Report (2012)
14. Exxon Mobil Corporation, 2011 Financial & Operating Review (2012)
15. Nandha, M., Faff, R.: Does Oil Move Equity Prices? A Global View. Energy Economics 30, 986–997 (2008)
16. Jones, D.W., Leiby, P.N., Paik, I.K.: Oil Price Shocks and the Macroeconomy: What Has Been Learned Since 1996. The Energy Journal 25, 1–3 (2004)
17. Vigdor, J.: The Economic Aftermath of Hurricane Katrina. Journal of Economic Perspectives 22(4), 135–154 (2008)
18. Pang, S., Song, L., Kasabov, N.: Correlation-aided Support Vector Regression for Forex Time Series Prediction. Neural Comput. Appl. 20(8), 1193–1203 (2011)
19. Master, J.: Mississippi River Floor of 2011 already a $2 Billion Disaster. Weather Underground (2011)