Volume 1, Issue 1
November 2017

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

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ARTICLE INFO

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

JEL classification:
C32, Q74, G32, G13.

Received: 12.May.2017
Received in revised: 02.Aug.2017
Accepted: 11.Aug.2017

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.

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 futuress 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 currently many investors including banks and fund managers as well as speculators who huge seek profits out of high volatility are active 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 establishment of oil futures and the supply of financial derivatives in the oil market, they are accounted several times more than the physical oil transactions. Oil derivatives are traded by the market players 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 maximize 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 existing 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 relative 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 related 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 Meloninna (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 contracts can reduce risk and can be used to measure the marginal value of commodity storage. Chin et al. (2005) examines the relationship between spot and futures prices for energy commodities (crude oil, gasoline, heating oil markets and natural gas). In particular, they examine whether futures prices are an unbiased and/or accurate predictor of subsequent 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 appropriate for leptokurtic distributions with fat tail. Using daily data the results showed that spot and futures returns have leptokurtic distribution 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 commodity 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 international 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 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).

$$F_{0,T} \approx E_0[S_T] \quad (1)$$

Where $F_{0,T}$ is the futures price at maturity date, which is reported at the current time (t=0) and E0[ST] 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

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

Variable	P-value	t-statistic	Critical values		
			1% level	5% level	10% level
F1	0.01	-3.93	-3.98	-3.42	-3.13
F2	0.04	-3.48	-3.98	-3.42	-3.13
F3	0.04	-3.43	-3.98	-3.42	-3.13
Srp1	0.00	-10.43	-3.98	-3.42	-3.13
Srp2	0.00	-9.94	-3.98	-3.42	-3.13
Srp3	0.00	-8.56	-3.98	-3.42	-3.13

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

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.71	0.07	9.17	0.00
MA(1)	-0.31	0.10	-2.97	0.00
Akaike Information Criterion (AIC)			-0.82	
Schwarz Information Criterion (SIC)			-0.80	

Table 3: Results of ARMA(2,1) estima tion with assumption of normal distri

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.32	0.06	5،15	0.00
MA(1)	0.45	0.05	8.04	0.00
Akaike Information Criterion (AIC)			4.26	
Schwarz Information Criterion (SIC)			4.29	

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

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.56	0.06	9.15	0.00
MA(1)	0.41	0.06	6.05	0.00
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

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.72	0.19	6.88	0.00
MA(1)	-0.26	0.13	-1.97	0.05
Variance equation				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**P-value**
C	0.00	0.00	6.52	0.00
RESID(-1)^2	0.71	0.10	6.59	0.00
GARCH(-1)	-0.36	0.05	6.73	0.00
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:

$$F_{t,T} - S_t = [E_t(S_T) - S_t] - \pi_{t,T} \quad (2)$$

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:

$$-\pi_{t,T} = F_{t,T} - E_t(S_T) \quad (3)$$

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:

$$\text{var srpt} = a_t + \beta_t \text{F}_t + u_t \quad (4)$$

Where var srpt is risk premium volatilities for futures contracts with maturity date at time t and Ft 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 invalidates 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-

Table 6: Results of GARCH(2,2) estimation with assumption of symmetric distribution for Srp2

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.20	0.06	2.89	0.00
MA(1)	0.44	0.06	6.83	0.00
Variance equation				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**P-value**
C	0.01	0.01	0.99	0.31
RESID(-1)^2	0.18	0.05	3.35	0.00
GARCH(-1)	0.83	0.04	20.31	0.00
Akaike Information Criterion (AIC)			3.65	
Schwarz Informa tion Cri terion (SIC)			3.71	

Table 7: Results of GARCH(2,2) estimation with assumption of symmetric distribution for Srp3

Variable	Coefficient	Standard error	t-statistic	P-value
AR(1)	0.42	0.06	6.16	0.00
MA(1)	0.57	0.06	9.16	0.00
Variance equation				
Variable	**Coefficient**	**Standard error**	**t-statistic**	**P-value**
C	0.02	0.01	1.22	0.22
RESID(-1)^2	0.15	0.04	3.29	0.00
GARCH(-1)	0.85	0.04	20.20	0.00
Akaike Information Criterion (AIC)			4.06	
Schwarz Informa tion Cri terion (SIC)			4.13	

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 and AIC and SIC criteria. The analysis of Durbin-Watson statistic and LM test in all of the above models showed that there is no auto-correlation in their disturbance terms. Thorough statistical analysis using DW and LM tests showed no auto-correlation in ARCH models, as Ljung-Box Q-test and the Mcleod-Lee tests rejected correlation of disturbance terms with their squared values. Finally the GARCH(1,1) for the risk premium of 1-month futures contracts and the GARCH(1,1) for the risk premium of 2-month futures contract and the GARCH(1,1) for risk premium of 3-month futures contract assuming a normal distribution for the risk premium variable was adopted as the best final models for calculation of the risk premium.

We start to model the conditional volatility as being a GARCH(1,1) process. A GARCH(1,1) specification would be enough since it has been shown to be a parsimonious representation of conditional variance that adequately fits many high-frequency time series (Bollerslev (1987) and Engle (1993)). As the results in Table 5 indicate that the return series exhibit statistically significant correlation in the first lag, an AR(1) and MA(1) structure is fitted on the Srp1. Results show that these coefficients are statistically significant at the 5 per cent level. Results verified that including Srp1 as an additional variable in the conditional variance equation leads to a very significant decrease in the autoregressive coefficient of the variance equation, i.e., $\alpha + \beta$ of the GARCH process, to close to one.

Table 8, 9, and 10 provide the estimation for the relationship between the risk premium volatilities 1-month, 2-month and 3-month maturities, which obtained in the previous step, and the crude oil futures price by OLS method.

We estimate three alternative model of volatility – one with contemporaneous Srp and the other with futures price. In addition, as discussed in the previous section, we also used futures 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

Variable	Coefficient	Standard error	t-sta tistic	P-value
C	0.0020	0.0087	0.2346	0.81
F1	0.0005	0.0001	3.2394	0.00
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

Variable	Coefficient	Standard error	t-sta tistic	P-value
C	-2.00	0.91	-2.18	0.02
F1	0.13	0.01	8.16	0.00
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

Variable	Coefficient	Standard error	t-sta tistic	P-value
C	-3.88	1.34	-2.89	0.00
F1	0.22	0.02	9.65	0.00
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 futuress 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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