Analysis of the linkage between Chinese crude oil futures and international crude oil price——An empirical analysis based on VAR model

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Abstract: Three years after the introduction of Shanghai crude oil futures, its smooth operation is of great significance to Chinese fight for the right to speak in the international crude oil pricing system. This article constructs VAR model, uses Granger causality test, impulse response function analysis, and variance decomposition analysis, and analyses the impact of Shanghai crude oil futures on the spot price of crude oil in the Asia-Pacific region and its participation in the international crude oil pricing system. The study found that Shanghai crude oil futures has significant guidance and influence on Oman crude oil futures. There is a two-way mean spillover effect between Shanghai crude oil futures and BRENT, WTI crude oil futures. Shanghai crude oil futures has been in line with the international crude oil price and has a certain impact on the spot price and futures price of the international crude oil markets.

1. Introduction

Since 2018, Chinese dependence on foreign crude oil has exceeded 70%, and it has become a major crude oil importing country in the world. However, the Asia-Pacific region has lacked influential crude oil pricing benchmarks for a long time. Asia-Pacific countries including China passively accept WTI and BRENT as the benchmark for crude oil pricing. The great fluctuation of the international crude oil price makes Chinese price system face great risks. Until March 26, 2018, the introduction of Shanghai crude oil futures opened a new journey for China to gain the voice of the international crude oil pricing system and the internationalization of Renminbi.

In the three years since the introduction of Shanghai crude oil futures, it has become the third largest crude oil futures after WTI and BRENT crude oil futures. It has withstood various geopolitical risks and extreme events at home and abroad. It can be seen that although Shanghai crude oil futures is young, it already has considerable influence. Does it have an impact on the crude oil spot in the Asia-Pacific region? How is its participation in the international crude oil price system? The exploration of these issues will reveal the role of Shanghai crude oil futures in the international and domestic dual cycles, fill the gaps in academic research in this regard, and help enhance the comprehensive strength and the international influence of Shanghai crude oil futures.

In this paper, empirical methods such as VAR model, Granger causality test, impulse response function analysis and variance decomposition analysis are used to test the price linkage relationship between Chinese crude oil futures market and the international crude oil futures markets and spot markets, so as to derive the price relationship between Chinese crude oil futures and crude oil spot in the Asia-Pacific region, and its participation in the international crude oil price system, reveal the development status of Shanghai crude oil futures market, analyse the ways of Chinese crude oil futures market to enhance the international influence, and put forward feasible suggestions and countermeasures.

2. Literature review

If these markets are not completely divided, market entities will speculate on price changes in other markets based on changes in the price of one market, so price changes in one market often lead to

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changes in price in other markets (King & Wadhwani, 1990). Scholars' researches on futures price linkage are classified according to research object, which can be divided into futures and spot market, futures and stocks, exchange rate, futures and other financial markets price linkage analysis.

Based on the perspective of the international geography, the analysis of price linkage between futures markets of the same commodity in different countries focuses on the transmission of information between mature futures markets and emerging futures markets. In the early research on agricultural product futures, Canadian wheat futures were guided by the price of American wheat futures (Booth et al, 1998). Among the major global crude oil futures markets, including London, New York, and Dubai, London and New York crude oil futures markets play a leading role in information spillovers (Liu & Li et al, 2008). Taking London copper futures and Shanghai copper futures as research variables, it is found that the influence of the London copper futures market on Shanghai copper futures market is greater than that of Shanghai copper futures market on the London copper futures market (Xiandan Li, 2009). Constructing a multivariate VAR(1)-GARCH(1,1)-BEEK model to conduct an empirical analysis of the returns between five oil and fat markets at home and abroad, it is found that the oil and fat futures income of the United States and Canada have unidirectional spillovers on the oil and fat futures income of China (Liu Song , Tang Tingfei, 2014). It can be found that the conclusion of these studies are often that more mature futures markets dominate, and emerging futures markets are guided by the price of mature futures markets.

With the extensive development of futures markets in the world, the researches on the price linkage of futures market have become more complicated. Few scholars have studied the multiple price relationships between multiple futures markets and spot market at the same time. Using Granger causality test and structural auto-vector regression (SVAR) and other models combined, it is found that the international futures price dominate domestic futures price, but also dominate domestic spot market price (Zhang Yishan et al., 2006). For example, there is a two-way information spillover between Shanghai fuel oil futures price and Singapore fuel oil spot price, and WTI crude oil futures price and Dubai crude oil futures price have stable information spillovers on both (Ma Chaoqun et al., 2009). The international cotton futures price guides the international cotton spot price, and the international cotton spot price and Zhengzhou cotton futures price guide Chinese cotton spot price (Zhu Houyan, 2019). It can be found again that the price guiding role of the mature futures market is more significant.

After the introduction of Shanghai crude oil futures, scholars focused on the price linkage between the international crude oil futures markets and Chinese crude oil futures market. At the initial stage of introduction, the international oil price shocks had a significant impact on Chinese crude oil futures market (Zhang Dayong, Ji Qiang, 2018). With the development of Shanghai crude oil futures, from a price point of view, Shanghai crude oil futures has been in line with the international crude oil price and has a certain influence on the international crude oil futures price. At the same time, the yields of Shanghai crude oil price have strong local characteristics (Dai Wenqun, Duan) Jiangjiao, 2019); from the perspective of mean spillover effects, WTI and BRENT futures yields have a one-way spillover effect on Shanghai crude oil futures yields (Gao Li, Gao Shixian, 2019); from the perspective of volatility spillover effects, there is a significant two-way volatility spillover effect between Shanghai crude oil futures and BRENT,WTI crude oil futures, and the volatility spillover effect lasts for a long time (Wang Liang et al, 2020).

Existing literatures have conducted a lot of researches on the price linkage of the futures market and found that a mature futures market can effectively respond to price fluctuations and adjust in time, reasonably avoid price risks, and play a major guiding role in the international futures markets. In the crude oil futures markets, WTI and BRENT crude oil futures have a profound impact on the international crude oil markets. As Chinese crude oil futures has not been listed for a long time and the data accumulation is not enough, scholars have focused on the impact of the international crude oil futures on Shanghai crude oil futures. Few literatures consider the linkage relationship between Shanghai crude oil futures price and the international crude oil futures and spot price. This article will conduct an empirical analysis of the impact of Shanghai crude oil futures on the Asia-Pacific crude oil spot market and its participation in the international crude oil system after the listing.

3. Theoretical basis and empirical model

3.1 Theoretical Basis of Price Linkage

The price linkage of the futures market theoretically means that when the price of a certain futures market changes, it will cause price changes in different degrees and directions in the relevant market. In fact, it shows the reaction of different markets to the same information. Price linkage is based on arbitrage, and the degree of linkage between markets reflects the operation of the market and the efficiency of information absorption to a certain extent.

1) *Market integration theory.* Market integration theory is divided into different time market integration theory, different product integration theory, and different space integration theory. This article selects the market integration theory of the same product at the same time in different spaces. In the short term, a certain product in a certain market is impacted by certain factors at a certain moment, which leads to violent fluctuations in its own price, which is transmitted to the price of the same product in other markets. It shows that the price of the same product in many markets fluctuates sharply in a short time. This similar price fluctuation can reflect the degree of linkage between different markets and the efficiency of information transmission between different markets.

2) *No-arbitrage equilibrium theory.* If there is a market integration relationship among multiple markets, price in different markets will keep changing simultaneously due to the existence of arbitrage between markets. The relationship between supply and demand in the market will also change due to the existence of arbitrage, which will further affect product price. If the market deviates from the equilibrium state, specifically when the price of financial assets deviates from the equilibrium price, with the occurrence of this process, arbitrage opportunities will also occur. The emergence of inter-market arbitrage will cause the price of various financial assets to converge towards the equilibrium price. Arbitrage will not end until the equilibrium price is restored again. When the price of financial assets returns to the mean value, the corresponding arbitrage opportunities will continue to decrease and eventually disappear.

3) *Information transmission and spillover effect theory.* According to the efficient market theory, the price of the market will reflect the information in the market to a certain extent. Therefore, the transmission of information has an important influence on price fluctuations. The mainstream transaction information providers obtain a large amount of transaction information, and reflect it in their next investment strategy to realize the information-price transmission after absorbing the information. The influence of the information absorption and transmission will be quickly transmitted to the entire market, and eventually promote the formation of a new effective equilibrium market price.

In the futures market, the spillover effect is that the futures products in different futures markets that are related to each other produce a coordinated movement on the changes in their price due to the transmission of information. This coordinated movement can be measured by the average change of market price and market returns. The measure of coordinated movement by the market price average index corresponds to the mean spillover effect. The mean spillover effect produces an expected response to clearer information, which essentially reflects the successive changes in different market price.

3.2 VAR Model and Application

1) *Model construction.* Traditional econometric methods are based on the description of variable relationships based on static economic theories. Once the dynamic relationship between variables is described, they cannot provide a strong proof. Sometimes it appears that endogenous variables can appear either at one end of the equation or at another end of the equation, making the estimation and inference of the model more complicated, and some important lagging variables may even be omitted.

In order to solve these problems, economists began to consider the use of non-structural methods to create models of relationships between various variables and analyse actual problems. In 1980, Sims proposed the vector autoregressive VAR model, which constructed the lag value of all endogenous variables in a system, thereby extending the univariate autoregression to a vector autoregressive model

composed of multiple time series variables to analyse the dynamic relationship of joint endogenous variables under unconstrained conditions. On the premise that the time series is stationary, if there are *n* endogenous variables and lag *p* period:

$$Y_{\mathrm{t}} = \begin{pmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{nt} \end{pmatrix}, Y_{\mathrm{t-1}} = \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \\ \vdots \\ y_{nt-1} \end{pmatrix}, \ldots, Y_{\mathrm{t-p}} = \begin{pmatrix} y_{1t-p} \\ y_{2t-p} \\ \vdots \\ y_{nt-p} \end{pmatrix} \quad (1)$$

$y_{1t}, y_{2t}, \ldots, y_{nt}$ represent *n* different endogenous variables, and the mathematical expression of its var (*p*) model is as follows:

$$Y_t = \alpha + \Pi_1 Y_{t-1} + \Pi_2 Y_{t-2} \cdots + \Pi_p Y_{t-p} + U_t, \mathrm{t} = 1, 2, \cdots, \mathrm{T} \quad (2)$$

$Y_t$is an n-dimensional sequence vector, Π_1, Π_2, $\cdots$, Π_p is the n * n-dimensional coefficient matrix to be estimated, $U_t$is n-dimensional disturbance term vector, *p* is lag order and *T* is the number of samples.

2) *Determine the lag order.* In many cases, the assumptions of the normal distribution of random error terms required by the likelihood ratio test cannot be satisfied in financial data. Therefore, the information criterion method is used to determine the lag order of all equations in the VAR model. The specific form of the corresponding information criterion is:

$$\mathrm{AIC} = -\frac{2l}{T} + \frac{2k}{T} \quad (3)$$

$$\mathrm{SC} = -\frac{2l}{T} + \frac{klogT}{T} \quad (4)$$

$$\mathrm{HQ} = -\frac{2l}{T} + \frac{2klong(\log(T))}{T} \quad (5)$$

Among them, *l* represents the log-likelihood value, *T* represents the sample size, and *k* represents the number of regression terms in all equations.

The lag order when the AIC value or SC value or HQ value reaches the minimum, is the lag order of the VAR model.

3) *Impulse response function.* In the VAR model, the influence of the random disturbance term ε_{t} on the sequence $\mathrm{y_t}$can be expressed by a dynamic multiplier:

$$\text{Dynamic multiplier } = \frac{\partial y_{t-j}}{\partial \varepsilon_t}, \mathrm{j} = 0, 1, 2, \cdots \quad (6)$$

For each time span *j*, there will be a corresponding dynamic multiplier. The dynamic multipliers of different time spans *j* are arranged in the order of *j* from small to large, and the path formed is the impulse response function, which describes the dynamic impact on the system at the time of shock is a measure of the impact of one standard deviation of the random error term of an endogenous variable on the current and future values of other endogenous variables.

4. Empirical analysis

4.1 Sample Selection and Data Processing

At present, about 50% of the global crude oil trade is priced with reference to BRENT crude oil futures, and WTI is the world's most traded commodity futures. BRENT and WTI both are the most important pricing benchmarks in the global oil markets and are sufficient to reflect the trend of the international crude oil price. As the delivery oil type with the largest trading volume of Shanghai crude oil futures, Oman crude oil spot price is selected as the corresponding crude oil spot price of Shanghai crude oil futures to facilitate the discussion on the impact of Shanghai crude oil futures on the Asia-Pacific crude oil spot.

Table.1. Variable definition table

Variable	Symbol	Data sources
BRENT futures	FBRENT	Choice
WTI futures	FWTI	EIA
Shanghai futures	INE	INE
OMAN spot	OMAN	Choice
BRENT spot	SBRENT	EIA
WTI spot	SWTI	EIA

As Shanghai crude oil futures is priced in Renminbi, BRENT and WTI crude oil futures spot price are converted into Renminbi price at the intermediate exchange rate announced by the People's Bank of China. We select the daily settlement price data of crude oil futures and spot price from March 26, 2018 to March 1, 2021. Due to the inconsistency of market holidays and trading hours, excluding holidays and non-trading data days, a total of 6 variables and a total of 648 trading days are obtained as observation data of the day.

4.2 Descriptive Statistics and Correlation Analysis

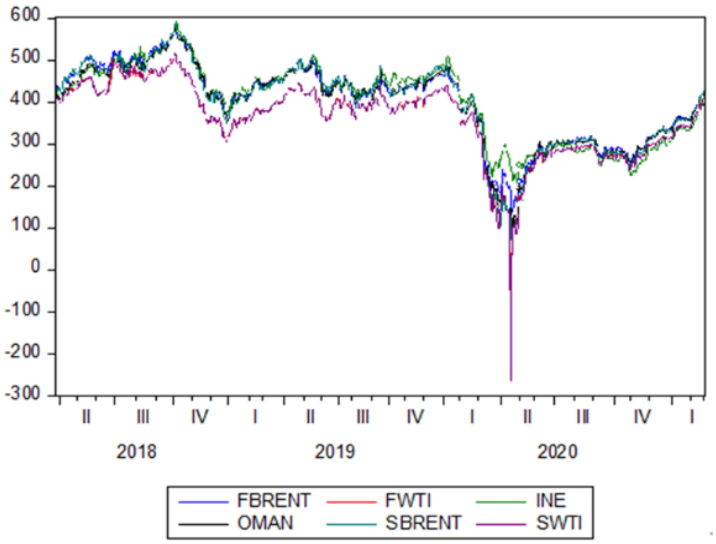

Figure 1. Crude oil futures and spot price trends

In Figure 1, from the perspective of the relationship between futures price and spot price, the futures price and spot price in each market are basically consistent; from the price trends of Chinese crude oil futures and the international crude oil futures, Shanghai crude oil futures and Brent crude oil futures are more consistent, and there is a big difference with WTI crude oil futures. In particular, in April 2020, due to the impact of the epidemic, American oil demand plummeted, and insufficient inventory capacity caused WTI crude oil futures price to fall to negative values. INE crude oil futures and BRENT crude oil futures were also greatly affected. The overall price of the spot markets and futures markets fell, and then gradually returned to stability. In contrast, the price of INE crude oil futures was the least affected under extreme market conditions, and it was able to take the lead in launching the market, driving fluctuations in overseas markets, indicating that Shanghai crude oil futures market has withstood the test of market turbulence and has had a certain impact on the international crude oil futures market.

It can be seen from Table 2 that the statistical characteristics of the average of Shanghai crude oil futures price are closer to those of BRENT crude oil futures. The standard deviation of WTI crude oil futures price series is the smallest, followed by the standard deviation of Shanghai crude oil futures price series, indicating that the deviation of futures price is relatively small. Due to the impact of the epidemic, the kurtosis of the FBRENT, INE, and OMAN price series is less than 3, which does not

conform to the "heavy tail" characteristics of financial data, while the skewness of the 6 series are all negative, showing a left-skewed distribution.

Table.2. descriptive statistical characteristics

Variable	Mean	Std.Dev.	Skewness	Kurtosis
FBRENT	400.38	92.96	-0.56	2.51
FWTI	360.84	87.67	-1.23	6.88
INE	401.31	92.57	-0.40	1.88
OMAN	395.00	95.86	-0.75	2.97
SBRENT	396.51	101.11	-0.81	3.13
SWTI	360.52	88.91	-1.22	6.68

At the same time, in Table 3, both domestic and foreign crude oil futures price and spot price are highly correlated, which is significant at the 5% level. Futures price in the three major markets are highly correlated with spot price. The correlation between WTI crude oil futures and its spot price is the strongest, while the correlation between Shanghai crude oil futures and Oman crude oil spot is the lowest. Among the crude oil futures, the price of the three major crude oil futures are closely related. The price of BRENT crude oil futures and INE crude oil futures have the strongest correlation, followed by BRENT crude oil futures and WTI futures price.

Table.3. Correlation analysis

Correlation	FBRENT	FWTI	INE	OMAN	SBRENT	SWTI
FBRENT	1					
FWTI	0.9667	1				
INE	0.9680	0.9105	1			
OMAN	0.9925	0.9657	0.9617	1		
SBRENT	0.9931	0.9722	0.9529	0.9945	1	
SWTI	0.9657	0.9990	0.9081	0.9646	0.9714	1

4.3 ADF Unit Root Test

The ADF unit root test was performed on the domestic and foreign crude oil futures price series and spot price series, and the results were all non-stationary series. In order to make the variables more stable, the ADF unit root test was performed after taking the logarithm of each price series, and the results showed that they were still non-stationary series. Next, take the first-order difference for each price series, and get the return rate series of 6 variables: DFBRENT, DFWTI, DINE, DOMAN, DSBRENT, DSWTI. After ADF unit root test, it is found that each series is a stationary time series, which can be established for the VAR model, the unit root test results are shown in Table 4.

Table.4. ADF unit root test results

Variable	1%	5%	10%	t	Prob.
DFBRENT	-2.56	-1.94	-1.62	-26.15	0.00
DFWTI	-2.57	-1.94	-1.62	-19.90	0.00
DINE	-2.57	-1.94	-1.62	-20.67	0.00
DOMAN	-2.57	-1.94	-1.62	-24.57	0.00
DSBRENT	-2.57	-1.94	-1.62	-25.57	0.00
DSWTI	-2.57	-1.94	-1.62	-24.82	0.00

4.4 Building a VAR Model

We establish a VAR model based on a stable sequence of returns. According to the information criteria of AIC, SC, and HQ, the optimal lag order is determined to be 8, and the VAR model has passed the exogeneity test and stability test. It can be seen from Figure 2 that the characteristics roots of the model are all located in the unit circle, indicating that the established VAR model is stable.

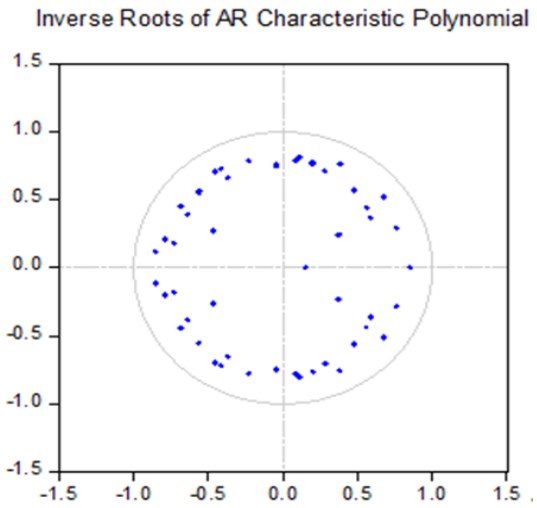

Figure 2. Stability test chart of VAR model

4.5 Granger Causality Test

In order to explore the mutual influence between variables, the Granger causality test is performed on the sequence of returns of each variable.

In Table 5, from the perspective of the guiding relationship between each crude oil futures and its crude oil spot, at the 5% significant level, Brent, WTI, INE crude oil futures yields changes are the Granger reasons of Brent, WTI, Oman crude oil spot yields changes. It shows that each crude oil futures market has a significant impact on its crude oil spot market. Among them, from the guiding relationship of Shanghai crude oil futures to Oman crude oil spot, it can be seen that Shanghai crude oil futures market has had an impact on its corresponding crude oil spot market. From the guiding relationship of the international crude oil futures to Oman crude oil spot, at the 5% significant level, BRENT crude oil futures yields changes are the Granger reason of the changes in Oman crude oil spot yields, and BRENT crude oil futures can have a significant impact on Oman crude oil spot yields.

From the perspective of the guiding relationship between various crude oil futures, at the 5% significant level, the changes in BRENT crude oil futures yields are the Granger reason of the changes in WTI and Shanghai crude oil futures yields, while the changes in WTI and Shanghai crude oil futures yields cannot have an impact on the changes in the yields of BRENT crude oil futures. So BRENT crude oil futures market has a one-way guiding role for WTI and Shanghai crude oil futures markets. The changes in WTI crude oil futures yields changes are the Granger reason of Shanghai crude oil futures yields changes, and Shanghai crude oil futures yields changes have no impact on the WTI crude oil futures yields. It can be seen that in the Granger causality test, the influence of foreign to domestic direction is more significant.

Table.5. Granger causality test

Dependent variables	Independent variables	Statistic	df	Prob.
DFBRENT	DFWTI	15.3178	8	0.0533
DFBRENT	DINE	2.6552	8	0.9541
DSBRENT	DFBRENT	47.6270	8	0.0000
DFWTI	DBRENT	25.0970	8	0.0015
DFWTI	DINE	8.3531	8	0.3998
DSWTI	DFWTI	18.8215	8	0.0158
DINE	DFBRENT	91.7334	8	0.0000
DINE	DFWTI	31.5840	8	0.0001
DOMAN	DINE	10.0688	8	0.0254
DOMAN	DFBRENT	145.8021	8	0.0000
DOMAN	DFWTI	10.06879	8	0.2602

4.6 Impulse Response Function Analysis

In order to further analyse the impact of Shanghai crude oil futures on the futures price and spot price of the international crude oil futures, impulse response function analysis can clearly and intuitively describe the dynamic impact between variables and the duration of the impact. A 25-period lagging impulse response analysis is carried out on the domestic and the international crude oil futures yields and spot yields series, so as to study the depth and breadth of the influence between variables.

From the perspective of the impact of various crude oil market futures on the spot in Figure 3, each crude oil spot yields responds to the impact of the crude oil futures yields, which means that each crude oil futures market has a mean spillover effect on the crude oil spot market, which is in line with the Granger causality test results. The impact of various crude oil futures on the crude oil spot lasts for a short time, indicating that the changes in the futures market can be quickly reflected in the spot market, thereby affecting the changes in spot price. Among them, WTI crude oil futures have the largest spillover effect on its crude oil spot, and the average spillover effect between Shanghai crude oil futures and Oman crude oil spot is the smallest. The BRENT crude oil futures market has a greater impact on the OMAN crude oil spot market than Shanghai crude oil futures market has on the OMAN crude oil futures market. It can be seen that the relationship between Shanghai crude oil futures and the Asia-Pacific market needs to be further strengthened.

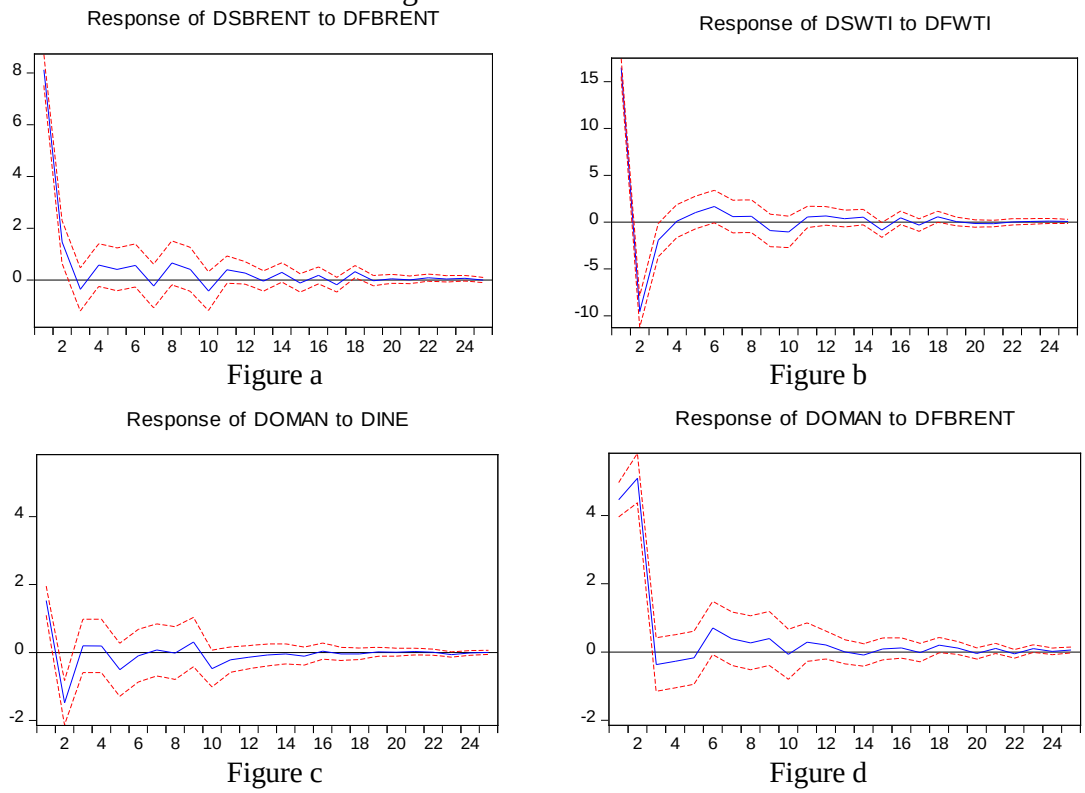

Figure a Figure b

Figure c Figure d

Figure 3. Impulse response of crude oil futures to spot

From Figure a and Figure b in Figure 4, it can be seen that after the yields of BRENT and WTI crude oil futures are hit by the information shock of a standard deviation, the yields of Shanghai crude oil futures will all be affected. In contrast, BRENT crude oil futures has a more significant impact on Shanghai crude oil futures, which is in line with the inference that the two are more correlated; WTI crude oil futures has a smaller impact on Shanghai crude oil futures, but it last longer. It can be seen that, as a newly established futures product, Shanghai crude oil futures interacts closely with the international crude oil futures, responding to fluctuations in the international crude oil futures market immediately and absorbing them in the short term.

It can be seen from Figure c and Figure d that, unlike previous studies, the yields of BRENT and WTI crude oil futures will be affected after Shanghai crude oil futures yields are impacted by the information shock of a standard deviation. In Figure c, the BRENT crude oil futures yields did not

change during the lag 1 period. It fluctuated slightly from the lag 2 period and converged to 0 in the lag 13 period. In Figure d, WTI crude oil futures yields gradually increased from the lag 1 period, reached a peak of about 1.2% in the lag 2 period, and then rapidly dropped to a negative value. After many fluctuations, it converged to 0 in the lag 11 period. The volatility of Shanghai crude oil futures yields has a greater impact on the WTI crude oil futures yields, and the BRENT crude oil futures yields are very weak, but the impact on the two international crude oil futures markets lasts a long time. It can be seen that Shanghai crude oil futures has a sustained impact on the international crude oil futures markets.

In contrast, there is a two-way mean spillover effect between the Shanghai crude oil futures yields changes and the international crude oil futures yields changes. The spillover effect of changes in the yields of Shanghai crude oil futures on the changes in BRENT crude oil futures yields is weak, and the changes in BRENT crude oil futures yields have a greater spillover effect on the changes in the Shanghai crude oil futures yields. Changes in Shanghai crude oil futures yields have greater spillover effects on changes in WTI crude oil futures yields. It can be seen that Shanghai crude oil futures market can quickly respond to and absorb fluctuations in the international crude oil futures markets, and has begun to have an impact on the international crude oil futures market during its gradual development, and the impact lasts for a long time, reflecting the new beginning of Renminbi pricing power.

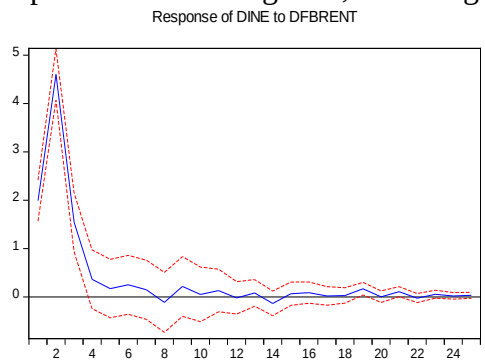

Figure a

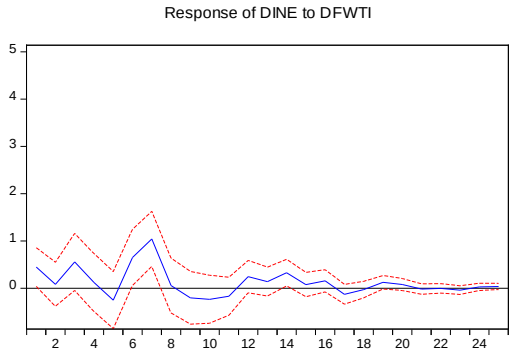

Figure b

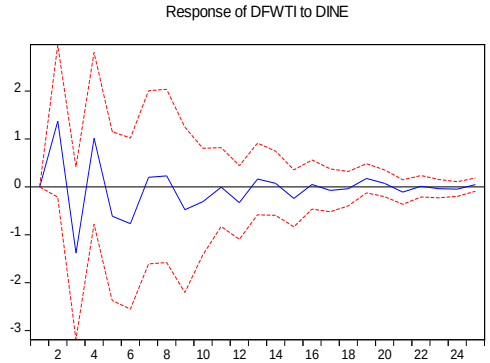

Figure c

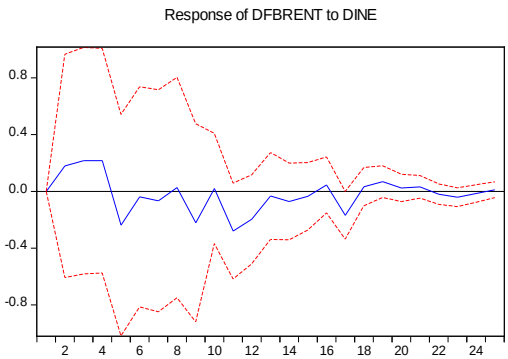

Figure d

Figure 4. Impulse response of INE

4.7 Variance Decomposition Analysis

We use variance decomposition to measure the contribution of changes in the variables from itself and others due to price changes, so as to further analyse the impact between variables.

It can be seen from Table 6 that when the price of Oman's crude oil is lagging for 1 period, contribution rate of Oman crude oil itself is about 55%, and then it is in a downward trend. In the lag 1 period, the price changes of BRENT crude oil began to exert its influence on the OMAN spot price, and the contribution rate of the changes was about 39%, and then gradually increased to about 45%. It can be seen that BRENT crude oil futures play an important guiding role in the price changes of Oman crude oil. In contrast, the impact of Shanghai crude oil futures price on the changes in Oman crude oil spot price is relatively weak, which is consistent with the results obtained by the impulse response function analysis.

Table.6. Variance decomposition table of Oman

Period	S.E.	DFBRENT	DFWTI	DINE	DOMAN	DSBRENT	DSWTI
1	7.1110	39.3960	0.1754	4.6126	55.8160	0.0000	0.0000
2	9.6225	49.5525	1.1951	4.8887	44.0893	0.2433	0.0310
3	9.7119	48.7901	2.5713	4.8394	43.3883	0.2423	0.1686
4	9.7719	48.2687	2.7923	4.8188	43.5832	0.3305	0.2066
5	9.8254	47.7746	3.0184	5.0338	43.1490	0.5559	0.4684
6	9.8888	47.6689	3.3049	4.9791	42.9571	0.5879	0.5021
7	9.9801	46.9531	4.7573	4.8940	42.3141	0.5874	0.4940
8	10.1515	45.4519	4.9480	4.7306	41.2032	2.9416	0.7248
9	10.1929	45.2345	4.9946	4.7844	40.8979	3.2576	0.8310
10	10.2790	44.4843	5.9068	4.9167	40.2235	3.2400	1.2286

It can be seen from Table 7 that when the price of BRENT crude oil futures is lagging for 1 period, its own contribution rate is 100%, and then its contribution gradually decreases to about 86%. At the beginning of the lag 2 period, the contribution rate of WTI and Shanghai crude oil futures price changes to BRENT crude oil futures price changes are 3% and 0.03%, and then gradually increased to 5% and 0.2%. Most of the price changes of BRENT crude oil futures are affected by its own changes, the impact of WTI crude oil futures price fluctuations is relatively weak, and the impact of Shanghai crude oil futures price fluctuations is minimal.

Table.7. Variance decomposition table of DFBRENT

Period	S.E.	DFBRENT	DFWTI	DINE	DOMAN	DSBRENT	DSWTI
1	9.5293	100.000	0.0000	0.0000	0.0000	0.0000	0.0000
2	9.7538	95.7791	3.1277	0.0339	0.9967	0.0230	0.0396
3	9.8162	94.6297	3.1477	0.0820	1.3303	0.0565	0.7537
4	9.8493	94.1105	3.1887	0.1297	1.3665	0.0981	1.1065
5	9.8851	93.5429	3.4450	0.1869	1.3985	0.3120	1.1148
6	9.9557	92.3684	4.2567	0.1857	1.7248	0.3454	1.1190
7	10.1240	89.3791	4.8734	0.1840	2.0365	2.1033	1.4237
8	10.2053	88.0824	4.7995	0.1817	2.7544	2.0862	2.0957
9	10.2603	87.1460	4.7625	0.2263	3.3465	2.0654	2.4534
10	10.2865	86.7393	5.0986	0.2255	3.4195	2.0591	2.4579

It can be seen from Table 8 that in the process of changes in WTI crude oil futures price, nearly 78% of the contribution rate is due to their own changes, and Brent crude oil futures also has an impact on the changes of WTI crude oil futures, accounting for about 20% of its contribution rate. Shanghai crude oil futures price changes have an impact on the WTI crude oil futures price changes, but the effect is relatively weak.

Table.8. Variance decomposition table of DFWTI

Period	S.E.	DFBRENT	DFWTI	DINE	DOMAN	DSBRENT	DSWTI
1	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000
2	21.9495	20.2962	78.8111	0.3904	0.3284	0.1496	0.0244
3	22.1537	19.9445	78.0291	0.7732	0.7097	0.1586	0.3849
4	22.2385	20.0957	77.4469	0.9759	0.8034	0.1905	0.4875
5	22.2784	20.0421	77.3895	1.0480	0.8292	0.1935	0.4976
6	22.6797	19.3541	75.2669	1.1259	1.0344	2.7185	0.5002
7	22.8918	19.1489	73.9999	1.1126	1.1045	4.0453	0.5889
8	23.1308	19.3383	72.5470	1.0994	1.2443	5.1917	0.5793
9	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000
10	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000

It can be seen from Table 9 that the contribution rate of Shanghai crude oil futures to itself in the lag 1 period was 86%, and then gradually decreased to 45%, while the contribution of BRENT crude oil futures to the changes in Shanghai crude oil futures in the 1 lag period reached about 13%, and then gradually increased to about 43%. It can be seen that changes in Shanghai crude oil futures price are mainly affected by changes in their own price and changes in BRENT crude oil futures price.

Table.9. Variance decomposition table of DINE

Period	S.E.	DFBRENT	DFWTI	DINE	DOMAN	DSBRENT	DSWTI
1	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000
2	21.9495	20.2962	78.8111	0.3904	0.3284	0.1496	0.0244
3	22.1537	19.9445	78.0291	0.7732	0.7097	0.1586	0.3849
4	22.2385	20.0957	77.4469	0.9759	0.8034	0.1905	0.4875
5	22.2784	20.0421	77.3895	1.0480	0.8292	0.1935	0.4976
6	22.6797	19.3541	75.2669	1.1259	1.0344	2.7185	0.5002
7	22.8918	19.1489	73.9999	1.1126	1.1045	4.0453	0.5889
8	23.1308	19.3383	72.5470	1.0994	1.2443	5.1917	0.5793
9	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000
10	19.2779	25.1617	74.8384	0.0000	0.0000	0.0000	0.0000

5. Conclusions and recommendations

5.1 Conclusions

Shanghai crude oil futures has been listed for three years, providing a smooth channel for the price discovery and transmission of Chinese energy commodities. This article comprehensively uses the VAR model, Granger causality test, impulse response function analysis, and variance decomposition analysis to analyse the transmission and mutual influence of price fluctuations between Shanghai crude oil futures and Oman crude oil spot, Shanghai crude oil futures market and BRENT, WTI two major international crude oil futures markets, and the following conclusions are drawn:

From the perspective of the impact of Shanghai crude oil futures market on the Oman crude oil spot market, Shanghai crude oil futures price trend is highly correlated with the Oman crude oil spot price; and the changes in the Shanghai crude oil futures yields are the Granger reasons for the changes in the Oman crude oil spot yields. In the impulse response function and variance decomposition analysis, the price changes of Shanghai crude oil futures have an impact on the changes of Oman crude oil futures price. It can be seen that Shanghai crude oil futures has had a significant guiding role and influence on Oman crude oil spot. However, compared with the impact of BRENT, WTI crude oil futures on their spot price, Shanghai crude oil futures have a lower correlation with Oman crude oil spot price, and BRENT, WTI crude oil futures have a greater impact on BRENT and WTI spot price. What needs more attention is that, as the delivery oil of Shanghai crude oil futures, Oman crude oil spot is more closely related to BRENT crude oil futures, and it is more affected by BRENT crude oil futures than Shanghai crude oil futures. The link between Shanghai crude oil futures and its delivery spot needs to be further strengthened.

From the perspective of Shanghai crude oil futures market's impact on the international crude oil futures markets, the price of Shanghai crude oil futures are highly correlated with the price of BRENT and WTI crude oil futures. Although BRENT and WTI are the Granger reasons of Shanghai crude oil futures, they have started to guide Shanghai crude oil futures. However, from the perspective of price trends, under extreme market conditions, Shanghai crude oil futures price is the least affected. It can also take the lead in launching the market and drive fluctuations in overseas markets. Shanghai crude oil futures market has withstood the test of market turbulence and has had an impact on the international crude oil futures markets to a certain extent. Furthermore, further investigation found that Shanghai crude oil futures market no longer passively accepts the impact of the international crude oil futures markets. From the perspective of change contribution, changes in Shanghai crude oil futures

price have an impact on BRENT and WTI crude oil futures price, but the effect is relatively weak. From the perspective of the impulse response function, there is a two-way mean spillover effect between the changes in Shanghai crude oil yields and the changes in BRENT, WTI crude oil futures yields, and even its impact on the changes in the WTI crude oil futures yields is greater than the impact of WTI on the changes in Shanghai crude oil futures yields. From the perspective of the duration of the impact, Shanghai crude oil futures can react and absorb the impact of BRENT and WTI crude oil futures in the short term, but it will have a continuous impact on BRENT and WTI crude oil futures.

5.2 Recommendations

1) *We should strengthen ties with the Asia-Pacific crude oil spot market.* Government departments ought to encourage state-owned and private enterprises to actively participate in the development of oil and gas resources in the Middle East, Africa, South America and Central Asia through mergers , acquisitions, participation in holdings and so on. Thus the establishment of overseas crude oil production bases and supply sources in China will not only ease the current supply of crude oil in China, but also win more shares of the international crude oil resources and a stronger voice in the international crude oil. It is also conducive to Chinese establishment of its own crude oil safety system in the long-term development of the future.

2) *We should benchmark to the world's top futures exchanges.* While giving full play to the institutional advantages of Chinese five-in-one regulatory system, we also ought to copy and promote international experience. We should form an international product sequence as soon as possible and create an international trading platform and international futures varieties. It is necessary to implement international market supervision on Shanghai crude oil futures, strengthen cooperation with commodity futures regulatory agencies in developed countries such as Europe and the United States, and adjust the dissatisfaction of foreign investors. At the same time, taking into account the Chinese characteristics is vital for us to open up the international market, and thus integrate with internationalization.

3) *We had better promote the reform of market infrastructure.* The smooth operation of the international futures markets requires not only supporting capital market innovations, but also a sound financial market structure, rich and diverse financial tools. Especially in the context of Sino-US trade frictions and large fluctuations in the foreign exchange market, foreign participants need tools to manage exchange rate risks, and urgent requirements for the launch of financial instruments such as foreign exchange futures.

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