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Dynamic Correlation Analysis of Futures Price Fluctuation of Crude Oil and Basis Difference in China Based on VAR Model

Hongguo Sun[1], Wenhui Li[1]
[1]*Department of Mathematics and Finance*
Hunan University of Humanities Science and Technology
Loudi, China, 417000

Abstract: This paper studies the interaction between the crude oil futures rate of return and basis difference between the highest price and the lowest price (BDP) of crude oil futures in China. From the perspective of long-term and short- term, the methods of granger causality test, impulse response function and variance decomposition are used to investigate the impacts of them.. The results show that, firstly, both in long and short term, there is an interaction between the crude oil futures rate of return and BDP of crude oil futures; secondly, the crude oil futures rate of return is mainly affected by its own fluctuations. At the same time, the fluctuation of the BDP of crude oil futures has a certain lag on the volatility of crude oil futures, and the current BDP of crude oil futures will affect t the crude oil futures rate of return within 10 periods lags ;at last, from the perspective of variance decomposition, the current error variance of crude oil futures can be explained by BDP of crude oil futures, which is up to 2%,the impact of the crude oil futures rate of return on current error variance of BDP of crude oil futures reaches 0.9%.
Keywords: Crude oil futures; Basis difference the highest price and the lowest price; Granger causality test; Impulse response; Decomposition

I. INTRODUCTION

On March 26, 2018, Chinese crude oil futures start online trading in Shanghai futures exchange, a subsidiary of Shanghai international energy trading center. Since the opening week, the investment atmosphere is rational and active, and the liquidity performance is good, the main contract volume and positions of Chinese crude oil are increasing day by day. Chinese crude oil futures are expected to balance the current benchmark prices of WTI and brent, which cannot truly reflect the supply and demand situation in the a sia-pacific market. Crude oil futures is also China's first international futures varieties, which help to crude oil futures market and financial market further opening to the outside ,crude oil is one of the most important commodities, and it is also the most difficult pricing goods. Data show that in the global market, financial futures trading volume accounts for 88% of total global futures trading volume, and commodity futures accounted for 10%, of which energy futures accounts for about a third of all commodities futures.

Sinopec daily(March 30,2018) say that China's crude oil futures are significantly different from the international prevailing west Texas intermediate crude oil (WTI) and brent crude oil futures. First, WTI and brent crude oil futures mark is light, sweet crude oil, while the launch of our country crude oil futures is intermediate sour crude. Second, WTI and brent futures respectively reflect the supply and demand of crude oil in the Americas and Europe, but they cannot accurately reflect the supply and demand dynamics in Asian markets.

At present, there are many documents on crude oil futures. Before the listing of crude oil futures in China, they mainly studied WTI and Brent crude oil. it mainly divided into the following aspects.

First, Some literatures study the price characteristics of international crude oil futures.YU W B, FAN Y,WEI Y M , JIAO J L (2004)studied studied the Brent futures market using the cointegration analysis. It approved that the Brent futures market is efficient within 5 months. Furthermore, it found that the impact of the price will continue 2 months by establishing a VECM which is very suitable for the efficient market. Combing the theories of commodity futures and energy economics , LI ZH,LIN B Q,XU J J (2014)constructs a MSIA(3)-VARX(1)model . The results show that there is obvious regime-switching character in the international futures market, and the stable status of regime 1 never appears again thereafter, the market status shifts between regime 2 and 3, which are characterized by ascending and descending in the price respectively.AS regime shifts, speculation has greater influence on price.

Second, some literatures study the influence of international crude oil futures on China's economic and financial market. LIU K, YANG C Y (2012) studied The Effect of International Oil Price's Fluctuation on Chinese Industry Index, they found that international oil price fluctuations has a significant effect on the part of the Chinese industry. WANG H G，DING W F (2013) focus on price movements between crude oil futures and a series of agricultural commodities. A comparative framework is applied to identify changes in relationships through time and various cointegration methodologies and causality tests. The results indicate that co — movement is a dynamic concept and that some economic and policy development may change the relationship between commodities. GUO Y J, SONG L, WANG F(2015) studied the Volatility Spillover Effects between Crude Oil Futures Market and Agricultural Product Futures Market, The study finds that the crude oil futures market and the agricultural products futures market are auto–correlated and there is Granger causality between the two; there is two–way volatility spillover effects between crude oil futures and corn soybean futures. HUANG H F, SHI ZH.(2017) studied on the dynamic interaction between international crude oil futures and China agricultural products futures using DCC-GARCH model. They found the international crude oil futures and the dynamic correlation between China's soybean futures higher than that of other agricultural products futures. ZHENG Y，MA Y (2018) analyzed the dynamic impact of international crude oil price on China's grain price based on TVP-VAR model. Results show that the impacts of international crude oil prices on domestic prices has obvious time-varying characteristic.

Based on the above literatures, this paper studies the interaction between the crude oil futures' return and basis difference between the highest price and the lowest price of crude oil futures in China. From the perspective of long-term and short- term, the methods of granger causality test, impulse response function and variance decomposition are used to investigate the impacts of them.

II. VAR MODEL

2.1 The expression of VAR (p)

Vector autoregressive models (VAR) are often used to study multivariate time series. ZHU X H (2015) found this model is relatively easy to estimate, and it can be estimated by least square method or maximum likelihood estimation method. The properties of this model have been extensively studied in the literature. In this paper, VAR model is used to study the dynamic correlation between the crude oil futures rate of return and the BDP of crude oil futures in China. According to TODA and YAMAMOTO (1995), the expression of VAR(p) model is as follows:

$$Y_t = \Phi_0 + \Phi_1 Y_{t-1} + \ldots + \Phi_p Y_{t-p} + E_t \quad (1)$$

Where $Y_t = (y_{1t}, y_{2t}, \ldots), \Phi_1, \Phi_p, \ldots, \Phi_p$ are coefficients to be estimate, Φ_0 is a vector of constants, and E_t is a vector well-behaved disturbances. t is linear time trend, p is the optimal lag length.

2.2 Model test

An accurate VAR (p) model should contain some test ,for example: causality test, system stable test and residual correlation test. The tests are as follows.

Firstly, in order to determine the long-term relationship among variables, it should test the causality between variables using Block Exogeneity Wald Tests, which is a chi squared distribution with 2 degrees of freedom. The null hypothesis is that *variable 1* is not the causality to *variable 2*.

Secondly, an accurate VAR(p) model must first be stable, so we should test the VAR(p) whether is stable or not using unit root test. The null hypothesis is that there is an unit root.

At last, the residual error of the accurate VAR(p) model should be white noise sequence. Therefore, it should test the continuity of residuals and cross-correlation.

2.3 Impulse response function

In order to study the short-term dynamic impact reaction among variables $Y_t = (y_{1t}, y_{2t}, \ldots)$, this research is based on GIRF, which is presented by KOOP et(1996) al. In multivariate statistical analysis, it usually assumed the $E(y_{it})$ to be 0, because the mean does not affect the response model of the y_{it} to any impact. In order to study the effect of $y_{jt-k}(k > 0)$ on y_{it}, while the other variables remain unchanged, in other words, we will study the y_{it} how to change when the y_{jt-k} increases by 1.From the VAR (p) model, we can get MA expression by recursive method. The coefficient matrix of MA expression is:

$$\Psi_i = \sum_{j=1}^{\min(i,p)} \Phi_j \Psi_{i-j}, i = 1, 2, \ldots \quad (2)$$

Lemma: The E_t is the sequence of uncorrelated new inference processes, whose mean is 0, positive definite covariance is $\sum_\varepsilon$, and for $j \geq 0, Cov(Y_i, \mathrm{E}_{t-j}) = \Psi_j \sum_\varepsilon$.
According to (2) and Lemma, RueyS.Tsay (2017) gave below equations:

$$Y_0 = \mathrm{E}_0 = \begin{bmatrix} 1 \\ 0 \\ \dots \\ 0 \end{bmatrix} \qquad Y_1 = \Psi_1 \mathrm{E}_0, Y_2 = \Psi_2 \mathrm{E}_0, \dots \tag{3}$$

The above equation shows that the Ψ_i is the coefficients of the impulse response function.

And the $\Psi_n = \sum_{i=0}^{n} \Psi_i$ is the total cumulative effect over the long term.

2.4 variance decomposition

According to the forms of VAR, SIMS (1980) proposed variance decomposition method to quantitatively measure the relationship between the variables, From the VAR (p) model, we can get MA expression by recursive method:

$$y_{it} = \sum_{j=1}^{k} (\varphi_{ij}^{(0)} \varepsilon_{jt} + \varphi_{ij}^{(1)} \varepsilon_{jt-1} + \varphi_{ij}^{(2)} \varepsilon_{jt-2} + \dots) \tag{4}$$

The variance is obtained. It is assumed that sequence ε_t has nothing to do with it:

$$E[(\varphi_{ij}^{(0)} \varepsilon_{jt} + \varphi_{ij}^{(1)} \varepsilon_{jt-1} + \varphi_{ij}^{(2)} \varepsilon_{jt-2} + \dots)^2] = \sum_{q=0}^{\infty} (\varphi_{ij}^{(q)})^2 \delta_{jj} \tag{5}$$

Here, $E(\varepsilon_{jt})^2 = \delta_{jj}$

Here, it is assumed that covariance matrix of vector of disturbing term is diagonal matrix, so the variance of y_t is the p diagonal matrix of the above variance:

$$\mathrm{var}(y_{it}) = \sum_{j=1}^{p} [\sum_{q=0}^{\infty} (\varphi_{ij}^{(q)})^2 \delta_{jj}] \tag{6}$$

The variance of y_t can be dissembled into p irrelevant influences. Therefore, in order to measure the degree of influence of each disturbing term on variance of y_t ,the following measurement is defined:

$$RVC_j = \frac{E(y_{it}{}^2)}{\mathrm{var}(y_{it})} \tag{7}$$

RVC is the relative variance contribution, that is ,to observe the influence of the j th variable on the i th variable according to the relative degree of contribution of the j th variable to the variable of y_t based on the variable of the impact.

III. EMPIRICAL ANALYSIS

3.1 Data selection and processing

This paper selects fifteen minute time series for future closing prices, highest prices and lowest of crude oil in China, which are recorded as closing, high and low. The sample data in this paper range from April 16, 2018 to May 31,2018,a total of 1125 data. All data come from Da zhi hui database. Figure 1 shows that during the period, all data experience a rising trend which means that after China's crude oil futures went public in March 26, 2018, the price of crude oil futures continue to rise, which means that investors are generally bullish on China's crude oil futures. The number of participating traders has increased, and the trading volume has grown rapidly. The graphs of raw data are as follows:

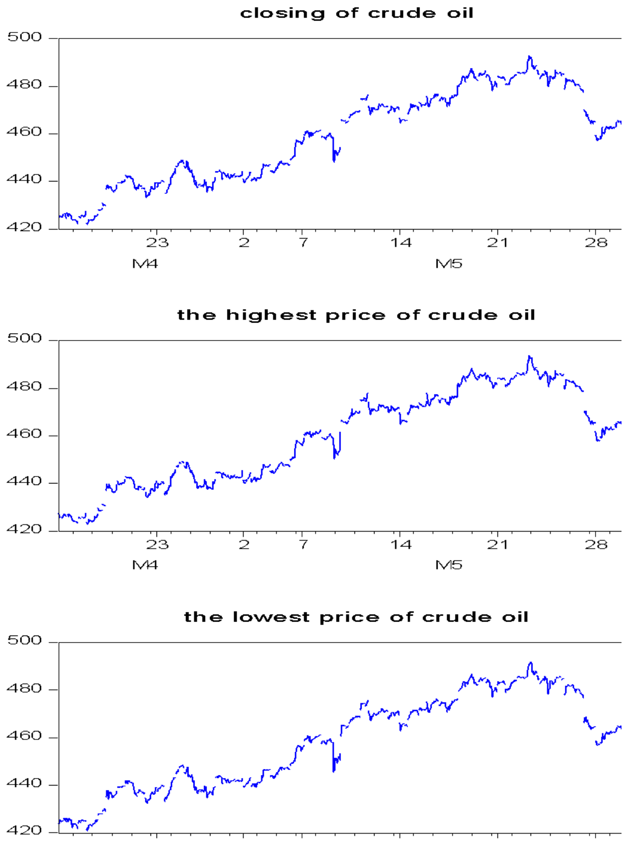


Fig. 1.the graph of raw data

In order to eliminate the unstationary in the time series, theories of closing crude oil prices are converted into returns by taking first differenced logarithms as $r_t = 100 * \ln(closing_t / closing_{t-1})$ (8)

The BDP of crude oil futures is recorded as

$$dp_t = 100 * (\ln high_t - \ln low_t) \quad (9)$$

3.2. ADF test

We firstly employ ADF test to determine whether the series are stable or not. From table 1,we know that the raw series of closing oil, highest oil and lowest oil are not stable. Table 1 shows that the futures prices of closing, high and low are not stable, while the sequences of r and dp are significant at 5% level and have passed the stationary test.

Table 1 ADF unit root test results of sequences

Variable	5% level	ADF statistic	Stationary test
closing	-2.863902	-1.594644	unstationary
high	-2.863902	-1.479868	unstationary
low	-2.863902	-1.653314	unstationary
r	-2.863904	-32.32052	stationary
dp	-2.863904	-17.04248	stationary

3.3. Result of causality test

In order to analyze the long-term relationship between r and dp, this week is based on causality test. The causality test statistic is a Chi-sq, its freedom is two. The significance of statistic means that the column variable granger causes the row variable in the long term. The results are shown in Table 2. Table 2 shows that the continuous compound interest of futures closing prices and the logarithm differences between the prices of highest and the lowest have significant interaction at the 5% level, illustration that the logarithm differences between the BDP if crude oil futures have significant predictive power to the rate of returns of crude oil ,while the returns of closing prices significantly influence the trend of the logarithm differences between the prices of highest and the lowest in the long term.

Table 2 Results of long-term causality test

Variable	r	dp
r	-----	10.23077 (0.0060)*
dp	6.670094 (0.0356)*	------

*represents significance of 5% level. The number of () is P-value of the statistic.

3.4 Results of lag structure

Based on the generalized impulse response function, this paper respectively investigates the dynamic impulse response between interest of futures closing prices and the logarithm differences between the prices of highest and the lowest.

Firstly, in order to select the best lag order, this paper establishes the VAR (2) model .According to LR,FRE,AIC,SC and HQ criterions, it selects the order of the model ,we find that the number of "*"is more than other order, so the lag order of these variables is 2,which means the VAR(2) is the best model. The results are as follows:

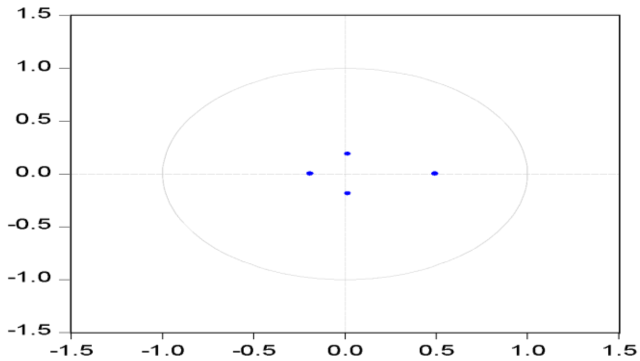
Table 3 the criterions of lag structure

Lag	LogL	LR	FPE	AIC	SC	HQ
0	301.0365	NA	0.002006	-0.535908	-0.526916	-0.532508
1	381.0196	159.5362	0.001751	-0.672078	-0.645102	-0.661880
2	395.8686	29.56492*	0.001717*	-0.691521*	-0.646561*	-0.674524*
3	396.3702	0.996910	0.001728	-0.685251	-0.622308	-0.661456
4	397.6228	2.485048	0.001736	-0.680328	-0.599400	-0.649734

Note: The"*"means it is the best order under one criterion.

3.5 System stable

An accurate VAR model must first be stable, this paper test whether the VAR (2) is stable or not ,it shows that all roots are within the unit circle, which means that the VAR (2) model is stable. The result is Fig.2 as follows:



3.6 Residual test

The residual error of the accurate model should be white noise sequence. Therefore, this paper also test the continuity of residuals and cross-correlation .results are Fig.3 and Table 4. Fig.3 shows that the residual sequence of crude oil futures returns has no autocorrelation, and the residual sequence of base difference between the highest and lowest prices of crude oil futures has no autocorrelation. There is also no cross-correlation between the residual series of base difference between the highest and lowest prices of crude oil futures and the residual series of crude oil futures yields. The correlation coefficients between the residuals were all within 2 standard error bounds, which indicates that the VAR (2) model has well fitted the data. Table 4 shows that according to the residual serial correlation LM tests, it can't reject the null hypothesis: No serial correlation at lags 1 to 3,which also means that the VAR (2) model has well fitted the data.

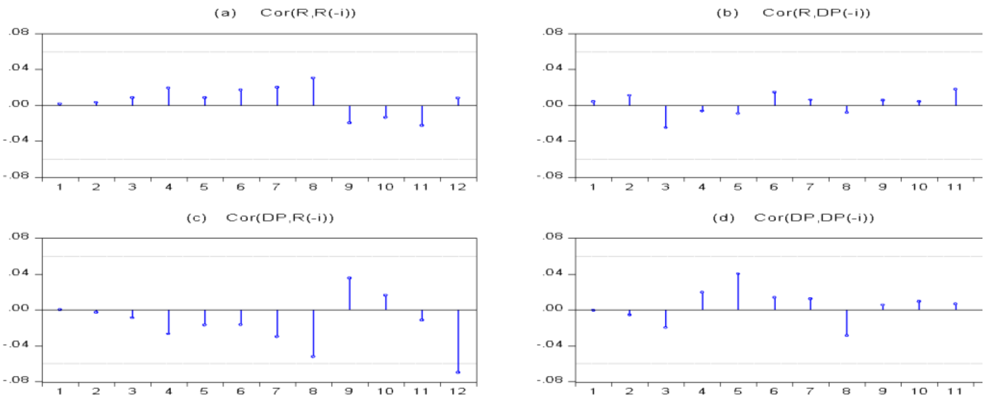
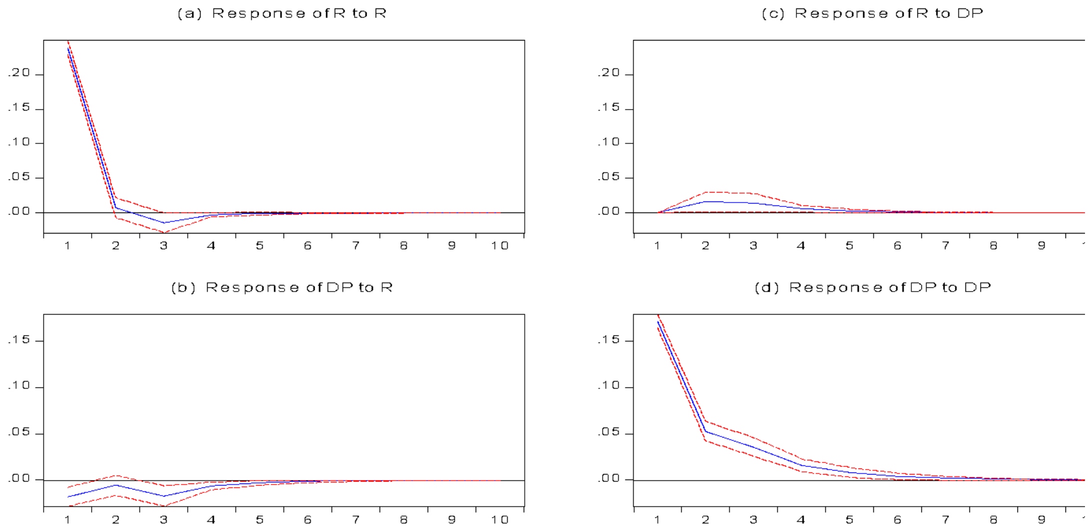


Table 4 VAR residual serial correlation LM tests

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	1.103749	4	0.8937	0.275882	(4, 2228.0)	0.8937
2	2.394124	8	0.9665	0.299023	(8, 2224.0)	0.9665
3	7.011378	12	0.8569	0.583888	(12, 2220.0)	0.8569

3.7 Results of impulse response

The results obtained by applying the method of GIRF to respectively investigate the impulse response function between interest of futures closing prices and the logarithm differences between the prices of highest and the lowest. Considering the short time span, the impulse response is set to be 10.The results are as follows Fig.3.



According to Fig.4.we can see several results:

Firstly, the impulse response curve of (a) which represents the rate of return of crude oil futures returns in each period lag to the rate of return of current crude oil futures ,it close to the horizon after three period lags .which shows that there has a strong positive impact from its own lag. The impact effect of the first period lag on itself is the greatest, which is manifested by the fact that each increase of 1 percentage point in rate of return of crude oil futures bring about an increase of 0.24 percentage points in rate of return of crude oil futures in the current period. The impact of the second period lag on the current rate of return is relatively small, which is almost 0, which is reflected in the increase of 1 percentage point in the second period lag, and the rate of return on crude oil futures is raised by 0.007 percentage points. The impact of the third period lag on the current rate of return is negative, which is reflected in the increase of 1 percentage point in the second period, and the rate of return on crude oil futures is fell by 0.014 percentage points. and the delayed impact effect after the third period tends to zero. That is, the impact effect of the crude oil futures rate of returns on itself mainly maintains three periods, and there is no impact effect after that. The cumulative impact effect of the first three periods reached 0.225 percentage points.

Secondly, the impulse response curve of (b) which represents the BDP of crude oil futures in each period lag to current rate of return crude oil futures is beneath to the horizon. The rate of return of crude oil futures is affected by BDP of crude oil futures, which is shown as a weaker negative impact. For each percentage point increase in the BDP of crude oil futures in the first period lag, the yield of crude oil futures in the current period will drop by 0.018 percentage points. For each increase of 1 percentage point in the second period lag, the return on crude oil futures fell by 0.006 percentage points, almost is zero. For the third period, the rate of return of crude oil futures fell by 0.017 percentage points, and the impact effect after the third period lagged is close to zero. That is, the impact effect of t the BDP of crude oil futures is mainly maintained in first three periods, and there is no impact effect after that. The cumulative impact effect in the first three periods reached 0.041 percentage points.

Thirdly, the impulse response curve of (c) which represents rate of return crude oil futures in each period lag to current BDP of crude oil futures is above to the horizon., which means the impulse response is positive. There is no impact effect on the BDP of crude oil futures in the first period lag, the coefficient is zero. For each increase of 1 percentage point in the second period lag, the BDP of crude oil futures in the current period will increase by 0.016 percentage points. For each increase of 1 percentage point in the third period lag , the BDP of crude oil futures in the current period will increase by 0.015 percentage points, and the impact effect after the third period lagged is close to zero. That is, the impact effect of the BDP of crude oil futures is mainly maintained in first three periods, and there is no impact effect after that. The cumulative impact effect in the first three periods reached 0.031 percentage points.

At last, the impulse response curve of (d) which represents the BDP of crude oil futures in each period lag to current BDP of crude oil futures is above to the horizon. The BDP of crude oil futures shows a strong positive impact due to its own impact effect. The specific performance is that the BDP of crude oil futures has a positive impact on itself in the period lag. For every 1 percentage point increase in the first period lag, it will bring about a 0.172 percentage point increase in the current period. For each percentage point increase in the second period lag, it will bring about 0.053 percentage points increase in the current period. For each percentage point increase in the third period lag, it will bring about 0.036 percentage points increase in the current period. Each increase of 1 percentage point in the fourth period lags ,it will bring about an increase of 0.016 percentage points in the current period. Each increase of 1 percentage point in the fifth period lag ,it will bring about an increase of 0.008 percentage points in the current period, and the impact effect will tend to zero after the fifth period lag. That is, the BDP of crude oil futures is mainly maintained in 5 periods lags by its own impact effects, and there is no impact effect after that. The cumulative impact effect in the first five periods lags reached 0.269 percentage points.

The impulse response shows that the crude oil futures' rate of return in current period mainly are influenced by itself, and the BDP of crude oil futures have some effects on the crude oil futures' rate of return, which together has the ability to forecast crude oil futures returns in future.

3.8 Results of variance decomposition

Variance decomposition method will be used to examine level of mutual influence among the crude oil futures returns and the BDP of crude oil futures. The results are respectively shown in Table 5 and Table 6.

Table 5Variance Decomposition of R:

Period	S.E.	R	DP
1	0.239327	100.0000	0.000000
2	0.239987	99.54389	0.456114
3	0.240869	99.17545	0.824553
4	0.240956	99.11772	0.882278
5	0.240974	99.10426	0.895744
6	0.240979	99.10091	0.899095
7	0.240980	99.10006	0.899944
8	0.240980	99.09985	0.900151
9	0.240980	99.09980	0.900202
10	0.240980	99.09979	0.900215

Table 6 Variance Decomposition of DP

Period	S.E.	R	DP
1	0.172679	1.089358	98.91064
2	0.180651	1.100452	98.89955
3	0.184932	1.907735	98.09227
4	0.185732	2.006818	97.99318
5	0.185936	2.029801	97.97020
6	0.185985	2.035243	97.96476
7	0.185997	2.036663	97.96334
8	0.186000	2.037008	97.96299
9	0.186001	2.037093	97.96291
10	0.186001	2.037114	97.96289

From the results of variance decomposition, it can be seen some conclusions as follows.

Firstly, table 5 shows variance decomposition of R (the rate of return of the crude oil futures).The current error variance of R can be significantly explained by itself, which is up to 99.1% and it can be explained by the BDP (basis difference between the highest price and the lowest price) of crude oil futures reaches 0.9% after the forth period lag. In the first period lag, the error variance of R is mainly explained by itself. In the second period lag, the ability of explaination reached 99.54 %. Afterwards, with the gradual delay of time, its ability of explaination shows a slow decline trend, with a relatively large decline between periods 1, 2, and 3, but the decline in the later period is relatively small, and it is basically stable after the fourth period lag, which is up to 99.1 %; In addition, the BDP of crude oil futures can also explain the error variance of R. In the first period lag, the BDP of crude oil futures contributed 0 to the error variance of R, while in the second period lag, the contribution rate rose to 0.46 %, and the contribution rate rose to 0.82 % in the third period lag, and the contribution rate rose to 0.88 % in the fourth period lag, which was close to 0.9 %.The contribution rate is basically maintained at 0.9 % level and it is in a stable state after four period lags.

Secondly, table 6 shows variance decomposition of BDP of crude oil futures. The current error variance of BDP of crude oil futures can be significantly explained by itself, which is up to 98% and it can be explained by the rate of return of crude oil futures reaches 2% after the forth period lags. In the first period lag, the error variance of BDP of crude oil futures is mainly explained by itself, which is up to 98.9%. Afterwards, with the gradual delay of time, its ability of explaination shows a slow decline trend, it is basically stable after the fourth period lags, which is up to 98%; In addition, the crude oil futures returns can also explain the variance of the BDP of crude oil futures of crude oil futures, its ability of explaination shows a slow upward trend. In the first period lag, the rate of return of crude oil futures contributed 1.089% to the variance of the BDP of crude oil futures of crude oil futures. In the second period lag, the contribution rate rose to 1.1 %, and the contribution rate rose to 1.9 % in the third period lag , and the contribution rate rose to 2.0 % in the fourth period lag, The contribution rate is basically maintained at 2.0% level and it is in a stable state after four period lags.

IV. CONCLUSION

This paper studies the crude oil futures returns and base difference between the highest price and the lowest price of crude oil futures, using VAR model, some main conclusions are obtained as follows:

First of all, both in the long and short term, there is an interaction between the crude oil futures returns and base difference between the highest price and the lowest price of crude oil futures. There is a two-way Granger causality between them. In the long run, there is a equilibrium relationship between them. In short term, there is a dynamic interaction between them.

Besides, the rate of return of crude oil futures is mainly affected by its own fluctuations. At the same time, the fluctuation of the BDP of crude oil futures has a certain lag on the volatility of crude oil futures, and the current basis difference will affect the yield of crude oil futures within 10 periods lags.

At last, from the perspective of variance decomposition, the current error variance of the rate of return of crude oil futures can be explained by the BDP of crude oil futures, which is up to 2%, the impact of crude oil futures' return on current error variance of BDP of crude oil futures reaches 0.9%, it is means the rate of return of crude oil futures are affected more higher by the BDP of crude oil futures in China.

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