Research On the Influence of China's Crude Oil Futures Market

Yadi Li*

School of Economics & Management. Nanjing University of Science & Technology, Nanjing, China

*Corresponding author: ady_0323@163.com

Keywords: Pricing Influence, Spillover Effect, Spillover Index.

Abstract: This article divides the influence of China's crude oil futures market on pricing power into three aspects: domestic influence, Asia-Pacific regional influence, and international influence. The daily settlement price of crude oil is analyzed based on the mean spillover effect of the VAR model and the volatility spillover index analysis based on static and dynamic perspectives. It can be concluded that China's crude oil futures market has produced a two-way and asymmetric spillover effect on the domestic crude oil market, the Asia-Pacific crude oil market, and the international crude oil market, but the impact on other markets is not as high as that by other markets and needs to be further improved.

1. Introduction

As an important strategic material, oil is not only an indispensable resource for the normal operation of industrial society, but also one of the centers of the game in international relations. Since 2018, China's dependence on foreign crude oil has exceeded 70%, making China's petroleum-related industries always bear the price risk brought about by large fluctuations in oil prices. In the long run, the *BP2035 World Energy Outlook* points out that China may become the world's largest oil consumer around 2030, then this high degree of external dependence will be one of the important factors of China's economic and political instability.

Shanghai crude oil futures have been listed for three years, with a cumulative transaction value of 44.10 trillion yuan, making it the third largest crude oil futures after WTI and Brent crude oil futures. In 2020, the new crown epidemic brought unprecedented drastic changes and challenges. Shanghai crude oil futures prices have maintained a high degree of linkage with international oil prices while also reflecting the characteristics of the Asian market. Under the new development pattern, is Shanghai crude oil futures market gradually changing from a "shadow market" to a "pricing center"? The direction and size of its influence on other crude oil markets is of milestone significance in serving the development of China's real economy, striving for the right to speak in the Asia-Pacific region and even the international crude oil pricing system.

2. Literature review

2.1 The influence of futures market pricing

The pricing power is more related to the benchmark price of international trade of bulk commodities. It is generally believed that the market where the benchmark price is generally used in international trade has the pricing power of the commodity. With the development of market globalization, the influence and connection between various markets have deepened, and the target of international traders' reference pricing is no longer unique. Chen Jun and Chang Qing (2010) first proposed the concept of using the international pricing influence of the futures market, but did not give a clear definition. Li Zixue (2015) proposed that the influence of international pricing is based on the international pricing center to measure the ability of a country's futures prices to affect the price of the international pricing center. The pricing center focuses on geographic location. The pricing center theory of Chang Qing (2001, 2006, 2017) points out that the pricing center is a futures

market that can form authoritative prices. On this basis, Yao Lin (2018) classified pricing influence into domestic influence, regional pricing influence, and international pricing influence according to the scope of influence of prices formed in the futures market. The corresponding three types of pricing centers are domestic pricing centers, regional pricing center and international pricing center.

2.2 Spillover effects in the crude oil market

In the study of mean spillover effects, with the development of the Shanghai crude oil futures market, there are different conclusions. Zhang Dayong and Ji Qiang (2018) found that Shanghai crude oil and international benchmark crude oil are closely related to each other and that fluctuations in international oil prices have a significant positive impact on China's crude oil futures market; Gaoli and Gao Shixian (2019) used the SVAR model to find that from futures returns rate, Shanghai crude oil futures initially have the function of price discovery. WTI and BRENT futures yields have a single spillover effect on Shanghai crude oil futures yields; Yang Yufei (2020) found on the basis of the VECM model that INE has initially obtained the Asian crude oil futures market. Liu Yinglin et al. (2019) found that from the perspective of prices, Shanghai crude oil futures are in line with international crude oil prices and have a certain influence on the international crude oil futures prices.

In the study of volatility spillover effects, Hanmao (1990) earlier proposed the "two-part test" of the GARCH model to test the volatility spillover effects. Ewing (2002) constructed a multivariate GARCH model and found that there is an asymmetric two-way volatility spillover effect between oil and natural gas markets. However, the main focus of the VAR model, VECM model, and GARCH family model is the existence, symmetry, and trend of spillover effects between time series, but they cannot quantify the size of spillover effects. In order to solve this problem and effectively measure the strength of the spillover effect, Diebold and Yilmaz (2009) are based on the VAR model to decompose the prediction error variance. Subsequently, Diebold and Yilmaz (2012) used generalized prediction error variance decomposition to improve the model in order to solve the problem of sorting variables in Cholesky decomposition. Awartan and Maghyereh (2013) adopted the Diebold and Yilmaz (2012) spillover index method, and found that the information transmission of return and volatility between oil and stock markets in GCC countries is bidirectional and asymmetric, and plays a leading role in the mechanism. Wang Qizhen and Wang Yudong (2018) used spillover indexes to explore the spillover effects of West Texas crude oil spot prices, US economic uncertainty, and China's stock market from both static and dynamic perspectives, and found that information transmission between the two markets is two-way asymmetric. Zhang Xueying(2020) calculated the spillover index between crude oil prices and the RMB exchange rate and found that the bargaining power of China's crude oil market and its influence on the international market still need to be improved.

The existing research on China's crude oil futures market mainly focuses on the price discovery function and the analysis of the linkage with other markets, and the research conclusions often find that China's crude oil futures market gradually exhibits the function of price discovery during the development process. In the linkage, mature futures market prices often lead to emerging futures market prices. However, China's crude oil futures market has been listed for three years, and there is no literature to conduct research on pricing influence. As for the current outstanding performance of China's crude oil futures market, whether it is changing from a "price taker" to a "pricing center" is yet to be known.

Based on the different scope of influence of the price formed by the futures market, this article will start from domestic influence, Asia-Pacific regional influence, and the international influence of China's crude oil futures market, and study the mean spillover effect and volatility spillover effect between different crude oil markets, based on the VAR model and the Diebold and Yilmaz (2012) spillover index method, combined with the rolling window technology to quantitatively analyze the direction and size of spillover effects from static and dynamic perspectives, to more accurately and visually understand the development status of China's crude oil futures market, in order to enhance influence and strive for crude oil pricing rights.

3. Crude oil futures market influence theory

In the international crude oil price system, the market where the benchmark price is located, such as U.S. dollar-denominated WTI and BRENT, has the pricing power of the crude oil futures market. The influence obtained through the pricing power is called the pricing power influence, which refers to the ability of the price formed in one futures market to influence another market, which is usually reflected by information transmission and spillover effects.

From this point of view, the pricing power is the influence of the price formed in a futures market on the pricing of other futures markets and international trade. The pricing center is the futures market with pricing power, focusing more on geographic location. The existing international crude oil pricing system uses WTI and BRENT markets as the pricing center, and Oman crude oil market as the pricing center in the Asia-Pacific region. Whether the price formed in Shanghai crude oil futures market will affect other markets is divided according to the range of influence of the price formed in the futures market. The influence of China's crude oil futures market can be divided into domestic influence, regional influence and international influence.

Domestic influence.One of the necessary conditions for crude oil futures to have international pricing influence is that the futures market has a good price discovery function. Based on the theory of expectations, it can be regarded as an unbiased estimate of the future price of its own spot. Based on the efficiency of information operation, it can be regarded as the price formed in the futures market that reflects all existing information. When new information appears in the market, investors will operate in the futures market, and then reflect the new information on the new futures price, and then transmit it to the spot market, so that the futures market price can guide the spot market. The domestic influence we are discussing here is the direction and magnitude of the information transmission of the domestic crude oil futures to domestic crude oil spot information.

Regional influence.The world crude oil trading is divided into three major markets: North America, Europe, and Asia. When a crude oil futures market has a strong influence in a certain range of the world and can influence the price benchmark selection of regional international trade, its influence in the region is the regional influence. The world's crude oil demand is shifting east. The spot price of Dubai crude oil is the oil price benchmark for oil-producing countries in the Middle East. Countries such as Japan, Singapore, and India have also launched their crude oil futures in an attempt to compete for the right to price crude oil. They are all priced in U.S. dollars. The policies of these countries are greatly influenced by the U.S. dollar, and the influence of the crude oil market is limited to neighboring countries. After the listing of RMB-denominated China's crude oil futures, it has become the world's third most traded crude oil futures. It has already had a certain influence in the Asia-Pacific region, but its influence needs to be further explored.

International influence.The price discovery function refers more to the relationship between spot prices and futures prices in a market. And it has a strong pricing influence in the world, and its price has a certain influence on the choice of pricing benchmarks for international trade, that is the international influence of the crude oil futures market. It is more embodied in the information or volatility spillover in one market that will affect other markets, which is the mutual influence or linkage relationship between crude oil futures and futures in multiple futures markets. All crude oil produced in the United States or sold to the United States is based on WTI, and more than two-thirds of the world's crude oil trading volume is based on BRENT crude oil. Therefore, the international crude oil benchmark prices are mainly based on WTI and BRENT.

4. Model building

4.1 VAR model

On the premise that the time series is stable, if there are n endogenous variables lagging p period, that is:

$$Y_{\mathrm{t}} = \begin{pmatrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{nt} \end{pmatrix}, Y_{\mathrm{t-1}} = \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \\ \vdots \\ y_{nt-1} \end{pmatrix}, \cdots, Y_{\mathrm{t-p}} = \begin{pmatrix} y_{1t-p} \\ y_{2t-p} \\ \vdots \\ y_{nt-p} \end{pmatrix}$$

$y_{1t}, y_{2t}, \ldots, y_{nt}$represents n different endogenous variables.The mathematical expression of the VAR(p) model is as follows:

$$Y_t = \sum_{i=1}^{p} \Phi_i Y_{t-i} + \varepsilon_t, \mathrm{t} = 1, 2, \cdots, \mathrm{T};\ \ \mathrm{i}=1, 2, \cdots, \mathrm{p} \tag{1}$$

Among them, Y_t is the n-dimensional column vector, Φ_i is the n*n-dimensional coefficient matrix to be estimated, ε_t is the n-dimensional disturbance item column vector, p is the lag order, and T is the number of samples.

4.2 DY spillover index

Aiming at the insufficiency of the VAR model, Granger causality test, multivariate GARCH model and other research methods that cannot quantify the size of the spillover effect, Diebold and Zilmaz (2009) based on the n-dimensional VAR model and based on the information of the prediction error variance decomposition, proposed a method for measuring spillover index of the spillover effect of financial market volatility. Diebold and Zilmaz (2012) improved the problem of unstable results due to variable sorting.

Based on the establishment of an n-dimensional VAR model with a lagging p order of stationary covariance, the moving average form of (1) is:

$$Y_t = \sum_{i=0}^{\infty} A_i \, \varepsilon_{t-i} \tag{2}$$

Among them, the coefficient matrix $A_0$is the unit matrix of n*n, when i<0, A_i=0; when i>0, the recursive process of A_i is satisfied:

$$A_i = \Phi_1 A_{i-1} + \Phi_2 A_{i-2} + \cdots + \Phi_p A_{i-p} \tag{3}$$

When analyzing the impact of information shocks on different markets, the KPPS method is used to directly decompose the generalized forecast error variance of the disturbance item variance covariance matrix, which avoids the disadvantages of different results caused by different time series orders, and more accurately analyzes the effects between various financial markets in the same period.

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \sum A_h' e_i)^2} \tag{4}$$

In the above formula, e_i is an n*1 column vector, the i-th element is 1, and the other elements are zero. σ_{jj} is the standard deviation of the prediction error of the j-th variable. The sum of the contribution proportions of the prediction error variance in the KPPS method is not necessarily equal to 1, that is$\sum_{\mathrm{j=1}}^{\mathrm{n}} \theta_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H}) \neq 1$, the variance decomposition is standardized according to the row sum of 1:

$$\tilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{n} \theta_{ij}^{g}(H)} \tag{5}$$

In formula (5), $\sum_{\mathrm{j=1}}^{\mathrm{n}} \tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H})=1$ and $\sum_{\mathrm{i,j-1}}^{\mathrm{n}} \tilde{\theta}_{\mathrm{ij}}^{\mathrm{g}}(\mathrm{H}) = \mathrm{n}$, so that the total spillover index, directional spillover index, and net spillover index of the system can be obtained.

The total spillover index is used to express the contribution ratio of the income or volatility spillover of n variables to the total forecast error variance. To measure the overall correlation of the financial markets in the system, the construction is as follows:

$$S^g(H) = \frac{\sum_{i,j=1,i\neq j}^{n} \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{i,j=1,i\neq j}^{n} \tilde{\theta}_{ij}^g(H)}{n} \cdot 100 \quad (6)$$

The directional spillover index measures the directionality of the spillover effects of different variables. The spillover index of market j from all other markets i is constructed as follows:

$$S_{\cdot i}^g(H) = \frac{\sum_{j=1,i\neq j}^{n} \tilde{\theta}_{ji}^g(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ji}^g(H)} \cdot 100 = \frac{\sum_{j=1,i\neq j}^{n} \tilde{\theta}_{ji}^g(H)}{n} \cdot 100 \quad (7)$$

Similarly, the spillover index of market i from other markets j is:

$$S_{i\cdot}^g(H) = \frac{\sum_{j=1,i\neq j}^{n} \tilde{\theta}_{ij}^g(H)}{\sum_{i,j=1}^{n} \tilde{\theta}_{ij}^g(H)} \cdot 100 = \frac{\sum_{j=1,i\neq j}^{n} \tilde{\theta}_{ij}^g(H)}{n} \cdot 100 \quad (8)$$

The net spillover index can analyze whether a certain market i is the receiver or transmitter of all other market shocks, and it can be obtained by subtracting two directional spillover indexes:

$$S_{ij}^g(H) = S_{\cdot i}^g(H) - S_{i\cdot}^g(H) \quad (9)$$

5. Empirical analysis

5.1 Sample selection and data processing

Daqing Oilfield is the largest oil production in China, and Shengli crude oil is the only domestically deliverable oil of Shanghai crude oil futures. In the Asia-Pacific region, as the deliverable oil type of Shanghai crude oil futures, the prices of Oman and Dubai crude oil have more references. BRENT crude oil futures prices and WTI crude oil futures prices are the most important pricing benchmarks in the global oil market.

Since Shanghai crude oil futures are priced in RMB, the crude oil prices are converted into RMB prices at the intermediate exchange rate announced by the People's Bank of China. Select the consecutive contract daily settlement price of Shanghai crude oil futures (INE), WTI, and BRENT crude oil futures and the daily settlement price of crude oil from Daqing, Shengli, Oman, and Dubai during the period from March 26, 2018 to March 26, 2021. Holidays and non-trading hours are inconsistent. The variables of the domestic crude oil market, the Asia-Pacific crude oil market, and the international crude oil market are defined as follows:

Table.1. Variable definition table

Domestic Crude Oil Market(INE、DQ、SL)			
variable	sign	Number of observations	Data Sources
Shanghai crude oil	INE	709	Wind
Daqing crude oil	DQ	709	Wind
Shengli crude oil	SL	709	Wind
Asia-Pacific Crude Oil Market(INE、OMAN、DUBAI)			
variable	sign	Number of observations	Data Sources
Shanghai crude oil	INE	709	Wind
Oman crude oil	OMAN	709	Wind
Dubai crude oil	DUBAI	709	Wind
International Crude Oil Market(INE、BRENT、WTI)			
variable	sign	Number of observations	Data Sources
Shanghai crude oil	INE	725	Wind
BRENT crude oil	BRENT	725	Wind
WTI crude oil	WTI	725	Wind

5.2 Descriptive statistics

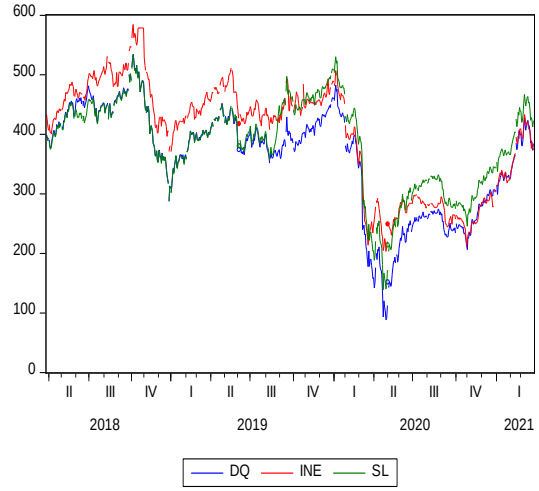

Figure a.Domestic crude oil price trends

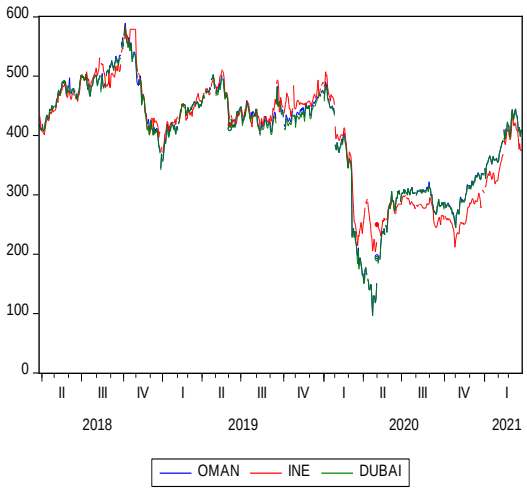

Figure b.Price trends in the Asia-Pacific region

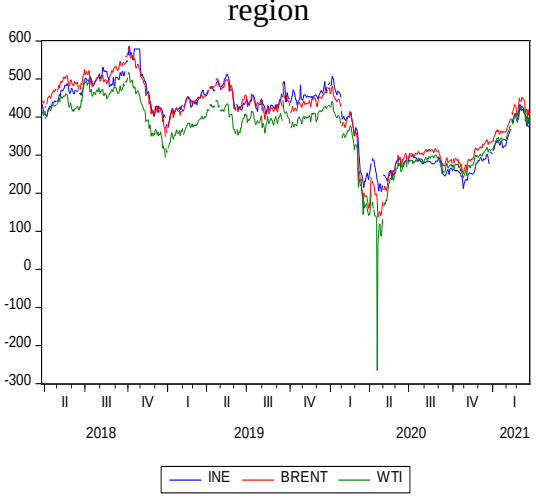

Figure c.International crude oil price trends

Figure 1. Crude oil price trends

In the domestic and Asia-Pacific markets, Shanghai crude oil futures prices are gradually in line with other crude oil prices, and gradually began to guide the fluctuations in other crude oil prices. In the international market, Shanghai crude oil futures and BRENT crude oil futures price trends are more consistent. The difference between Shanghai and WTI crude oil futures prices is large. In particular, in April 2020, due to the impact of the epidemic, the price of WTI crude oil futures fell to a negative value, and the overall price of the international futures market fell. The price of INE crude oil futures was the least affected under extreme market conditions, and it was the first to launch the market in the Asia-Pacific region, driving fluctuations in overseas markets. It can be seen that the INE crude oil futures market has had an impact on other crude oil markets.

It can be seen from Table 2 that in the domestic crude oil market and the international crude oil market, Shanghai crude oil futures fluctuate sharply, which is in line with the fact that the international crude oil market is more mature than China's crude oil market. Crude oil prices are relatively close in countries in the Asia-Pacific region, and Shanghai crude oil futures have the least volatility, and they have begun to make their mark in the Asia-Pacific region. Among them, the kurtosis of INE, DQ, SL, and BRENT price series is less than 3, and the skewness of each price series is negative, showing a left-skewed distribution, rejecting the assumption of normal distribution.

Table.2. Descriptive statistics

Domestic Crude Oil Market(INE、DQ、SL)						
Variable	Mean	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
INE	399.08	584.80	203.90	92.48	-0.43	2.00
DQ	359.93	534.62	88.81	89.25	-0.73	2.75
SL	385.25	533.79	139.47	76.87	-0.66	2.88
Asia-Pacific Crude Oil Market(INE、OMAN、DUBAI)						
Variable	Mean	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
INE	399.08	584.80	203.90	92.48	-0.43	2.00
OMAN	397.40	589.46	97.00	93.62	-0.80	3.17
DUBAI	395.67	581.24	96.14	93.34	-0.81	3.17
International Crude Oil Market(INE、BRENT、WTI)						
Variable	Mean	Maximum	Minimum	Standard Deviation	Skewness	Kurtosis
INE	399.09	584.80	203.90	92.57	-0.43	2.00
BRENT	402.01	586.66	136.76	92.31	-0.67	2.73
WTI	362.64	517.37	-265.88	85.70	-1.27	6.99

In the correlation analysis, the correlation coefficient between each variable is greater than 0.9, showing a high degree of correlation. Shanghai crude oil futures have integrated into the domestic crude oil market, the Asia-Pacific crude oil market, and the international crude oil market, forming a good interaction.

5.3 ADF stationarity test

ADF test was performed on each crude oil price series, and the results were all non-stationary series at a significance level of 1%. In order to make the variables more stable, the ADF test was performed after taking the logarithm of each price series, and the results still showed that they were all non-stationary series. Take the first-order difference for each crude oil price logarithmic series, and obtain the return rate series of each variable as: RINE, RDQ, RSL, ROMAN, RDUBAI, RBRENT, RWTI. After ADF test, it is found that each series is a stationary time series, we can build a VAR model.

5.4 Empirical analysis of domestic influence

(a) Mean spillover effect of domestic influence

Establish a VAR model based on a stable sequence of returns RINE, RDQ, and RSL. According to the information criteria of AIC, SC, and HQ, the optimal lag order is determined to be 7. The VAR model has passed the exogeneity test and stability test. The established VAR model is stable.

Table.3. Granger causality test in the domestic crude oil market

Dependent variable	Independent variable	obs	F-Statistics	Prob.
RINE	RDQ	706	21.3852	1.E-09
RINE	RSL	706	23.0921	2.E-10
RDQ	RINE	706	4.83938	0.0082
RDQ	RSL	706	2.10860	0.1222
RSL	RINE	706	3.19586	0.0415
RSL	RDQ	706	3.39651	0.0340

At the 5% significance level, Shanghai crude oil futures and Daqing crude oil spot, Shanghai crude oil futures and Shengli crude oil spot are mutually Granger reasons. Shanghai crude oil futures have established a good interactive relationship with the domestic crude oil spot market, and initially have the price discovery function.

The impulse response analysis of the domestic crude oil futures and spot yield series for the same period and lagging 25 periods. After giving RINE a new interest shock, both RDQ and RSL oscillated

many times and then converged to 0. It can be seen that Shanghai crude oil futures can have a long-term impact on domestic crude oil spot. The impact of the domestic crude oil spot market on Shanghai crude oil futures market will not last for a long time. The impact of Shengli crude oil on Shanghai crude oil futures is smaller than that of Shanghai crude oil futures on Shengli crude oil, while the impact of Daqing crude oil spot on Shanghai crude oil futures market is greater than that of Shanghai crude oil.

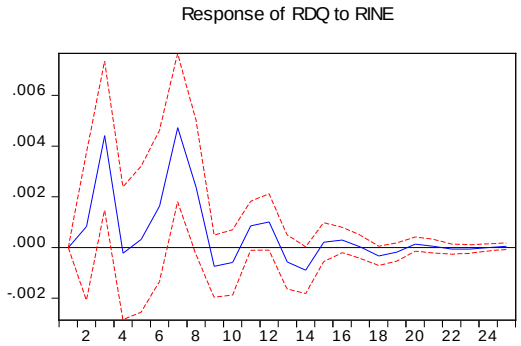

Figure a. Response of RDQ to RINE

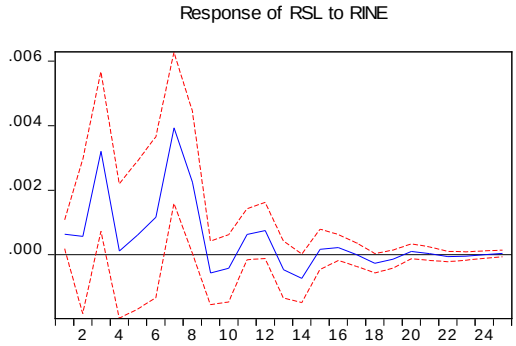

Figure b. Response of RSL to RINE

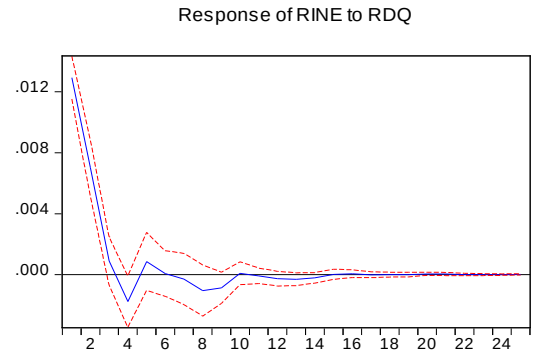

Figure c. Response of RINE to RDQ

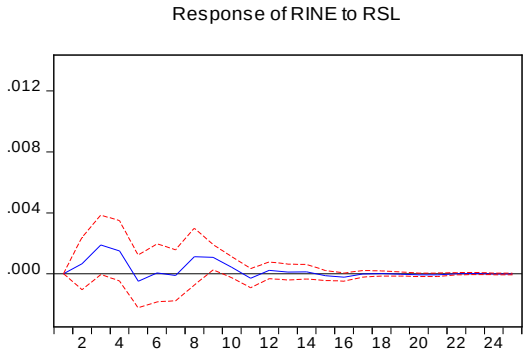

Figure d. Response of RLIN to RSL

Figure 2. Impulse response of domestic crude oil spot and RINE

(b) Volatility spillover effect of domestic influence

According to the VAR model of the domestic crude oil market, the optimal lag order is 7. After the generalized forecast error variance decomposition, the volatility spillover index of each variable obtained is shown in Table 4.

Table.4. Domestic crude oil market spillover index

	RINE	RDQ	RSL	From others
RINE	54.12400	22.84443	23.03157	45.87600
RDQ	15.13201	43.26399	41.60399	56.73601
RSL	15.18405	41.58034	43.23561	56.76439
To others	30.31607	64.42476	64.64557	Total spillover
Net	-15.5599	7.688757	7.871177	53.12547

In Table 4, the total spillover index and the directional spillover index are both greater than zero, indicating that there is a volatility transmission between Shanghai crude oil futures, Daqing crude oil, and Shengli crude oil. The total spillover index is 53.12547%, indicating that half of the changes in the system can be explained by the interaction between the three markets, and the overall level of linkage is relatively high, which is consistent with the conclusion of the Granger causality test that the three variables are mutually causal. The spillover index on the diagonal indicates that the contribution of Shanghai crude oil futures, Daqing crude oil, and Shengli crude oil to the variance mainly comes from themselves. The spillover index of a certain variable to other variables is different from the spillover index of other variables, which shows that the directional spillover index is

bidirectional and asymmetric. Daqing crude oil and Shengli crude oil have the largest spillover effects to other markets. The spillover index of Shanghai crude oil futures to other markets is 30.31607%. It can be seen that Shanghai crude oil futures have exerted a certain influence in the domestic crude oil market. But due to the short-listing time, the influence is not as strong as the domestic crude oil spot market that has existed for a long time. Therefore, the net spillover index of Shanghai crude oil futures is negative, indicating that its spillover effect on the domestic crude oil spot market is smaller than the spillover effect of the domestic crude oil spot market on it.

The volatility spillover index table reflects the two-way asymmetric volatility spillover effect of the domestic crude oil market from a static perspective. Combined with the rolling window technology, the window period is set to 50 to study the relationship between Shanghai crude oil futures and Daqing crude oil, Shengli crude oil markets from a dynamic perspective.

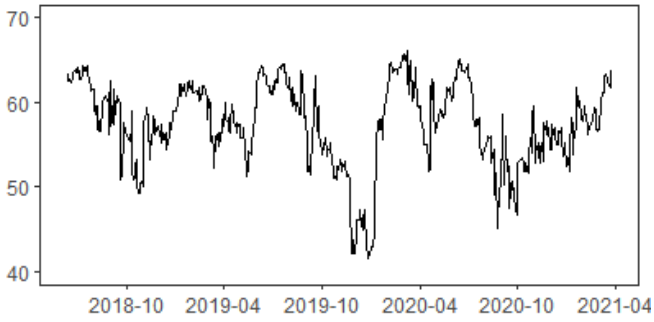

Figure 3. Dynamic series of the total spillover index of the domestic crude oil market

As can be seen from the above figure, the total spillover index of Shanghai crude oil futures, Daqing crude oil, and Shengli crude oil fluctuates from 50% to 65% during the sample period. At the beginning of 2020, because of the new crown epidemic, international crude oil prices fluctuated sharply, the domestic crude oil market was implicated by the fluctuations in the international crude oil prices, and the overall spillover index of the domestic crude oil market dropped sharply. It can be seen that when special events come, the domestic crude oil market is greatly affected by the international community, and it is very important for our country to establish crude oil futures so that can play an important role in the international crude oil pricing system.

In Figure 4, the directional spillover index of Shanghai crude oil futures market to other domestic markets fluctuates in the range of 0-15%, and the directional spillover index of other domestic markets to the Shanghai crude oil futures market fluctuates in the range of 10% to 20%. Combined with the dynamic changes of spillover indexes in other domestic markets, under the rolling sample, the directional spillover index is bidirectional and asymmetric. Shanghai crude oil futures has already had a certain influence on other domestic markets, but it is not as effective as other domestic markets. Therefore, its net spillover index is negative. However, at the beginning of 2021, the net spillover index of Shanghai crude oil futures has been greater than 0 for a period of time, which indicates that Shanghai crude oil futures market is gradually exerting influence.

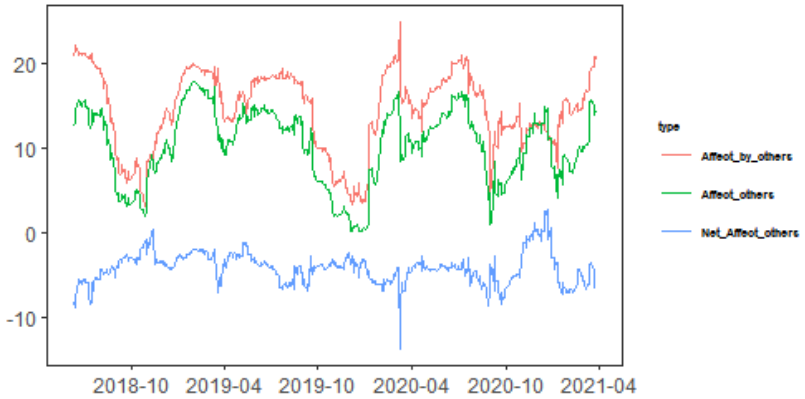

Figure 4. Dynamic series of INE's spillover index to other domestic markets

5.5 Empirical analysis of Asia-Pacific regional influence

(a) Mean spillover effect of Asia-Pacific regional influence

Establish a VAR model based on a stable series of returns RINE, ROMAN, and RDUBAI. According to the information criteria of AIC, SC, and HQ, the optimal lag order is determined to be 8. The VAR model has passed the exogeneity test and stability test. The established VAR model is stable.

Table.5. Granger causality test in the Asia-Pacific crude oil market

Dependent variable	Independent variable	obs	F-Statistics	Prob.
RINE	ROMAN	706	29.3946	6.E-13
RINE	RDUBAI	706	24.7774	4.E-11
ROMAN	RINE	706	3.19584	0.0415
ROMAN	RDUBAI	706	2.50713	0.0822
RDUBAI	RINE	706	3.81523	0.0225
RDUBAI	ROMAN	706	7.02427	0.0010

At the 5% level of significance, RINE is the Granger cause of ROMAN and RDUBAI, and ROMAN and RDUBAI are also the Granger cause of RINE. Oman crude oil is an important crude oil benchmark price in the Asia-Pacific region and has a great influence on the Asia-Pacific crude oil market. Shanghai crude oil futures can interact with Oman crude oil, indicating that China's crude oil futures already have a certain influence in the Asia-Pacific region.

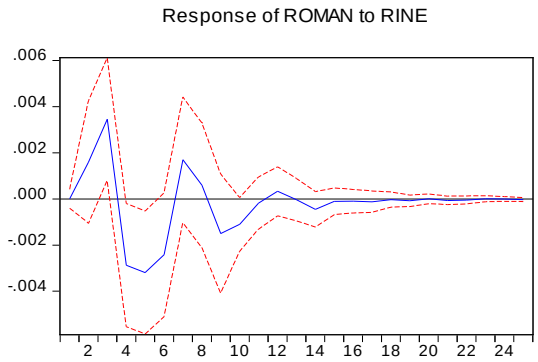

Figure a. Response of ROMAN to RINE

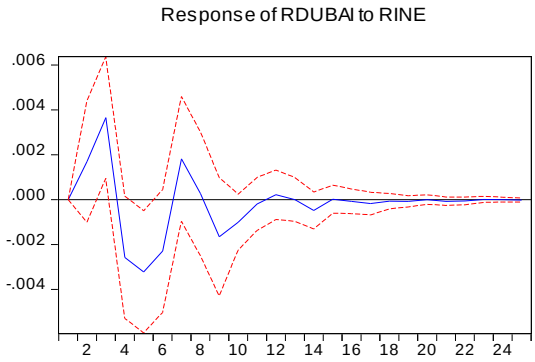

Figure b. Response of RDUBAI to RINE

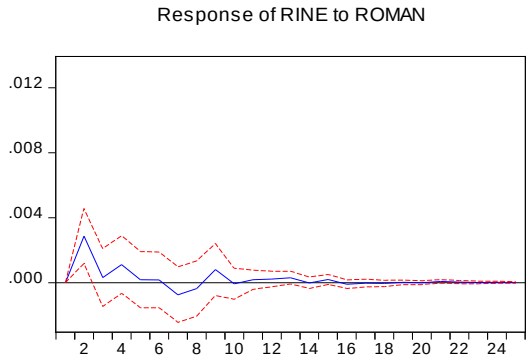

Figure c. Response of RINE to ROMAN

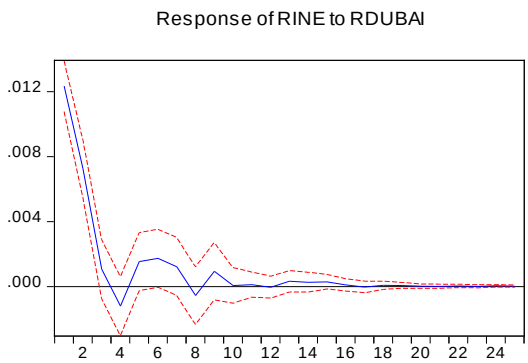

Figure d. Response of RINE to RDUBAI

Figure 5. Impulse response of the Asia-Pacific region crude oil spot and RINE

Based on the same period and 25-period impulse response analysis of the series of the crude oil market in the Asia-Pacific region, from the perspective of the degree of influence, the price of Shanghai crude oil futures has a greater impact on the price of Oman crude oil. Between Shanghai crude oil futures and Dubai crude oil, Dubai crude oil prices have a greater impact on Shanghai crude

oil futures prices. From the perspective of the duration of the impact, the impact of Dubai Crude Oil and Oman Crude Oil on Shanghai Crude Oil Futures lasts for a relatively short time, indicating that Shanghai Crude Oil Futures can quickly respond to and absorb the fluctuations in crude oil prices in the Asia-Pacific region. While Shanghai Crude Oil Futures has long-term effects on Oman and Dubai crude oil.

(b) Volatility spillover effect of Asia-Pacific regional influence

According to the VAR model of the crude oil price system in the Asia-Pacific region, the optimal lag order is 8. After the generalized forecast error variance decomposition, the spillover index of each variable obtained is shown in the following table:

Table.6. Asia-Pacific crude oil market spillover index

	RINE	ROMAN	RDUBAI	From others
RINE	54.8443	22.6501	22.5055	45.1557
ROMAN	12.9888	43.9538	43.0573	56.0462
RDUBAI	13.2309	42.8070	43.9621	56.0379
To others	26.2197	65.4571	65.5629	Total spillover
Net	-18.9359	9.4110	9.5250	52.4132

In Table 6, there is volatility transmission among Shanghai crude oil futures, Oman crude oil, and Dubai crude oil. The total spillover index is 52.4132%, indicating that half of the changes in the system can be explained by the interaction between the three markets, and the overall level of linkage is relatively high, which is consistent with the conclusion of the Granger causality test that the three variables are mutually causal. The directional spillover index is two-way and asymmetric. Oman crude oil and Dubai crude oil have the largest spillover effects to other markets. The spillover index of Shanghai crude oil futures to other markets is 26.2197%, which shows that Shanghai crude oil futures have already exerted a certain influence in the crude oil market in the Asia-Pacific region, but due to the short-listing time, the influence is not as strong as the crude oil spot market in the Asia-Pacific region that has existed for a long time. Therefore, the net spillover index of Shanghai crude oil futures is negative, indicating that its spillover effect on the spot crude oil market in the Asia-Pacific region is smaller than the spillover effect on it by the spot crude oil market in the Asia-Pacific region.

The volatility spillover index table reflects the two-way asymmetric volatility spillover effect of the crude oil market in the Asia-Pacific region from a static perspective. Combined with the rolling window technology, the window period is set to 50.

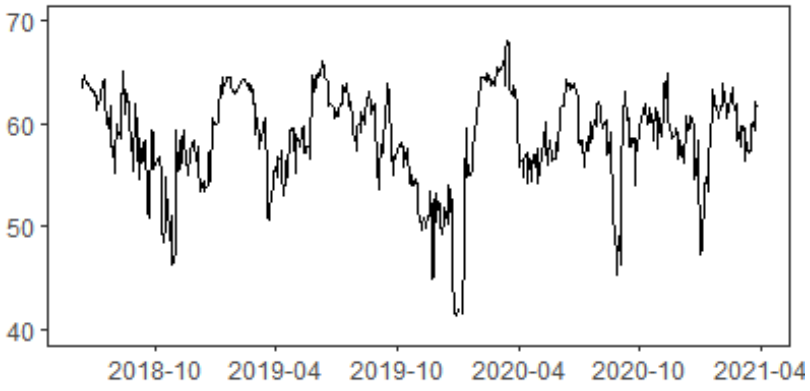

Figure 6. Dynamic series of the total spillover index of the Asia-Pacific region

As can be seen from the above figure, the total spillover index of Shanghai crude oil futures, Oman crude oil, and Dubai crude oil fluctuates from 50% to 65% during the sample period. At the beginning of 2020, because of the new crown epidemic, the crude oil market in the Asia-Pacific region was affected by the fluctuations in the international crude oil prices. The overall spillover index fell sharply and then gradually recovered, which shows the rapid response and timely absorption of the Asia-Pacific market.

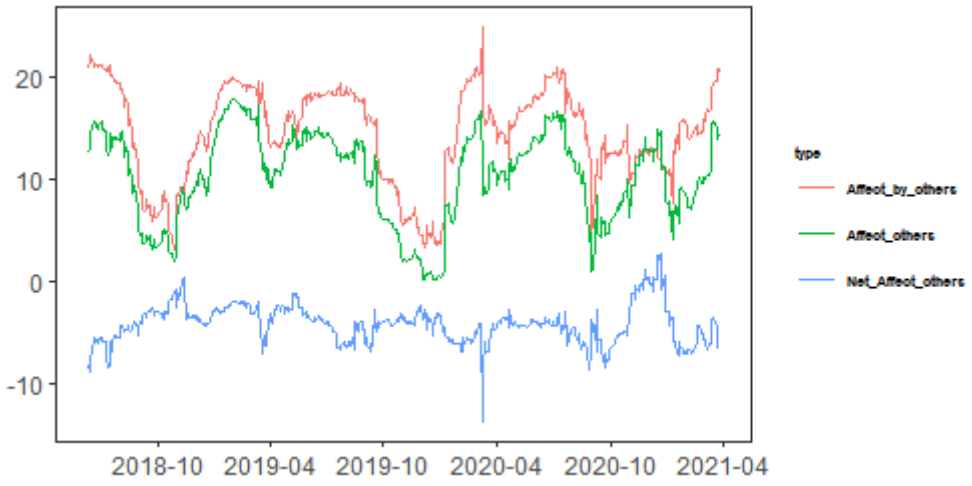

Figure 7. Dynamic series of INE's spillover index to the Asia-Pacific regional markets

In Figure 7, the directional spillover index is also bidirectional and asymmetric. The directional spillover index of Shanghai crude oil futures market to other markets in the Asia-Pacific region fluctuates in the range of 0-15%, and the directional spillover index of other markets in the Asia-Pacific region to Shanghai crude oil futures market fluctuates in the range of 5% to 20%. Shanghai crude oil futures already have a certain degree of influence on other markets in the Asia-Pacific region, but they are not as effective as other markets in the Asia-Pacific region, so its net spillover index is negative. However, at the beginning of 2021, the net spillover index of Shanghai crude oil futures appeared to be greater than 0 for a period of time, indicating that the Shanghai crude oil futures market is gradually exerting its influence in the Asia-Pacific region.

5.6 Empirical analysis of international influence

(a) Mean spillover effect of international influence

Establish a VAR model based on a stable series of returns RINE, RBRENT, and RWTI. According to the information criteria of AIC, SC, and HQ, the optimal lag order is determined to be 8. The VAR model has passed the exogeneity test and stability test. The established VAR model is stable.

At the 5% significance level, RBRENT and RWTI are Granger reasons for RINE. RINE and RBRENT are Granger reasons for each other, which better explains the phenomenon that INE and BRENT crude oil futures prices are closer. But RINE is not the Granger reason of RWTI, which shows that Shanghai crude oil futures has a limited radiation range in the international crude oil price system and cannot guide the changes in WTI crude oil futures prices.

Table.7. Granger causality test for international crude oil price series

Dependent variable	Independent variable	obs	F-Statistics	Prob.
RINE	RBRENT	722	156.966	3.E-57
RINE	RWTI	718	130.859	4.E-49
RBRENT	RINE	722	3.09152	0.0460
RBRENT	RWTI	718	0.24993	0.7789
RWTI	RINE	718	0.70601	0.4940
RWTI	RBRENT	718	6.22451	0.0021

An impulse response analysis of the international crude oil futures series over the same period and lagging 25 periods shows that, from the perspective of the degree of the impact, the impact of BRENT on Shanghai crude oil futures is less than that of Shanghai crude oil futures on BRENT crude oil futures, while the impact of WTI on Shanghai crude oil futures is greater than that of Shanghai crude oil futures on WTI crude oil futures. Shanghai crude oil futures have begun to show their unique characteristics in the international crude oil futures market. From the perspective of the duration of the impact, Shanghai crude oil futures have shown that they can quickly respond to and absorb

changes in the international market, and can have a long-term sustained impact on the international crude oil futures market. It can be seen that the basic functions of Shanghai crude oil futures have been completed.

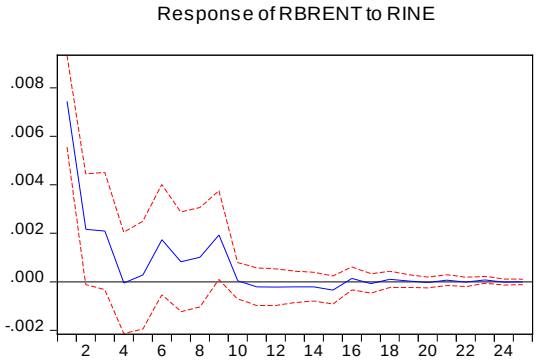

Figure a. Response of RBRENT to RINE

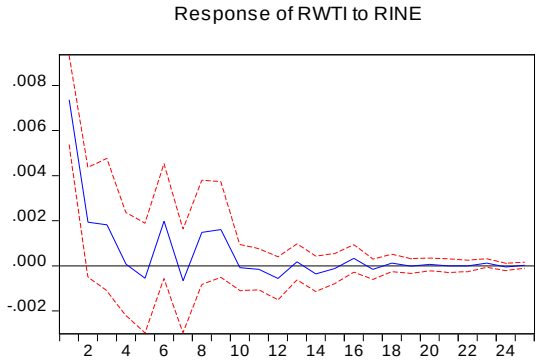

Figure b. Response of RWTI to RINE

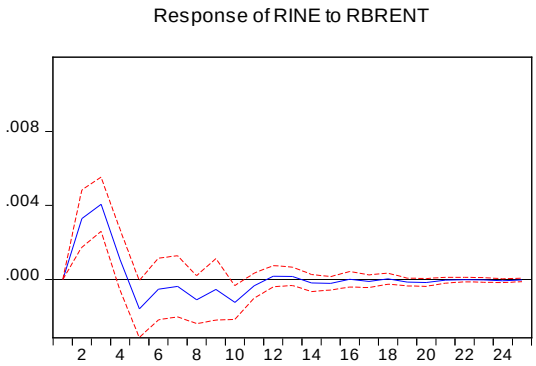

Figure c. Response of RINE to RBRENT

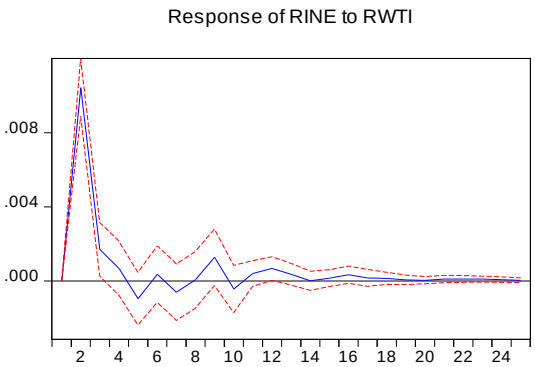

Figure d. Response of RINE to RWTI

Figure 8. Impulse response of the international crude oil futures and RINE

(b) Volatility spillover effect of international influence

According to the VAR model of the international crude oil market, the optimal lag order is 8. After the generalized forecast error variance decomposition, the volatility index of each variable obtained is as follows:

Table.8. International crude oil market spillover index

	RINE	RBRENT	RWTI	From others
RINE	54.9374	24.0257	21.0370	45.0626
RBRENT	3.2586	53.7597	42.9816	46.2403
RWTI	1.4781	42.2862	56.2356	43.7644
To others	4.7367	66.3119	64.0186	Total spillover
Net	-40.3259	20.0717	20.2542	53.12547

In Table 8, there is volatility transmission among Shanghai crude oil futures, WTI crude oil futures, and BRENT crude oil futures. The total spillover index is 45.0224%, indicating that the overall level of linkage in the international crude oil market is relatively high. The non-diagonal directional spillover index is two-way and asymmetric. Because the trading volume of BRENT crude oil futures accounts for more than two-thirds of the world, it is understandable that BRENT crude oil futures has the largest spillover effect on other markets. The spillover index is 4.7367%, which shows that Shanghai crude oil futures have limited influence in the international crude oil futures market, which is very weak compared to WTI and BRENT. Therefore, the net spillover index of Shanghai crude oil futures is -40.3259%. Compared with the domestic crude oil market and the crude oil market in the

Asia-Pacific region, Shanghai crude oil futures in the international crude oil market have not yet obtained the right to speak.

The volatility spillover index table reflects the two-way asymmetric volatility spillover effect of the international crude oil market from a static perspective. Combined with the rolling window technology, the window period is set to 50.

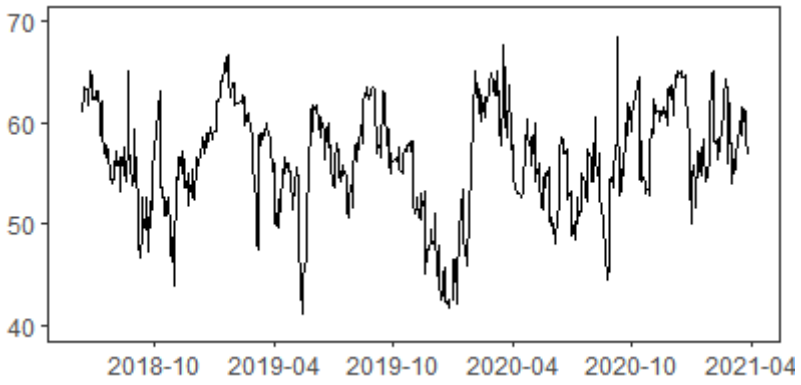

Figure 9. Dynamic series of the total spillover index of the international market

It can be seen from the above figure that the total spillover index of Shanghai crude oil futures, WTI crude oil futures, and BRENT crude oil futures fluctuates from 45% to 65% during the sample period.The special attributes of crude oil as a political resource, the OPEC crude oil production mobilization, the Iran nuclear agreement, the Sino-US trade war and other crude oil price uncertainties will cause the overall spillover index to fluctuate sharply.

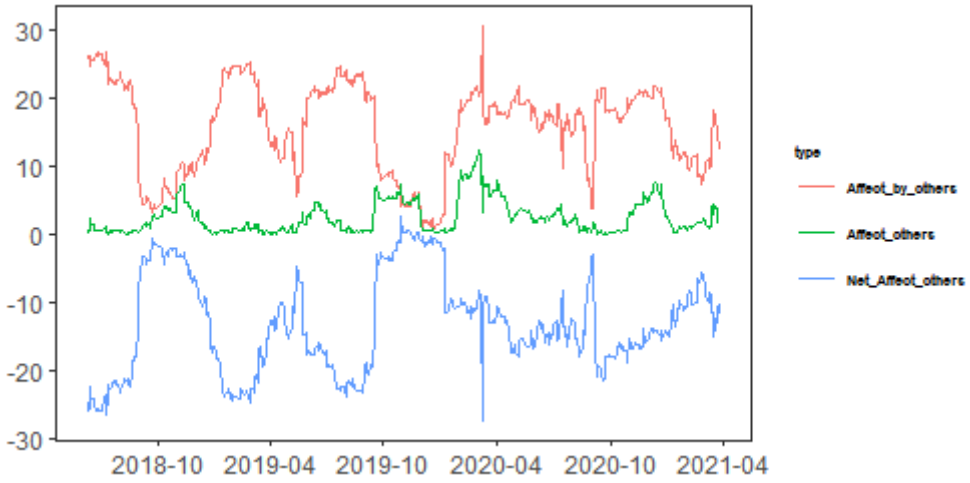

Figure 10. Dynamic series of INE's spillover index to other international markets

In Figure 10, under the rolling sample, the directional spillover index is bidirectional and asymmetric. The directional spillover index of the Shanghai crude oil futures market to other international markets fluctuates in the range of 0% to 10%, and the directional spillover index of other international markets to Shanghai crude oil futures market fluctuates in the range of 0% to 25%. The influence of Shanghai crude oil futures in other international markets is weak. They are still receiving information shocks, so their net spillover index fluctuates between -30% and 0.

6. Conclusion and suggestion

6.1 Conclusion

According to the different scope of influence of the price formed by the futures market, this paper analyzes the influence of China's crude oil futures market on the domestic crude oil market, the Asia-

Pacific crude oil market, and the international crude oil market by means and volatility spillover effects. The conclusions are as follows:

In general, China's crude oil futures market has been integrated into the domestic crude oil market, the Asia-Pacific regional crude oil market, and the international crude oil market. It has formed a good interaction with other markets and has a long-term and sustained impact on other markets. However, due to the short time for the establishment of China's crude oil futures market, the volatility spillover index for the domestic crude oil market and crude oil market in the Asia-Pacific region is around 30%, but the volatility spillover index for the international crude oil market is only about 4%. It has less influence on other markets than other markets on it, especially in the international market. Although China's crude oil futures market has achieved gratifying results, there is still a long way for the pricing center.

(2) In the domestic and Asia-Pacific crude oil markets, from the perspective of the direction of influence, Shanghai crude oil futures and other markets affect each other, but Shanghai crude oil futures market has a more lasting impact on other markets. In terms of influence, China's crude oil futures have a two-way and asymmetrical spillover effect with other markets, but it is not as good as the spillover effect caused by other markets. At the beginning of 2021, the net spillover index of Shanghai crude oil futures appeared to be greater than 0, indicating that Shanghai crude oil futures market is gradually exerting influence in China and the Asia-Pacific region.

(3) In the international crude oil market, from the perspective of the direction of influence, Shanghai crude oil futures can guide changes in BRENT crude oil futures prices, but cannot guide changes in WTI crude oil futures prices, and are more impacted by WTI crude oil prices. From the perspective of influence, China's crude oil futures have a two-way and asymmetric spillover effect with other markets. The influence of Shanghai crude oil market exists, but it is very weak compared to WTI and BRENT.

6.2 Suggestion

In summary, Shanghai crude oil futures have already had an impact on the domestic crude oil market, the Asia-Pacific regional crude oil market, and the international crude oil market, but the degree of influence is not as high as the degree of influenced by others, and efforts are still needed to enhance the influence:

(1) Improve the futures market system construction and enhance domestic influence. The influence of crude oil futures market in China requires a good market system and a good policy environment. The first step is to advance the futures law legislation. Standardize the order of the futures market and safeguard the interests of the subjects of the futures market. The second step is to deepen the reform of the futures market system and mechanism. Reform the examination and approval system of listed products on exchanges to give them more autonomy, encourage futures companies to carry out market innovation and product innovation activities. The third step is to optimize the investor structure. Lower the barriers to entry for international investors and promote international cooperation. The fourth step is to strengthen the supervision of the futures market. Regulatory standards and guidelines should gradually integrate with the international market, strengthen investor education, popularize futures market knowledge, and focus on risk education.

(2) Encourage crude oil trade along the “Belt and Road” to enhance the influence in the Asia-Pacific region. The first step in the internationalization of China's crude oil futures is to become the benchmark crude oil price in the Asia-Pacific region. Among the countries along the “Belt and Road”, Singapore, Indonesia, Iran, and Iraq are all important participants in the international crude oil trade. Take advantage of the “Belt and Road” construction to allow important crude oil trading countries along the route to participate in China's crude oil futures trading, thereby promoting the process of China's crude oil futures as a benchmark for crude oil settlement and advancing the influence of China's crude oil futures in the Asia-Pacific region.

(3) Promote the internationalization of the RMB and enhance its international influence. China's crude oil futures market is settled in RMB, foreign investors have to consider exchange rate factors when trading, and China's futures market still has problems with a weak foundation and a late start.

The RMB internationalization reform should be steadily promoted with a strategic, global and overall perspective. Thereby enhancing the influence of the renminbi in international settlements, perfecting the reform of exchange rate marketization, realizing the free convertibility of the renminbi, and guiding foreign investors to participate in China's crude oil futures market transactions, enhancing the international influence of China's crude oil futures market.

Acknowledgements

The author gratefully acknowledges the financial support from Postgraduate Research & Practice Innovation Program of Jiangsu Province KYCX20_0350.

References

[1] KingMA, WadhwaniS.Transmission of Volatility Between Stock Markets [J]. Review of Financial Studies, 1990(3): 5-33.

[2] Lin S X, Tamvakis M N.Spillover Effects in Energy Futures Markets[J] .Energy Economics, 2001(1): 43-56.

[3] Diebold F X, Yilmaz K.Measuring financial asset return and volatility spillovers, with application to global equity markets [J].The Economic Journal, 2009, 119(534): 158-171.

[4] Chen Jun, Chang Qing.Research on influence of China’s futures market on international pricing Technology Economics, 2010, 29(3).

[5] Diebold F X, Yilmaz K.Better to give than to receive: Predictive directional measurement of volatility spillover [J].International Journal of Forecasting, 2012, 28(1): 57-66.

[6] Zhang Y J, Sun Y F.The dynamic bolatility spillover between European carbon trading market and fossil energy market [J].Journal of Cleaner Production, 2016, 112: 2654-2663.

[7] Yao Lin.Research on improving the impact of international pricing of commodity futures in China [J]. Price:Theory & Practice, 2018, 38(11): 83-86.

[8] Zhang Dayong, Ji Qiang.Research on the Dynamic Risk Spillovers for China’s Crude Oil Futures [J]. Chinese Journal of Management Science, 2018, 26(11): 42-49.

[9] Liu Yinglin, Liu Yonghui, Ju Zhuo.The Impact of International Crude Oil Price Fluctuation on Chinese Commodity Futures—Base on the Correlation Structure Breakpoint Model [J]. Chinese Journal of Management Science, 2019, 27(2): 31-40.

[10] Zhang Xueying.The spillover effect of China’s crude oil futures based on spillover index [D]. Jinan:Shandong University, 2020.