Study of short term relation between volatility in crude oil spot and future markets

Ensieh Shojaeddini[1], Shahram Golestani[2]

[1.] Faculty of Economic, University of Tehran, Tehran, Iran,
[2.] Faculty of Management and Economic, University of Shahid Bahonar, Kerman, Iran
shojaeddini@alumni.ut.ac.ir

Abstract: Volatility is one of the main characteristics of oil markets and since the fluctuations of oil prices have an undeniable effect on the countries economy, modeling and forecasting the volatility of these markets have been focus of economic researchers. In this study, in addition to modeling the volatility of oil future and spot prices in two markets of West Texas Intermediate and the north sea Brent, the relation between the volatility of these markets is investigated. ARIMA- GARCH and LS models are employed for estimation. Based on the obtained results, by changing the volatility in each of oil spot and future markets, the volatility in other markets will change by a ratio more than one. Based on Engel-Granger causality test, the causality between variables volatility is bidirectional and generally indicates that presence of volatility in each of crude oil markets in short term results in more volatilities in other crude oil markets.

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1. Introduction

Nowadays, oil is the most strategic and politic product in the world and also is the most important trading commodity in the world in terms of value and volume of transaction. So its price variations have many effects on the economy of countries and their financial sectors whether they are importers or exporters. In macro level the increase of oil prices in oil importing countries results in the increase of imports nominal value and decrease in economic growth and also has an effect on stock market and the performance of non-oil industries. On the other hand in oil- exporting countries this increase results in the improvement of economic growth and positive effects on the operation of oil companies and industries. But volatility in oil market is non favorable for both importers and exporters. The sensitivity to the oil price variations is different in various sectors and industries and this elasticity determines the amount of the tolerated risk and the risk transferred by the industries to the consumers and other sectors (Hammoudeh and Li, 2003).

Variations in world oil prices may lead to different crises, effect on prices level and rising the inflation and intensifying the recession in oil-importing and oil-exporting countries. The degree of fluctuations or instability in oil price has a significant effect on the risk of oil industrial producers and consumers and is a determinant factor in derivation the pricing and investment decisions in oil production or consumption. With respect to the mentioned reasons oil price is important both economically and politically and the economic researchers have been looking for the price structure of this product and its modeling so that the policy makers can make the necessary decisions by forecasting the variations of oil prices and its effects on the economy.

Many studies have been conducted on the volatility of oil prices. Some of these studies have investigated the effect of oil prices volatility on the economic sectors and variables and some have investigated modeling and forecasting the volatility.

Lewis (1993) forecasted the volatility of crude oil price over the period of 1986 – 1994 using GARCH (1,1) model. Duffie and Gray (1995) forecasted the volatility of heating oil over the period of 1988 to 1992 using GARCH (1,1) and EGARCH (1,1) models. Daruelsson (1998) estimated a multivariable random volatility model using the simulated maximum likelihood technique and compared it with a multivariable GARCH model. Based on his results multivariable random volatility mode has fewer parameters and higher likelihood valuation (worth) than multivariable GARCH models.

Benassay et al. (2007) investigated the convergence and causality between real oil price and real dollar price over the period of 1974 to 2004 and based on their results by 10 percent increase in oil prices, dollar price will increase by 4.3 percent and the causality direction is from oil price to dollar price.

Using the daily data of WTI oil spot and future prices Yu-Shao Liu et al. (2011) investigated the relationship between these prices employing Breitung ranking test. Then they estimated asymmetric TECM GJR-GARCH model in the presence of asymmetric price and in volatility transfer of oil spot and future markets to obtain the short term and long term dynamic adjustments. Based on their findings the relation between oil future prices and oil spot prices are cointegrated and nonlinear in long term which approves the expectations hypothesis. Also they found that despite of bad news in spot and future markets the volatility increases and there are asymmetric effects in both spot and future markets based on their conditional variance models.

Arouri et al. (2012) predicted the conditional volatility of oil spot and future prices using GARCH models by taking into account the structural breaks and long-term models. Based on their results there is parameters volatility among nine GARCH models in five models and the long term effect exists in all series. They found that FIGARCH model estimates the data better but the volatility degree decreases significantly after the structural break.

Giang Ji and Ying Fan (2012) investigated the effect of crude oil market on non energy products market including agriculture and metals. They considered the U.S. dollar index as an exogenous shock and investigated the price and examined the volatility between product markets by developing an EGARCH model and establishing a relation between different times.

Based on their results crude oil market has minor volatility effects on non energy products market. The relation is amplified after the crisis and also the effect of the U.S. dollar index on product markets is weakened after the crisis.

Aijun Hou and suardi (2012) forecasted the volatility of oil prices in Brent and WTI markets using nonparametric GARCH model. By studying the forecasting power they found that this method is more appropriate than parametric GARCH models.

In the studies conducted so far the volatility of oil prices has been forecasted and modeled separately in each market but the relation between them has not been investigated. This paper investigates the short-term relation between the volatility of oil spot and future prices in each of WTI and Brent markets and also the relation between the volatility of two spot prices markets. The monthly Brent and WTI crude oil spot prices and crude oil future prices have been employed in the form of four types of contracts over the period of April 1981 to March 2012.

In other words we want to know that if there is a shock in WTI crude oil spot market whether this shock has an effect on the volatility of Brent crude oil spot prices and the volatility of Brent and WTI oil future prices and How great this effect is in short term. Moreover the relation between crude oil spot and future prices in two mentioned markets is investigated the details of which is presented in appendix 1.

2. Modeling the random volatility

Random volatility models are employed to investigate the prices volatility in short term. These models cannot explain the characteristics of long term observations of volatility level. There are many random models such as Haston, CEV. SABR, GARCH, 3/2, Chen models.

Since the family of GARCH models is employed to study the volatility we explain only this model.

2-1 ARCH- GARCH models

In econometrics the autoregressive conditional heteroscedasticity models are employed to explain and model time series observations which their variances don't follow normal process due to different reasons (different conditions) such as shock, policy. In this way the variance in every period has a relation with its previous period and will be conditional. The market experiences volatility If these effects increase in each period. The family of ARCH- GARCH models includes many types such as ARCH, GARCH, NAGRCH, IGARCH, EGRCH, GARCH- M, QGARCH, GIR-GARCH, TBARCH and FGARCH. Since only GARCH and ARCH models have been employed in this study a brief description of these models is presented.

2-1-1 ARCH (P) model

Suppose that we have a function as:

$$y_t = \beta_0 + \sum_{i=1}^{n} \beta_i x_{it} + \sum_{j=1}^{n} \varphi_j y_{t-j} + e_t$$

Since $S_t^2 = \frac{\sum e_t^2}{n-1}$ is the general form of an ARCH (P) model as follows:

$$\delta_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \delta_{t-i}^2 + \varepsilon_t$$

Where ε_t is independent identically distributed normal random variable with the mean and variance zero and δ_ε^2.

2-1-2 **GARCH (p,q) model**

A GARCH (p,q) model is in general form as follows:

$$\delta_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \delta_{t-i}^2 + \sum_{j=1}^{q} \lambda_j \varepsilon^2_{t-j}$$

Where ε_t is independent identically distributed normal random variable with the mean and variance zero and δ_ε^2. This model indicates the presence of the multiplied effect of shock on time series variance. In other words time series variance not only is a function of previous period variances but also is a function of previous periods shock.

3. Modeling the volatility of oil prices

In this study ARIMA – GARCH, LS and ML-ARCH models are employed to estimate the model. Such that each variable is regressed on itself and due to the variables stationary ARIMA model is employed. The optimized values of p and q are also obtained using Akaike and schwartz criteria. The equation of each variable is generally as follows:

$$(1-\sum_{i-1}^{p}\alpha_i L^i)\,P_t = (1+\sum_{i-1}^{q}\theta_i L^i)\,\varepsilon_t \quad (1)$$

$$et \sim iid, N(0,\sigma^2)$$

That to find the conditional variance time series the optimized ARCH- GARCH equation is obtained that general form of it is as follows:

$$\delta_t^2 = \alpha_0 + \sum_{i=1}^{p}\alpha_i\delta_{t-i}^2 + \sum_{j=1}^{q}\lambda_j\varepsilon^2{}_{t-j} \quad (2)$$

After determining the conditional variance time series of oil prices the relation between these series is investigated using LS and ML-ARCH methods and if there exists variance heteroscedasticity the ARCH-GARCH model is employed.

4. Data and model estimation

4-1 Data

Oil spot prices are oil prices in every moment which are different in each of West Intermediate Texas (WTI) and Brent markets depending on their quality. Oil future prices are the contracts of buying and selling oil which are related to the future and are divided into different types of one- month, two – month and etc. based on the time period. The extent of oil price fluctuations in different markets is known as volatility that is usually expressed as standard deviation. With respect to oil price fluctuations the volatility exists in all spot and future markets of Brent and WTI. Observing the variations of oil prices conditional variance one can identify the volatility in these markets (Figures 1, 2 and 3).

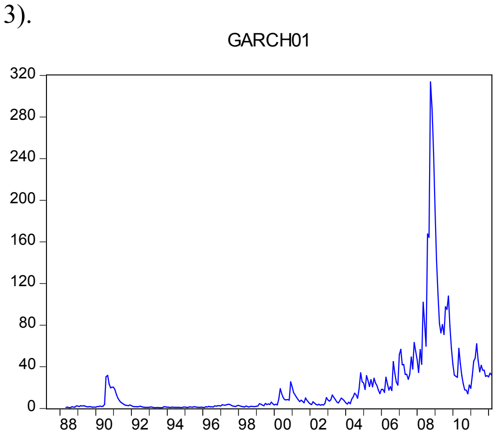

Figure 1. Conditional variance of Brent crude oil spot prices

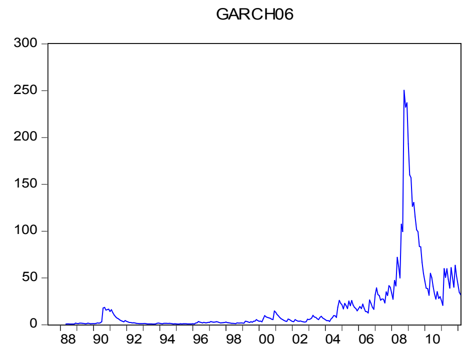

Figure2. Conditional variance of WTI crude oil spot prices

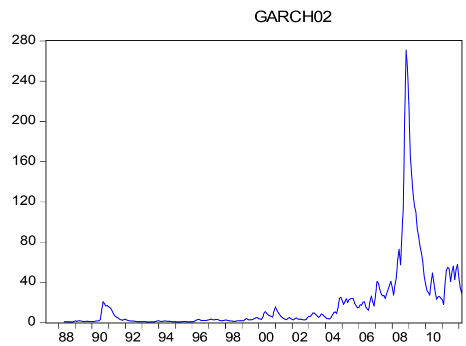

Figure 3. Conditional variance of crude oil future prices (contract1)

The data employed in this study are monthly which are: WTI and Brent crude oil spot prices and crude oil future prices including crude oil future contracts of Cushing, OK types 1, 2, 3 and 4. The Data are related to the period of April 1987 to March 2012 and are expressed as the U.S. dollar per each barrel all of which are taken from International Energy Agency website.

Each contract expires on the third business day prior to the 25th calendar day of the month the delivery month. If the 25th calendar day of the month is a non-business day, trading ceases on the third business day prior to the business day proceeding the 25th calendar day. After a contract expires, Contract 1 for the remainder of that calendar month is the second following month. The future contracts types 2,3 and 4 are contracts that their due date is in the months after the contract type 1 (second, third and forth months). In other words the future contracts types 1 to 4 are one – month, two- month, three-month and four- month contracts, respectively.

A dummy variable is used to show the January effect in model estimation.

4-2 Model estimation

After estimating all equations and conducting the related tests such as auto correlation, heteroscedasticity, presence or absence of dummy variables tests the conditional variance autoregressive equations of variables are obtained (appendix 2). Then the time series of the mentioned equations conditional variance are obtained. The relation between the variances is investigated using ML-ARCH method. The results obtained are as follows:

$$G(dbsp)_t = -0.17 + 1.08G\,(dfc1)_t + 0.21G\,(dbsp)_{t-1} + 0.04G\,(dbsp)_{t-2} + 0.26\varepsilon_{t-1} + 0.15\varepsilon_{t-2}\ (R2 = 0.94)$$
(-9.22) (215.17) (5.65) (1.80) (7.91) (10.99)

$$G(dbsp)_t = -0.13 + 1.18G\,(dfc2)_t - 0.35G\,(dbsp)_{t-1} - 0.05G\,(dbsp)_{t-2} + 0.30G\,(dbsp)_{t-3} + 0.95\varepsilon_{t-1} + 0.69\varepsilon_{t-2}\ (R2 = 0.96)$$
(-1.48) (91.11) (-7.09) (-1.78) (15.08) (27.07) (28.93)

$$G(dbsp)_t = -2.90 + 2.44G\,(dfc3)_t + 1.81G\,(dbsp)_{t-1} - 0.80G\,(dbsp)_{t-2} - 0.87\varepsilon_{t-1}\ (R2 = 0.95)$$
(-3.82) (89.57) (15.38) (-6.65) (-11.82)

$$G(dbsp)_t = -3.09 + 2.43G(dfc4)_t + 1.04G(dbsp)_{t-1} - 0.24\varepsilon_{t-1}\quad (R2 = 0.94)$$
(-1.58) (52.71) (39.80) (-2.63)

$$G(dwsp)_t = -0.12 + 1.03G(dfc1)_t - 0.89G(dwsp)_{t-1} - 0.06G(dwsp)_{t-2} + 0.08G(dwsp)_{t-3} + 0.82\varepsilon_{t-1}\quad (R2 = 0.98)$$
(-5.78) (300.10) (-24.37) (-2.52) (5.94) (32.34)

$$G(dwsp)_t = 0.03 + 1.14G(dfc2)_t - 0.80G(dwsp)_{t-1} - 0.09G(dwsp)_{t-2} + 0.39G(dwsp)_{t-3} + 1.11\varepsilon_{t-1} + +0.73\varepsilon_{t-2}\quad (R2 = 0.98)$$
(0.41) (522.96) (-54.26) (-5.19) (33.12) (100.88) (67.17)

$$G(dwsp)_t = -0.02 + 1.45G(dfc3)_t + 0.61G(dwsp)_{t-1} - 0.70G(dwsp)_{t-2} + 0.66G(dwsp)_{t-3} + 0.24\varepsilon_{t-1} + +0.88\varepsilon_{t-2}\quad (R2 = 0.98)$$
(-.18) (154.45) (5.47) (-5.61) (7.84) (2.83) (11.63)

$$G(dwsp)_t = 0.30 + 1.27G(dfc4)_t + 0.40G(dwsp)_{t-1} - 0.16G(dwsp)_{t-2} - 0.35G(dwsp)_{t-3} + 0.57G(dwsp)_{t-4} + 0.62\varepsilon_{t-1} + 0.45\varepsilon_{t-2} + 0.77\varepsilon_{t-3} + 0.17\varepsilon_{t-4}\quad (R2 = 0.97)$$
(5.13) (54.39) (4.25) (-1.54) (-4.20) (14.17) (5.88) (7.68) (13/17) (3/67)

$$G(dbsp)_t = 9.49 + 1.55G(dwsp)_t + 1.50G(dbsp)_{t-1} - 1.15G(dbsp)_{t-2} + 0.65G(dbsp)_{t-3} - 0.72\varepsilon_{t-1} + 0.59\varepsilon_{t-2}\ (R2 = 0.94)$$
(0.14) (127.37) (14.50) (-7.02) (6.38) (-6.67) (6.95)

The above variables represent the conditional variance time series related to auto regressive equation of DBSP (Brent crude oil spot price), DFC1 (the price of future contract type 1), DFC2 (the price of future contract type 2), DFC3 (the price of future contract type 3), DFC4 (the price of future contract type4) and DWSP (west Texas intermediate crude oil price) variables. The first four equations show the extent of relationship between the dependent variable G (dbsp) and Crude oil future prices in all of which the coefficients of descriptive variables are greater than one and indicate that the change of volatility in a future market results in more changes of volatility in Brent crude oil spot market. The second four equations show how the volatility of different types of crude oil future contracts affects Brent spot prices. In these equations the coefficients of descriptive variables are also greater than one and indicate that the change of volatility in one of future prices results in more changes in volatility of WTI spot prices.

Another point is that the volatility in future contracts types 3 and 4 (with later due date) has more effects on the volatility of spot prices than future contracts types 1 and 2.The last equation shows the relation between spot prices volatility in two markets of WTI and Brent and indicates that the change of volatility in WTI spot prices market leads to more changes in volatility of Brent spot prices market. Moreover Granger- Engel causality lest is employed to determine the causality direction based on which the causality in each crude oil market leads to more changes in volatility of other crude oil markets.

5. Conclusion

In this study the relation between the volatility of crude oil spot and future prices in two markets of Brent and WTI was investigated and the results indicate that there is a close relation between future and spot prices and also between their volatilities. Based on the above findings if there is a shock in one of oil future prices market a greater shock will occur in spot prices and vice versa. More over the presence of volatility in WTI or Brent spot prices market results in more volatilities in other markets.

Appendix 1: The relation between oil prices

In the study of the relation between oil spot and future prices in Brent and WTI markets since all variables are integrated with the degree of one. The error terms of the equations is examined and in case of stationary the variables difference are replaced by the variables themselves and are estimated. After conducting the related tests and resolving the variance heteroscedasticity and auto correlation the estimation results and their t or z statistics are given as follows:

$DBSP_t = - 0.07 + 1.04DFC_{1t} + 0.04DBSP_{t-1}(R^2 = 0.88)$
(- 1.88) (151.30) (2.07)

$DBSP_t = - 0.008 +1.07DFC_{2t} - 0.84DBSP_{t-1}+ 0.93\ MA(1) \quad (R^2 = 0.91)$
(-0.23) (93.27) (-11.17) (22.56)

$DBSP_t = 0.04 + 1.04DFC_{3t} + 0.29DBSP_{t-1}(R^2 = 0.92)$
(0.38) (52.69) (5.2)

$DBSP_t = - 0.04 + 1.08\ DFC_{4t} - 0.9\ DBSP_{t-1}+ 0.97\ MA(1) \quad (R^2 = 0.90)$
(-1.17) (84.37) (-36.67) (166.94)

$WSP_t = 0.01 + 1.00\ FC_{1t} + 0.50\ WSP_{t-1} +0.18\ WSP_{t-2} – 0.16\ MA(1) \quad (R^2 = 0.99)$
(0.50) (2212.92) (2.10) (1.58) (-0.59)

$WSP_t = -0.65 + 1.03\ FC_{2t} + 0.96\ WSP_{t-1} \quad (R^2 = 0.99)$
(-2.12) (200.18) (51.46)

$WSP_t = -1.69 + 1.07\ FC_{3t} + 0.27\ WSP_{t-1} +0.68\ WSP_{t-2} – 0.80\ MA(1) \quad (R^2 = 0.99)$
(-2.28) (118.87) (1.39) (3.57) (5.40)

$WSP_t = -3.11 + 1.10\ FC_{4t} + 0.34\ WSP_{t-1} +0.63\ WSP_{t-2} – 0.79\ MA(1) \quad (R^2 = 0.99)$
(-2.53) (86.69) (2.09) (3.88) (6.50)

With respect to the above results the coefficient of descriptive variables in all equations is about one and it means that the change in any of oil prices will change other prices by the same ratio (proportion). The relation between oil spot and future prices in each of oil markets is very close and a change in each of spot and future prices will change the other prices by nearly the same ratio. Also Engel-Granger causality test is employed to determine the causality direction and based on the results the causality is bidirectional in all variables.

Appendix2: variables conditional variance autoregressive equations

DBSP=0.01-0.57AR(1)-0.01AR(2)+0.08AR(12)+0.21Dum+0.85MA(1)+0.08MA(2) $R^2 = 0.07$
(0.11) (-0.94) (-0.03) (1.32) (0.45) (1.43) (0.2)

DFC1=-0.01-1.15AR(1)-0.19AR(2)+0.01AR(12)+0.63Dum+1.44MA(1)+0.45MA(2) $R^2 = 0.09$
(-0.07) (-17.19) (-2.91) (1.04) (1.64) (46.41) (13.01)

DFC2=0.01-1.13AR(1)-0.16AR(2)+0.01AR(12)+0.46Dum+1.44MA(1)+0.45MA(2) $R^2 = 0.11$
(0.16) (-6.03) (-1.12) (0.36) (1.13) (8.36) (3.00)

DFC3=0.02+1.40AR(1)-0.62AR(2)-0.05AR(12)+0.23Dum-1.14MA(1)+0.35MA(2) $R^2 = 0.22$
(0.35) (10.23) (-4.43) (-1.96) (0.53) (-7.50) (2.27)

DFC4=0.02+1.42AR(1)-0.64AR(2)-0.05AR(12)+0.14Dum-1.16MA(1)+0.37MA(2) $R^2 = 0.23$
(0.45) (11.49) (-5.00) (-1.90) (0.37) (-8.25) (2.56)

DWSP=-0.03-1.14AR(1)-0.18AR(2)+0.01AR(12)+0.70Dum+1.44MA(1)+0.45MA(2) $R^2 = 0.08$
(-0.23) (-12.68) (-2.21) (1.01) (1.55) (31.11) (10.01)

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