Minimum Variance Crude Oil Hedging Using Futures

Hanryano Yehezkiel Lethe Sarungallo, and Budhi Arta Surya

***Abstract*— Futures as a kind of derivative has been widely-used as a hedging instrument. This paper elaborates crude oil as its underlying asset. Timeframe of the sample spans approximately a year from November 20, 2012 to November 19, 2013 with daily settlement included. The commodity used is light sweet crude oil from the WTI Cushing refinery, TX, USA. Futures contract used as the derivative is CLJ2014 with expiration date of April 2014.
The method of the hedging strategy using futures in this paper is by minimizing variance between the futures and the spot price. By that, the hedger would not be exposed to the risk of price volatility through combination of optimal hedge ratio and the value of the portfolio over time. This may seem simple but has proven to be effective, especially for futures.

***Keywords*— crude oil, futures, hedging, min-variance

I. Introduction

GLOBALIZATION has shaped the world into one giant interconnected system. One event may triggers effect in the other end of the globe. That leads to the ever-increasing uncertainty and reducing the risks exposed has never been so essential. With globalization spreading into the most remote places on earth, the effects of one major cause can no longer be ignored but rather to be considered as equal as an event happens nearby.

Crude oil as one of the largest commodity market in the world has shaped the way we live for tens of years and still counting [1]. The recent events of war and terrorism, oil spill and illegal tapping have reduced trust in the eye of investors toward crude oil operation. Apart from that, the volatility of crude oil price itself is incredibly high that it reached US$134 in mid-2008 and plummeted into US$32 at the end of the year [2]. With such uncertainty embedded within crude oil market, investors and industries must consider to protect their investment by any means necessary. One way to reduce the risk is through the practice of hedging, which is widely-known in investment world. Unlike insurance, hedgers do not pay premium, but instead give up a portion of potential financial gain [3].

Hedging is a way to transfer risk through financial instruments available and conducted using certain strategies according to the type of derivative used and its underlying asset [4]. Crude oil as the commodity widely used all over the world has significant effect and thus ideal to be hedged by industries and investors.

Hanryano Yehezkiel Lethe Sarungallo is with the School of Business and Management, Institut Teknologi Bandung, Jawa Barat, 40132 Indonesia (corresponding author's phone: +62 81908438793; e-mail: hanryano@sbm-itb.ac.id).

Budhi Arta Surya is with the School of Business and Management, Institut Teknologi Bandung, Jawa Barat, 40132 Indonesia (e-mail: budhi.surya@sbm-itb.ac.id).

II. Literature Review

A. Mechanism of Futures Market

Futures contract is an agreement to buy or sell an asset for a specific time in the future with certain price and tradable through futures exchange [5]. Futures price can be contrasted with spot price with different delivery time where spot price is the price determined for immediate or almost immediate delivery.

Each futures contract has particular specification depending on its underlying asset. For crude oil futures traded on Chicago Mercantile Exchange (CME), the underlying asset is Light Sweet Crude Oil from WTI Cushing. Most crude oil futures contract has a 1,000 barrels size or around 42,000 gallons each. Crude oil futures traded on CME has four delivery months: January, April, July, and October [6]. When a contract expired not on the delivery month, it shall be delivered on the closest subsequent delivery period.

B. Hedging with Futures

In hedging, the objective is usually to neutralize risk as far as possible [4]. For example an investor would gain US$1,000 for every cent gained and on the contrary lose US$1,000 for a cent decrease in price over the next four months period. This would require a US$1,000 loss for every cent gained and US$1,000 gain for every declining cent in order to offset the risk through futures.

There are mainly two types of hedging: taking long and short position. The long position is intended for investors or companies who need the commodity in the future and willing to lock the price in advance [7]. However, a hedger can also take long position by not taking the delivery as it could possibly be costly and complicated. On the contrary, short hedge is usually used for those who already own the asset and would like to sell them some time in the future [5].

In reality, cross hedging needs to be conducted where no exact asset is available on futures. This is basically hedging different types of asset [5]. For example a company would use heating oil, but rather hedge with crude oil futures to offset the risk as no heating oil futures is currently exist in the market. Hedging with futures contract will incur what is called as basis. It is the difference between spot and futures price and will be reduced over time as the contract approaches its

http://dx.doi.org/10.15242/ICEHM.ED0814078

expiration. The key that affects basis in hedging with futures is the asset underlying and the choice of delivery month [5]. Cross hedging as mentioned previously has different type of asset underlying with futures contract.

C. Minimum Variance Hedging

In minimum variance hedging, the goal is to minimize the difference on change of spot price and change in futures price. With smaller variance, the risk exposed to the asset will be greatly reduced. However, in order to achieve the goal one must be sure of the optimal hedge ratio, as it cannot be too big or small in value.

(Dependence of variance on hedge ratio)

The minimum variance hedging can be obtained using simple statistics;

$r = \log_T/\log_t$

$$\mu = \frac{\sum_{i=1}^{n} r}{n}$$

σ_S = standard deviation of r_S

σ_F = standard deviation of r_F

$$\rho = \frac{\sigma_{SF}}{(\sigma_S \sigma_F)}$$

With first order derivation in subject to hedge ratio as follows

$$\sigma^2 = \sigma_S^2 + h^2\sigma_F^2 - 2h\sigma_{SF} = \sigma_S^2 + h^2\sigma_F^2 - 2h\rho\sigma_S\sigma_F$$

In order to reach for the minimum value of variance in the hedge ratio (h), the second order of Euler condition is derived within the formula below, and the optimal hedge ratio h* can be reached [8]

$$\frac{\partial\sigma^2}{\partial h} = 2h\sigma_F^2 - 2\rho\sigma_S\sigma_F = 0$$

Checking the second order condition,

$$\frac{\partial^2\sigma^2}{\partial h^2} = 2\sigma_F^2 > 0$$

With the minimum h, then the optimal hedge ratio is

$$h = \rho\frac{\sigma_S}{\sigma_F}$$

After the hedge ratio has been obtained, the optimal number of contracts is calculated through the following formula

$$N* = \frac{h * Q_A}{Q_F}$$

Where Q_A is the size of hedged position, Q_F is the size of one futures contract (in units), and N* is the optimal future contracts for hedging

Despite that the number of contracts through the entire time series has been found, the volatility during the period holds the uncertainty when there are ups and downs during the period, not to mention the possibility of crisis and other inevitable events which greatly affecting the price of the commodity. In this case, tailing the hedge is the most appropriate way to hedge against the daily settlement using the following formula

$$N* = \frac{h * V_A}{V_F}$$

V_A = dollar value of position being hedged

V_F = dollar value of one futures contract (futures price times Q_F)

The most important assumptions in the minimum variance hedging are production is deterministic and all wealth is in cash position [9]. It means that the requirement of the futures market and the mechanism of delivery have all been set and the payment made uses cash instead of bond or other type of payment.

III. Methodology

This research is an independent research using existing data available on the internet. Firstly, in order to find out methods used for hedging, researcher would seek for the derivative instrument and its corresponding or suitable spot market. Taking into account the vast usage of crude oil, then it is determined to be the commodity analyzed on this paper.

The data were collected based on the similarity and correlation of both spot and the futures market. Firstly, historical price data of spot price was taken from www.eia.gov and used Light Sweet Crude Oil from WTI Cushing refinery, TX, USA [2]. Similar to the spot price, futures contract was based on the WTI Cushing spot price which used the Chicago Mercantile Exchange futures contract CLJ2014 expired in April 2014 [10].

The followed step was to seek for the best hedging strategy out of all methods available. Within a simple futures market mechanism, there was a limitation of strategies suitable to be implemented with it. Minimum variance was chosen by taking into account its simplicity and compatibility with data available. Afterwards, began the data analysis which primarily consists of three parts: determining hedge ratio, finding the appropriate optimal number of contracts and the tailed hedge, as well as supportive results backing the findings. It is extremely necessary to ensure the results were approximately correct and checked with comparison to other non-optimal results. Once all analysis had been completed, the writing and drafting of the entire paper shall be quickly obtained. Researcher started from the drafting of data analysis which transformed the calculations into the appropriate paper-form, then orderly began to move on into introduction, literature review, methodology, and conclusions. Despite the analysis had been done in the first place, the last chapter could not be fully completed when other parts were still missing.

IV. Data Analysis

The data collected for the research was taken on April 2014 with approximately one-year timeframe from 20 November 2012 to 19 November 2013 and utilizing the daily settlement for all calculations. The daily mean return of crude oil (μ) is estimated to be 0.019% and 0.013% for futures contract, while standard deviation (σ) on spot price equals to 0.01175 and 0.00923 for futures contract. Coefficient of correlation (ρ) between the underlying asset and its futures contract is approximately 0.915 over the period.

The basic results are all obtained and the hedge ratio (h*) can be calculated. Using the previous results, the optimal hedge ratio is 1.165 with 1/1000 approximation. This shows every one part of crude oil requires 1.165 times number of futures contract with exactly the same amount. Considering the hedger would like to hedge 1,000,000 gallons of crude oil for any purpose, this equals to 42,000 barrels. The synchronization of the units used is essential to ensure the validity and avoid bias in the result. Taking into account of one futures contract specification is for one thousand barrels of crude oil, we can compute optimal number of contracts. Using the obtained data above, approximate number of optimal contracts to hedge is 28 contracts.

Below is the movement of spot and futures prices over the timeframe and it is visible that hedger would not be able to hedge effectively in reality only depending with one single optimal number of contract.

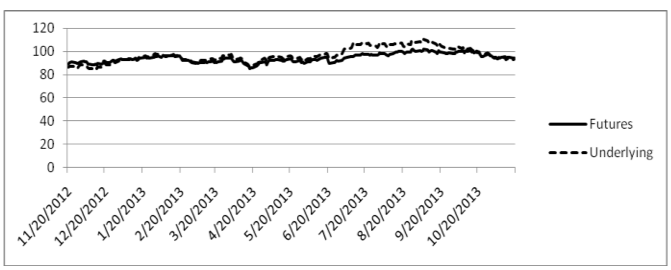

Fig. 1 movement of spot and futures prices over the timeframe

At one point, the futures price is more expensive but the price movement suggests the spot price increases in tremendous amount compared to futures. The difference will soon increase the amount of contracts required to hedge such increase in spot price. This creates uncertainty on the difference between spot and futures price. In this part of analysis, the number of contracts will be adjusted according to the then present time prices. The different number of contracts is the result of the different value of both futures and spot price over time.

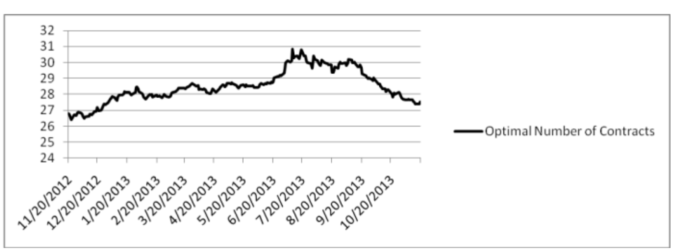

Fig. 2

Using the minimum variance hedging, the approximate optimal number of contract on a daily basis for hedger has been obtained above. The contracts are based on the movement of the spot/futures price and will reduce the variance between them. As mentioned before, the number of contract from June 2013 to September 2013 increased sharply to offset the jumping price of crude oil in the spot market. Fig 2 shows the number of contracts using tailing the hedge method in order to allow for the impact of daily settlement. The result of using the tailed hedge above is explained in the chart below.

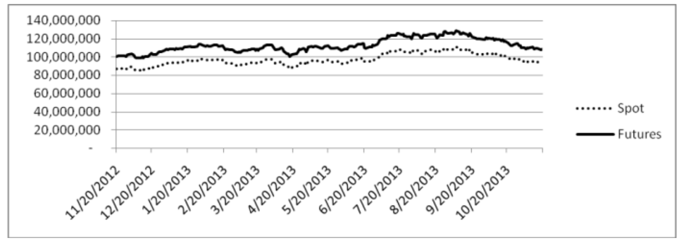

Fig. 3 result of using the tailed hedge

The figure shows how small the difference between spot and futures prices is. This guarantees the hedging goal which is to obtain as little as possible variance between the commodity and futures.

The results of this research have been collected. However, to ensure the optimality of the hedge ratio (which in this paper is still considered as an approximate value), researcher will use perturbation theory in supporting the results. Out of the hedge ratio (h*) founded, this paper also acknowledges the other value of hedge ratios (h) around it: 0.9, 1.0, 1.1, and 1.2. With the same methods used after hedge ratio has been obtained, below is the comparison between h* and h performances over the same period of time.

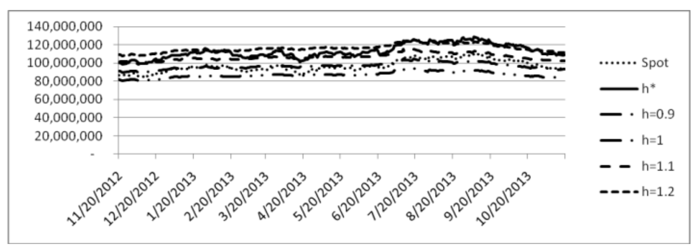

Fig. 4 comparison between h* and h performances over the same period of time

Visible from the figure, the other hedge ratios will give less high-performing results. The variance obtained other than h* is far greater over time compared to h*. This proves the effectiveness of h* in reducing the variance and shows great deal of reliability. Setting lower hedge ratio with h =0.9 and 1.0 resulted in lower value of futures and on the other hand setting similar or higher hedge ratio would create a crossed or higher value of the futures compared to the optimal hedge ratio results. Surprisingly, the other four hedge ratios used for approximation have similar movement.

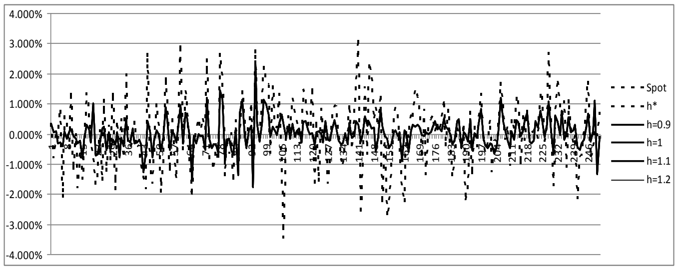

Fig. 5 volatility value across different hedge ratios and spot price

Fig 5 shows the volatility value across different hedge ratios and spot price. As mentioned before, h* values mimicked the spot price until it seems to be overlaid. However, the other non-optimal hedge ratios are also mimicking each other, making the figure as if only comprised of two different values.

V. Conclusions

Hedging with basis as a way to transfer risk is observed and applied in this paper. Within the specific timeframe, optimal hedge ratio is 1.165 which shows how great the price movement in spot market compared to what happens with futures. This does not prevent hedger from obtaining the optimality over time. Within this paper, tailing the hedge on the daily basis is proven to be effective with the hedge ratio given. It shows how reactive the futures price is when applied with the minimum variance. The more volatile the spot price, the changing in number of contracts required would be higher as well. Nevertheless, hedger should never rely solely on one method but rather to compare a range of methods and find the best solution for their investment. The minimum variance hedging is intended to find the lowest possible variance between spot and futures market, but in reality the spot is probably not perfectly available in futures or other derivatives thus requiring other strategy and uses different approach.

References

[1] World Trade Organization, *International Trade* Statistics, Lausanne, Switzerland: World Trade Organization, 2011

[2] U.S. Energy Information Administration (n.d.), *Cushing, OK WTI Spot Price FOB (Dollars per Barrel)*. Available from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RWTC&f=D (accessed March 2014).

[3] D. Harder, *Difference between Insurance and Hedging.* Available from http://www.ehow.com/info_12107779_difference-between-insurance-hedging.html (accessed July 2014)

[4] J. Hull, *Fundamentals of futures and options markets* (7^{th} ed.), Boston, MA: Pearson/Prentice Hall, 2011, pp. 22-24.

[5] J. Hull, *Options, Futures, and Other Derivatives* (9^{th} ed.), Boston, MA: Pearson/Prentice Hall, 2011, pp.

[6] CME Group. *Crude Oil Futures Contract Specs.* Available from http://www.cmegroup.com/trading/energy/crude-oil/light-sweet-crude_contract_specifications.html (accessed April 2014).

[7] National Futures Association, *Opportunity and Risk: An Educational Guide to Trading Futures and Options on Futures,* Chicago, IL: National Futures Association, 2006, pp. 17-36.

[8] C. Dahl, *International Energy Markets: Understanding Pricing, Policies, and Profit,* Tulsa, Okla.: PennWell, 2004, pp. 380-388.

[9] Sergio H. Lence, "Relaxing the Assumptions of Minimum-Variance Hedging," *Journal of Agricultural and Resource Economics*, vol. 21, June 1996, pp. 39-54.

[10] Chicago Mercantile Exchange, *Crude Oil Futures, April 2014 (CLJ2014).* Available from http://www.quandl.com/CME/CLJ2014 (accessed March 2014).