# Some Preliminary Considerations about Hedging Effectiveness for Crude Oil Market

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All countries consume crude oil or oil products. Both producers and consumers are highly concerned about crude oil prices. The crude oil prices are being directly affecting by several factors such as economic, political, geopolitical, and technological, oil reserves, available stocks and weather conditions, among others. On other hand the crude oil prices fluctuations influence directly the world economy. Compared to the financial assets the crude oil prices have had an elevated volatility in recent years. Therefore, studies of crude oil prices movements and co-movements are highly complex. So the academics and practitioners are developing many studies about themes related with crude oil prices. The economic agents indirectly involved with crude oil negotiations, such as the planners of firms or governments, are looking for related petroleum prices forecasting models construction studies, while the agents directly involved are looking for the hedge strategies studies as well. The hedge strategies allow negotiators that have short and long positions in the market protection against prices fluctuations. This paper examines the performance of bivariate volatility models for the crude oil spot and futures returns of the Western Texas Intermediate – WTI type barrel prices. Besides the volatility of spot and future crude oil barrel returns time series, the hedge ratio strategy is examined through the hedge effectiveness. Thus this study show hedge strategies built using methodologies applied in the variance modeling of returns of crude oil prices in the spot, and future markets, and covariance between these two markets returns, which correspond to the inputs of the hedge strategy shown in this work. From the studied models, the chosen one was the bivariate GARCH in a Diagonal VECH representation. The methodologies used here take into consideration more realistic assumptions for the returns distribution more realistic than other methods that have been used in the financial literature: the heteroskedasticity and the non normality. The data used is logarithm returns of daily prices quoted in dollars per barrel from November 2008 to May 2010 for spot and future contracts, in particular the June contract.

## 1. Introduction

The motivation of this work is the relevance of crude oil international market growth, the biggest market among the commodity markets. This led to a development of derivative markets of this commodity, in particular, future contracts markets, or simply future markets. This development brought sophisticated strategies. Among these strategies there are many for risk reduction of physical positions, investments in crude oil or other related to this commodity movements.

In an informational efficient market, future and spot prices must be associated. So these prices are determinant for hedge strategies studies. The hedge strategies allow negotiators that have short and long positions in the market protection against prices fluctuations. The most widespread hedge strategy named minimum variance model, was selected among several models for hedge strategies this study. The part of risk that could be eliminated with minimum variance hedge ratio, or MV hedge ratio, can be determinated using a measure from a hedging effectiveness introduced in the finance literature by Edrington (1979).

The aim of this paper is to examine the performance of two bivariate volatility models for the crude oil spot and futures returns of the Western Texas Intermediate – WTI type barrel prices. Besides that it assesses the volatility of spot and future crude oil barrel returns time series and the hedge ratio strategy that is evaluated through the hedge effectiveness.

The remaining of this work is organized in the following form. The next section the literature of volatility models is briefly reviewed. The methodological approach and the sample used are presented in section 3 and 4, respectively. Finally the results and the final remarks are given in section 5.

## 2. Volatility Models: a Brief

For the determination of hedge ratio estimate volatility is fundamental. Several methods allow the estimate volatility, or variance, of crude oil return distributions. This estimate can be accomplished with univariate or multivariate volatility models, these models must take into consideration the heteroskedasticity of return distributions of crude oil prices. That is, taking into consideration the time-varying characteristic of hedge ratio. In a study about United Kingdom inflation behavior, Engle (1982) presented a more realistic volatility model than others presented before in finance literature: the Autoregressive Conditional Heteroskedasticity Model – ARCH model. This seminal work elaborated by Engle (1982) shows the way to estimate conditional variance observing the heteroskedasticity characteristic of financial time series. There is a family of models constructed from ARCH model, or which uses a similar methodological approach. Bollerlev (1986) introduced a generalization of ARCH model designated by Generalized Autoregressive Conditional Heteroskedasticity Model – GARCH model. And Engle et al. (1987) suggested the ARCH in mean or ARCH-M, in which the conditional variance influences the mean. Besides estimating the variance it is necessary to estimate the covariance between spot and future returns. Bollerslev et al. (1988) generalized the ARCH-M model proposing VECH, the multivariate model. An important constraint of the VECH model refers to a covariance matrix which must be definite positive. For that reason Engle et al. (1995) proposed another parameterization for multivariate GARCH model named BEKK. The BEKK model has less restrictions easier implementation than the VECH model. Another multivariate model constructed was the Dynamic Conditional Correlation (DCC) proposed model were the covariation is dynamic and the correlation coefficient is not. According to Engle (2002), this model consists in estimating the arguments in two steps: univariate GARCH series and after the correlations. Baillie & Myers (1991) applied the univariate and multivariate models, specifically the ARCH model in the VECH version, with several parameterizations, to estimate hedge ratio of selected commodities. Bollerslev (2009) presented a glossary to ARCH, a large list of ARCH acronyms that were presented in the financial literature.

## 3. Methodological Approach

The hedging procedure consists in mixing or associating short or long positions in a constructed portfolio trying to reduce the risk. That is, to minimize the returns variations of an asset, or barrel of crude oil as dealt in this work. The return of portfolio with spot and future position, can be formulate in the following form:

$$R_{Pt} = R_{St} - h_t R_{Ft}$$

where $R_{Pt}$ is the portfolio return at time $t$, $R_{St}$ is the spot return at time at time $t$, $R_{Ft}$ is the future return at time $t$. The variance of the hedged portfolio conditioned on the information available at time $t - 1$ can be represented by the expression:

$$Var(R_{Pt}|I_{t-1}) = Var(R_{St}|I_{t-1}) - 2h_t \operatorname{cov}(R_{St}, R_{Ft}|I_{t-1}) + h_t^2 Var(R_{Ft}|I_{t-1})$$

where $Var(R_{St} \mid I_{t-1})$ and $Var(R_{Ft} \mid I_{t-1})$ are variance conditional and cov $(R_{St}, R_{Ft} \mid I_{t-1})$ is the covariance conditional of the spot and future returns, respectively. The optimal hedge ratio is the $h_t$ which minimizes the conditional variance, or the risk, of the hedged portfolio. As Baillie & Myers (1991) showed, the partial derivative of the conditional variance with respect to $h_t$ is the optimal hedge ratio at time $t$ conditioned on the information available at time $t$ -$1$, given by:

$$h_t \big| I_{t-1} = \frac{\operatorname{cov}(R_{St}, R_{Ft} \big| I_{t-1})}{Var(R_{Ft} \big| I_{t-1})} \quad .$$

To compare the performance of optimal hedge ratio between the models or methodologies used in this work as suggested in Ku et al. (2007) the hedging effective index –*HE* can be used and expressed as follows:

$$HE = \frac{Var_{unhedged} - Var_{hedged}}{Var_{unhedged}}$$

where $Var_{hedged}$ represent the variance of hedged portfolio and $Var_{unhedged}$ is the variance of spot returns, or unhedged portfolio. As Tansuchat et al. (2010) observe: "a higher *HE* indicates a higher hedging effectiveness and larger risk reduction, such that a hedging method with a higher *HE* is regarded as a superior hedging strategy". Another definition for the hedging effective index – *HE** is the proportion of the variance eliminated thought a hedge strategy and can be denoted as proposed by Hull (2005):

$$HE^* = h^2 \frac{Var(R_{Ft} \big| I_{t-1})}{Var(R_{St} \big| I_{t-1})}$$

This way, the better hedge effectiveness is close to one. And the number of future contracts necessary to accomplish the hedge at the time *t* is given by:

$$N_t^* = h_t \frac{SpotQuote}{FutureQuote}$$

To estimate the parameters presented here volatility models must be used. The volatility models employed in this work take into account the non normality of the returns and are described below. These models consider the t of Student distribution for the returns.

The multivariate GARCH model applied here is the VECH diagonal presented by Bollerslev et al. (1988) that consist in estimating the following equation proposed by Ding & Engle (2001):

$$H_t = C + D \bullet e_{t-1} e_{t-1}^T + G \bullet H_{t-1}$$

where • is the Hadamard product and $H_t$ represent the variance-covariance matrix at time *t*. The bivariate case to the ARCH(1) and GARCH(1,1), respectively, are described as follows:

$$\begin{bmatrix} h_{11,t} \\ h_{21,t} \\ h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} \\ c_{21} \\ c_{22} \end{bmatrix} + \begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \bullet \begin{bmatrix} e_{1,t-1}^2 \\ e_{2,t-1} e_{1,t-1} \\ e_{2,t-1}^2 \end{bmatrix}$$

$$\begin{bmatrix} h_{11,t} \\ h_{21,t} \\ h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11} \\ c_{21} \\ c_{22} \end{bmatrix} + \begin{bmatrix} d_{11} & 0 & 0 \\ 0 & d_{22} & 0 \\ 0 & 0 & d_{33} \end{bmatrix} \bullet \begin{bmatrix} e_{1,t-1}^2 \\ e_{2,t-1} e_{1,t-1} \\ e_{2,t-1}^2 \end{bmatrix} + \begin{bmatrix} g_{11} & 0 & 0 \\ 0 & g_{22} & 0 \\ 0 & 0 & g_{33} \end{bmatrix} \bullet \begin{bmatrix} h_{11,t} \\ h_{21,t} \\ h_{22,t} \end{bmatrix}$$

To calculate the mean estimates of spot and future returns represented by *r*, an autoregressive model of order 1 (AR(1)) was used which can be described, for the bivariate case, as follows:

$$\begin{bmatrix} r_{1,t} \\ r_{2,t} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} + \begin{bmatrix} b_{1,1} \\ b_{1,2} \end{bmatrix} \bullet \begin{bmatrix} r_{1,t-1} \\ r_{2,t-1} \end{bmatrix} + \begin{bmatrix} e_{1,t} \\ e_{2,t} \end{bmatrix}$$

## 4. Data – The Sample Used

To reach the objective of this work the collected data consisted of daily crude oil prices of WTI type in the spot and future market, specifically the June contract, quoted in US$ per barrel from November 2008 to May 2010, while the spot price series were obtained from Energy information Administration – EIA, the official Energy Statistics from United States of America. While the future prices of June contract were obtained from Bloomberg web site.

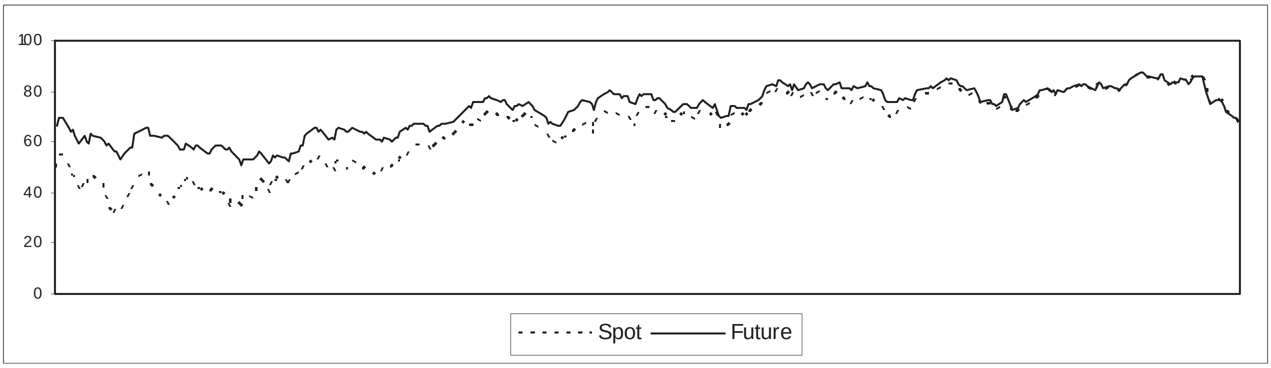


*Figure 1 – Spot and Future the WTI Prices*

The figure 1 above shows the plot of these time series. The plot presented indicates a strong association between crude oil spot and future prices. Also in this plot it can be observed the basis variation and the convergence of prices at the contract expiration date. From these daily prices time series the returns time series are calculated with the equation below:

$$R_t = \ln\left(\frac{price_t}{price_{t-1}}\right) \quad ,$$

where $R_t$ is return of the price at time *t*, $price_t$ = quote the price at time *t*, $price_t$ = quote price at time $t - 1$.

| Statistics | Spot | Future |
|---|---|---|
| *Mean* | 0.000837 | 0.000055 |
| *Median* | -0.000142 | 0.000437 |
| *Maximum* | 0.135455 | 0.080546 |
| *Minimum* | -0,127431 | - 0.072437 |
| *Std. Deviation* | 0.034584 | 0.021870 |
| *Skewness* | 0.170808 | 0.045856 |
| *Kurtosis* | 5.799988 | 3.998195 |
| *Jarque-Bera* | 123.3278 | 15.57447 |
| *(p-value)* | (0.00000) | (0.000415) |
| *N* | 372 | 372 |

*Table 1 – Statistics of Returns Summary*

The spot and future returns time series are the data used in this work to estimate the volatility models implemented for hedge strategies that were done. The table 1 presents the statistics of returns summary. The descriptive statistics for the returns series of crude oil prices, presented in table 1, show a very low average for spot and future returns, near zero. But the standard deviation for the two time series is higher, once these markets volatility are very high. Another characteristic here and in the financial assets time series in general is the high kurtosis, which indicates fat tails distributions. The skewness coefficients are positive which demonstrate that these series have a longer right than left tail therefore have greater gains than losses. This occurs for spot prices that are slightly higher. It is must be highlighted that the normality can not be accepted as expected, as generally occurs with returns time series of financial assets, or commodities. It can be observed that Jarque-Bera statistics of crude oil returns in spot and future markets are statistically significant, therefore the distribution of these series is not normal.

## 5. Results and Final Remarks

The results of the volatility estimated are shown below in the figure 3 thought the variance of the spot and future returns. The model selected among others was the VECH diagonal implemented in software Econometric Views. This model was estimated with an autoregressive model, that is, the model AR(1) mentioned above for the mean , without intercept or the parameter *a*. The variance equation was a GARCH model and the matrix *C*, matrix *D* and matrix *G* are, respectively, rank one, indefinite and indefinite. The t distribution was used with 7.2 degrees of freedom, estimated in the model. This specification has the best performance between the other multivariate models estimated in this study. Figures 4 and 5 below present the hedge ratio and hedge effectiveness obtained from the results of the VECH diagonal model selected.

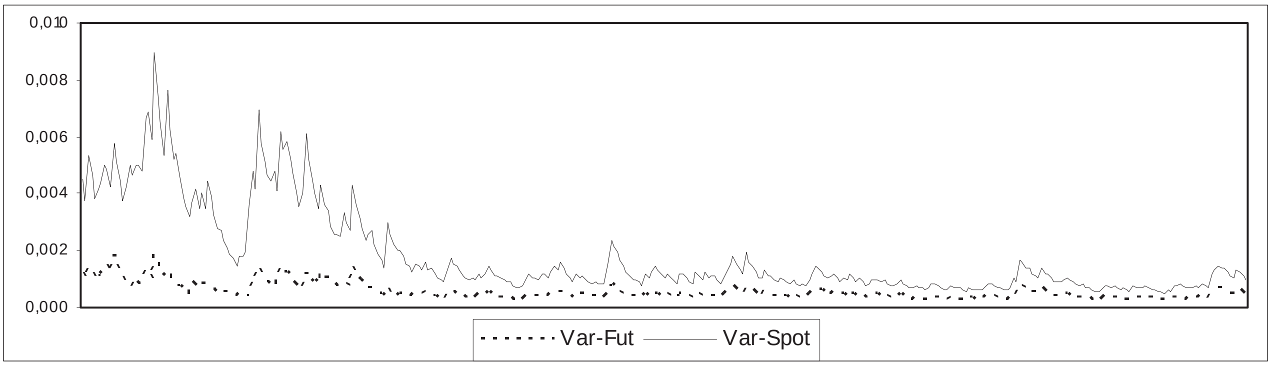


*Figure 2 – Spot and Future Returns Volatility of the WTI Prices*

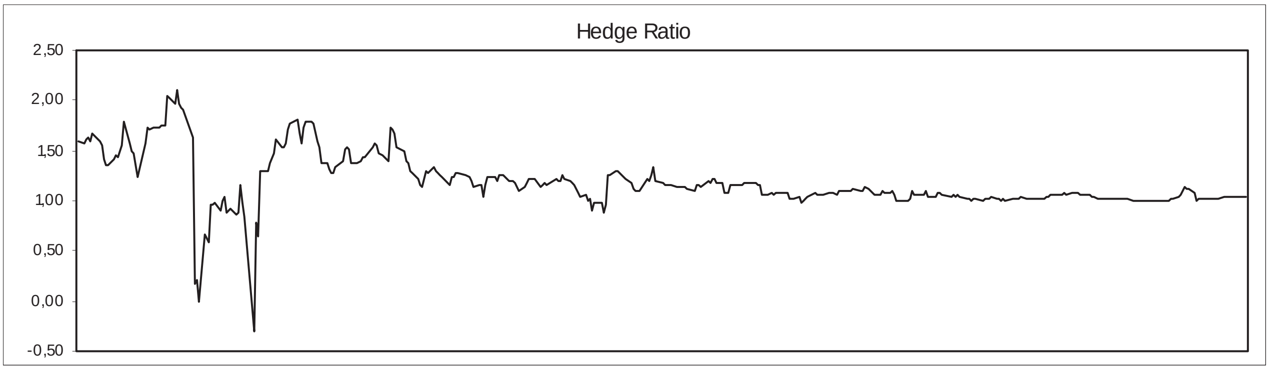


*Figure 3 – Minimum Variance Hedge Ratio*

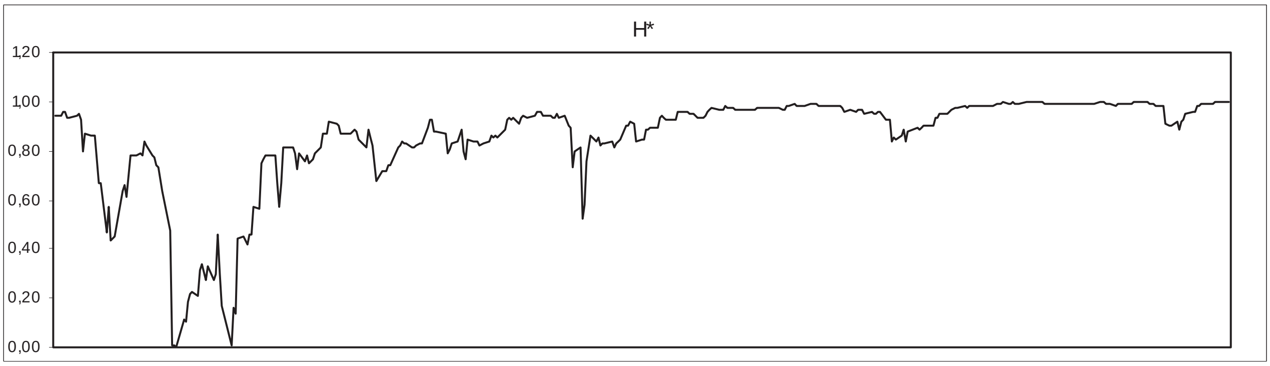


*Figure 4 – Hedge Effectiveness (H*)*

These plots confirm this model outstanding performance. From these plots it is possible to infer, that the hedge ratio and the hedge effectiveness prompt react to market volatility specially the spot market volatility.

The crude oil market was much affected by the 2008 global crisis until April 2009, as shown in the plots presented here. After April 2009 the hedge effectiveness is close to unit which is this measure maximum for hedge performance, apart from the period around July 2009.

The aim of this paper was to show a hedge strategy for the crude oil market and the volatility estimate to do this. This way classical and Bayesian models were implemented to carry out the minimum variance hedge. Therefore the results presented here were obtained from the selection of these studied models. Given the relevance of the theme dealt here it is import to point out that the inferences can be enlarged with the utilization of other models, methodologies or samples.

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