# Volatility Modeling for Spot and Futures of Crude Oil – Evidence from Pakistan

**Abdul Rafay**
*Associate Professor, Department of Finance @ SBE, University of Management & Technology (UMT),*
**Usman Javed Gilani**
Assistant Professor, Department of Finance @ SBE, University of Management & Technology (UMT),
**Muhammad Abu Bakar Naeem**
MS Scholar, University of Management & Technology (UMT),
**Maham Ijaz**
MS Scholar, Department of Finance @ SBE, University of Management & Technology (UMT)

## Abstract

*In this article, we study the volatility of Spots and Futures of Crude Oil using daily data from the period 2010-2013. We examine both the Crude Oil Spots and Crude Oil Futures traded on the Pakistan Mercantile Exchange. Our main findings suggest that (1) shocks tend to persist over a long period of time for both Crude Oil Spots and Crude Oil Futures; and (2) shocks have asymmetric effect on the volatility. Hence our findings indicate that behavior of Crude Oil Spots prices and Crude Oil Future prices tends to vary over time.*

Keywords: *Asymmetry, Crude Oil, EGARCH, Shock Persistence, Volatility*

During last 20-30 years, crude oil has obtained the position of leading traded commodity in the world. It accounts for about 10% of world trade and is considered as one of the most significant and active commodity market (Verleger, 1993). Crude oil is playing a significant role in economy, as two-third of energy demands in the world is covered by crude oil. As far as market dealing is concerned, crude oil is traded under a variety of contract agreements including spots as well as futures. Crude oil has generally found to be traded nearer the time of production, and is transported at the time when oil runs from the stocking terminal towards the ship point of free on board (FOB). Thus, prices as spot ones are estimated for instant delivery of commodity (oil) as prices on FOB. In international trading four major benchmark of oil in these days are: (1) WTI; named as West Texas Intermediate, USA reference crude oil, (2) Brent, as North Sea reference crude oil, (3) Dubai, as Middle East as well as Far East benchmark for crude oil, (4) Tapis, as Asia-Pacific region's benchmark for crude oil.

Uncertainty is considered as a significant issue in the field of finance and generally found to be non-measureable, so the externalities effect of volatility markets as well. As a result, a term, volatility spillover, occurs. Volatility spillover happens when changes in volatility within one market produce a lagged impact on volatility occurring in some other markets, over and above restricted effects.

The capacity of the unpredictability implied by option prices to predict future precariousness is considered a measure of the information content of option prices. It has been repeatedly verified in the literature and the results have been slightly mixed. In general, the results of the studies on information content of implied unpredictability offer adequate indication of its efficiency and greater predictive ability. However, implied unpredictability is an upward-biased interpreter of future realized unpredictability, such that the implied unpredictability is on average higher than the realized unpredictability. One of the possible clarifications for the bias in implied unpredictability is the presence of an unpredictability risk premium.

When unpredictability forecast is produced, the participants of energy market identify the most exact estimate yield by model. It also finds whether the complex time series models contribute any significant unpredictability information beyond that contained in option prices. Day & Lewis (1993) describes relative facts and predictive influence of implied unpredictability and ARCH-type forecast forecasts for crude oil future prices. Duffie & Gray (1995) link the forestalling precision of ARCH type models, Markov switching models, and implied uncertainties for natural gas markets, heating Oil and crude oil.

In order to forecast of volatility in energy sector, participants have to pick up which model is accurate for the forecasting of data and also take into consideration whether the respective model under consideration (like time series models), depicts any information regarding volatility that includes the option prices. Day & Lewis (1993) performed ARCH- type forecasts for crude oil futures and implied volatility in comparison with the information content and forecasted power. A study conducted by Xu & Taylor (1996) shows that currency options market for forecasting is checked by the efficiency of PHLX. Regarding volatilities of crude oil and natural gas markets Duffie & Gray (1995) conducted study work by using accuracy of Markov switching models and ARCH type models.

The generalized autoregressive conditional model is widely used to define the concept of uncertainty. The volatility modeling is plays a significant role in hedging, price derivatives and handling risk.

Most of the published researches about volatility modeling focus on bond, equity and exchange rate markets and pays little attention on commodities markets. Studies revealed that since 1980s, volatility in prices of crude oil is significantly higher than other energy products (Regnier, 2007). Because of its importance in overall economy, large fluctuations in oil prices adversely impacts not only macro economy but also financial markets (Sharma et al., 1998). The purpose of this article is to determine the model volatility of crude oil spots and futures by using the ARCH/GARCH Model.

## Literature Review

A detailed research has been conducted on modeling volatility particularly in financial markets. It is an area of interest for the researchers because it helps the researchers for managing risks, derivatives pricing, hedging, portfolio selection and poliy makking. However, understanding the volatility factor in crude oil price is critical. Tenacious variations in volatility can create risks for the investors, and thus investment in oil inventories will be at a crucial stage. Volatility is a significant perspective of derivative valuation, investment and decisions regarding tied to the consumption as well as production of natural oil (Pindyck, 2004).

Federer (1996) states as the crude oil becomes more volatile, it creates more uncertainty, thus causing economic instability for the countries heavily engaged in oil trading (import/export). One mechanism states that there are symmetric effects of shocks in oil price; positive shocks cause reduction in economic growth, however, negative shocks increase growth. Hamilton (1983) considered the period after Second World War up to 1973 and found that economic activity of that period was strongly correlated with oil prices. This relationship had been weakened after crisis. Hooker (1996) found out the reduced linear relationship between oil prices and those of economic activities since 1973. The mechanism that explains the asymmetry in the relationship of oil prices with that of economic activities lies in the theories regarding investment as well as real options (Bremnan & Schwertz, 1985; Bremnan, 1990).

Some studies investigate the direct effects of uncertainty in oil price on the economic activities. Pindyck (1991) considered many uncertainty issues and stated that recessions of 1980 and 1982 may have been subsidized due to these uncertainties in oil prices. Federer (1996) found that uncertainty in oil prices had unfavorably exaggerated output in United States from 1970 to 1990. Edelstein & Kilian (2007) and Kilian & Vigfusson (2009) found slight evidence of asymmetries caused due to uncertainty effect. It has been studied that demand shocks, uneven investment and lethargic energy production could be the reasons for oil price jumps (Wirl, 2008). The uncertainty in oil prices elucidates two features of oil prices and output relationship. One is the failure of mid 1980s vivid oil prices drop to produce rapid growth in output. Other is the failure of increased oil prices from 2002 to 2008 for reducing recession more eagerly (Serletis & Elder, 2010).

It has also been researched that the variations in oil prices at international level has an impact on various macroeconomic factors such as; inflation, GDP, growth as well as exchange rates, stock markets (Davis & Haltiwanger, 2001; Hooker, 2002). Guo & Kliesen (2006) used the daily crude oil futures traded in NYMEX and described the results that oil price volatility measures of 1984 to 2004 had adverse and substantial effect on U.S macro-economic measure; like consumption, fixed investment and employment rates. This depicts that increased prices of crude oil matters less than increased volatility. Kilian (2008) reviewed that shocks in prices of oil and transmission of these shocks through channels has a noteworthy impact on U.S as well as global economy. However, speculation has played an important role in sharp increase in prices. These speculative behaviors have also been reported by Gaballero et al. (2008) and Hamilton (2009) in crude oil prices projection processes.

The volatility of oil prices over past years has increased interest regarding relationship of oil prices with economy as well as monetary markets. Chenn et al. (1986) contended no impact of oil prices towards the stock prices trends. However, Jones & Kaul (1996) stated that impact of oil prices in stock returns vary country to country, depending upon the production and consumption level of oil. They also found that post war period increase in prices of oil had a noteworthy influence on stock returns. Sadorsky (1999) reported that increase in prices of oil has a noteworthy negative effect on U.S. stocks. Driesprong et al. (2008) studied if stock prices are predicted by the changes in oil prices. They found that sensitivity to changes in oil prices vary from country to country. Park & Ratti (2008) found that oil prices have a greater role in the stock market of countries specialized in importing oil. Here stock markets are less affected by oil price changes.

On hypothetical grounds, shocks in prices of oil exert an effect on stock market returns by exerting their impact on predictable earnings (Jones et al., 2004). Pollet (2002) and Driesprong et al. (2008) reported that globally, variations in oil-price found to have prediction about stock market returns. Some researchers reported that volatility in oil-price has proved to have a negative impact on stock prices (Apergis & Miller, 2008). In another study, there has been found negative correlation between price and volatility that proved tobe a better forecasting result for changes in prices of crude oil (Morana, 2011).

Various models have been used previously by the researches to analyze the volatility in crude oil markets. A sophisticated econometric model has been used by Humington (1994) in 1980s. Another model named as probabilistic one has been applied by Abranson & Finiza (1995) for oil prices prediction. Morona (2001) worked on forecasting short-term oil prices, based on crude oil price GARCH properties, using semi-parametric statistical method. Similarly, VAR (value at risk) model has been used for U.S oil price prediction (Mirmrani & Li, 2004). Error correction model (ECM) has also been used by Lanza et al. (2005) for projecting crude oil as well crude oil products’ prices.(Bekiros & Diks, 2008)

Various experiments have, however, revealed that using these econometric traditional models might decrease the forecasting performance. The reason lies in the phenomena that these models are based on linear assumptions and are unable to cover non-linear patterns in price series of crude oil. Thus, ARCH/GARCH approach covering various models has been put forward for the projection of crude oil prices.

Day & Leiwis (1993) compared volatility predictions/ forecasts of oil prices using GARCH and EGARCH, along with implied and histoical volatility. They reported the results showing both implied along with EGARCH or GARCH as conditional volatilities provides the information about volatility. Morana (2001) and Sadorsky (2002) stated that ARMA & ARCH type models tend to forecast quite accurately, as they cover linear as well as non-linear time series models. But if the data under study is non-linear and chaotic for projecting oil prices process, linear and non-linear models do not appear to be ideal. This is because; the parametric ARCH type models will have changing means and variances in such a situation. Some researchers neglected those structural breaks in GARCH parameters that tend to induce upward partialities in estimating GARCH based conditional volatility persistence (Arouri et al., 2010).

Sadorsky (2006) preferred univariate, state-space as well as bivariate models for crude oil price predictions. He concluded GARCH with single equation to outperform other models for the prediction of oil price futures. A period from 1991 to 2006 has been examined by Narayan & Narayan (2007) for conditional volatility projection of crude oil prices through ARCH-GARCH methods and reported enduring and asymmetric effects of price shocks on volatility. Marzo & Zagagli (2007) researched on predicting crude oil prices based on closing-day futures traded in NYMEX, using linear GARCH models. These volatility models had been compared in the study and results depicted that EGARCH and GARCH-G models perform best in underlying scenario. However, GARCH-G performs best for one to three days ahead short horizon. On contrary, no model had been identified to be superior for one week horizon. Agnolucci (2009) worked on the oil futures that are traded in NYMEX and covered the data up to 2005. He compared implied volatility model with those of GARCH type models, and concluded that later performs better than implied volatility models. For forecasting scenarios, he further suggested that the CGARCH model seems to perform better than GARCH.

Another study used various GARCH models for forecasting volatility power of competitive GARCH models. The study compared standard GARCH, CGARCH (component GARCH), IGARCH (integrated GARCH) and FIGARCH (fractional integrated GARCH). Three benchmarks for oil prices had been used, named as WTI (USA), Dubai (Middle East), Brent (North Sea). The results identified CGARCH and FIGARCH to be better measures of modeling and projecting the persistence of crude oil returns volatility, as compared to standard GARCH and IGARCH(El et al., 2010). Wei et al. (2010) also compared the aptitude of GARCH type models to predict the volatility in crude oil prices and reported that these models outperforms in few areas. Vo (2009) compared the forecasting ability of four different models: (1) a Markov switching stochastic volatility (MSSV) model, (2) a stochastic volatility (SV) model, (3) a GARCH model, and (4) a Markov switching (MS) model and finally documented that nonlinear GARCH model outperforms all others. Thus, to model volatility, this article uses GARCH type models. It covers most recent years related to the prices of crude oil, as previous researches have proved these models to outperform all other models.

## Data Analysis and Results

The data required for the purpose of analysis is the returns on the crude oil spots. In order to calculate the returns we use daily spot prices of crude oil, obtained from Thompson Reuter's database and the data on crude oil futures, obtained from PMEX (Pakistan Mercantile Exchange). We used the closing price of Crude100 future contract as Crude Oil Futures. The price taken as daily prices is the closing price of each traded day. For the purpose of modeling, the data on crude oil spots span from January 4, 2010 to December 31, 2013 – a total of 1,008 observations.

Table 1. *Summary Statistics*

| | Mean | SD | Skewness | Kurtosis | Max | Min |
|---|---|---|---|---|---|---|
| Oil Prices | 91.598 | 9.831 | -0.157 | 2.281 | 113.39 | 64.78 |
| Oil Futures | 92.3999 | 9.471171 | -0.19251 | 2.36346 | 113.83 | 69.54 |

Table 2. *Dickey Fuller Test*

| Returns | p-value for Z(t) |
|---|---|
| Crude Oil Spot | 0.0000 |
| Crude Oil Future | 0.0000 |

Table 1 shows that mean price of crude oil over the period 2010-2013 is $91.58 per barrel. The maximum and minimum prices are $113.39 and $64.78 respectively. The mean price of crude oil futures is $92.4 with the standard deviation of $9.47. The maximum price of oil futures is $113.83 and the minimum price of $69.54. The summary statistics table also shows us that the return series has kurtosis greater than 2, indicating the presence of fat tails. It is also analyzed that both the prices and the return series are not normal. Table 2 shows the Dickey Fuller test on the crude oil spot and 1-month future contracts returns series. From that we see that the return series is stationary, which is required for time series analysis.

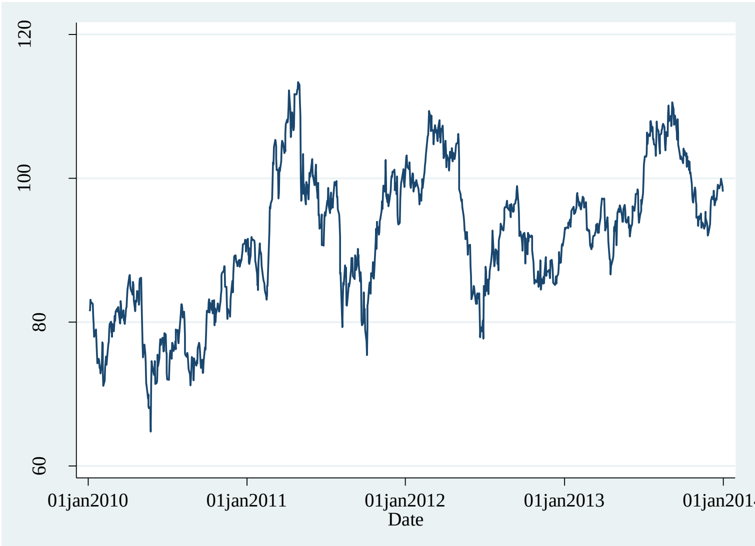


*Figure 1.* Line Plot of Crude Oil prices

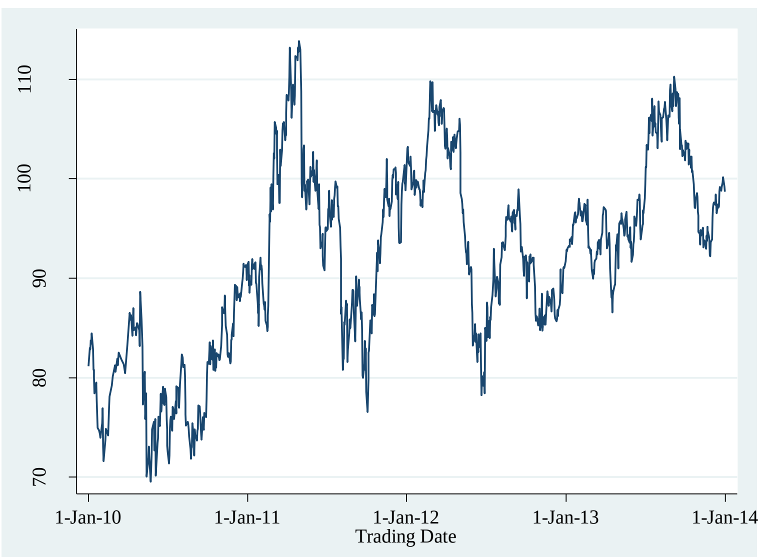


*Figure 2.* Line Plot of Crude Oil Future

From Figure 1 and 2, we analyze that the crude oil prices, crude oil futures are showing upward trend. We also see that the prices of crude oil and the associated futures contracts are showing unsteady behavior.

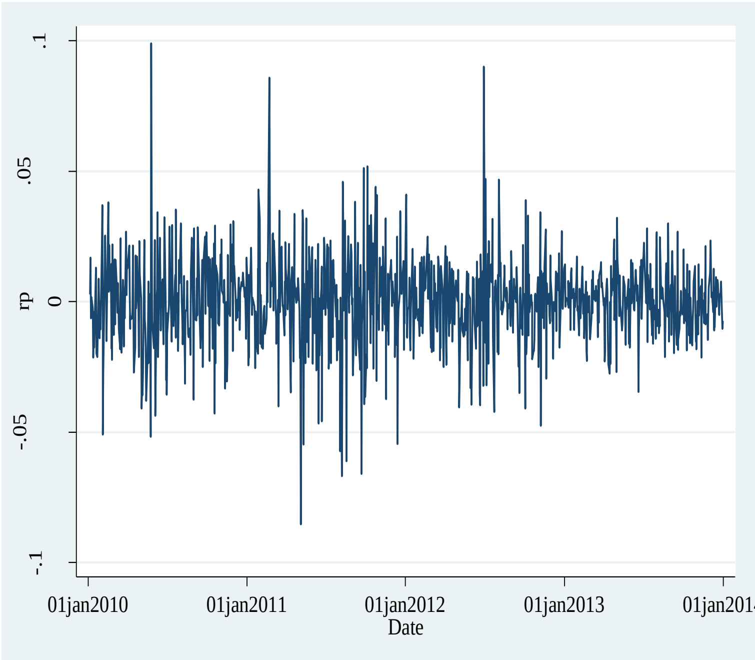


*Figure 3.* Line Plot of Returns (Crude Oil Spots)

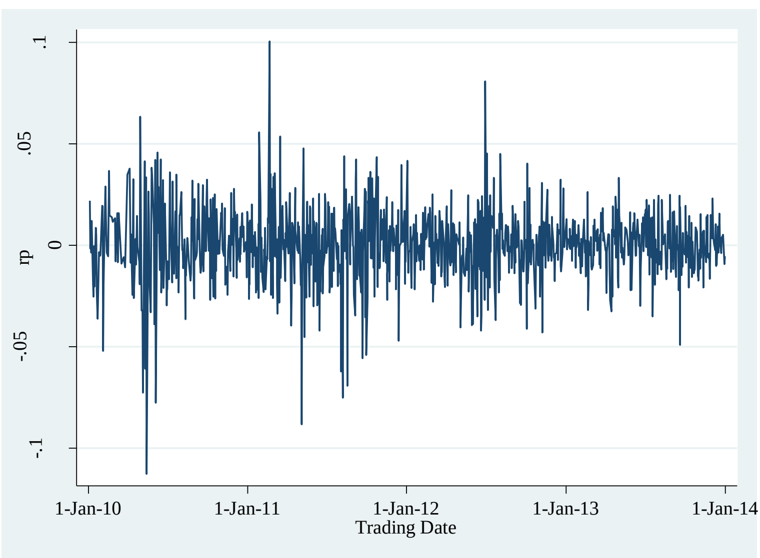


*Figure 4.* Line Plot of Returns (Oil Futures)

Figure 3 and 4 shows the line plot for returns, from that we also get the evidence of volatility clustering i.e. periods of high volatility are followed by periods of serenity.

**Model**

Following is the representation of returns of crude oil spots

$$R_t = \frac{(P_t - P_{t-1})}{P_{t-1}}$$

Where$P_t$ the price of crude is oil and $P_{t-1}$is the previous day price of crude oil. We calculated returns by subtracting the log of prices at the beginning of the period from the log of prices at the end of period.

$$r_t = \ln(1 + R_t) = \ln\left(\frac{P_t}{P_{t-1}}\right)$$

To test the conditional heteroskedasticity we used the ARCH-LM test of squared residuals. The ARCH-LM test indicates the presence of conditional heteroskedasticity. We observe Null hypothesis of arch-lm test based on ARMA; we observe statistics and reject null hypothesis which is NO ARCH effect. Therefore we suggest return series is hetroskedasticity. EGARCH model suggested by Nelson (1991) is used which is an extension of the GARCH model in order to model the volatility of oil price spots and oil price futures. A conditional normal distribution is assumed having the following mean and variance equations:

**Mean Equation**

$$r_t = c + \sum_{i=1}^{p} \delta_i + r_{t-i} + \varepsilon_t + \sum_{j=1}^{q} \vartheta_j + \varepsilon_{t-j}$$

**Variance Equation**

$$\log(\sigma_t^2) = \omega + \alpha\left(\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| - \sqrt{\frac{2}{\delta}}\right) + \gamma\frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta\log\sigma_{t-1}^2$$

We favor the EGARCH model because it does not impose restrictions on$\alpha$, $\gamma$ and $\beta$. EGARCH allows for more natural interpretation of size and persistence of shocks.The $\beta$ estimate evaluates whether shocks are persistent or not.$|\beta| < 1$ confirms stationarity, which is required for the analysis of time series data.The $\gamma$ parameter captures the asymmetric volatility. If $\gamma > 0$, then positive shocks give rise to higher volatility.The magnitude of conditional shocks on conditional variance is represented by $\alpha$.

## Empirical Findings

We notice that for both crude oil spots and crude oil futures, our $\gamma$ coefficient is positive and significant at 1%. Hence we can say that the positive shocks have more impact on volatility, whereas negative shocks impact less on the volatility of crude oil spots and crude oil futures. This also shows that shocks have asymmetric effect on crude oil prices as both negative and positive shocks have different impact on the volatility. $\beta$ Co-efficient that captures persistence of shocks, is positive and statistically significant at 1%. The value of the coefficient 0.66 for crude oil spots and 0.79 for crude oil futures suggests that the shocks tend to persist over long period of time. It is noticed that the value of the coefficient is close to 1, which indicates that the shocks to the volatility do not die out rapidly. It also indicates that shocks have permanent effect on the volatility. The value of $\alpha$ coefficient is -.146 for crude oil spots and -0.437 for crude oil futures, which indicates the magnitude of the conditional shocks. Negative sign can be eliminated as it is the magnitude. The $\alpha$ coefficient for crude oil futures is not statistically significant. Hence have a little or no impact on the model. In view of the foregoing, it is clearly evident that shocks to crude oil spots and crude oil futures volatility have asymmetric and persistent effect.

## Conclusion

This purpose of this paper is to model the volatility of the crude oil spots and crude oil futures. To model the volatility we used EGARCH (exponential GARCH) model which is an extension of the GARCH model. The aim was to check whether shocks have asymmetric and persistent effects on volatility. Our results indicate that shocks have asymmetric effect on the volatility of crude oil spots as well as the volatility of the crude oil futures. Our results suggest that prices are not stable. Our findings confirm that negative shocks that give rise to the oil prices are not fully compensate for by the positive shock that reduces the oil price. The effects from the shocks tend to be persist over a long period of time. Also when modeling the oil prices we need to keep in mind about the regime shifts. Hence whether there is political or economic shift, there will be impact on the volatility of crude oil, which will lead to the increase or decrease of the price of crude oil, depending whether the shocks are of positive or negative nature.

Table 3. *Parameters of Mean Equation (ARMA)*

| | Oil Price | Oil Futures |
|---|---|---|
| C | 0.0001786 | 0.0002487 |
| | (0.0005496) | (0.000576) |
| δ1 | `-0.8481145*** | `-1.384666* |
| | (.4828056) | (0.0209378) |

| | | |
|---|---|---|
| δ2 | | `-0.9584329* |
| | | (0.0216773) |
| ϑ1 | 0.8379404*** | 1.335637* |
| | (.4946124) | (0.0318677) |
| Θ2 | | 0.9178685* |
| | | (0.0314334) |

Note: ***, **, * indicate statistical significance at 10%, 5% and 1%.
Standard Error in Parenthesis.

Table 4. *Parameters of Variance Equation (EGARCH)*

| | Oil Price | Oil Futures |
|---|---|---|
| Ω | `-2.742574* | `-1.678011** |
| | (0.9090799) | (0.8227037) |
| $\alpha$ | `-0.14567* | -0.0437722 |
| | (0.03768) | (0.0335897) |
| $\gamma$ | 0.4680849* | 0.5983219* |
| | (0.0558665) | (0.0508991) |
| $\beta$ | 0.6630586* | 0.7906651* |
| | (0.1117893) | (.1025825) |

Note: ***, **, * indicate statistical significance at 10%, 5% and 1%.

## References


Agnolucci, P. (2009). Volatility in crude oil futures: A comparison of the predictive ability of GARCH and implied volatility models. *Energy Economics, 31*, 316–321.

Apergis, N., & Miller, S. M. (2008). Do Structural Oil-Market Shocks Affect Stock Prices? *Department of Economics Working Paper Series.*

Bekiros, S. D., & Diks, C. G. H. (2008). The relationship between crude oil spot and futures prices : Cointegration , linear and nonlinear causality, *30*, 2673–2685.

Brennan, M. (1990). Latent assets. *Journal of Finance*, *45*, 709-730.

Brennan, M., & Schwartz. E. (1985). Evaluating Natural Resource Investment. *Journal of Business*, *58*, 1135-1157.

Chen, N. F., Roll, R., & Ross, S. A. (1986). Economic Forces and the Stock Market. *Journal of Business, 59*, 383-403.

Cheong, C.W. (2009). Modeling and forecasting crude oil markets using ARCH-type models. *Energy Policy, 37*, 2346-2355.

Davis, S. J., & Haltiwanger, J. (2001). Sectoral Job Creation and Destruction Responses to Oil Price Changes. *Journal of Monetary Economics, 48*, 465-512.

Day, T. E., & Lewis, C.M. (1993). Forecasting futures market volatility. *Journal of Derivatives, 1*, 33-50.

Driesprong et al. (2008). Striking oil: Another puzzle? *Journal of Financial Economics, 89*, 307-327.

Duffie D., & Gray S. (1995). Volatility in Energy Prices: Managing Energy Price Risk. *RiskPublications London*, pp. 39 - 55.

El, M., Arouri, H., Nguyen, D. K., & Lahiani, A. (2010). Forecasting the conditional volatility of oil spot and futures prices with structural breaks and long memory models, 2 - 33.

Elder, J., & Serletis, A. (2009). Oil price uncertainty in Canada. *Energy Economics*, *31*(6), 852–856.

Ferderer, J.P. (1996). Oil Price Volatility and the Macroeconomy.*Journal of Macroeconomics*, *18*, pp. 1-26.

Guo, H., & Kliesen, K. L. (2005). Oil Price Volatility and U . S . Macroeconomic Activity, 669–684.

Hamilton,J. D. (2009). Causes and Consequences of the Oil Shock of 2007-08, *Brookings Papers on Economic Activity*, 215-259.

Hooker, M.A. (1996). What Happened to the Oil Price-Macroeconomy Relationship? *Journal of Monetary Economics, 38*, 195-213.

Hooker, M. A. (2002). Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime. *Journal of Money, Credit and Banking, 34*, 540-561.

Jones, C. M., & Kaul, G. (1996). Oil and the Stock Market. *Journal of Finance, 51*, 463-491.

Jones, D. W., Leiby, P. N.,& Paik, I. K.(2004). Oil price shocks and the Macroeconomy: What has been learned since 1996.*The Energy Journal, 25*, 1-32.

Kilian, L. (2007). The Impact of Oil Price Shocks on the U . S . Stock Market, 1 - 35.

Kilian, L., &Vigfusson, R. (2009). Are the Responses of the U.S. Economy Asymmetric in Energy Price Increases and Decreases? *Working Paper, University of Michigan*.

Marzo, M., & Zagaglia, P. (2007). Volatility forecasting for crude oil futures, 2 - 33.

Morana, C. (2001). A semiparametric approach to Short-Term Oil Price Forecasting. *Energy Economics 23*, 325-338.

Narayan, P. K., & Narayan, S. (2007). Modelling oil price volatility. *Energy Policy*, *35*(12), 6549–6553.

Park, J. W., & Ratti, R. A. (n.d.) (2007). Oil price shocks and Stock markets in the U . S . and 13 European Countries, 1 - 31.

Pollet, J. (2002). Predicting Asset Returns with Expected Oil Price Changes. *Working Paper, Harvard University.*

Regnier, E. (2006). Oil and Energy Price Volatility. *Energy Economics 29*, 405 - 427.