The Effect of Crude Oil Futures Prices on Risk Premium Volatilities in the Futures Market

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**ABSTRACT**

This paper explores the impact of crude oil futures prices on risk premium volatilities in the NYMEX futures market. For this purpose, the ARCH and GARCH methods are used to model risk premium volatilities and explore how crude oil futures prices influence the risk premium volatilities in futures contract with a maturity of one-month, two-month and three-month over 1990-2014. In addition, it examines the impact of various maturities for futures contracts. The results indicate positive and statistically significant relationship between risk premium volatility and crude oil futures prices, and this relationship varies across the maturity length with change in maturity length. The longer the futures maturities, the higher the impact of futures crude oil prices on risk premium volatility is anticipated.

**Keywords:** Crude oil futures prices, Risk premium volatility, NYMEX futures market, ARCH and GARCH, Volatility modeling

**JEL classification:** C32, Q74, G32, G13.

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1. Introduction

Oil is an international strategic commodity where economic activities depend on it and its pertinent markets. High volatilities closely in oil prices and the resulting financial risks encouraged oil producers to cover those risks resulted in creation of futures markets and its rapid growth. Given the intrinsic volatilities in oil prices and the impacts on global economy, understanding the oil price formation process and its prediction helps reducing volatility risks.

The global financial crisis of 2008, an ongoing major financial crisis, could have affected stock volatility. The crisis which was triggered by the subprime mortgage crisis in the United States became prominently visible in September 2008 with the failure, merger, or conservatorship of several large United States-based financial firms exposed to packaged subprime loans and credit default swaps issued to insure these loans and their issuers. The financial crisis created risks to the broader economy which made central banks around the world to cut interest rates and various governments implement economic stimulus packages to stimulate economic growth and inspire confidence in the financial markets. The financial crisis could have affected the uncertainty in the demand for oil, thus, causing uncertainty in the price of oil (Olowe, 2011). Crude oil is one of the most important energy in the world. The price of the crude oil will affect the development of the economy and the trend of the financial market. Crude oil market is also the largest international trade market, and any price change of the crude oil will affect the international energy market. In that situation, the price change of the crude oil gives a big signal to the market. Many investors, financial analysts will pay great attention to the price, return and risk of the crude oil. To avoid the price risk, an important method is taking the futures price contract for hedging. From that reason, it needs to analyze the risk of the crude oil futures contract hedging for the investors and financial analysts.

The dual nature of crude oil as a physical commodity and financial asset in one hand and existence of several other factors influencing the spot oil market as well as futures on the other hand

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has made oil market’s analysis a very complicated issue. In the
past, only oil traders were active in crude oil markets, while cur-
cently many investors including banks and fund managers as well
as speculators who huge seek profits out of high volatility are ac-
tive in the market. The risk of oil price volatilities is hedged by oil
funds or financial derivatives.

Although less than three decades have passed since the estab-
lishment of oil futures and the supply of financial derivatives in the
oil market, they are accounted several times more than the physi-
cal oil transactions. Oil derivatives are traded by the market play-
ers with diverse motivations. Hedging oil price volatility is one
of the main intentions behind the paper transactions to reduce the
risk of unfavorable price volatilities. Activities in futures market
are not merely limited to risk hedging. Traders and risk appetite
participants are also looking for arbitrage opportunities to maxi-
imize profitability.

The paper investigates the relationship between futures prices
and volatility in the crude oil futures market as one of the factors
affecting market participants’ decisions using monthly data during
1990:1 to 2014:12. This paper will focus on the risk premium of
the crude oil futures prices.

The paper is organized as follows. Section 2 reviews the exist-
ing literature. Empirical results are provided in Section 3. The final
section contains the conclusions and policy implications.

2. Literature review

Hamilton and Wu (2014) show that interactions between
commercial producers or financial investors and arbitrageurs can
produce an affine factor structure to commodity futures prices,
and develop new algorithms for estimation of such models using
unbalanced data sets in which the duration of observed contracts
changes with each observation. The results are consistent with the
claim that index-fund investing has become more important rela-
tive to commercial hedging in determining the structure of crude
oil futures risk premium over time. Haase and Zimmermann
(2013) state risk premiums of commodity futures are directly re-
lated to the physical scarcity of commodities and propose a simple
decomposition of spot prices into a pure asset price plus a scarcity
related price component. The results confirm that two separate
commodity-specific risk premiums affect the pricing of crude oil
futures contracts: a net hedging pressure premium and a scarcity
premium. The two premiums show different cyclical characteristics.
In another research Melonimna (2011) studies the existence
of risk premium in crude oil futures prices with simple regression
and Bayesian VAR models. It also studies the importance of three
main risk premium models in explaining and forecasting the risk
premium in practice. Piglidin (2009) calculated the risk criterion
for WTI crude oil and Henry Hub’s natural gas, and showed that
because of fat tail of distribution, GED-GARCH method performs
better than any alternative. He also used Granger causality to show
that there is a significant risk spillover from oil market to natural
gas market, while there is no spillover in the reverse direction. In
another study Fan et al. (2008) calculate returns on WTI and Brent
crude oil spot market based on GED-GARCH models. Furthermore,
according to a new concept of Granger causality in risk, a kernel-based test is proposed to detect extreme risk spillover effect
between the two oil markets. Results reveal that there is significant
two-way risk spillover effect between WTI and Brent markets.

Moosa and Al-loughani (1994) reveals the existence of a time
varying risk premium using the GARCH model. Also they show
futures prices are unbiased for efficient forecasting of spot prices.
Pindyck (2001) discusses how spot prices, commodity futures
contracts, production and inventory levels are interrelated, and are
determined via equilibrium in interconnected markets. Pindyck
shows how equilibrium in these markets affects and is affected
by changes in the level of price volatility and using data from the
1980s and 1990s, he examined this issue for crude oil, heating oil
and gasoline. Results show that similar to inventories, futures con-
tracts can reduce risk and can be used to measure the marginal
value of commodity storage. Chin et al. (2005) examines the rela-
tionship between spot and futures prices for energy commodities
(crude oil, gasoline, heating oil markets and natural gas). In par-
icular, they examine whether futures prices are an unbiased and/or
accurate predictor of spot prices. Results show that futures prices
are unbiased predictors of futures spot prices, with the exception in the natural gas markets at the 3-month horizon. Naiini et al. (2013 ) examined the spillover effect risk between
the price return on spot and futures markets. This study discussed that
the volatility of oil prices in international markets poses players
to high potential risks. In this study, Upside and Downside Risks
are estimated by using the GED-GARCH method that is appropri-
te for leptokurtic distributions with fat tail. Using daily data the
results showed that spot and futures returns have leptokurtic dis-
tribution with fat tails. There is also a significant upside spillover
effect risk from futures to spot price returns at 99% confidence
level as for oil price increases during 2000.

3. Theoretical approach and empirical results

The derivative markets become popular during the 1980s, and
still in a huge growth trend from the past three decade. The com-
mmodity derivative market is an extremely important part of the
derivative market and is also the earliest application in derivative
markets which includes futures, options and forwards contract.
Crude oil is simply the largest commodity trade in the interna-
tional trading market and belongs to the energy market. The energy is
a rare resource in the world especially for crude oil. Many useful
things need oil such as power, gas, and gasoline. From this reason,
the demand of crude oil increased significantly during the recent
years. Many investors, oil companies, government trade crude oil

predicted
In the market (Liao, 2013).

If futures prices are not equal or close to the expected Spot price, traders will speculate. The speculators will profit by selling futures and purchasing commodity next month and delivering it to buyers of futures contracts. The success of this strategy depends on the realization of traders’ forecasting of the futures spot price. In contrast, if futures prices are lower than the expected futures price on the Spot market, speculators will buy futures and gain profits from receiving the commodity at maturity date and selling it at spot price. Therefore, the presence of speculators in the market will cause futures prices to be approximately equal to the expected futures price on the Spot market, because as significant differences between the futures price and the expected futures price on the Spot market will provide great opportunities for speculators.

In other words, as delivery period is approached, the futures price converges to the spot price. If the futures price is below the spot price prior to the delivery period, then traders expect the futures price to fall, but if futures prices are above the expected price on the Spot market, traders expect that futures price will tend to rise. This issue can be expressed in the form of equation (1).

\[ F_{0,T} \approx E_0[S_T] \]  

Where \( F_{0,T} \) is the futures price at maturity date, which is reported at the current time \((t=0)\) and \( E_0[S_T] \) is the expected futures price in spot market which is formed at the current time. Equation (1) shows that futures price is very close to the spot price expecting at the maturity date of futures contracts. This relation is approximate due to the existence of transaction cost and the difference in risk aversion degrees.

The transaction costs will not make futures prices equal to the expected futures price on the Spot market, because transaction costs will eventually be added to the cost of purchasing the commodity in the futures contract.

In analyzing the role of risk aversion, traders in the futures market can be divided into two groups: risk hedger and speculators. Although many risk hedgers engage in speculative activities, and many speculators engage in risk-hedging, risk hedger are those who enter the market with the knowledge of the defined risk of a given commodity but speculators enter the market with risk aversion and looking for great profitable opportunities. Traders who are risk averse accept that the expected benefit from their risk exposure is greater than or equal to its loss. Most traders are risk averse in financial markets, so they are looking for a situation

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### Table 1: Unit-root tests of Augmented Dickey-Fuller (ADF)

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>0.01</td>
<td>-3.93</td>
</tr>
<tr>
<td>F2</td>
<td>0.04</td>
<td>-3.48</td>
</tr>
<tr>
<td>F3</td>
<td>0.04</td>
<td>-3.43</td>
</tr>
<tr>
<td>Srp1</td>
<td>0.00</td>
<td>-10.43</td>
</tr>
<tr>
<td>Srp2</td>
<td>0.00</td>
<td>-9.94</td>
</tr>
<tr>
<td>Srp3</td>
<td>0.00</td>
<td>-8.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Critical values</th>
<th>1% level</th>
<th>5% level</th>
<th>10% level</th>
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<td></td>
<td>-3.98</td>
<td>-3.42</td>
<td>-3.13</td>
</tr>
<tr>
<td></td>
<td>-3.98</td>
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<td>-3.42</td>
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</tr>
<tr>
<td></td>
<td>-3.98</td>
<td>-3.42</td>
<td>-3.13</td>
</tr>
</tbody>
</table>

### Table 2: Results of ARMA(1,1) estimation with assumption of normal distribution for Srp1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>0.71</td>
<td>0.07</td>
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<tr>
<td>MA(1)</td>
<td>-0.31</td>
<td>0.10</td>
<td>-2.97</td>
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</tbody>
</table>

Akaike Information Criterion (AIC)  4.75
Schwarz Information Criterion (SIC)  4.77

### Table 3: Results of ARMA(2,1) estimation with assumption of normal distribution

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>0.32</td>
<td>0.06</td>
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<tr>
<td>MA(1)</td>
<td>0.45</td>
<td>0.05</td>
<td>8.04</td>
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</table>

Akaike Information Criterion (AIC)  4.26
Schwarz Information Criterion (SIC)  4.29

### Table 4: Results of ARMA(1,1) estimation with assumption of normal distribution for Srp3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR(1)</td>
<td>0.56</td>
<td>0.06</td>
<td>9.15</td>
<td>0.00</td>
</tr>
<tr>
<td>MA(1)</td>
<td>0.41</td>
<td>0.06</td>
<td>6.05</td>
<td>0.00</td>
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</tbody>
</table>

Akaike Information Criterion (AIC)  4.75
Schwarz Information Criterion (SIC)  4.77

### Table 5: Results of GARCH(1,1) estimation with assumption of symmetric distribution for Srp1

<table>
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<tr>
<th>Variable</th>
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<th>P-value</th>
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<td>AR(1)</td>
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<td>0.19</td>
<td>6.88</td>
<td>0.00</td>
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<tr>
<td>MA(1)</td>
<td>-0.26</td>
<td>0.13</td>
<td>-1.97</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Variance equation

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.00</td>
<td>0.00</td>
<td>6.52</td>
<td>0.00</td>
</tr>
<tr>
<td>RESID(-1)</td>
<td>0.71</td>
<td>0.10</td>
<td>6.59</td>
<td>0.00</td>
</tr>
<tr>
<td>GARCH(-1)</td>
<td>-0.36</td>
<td>0.05</td>
<td>6.73</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Akaike Information Criterion (AIC)  -1.16
Schwarz Information Criterion (SIC)  -1.09
where their exposure to risk is sufficiently offset. Hence, the activity of speculators in futures markets is profitable when there is a real change in futures prices. This issue has long been of interest to economists. Keynes (1930) and Hicks (1939) concluded that speculators would not trade futures unless their expected profits were positive. On the contrary, risk hedgers are willing to accept losses in risk hedging strategies because they benefit from risk reduction.

The literature on risk premiums in commodities prices dates back to the theory of Normal Backwardation, introduced by Keynes (1930), which compares futures prices to expected futures spot prices. This theory is based on difference between the current futures price maturing at time T and the current spot price. Thus, the risk premium is defined as the difference between the expected futures spot price at T and the current futures price for maturity T: 

\[ F_{t,T} - S_t = \left[ E_t(S_T) - S_t \right] - \pi_{t,T} \tag{2} \]

where \( F_{t,T} \) is the futures price at t for a futures contract expiring at T, \( S_t \) is the spot price at time t, and where the basis difference is divided into the difference between the expected spot price at T (\( E_t(S_T) \)) and the current spot price, and a risk premium (\( \pi_{t,T} \)). According to equation (2), the risk premium can be defined:

\[ -\pi_{t,T} = F_{t,T} - E_t(S_T) \tag{3} \]

Which is the definition used in this paper as well. When the risk premium can be studied after time T, we will talk of the ex post risk premium. In its earliest form, the theory of Normal backwardation asserts that in order to induce storage, futures price and expected futures spot prices have to rise over time to compensate storage holders for the costs of storage.

This paper investigates the effect of crude oil futures prices on risk premium volatilities in the NYMEX futures market. The following equation is used to evaluate the relationship between risk premium volatilities and futures prices:

\[ \text{var srpt} = \alpha_t + \beta_t F_t + u_t \tag{4} \]

Where var srpt is risk premium volatilities for futures contracts with maturity date at time t and \( F_t \) is a crude oil futures price (WTI) in NYMEX futures market with maturity date at time t. SRP1, SRP2 and SRP3 stand for risk premium for 1-month, 2-month and 3-month maturities futures contracts respectively.

Nelson and Plosser (1982) argue that almost all macroeconomic time series typically have a unit root. Thus, by taking first differences the null hypothesis of nonstationarity is rejected for most of the variables. Unit root tests are important in examining the stationarity of a time series because nonstationary regressors invalidate many standard empirical results and thus requires special treatment. Granger and Newbold (1974) have found by simulation that the F-statistic calculated from the regression involving the nonstationary time-series data does not follow the Standard distribution. This nonstandard distribution has a substantial rightward shift under the null hypothesis of no causality.

Thus the significance of the test is overstated and a spurious result is obtained. The presence of a stochastic trend is determined by testing the presence of unit roots in time series data. Non-stationarity or the presence of a unit root can be tested using the Dickey and Fuller (1981) tests. If a time-series is found to be non-stationary, a filtering mechanism such as the first difference of the variable can be employed to induce stationarity for univariate model estimation.

Results of ADF test for stationarity are reported in Table 1. The null hypothesis of a unit root can be rejected in the level of the variables. The results in Table 1 unanimously confirm that all variables are stationary. The optimal lag in the ADF test is automatically selected based on the Schwarz Info Criterion (SIC).

Considering the stationarity of the time series, the Box-Jenkins method is used to choose the best right ARMA(p,q) models as shown in Table 2, 3, and 4.

Results show that these coefficients are statistically significant at the 5 per cent level. The ARCH-test was also performed before an estimation of the GARCH model. The values of Ljung-Box-
Pierce portmanteau tests for the first ten and twenty order serial correlations in the squared intraday returns respectively. The value for the all of coefficient are statistically significant at a 5% level and indicate a strong persistence for intraday volatility and existence of ARCH effect.

Because the mostly of time series in which the error terms have non-constant variance we use GARCH model. GARCH processes differ from homoskedastic models, which assume constant volatility and are used in basic ordinary least squares (OLS) analysis. GARCH processes, being autoregressive, depend on past squared observations and past variances to model for current variance. The GARCH model is used to consider the conditional variance of residuals in ARMA models. The ARMA(1,1) – GARCH(1,1) models has statistically the best results based on the t-student’s distribution of residuals in ARMA models. the ARMA(1,1) – GARCH(1,1) process are autoregressive, depend on past squared observations and past variances to model for current variance.

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The effect of crude oil futures price on risk premium volatilities in NYMEX crude oil futures market was examined through ARCH and GARCH models. The effect of crude oil futures price on risk premium volatilities is investigated in futures contracts with a maturity of 1-month, 2-month and 3-month over the years 1990-2014. We used unit root test to show that research variables are stationary at the level. The final model estimation showed a direct relationship between risk premium and crude oil pieces as explainable variable in model. The results are self-explanatory showing a direct impact from crude oil futures price on risk premium volatilities for 1 to 3 months maturities. From above discussions and analyses, the risk premium plays an important role for the derivative markets, especially for futures markets. Investors can figure out the risk and decide whether to invest in the futures market depending on their risk tolerance.

### Table 8: Results of final model for Srp1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.0020</td>
<td>0.0087</td>
<td>0.2346</td>
<td>0.81</td>
</tr>
<tr>
<td>F1</td>
<td>0.0005</td>
<td>0.0001</td>
<td>3.2394</td>
<td>0.00</td>
</tr>
</tbody>
</table>

F-statistic: 0.00

Akaike information criterion (AIC): -2.08

Schwarz information criterion (SIC): -2.05

Durbin-Watson (DW): 1.58

### Table 9: Results of final model for Srp2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
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<td>C</td>
<td>-2.00</td>
<td>0.91</td>
<td>-2.18</td>
<td>0.02</td>
</tr>
<tr>
<td>F1</td>
<td>0.13</td>
<td>0.01</td>
<td>8.16</td>
<td>0.00</td>
</tr>
</tbody>
</table>

F-statistic: 0.00

Akaike information criterion (AIC): 7.21

Schwarz information criterion (SIC): 7.23

Durbin-Watson (DW): 2.05

### Table 10: Results of final model for Srp3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
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<td>C</td>
<td>-3.88</td>
<td>1.34</td>
<td>-2.89</td>
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</tr>
<tr>
<td>F1</td>
<td>0.22</td>
<td>0.02</td>
<td>9.65</td>
<td>0.00</td>
</tr>
</tbody>
</table>

F-statistic: 0.00

Akaike information criterion (AIC): 7.98

Schwarz information criterion (SIC): 8.01

Durbin-Watson (DW): 1.79

### 4. Conclusion

The effect of crude oil futures price on risk premium volatilities in NYMEX crude oil futures market was examined through ARCH and GARCH models. The effect of crude oil futures price on risk premium volatilities is investigated in futures contracts with a maturity of 1-month, 2-month and 3-month over the years 1990-2014. We used unit root test to show that research variables are stationary at the level. The final model estimation showed a direct relationship between risk premium volatilities for futures contracts of 1-month to 3-month with pertinent futures oil prices. Based on the estimations by changing a unit in 1-month, 2-month and 3-month futures prices, the
risk premium volatility for 1-month, 2-month and 3-month futures will change by 0.0004, 0.14 and 0.25 units respectively. It is worth noting that there is a positive and significant relationship between risk premium volatilities and crude oil futures price, and the relationship between risk premium volatilities and futures prices varies with changes in maturity. The longer the futures maturities, the higher is the impact of crude oil futures price on the risk premium volatilities which is in line with the theory of Normal Backwardation. The expected compensation from a long position is lower on average in the recent data, often significantly negative when the futures curve slopes upward. We suggest that increased participation by financial investors in futures markets may have been a factor in changing the nature of risk premium in crude oil futures contracts.

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