The dynamic correlation between oil price shocks and Chinese stock market---Decomposition of oil price shock based on SVAR model

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Abstract: This paper extends the literature on the relationship between oil price shocks and Chinese stock market from both the aggregate and industrial level by decomposing oil price shocks into four sources based on the four-variable SVAR model. Empirical results show that the positive impulse of future speculative shock only stimulates the sharp rise of oil price in the short term, with a reversal in the later period. On the aggregate level, Shanghai composite index has positive connections with the oil price volatility driven by the oil aggregate demand shock and speculative shock, which are accompanied by obvious time-varying characteristics. Meanwhile, on the industrial level, the fluctuation of oil price driven by the oil supply shock can only have a stable impact on the energy industry index, while that driven by the oil aggregate demand shock will have a positive influence on a wider range of industries. Specially, the oil price driven by the speculative shock has the same rise and fall with the financial industry index.

1. Introduction

Since China has become the world's largest oil importer, the impact of oil price fluctuation on the economy is more significant. As a barometer of economy, whether the price of stock market affected by oil price and what is the specific impact of the oil price, these problems have attracted the attention of many scholars.

Existing research shows that the rise in crude oil prices has a significant negative impact on the real economy [1,2], while the impact of crude oil price changes on the stock market presents a complex result, which has not yet formed a unified conclusion [3,4]. This is inextricably linked to the nonlinear and complex characteristics of crude oil and stock markets [5]. On the one hand, crude oil price is affected by multiple factors, so the impact of crude oil price changes related to different factors on the stock market is different [6]. On the other hand, with the increasing activity of commodity futures market, commodity market gradually presents the financial nature, resulting in the impact of crude oil price shock on the stock market shows frequent changes. Therefore, it can provide a more in-depth perspective of the interaction between international crude oil and stock market by including the time-varying characteristic and the different driving factors of oil price simultaneously in the research framework.

Although the change of crude oil price is generally considered as an important factor of stock price fluctuation, there is no consensus on the relationship between stock price and crude oil price. Some scholars found that oil price shock has a negative correlation with stock return [7, 8], while others believe that oil price shock has a positive impact on stock return [9]. In addition, some studies show that oil price shock has no significant impact [10, 11]. According to existed studies, it is different research methods, research objects and research angles that lead to different conclusions. Subsequently, scholars have carried out in-depth exploration on the causes of the results of differentiation. Scholars have found that there are significant differences in the impact of crude oil price changes driven by different influencing factors on the stock market [12-15]. With respect to the study of the impact of different oil price shocks on the U.S. stock price, Kilian divides the oil price

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shocks into supply shocks, global economic aggregate demand shocks and specific demand shocks in the crude oil market, finding that supply shocks have no significant impact on cumulative stock returns. The impact of the unexpected global economic expansion driven oil price rise on the cumulative stock returns in the first year has a sustained positive impact, while the impact of specific demand in the crude oil market has a negative correlation with the stock price [12]. Lagalo found that economic demand shock and preventive demand shock have more important impact on all sectors than supply shock [16]. From the perspective of the time span and number of sectors, preventive demand shock has the most lasting and extensive effect. At the same time, the energy intensity of U.S. industry is not significantly related to the impact of structural oil shocks. Caporale and Spagnolo found that oil price volatility is positively correlated with stock return rate under the impact of demand, the stock return rate of oil and gas sector is negatively correlated with oil price volatility under the impact of supply, while the correlation between oil price volatility and stock return rate is not significant under the impact of preventive demand [17].

To sum up the previous studies, most of them failed to identify the source of the oil price shock effectively when studying the impact of crude oil price shock on the stock market, only considering the economic fundamentals such as supply and demand factors. Meanwhile, most of them only stay at the aggregate level of the market, without describing the dynamic correlation between the international crude oil market and the stock market from the industrial level. The most important contribution of this paper lies in that it integrates the different sources of oil price shock, time-varying correlation, and industrial level analysis into a unified framework to study the relationship between oil price and China's stock return. The main contributions of this paper are listed as follows. Firstly, considering different sources of oil price fluctuation, most of the studies refer to Kilian and Park[12], which divides the oil price shock into crude oil supply shock, global economic aggregate demand shock and oil market-specific demand shock with three-variable SVAR model. Furthermore, this paper takes the futures speculative shock into consideration, extending the model to four-variable SVAR model. It will provide more clearly observation of the dynamic impact of financial speculative forces on the correlation between the two markets. Secondly, in addition to examining the impact of international oil price shocks on China's stock market from the aggregate level, this paper also tries to find more evidences from the industrial level. This attempt can fully reveal the characteristics of impacts among different industries. Finally, by including the time factor into the research framework, it will unmask the dynamic correlation between international crude oil prices and the Chinese stock market at different historical stages from a dynamic perspective with the use of DCC-GARCH model.

2. Data And Methods

2.1 Variables and data

Since the earliest position report of CFTC traders can be traced back to January 2005, and Kilian economic index is updated to June 2019, we choose the monthly data over the sample January 2005 to June 2019. The variables and data sources used in this paper are described in detail below.

$prod_t$ Represents global crude oil production to measure global crude oil supply. The data comes from the official website of the Energy Information Association (EIA). Take natural logarithm of prodt to eliminate fundamental unit and reduce heteroscedasticity. Its first order difference $\Delta prod_t$ is the rate of change in global crude oil production.

rea_t Is the index of global real economic activity, which measures the total demand of the global economy? This paper uses the Kilian index, and the data comes from Kilian's personal homepage.

nc_t Represents the proportion of non-commercial net position, which is constructed according to Sanders, Boris and Manfredo [18] to measure the financial speculative power of crude oil futures market. The calculation formula is$\mathrm{nc}_t = (\mathrm{ncl}_t - \mathrm{ncs}_t)/\mathrm{ncl}_t + \mathrm{ncs}_t + 2\mathrm{ncsp}_t$, where ncl represents the number of non-commercial long positions, ncs represents the number of non-commercial short positions, and $ncsp$ represents the number of non-commercial arbitrage positions. This structure can eliminate the scale factor, and show the direction of pressure on crude oil price caused by speculative forces in futures market. The data comes from the position report of light and low sulfur crude oil traders on the New York Mercantile Exchange reported by the Commodity Futures Trading Commission (CFTC), and the monthly position data is obtained by simply averaging the weekly report data.

rop_t Represents the actual price of international crude oil and uses the spot price of WTI crude oil. The data is from EIA website. The nominal oil price is reduced to the actual oil price with the US CPI, and the natural logarithm is taken. The first-order difference, Δrop_t is the change rate of international oil price.

R Represents the stock index return. Shanghai Composite Index (henceforth SCI for short) is selected as the total index of China's stock market, and CSI 300 industry index is selected as the industry stock index. The data comes from the RESSET. CSI 300 industry index compiled by China Securities Index is divided into ten first-class industries, including energy, materials, industry, consumption, optional consumption, medicine, finance, information, tele-communications and public utilities. First, the daily closing price of the index is taken as the monthly average, then the Chinese CPI is reduced to the actual value, and finally the stock index return is calculated.

2.2 Identification of oil price shocks

Based on the three-variable model Kilian and Park (2009), a four-variable SVAR model is established in this paper. The specific form is as follows:

$$C_0 y_t = \alpha + \sum_{i=1}^{p} C_i\, y_{t-i} + u_t \tag{1}$$

$y_t = (\Delta \mathrm{prod}_t, \Delta \mathrm{rea}_t, \mathrm{nc}_t, \Delta \mathrm{rop}_t)'$, $\mathrm{prod}_t, \mathrm{rea}_t, \mathrm{nc}_t, \mathrm{rop}_t$ are respectively global crude oil production, global economic entity activity level (i.e. total economic demand), proportion of non-commercial positions in crude oil futures (i.e. futures speculation), and actual oil price, △ represents first-order difference. u_t Is the structural shock vector, representing oil supply shock, aggregate demand shock, futures speculative shock and other oil special shock? Assuming C_0 is invertible, multiply the two sides of the equation of SVAR model by ${C_0}^{-1}$ at the same time, and the simplified SVAR model is as follows:

$$\begin{aligned} y_t &= {C_0}^{-1}\alpha + {C_0}^{-1}\sum^{p} C_i\, y_{t-i} + {C_0}^{-1}u_t \\ &= \emptyset_0 + \sum^{p} \emptyset_i\, y_{t-i} + \varepsilon_t \end{aligned} \tag{2}$$

Where ε_t is the disturbance term of the simplified model, which can be regarded as the linear combination of the structural disturbance term, i.e. $\varepsilon_t = {C_0}^{-1}u_t$. The SVAR model can be identified as long as we apply certain constraints to${C_0}^{-1}$:

$$\varepsilon_t \equiv \begin{bmatrix} \varepsilon_t^{\Delta\mathrm{prod}} \\ \varepsilon_t^{\Delta\mathrm{rea}} \\ \varepsilon_t^{nc} \\ \varepsilon_t^{\Delta\mathrm{rop}} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 & 0 & 0 \\ c_{21} & c_{22} & 0 & 0 \\ c_{31} & c_{32} & c_{33} & 0 \\ c_{41} & c_{42} & c_{43} & c_{44} \end{bmatrix} \begin{bmatrix} u_t^{oil\ spply\ shock} \\ u_t^{\text{aggregate demand shock}} \\ u_t^{speculation\ shock} \\ u_t^{\text{other oil special shock}} \end{bmatrix} \tag{3}$$

Where, ε_t represents the disturbance of global crude oil production, global real economic activities, non-commercial positions in crude oil futures market and real oil price variables, which comes from the structural shock vector u_t in the system.

According to the requirement that $k * (k-1)/2$ constraints should be applied to the k-element p-order SVAR model, six short-term constraints are imposed to $C_0{}^{-1}$, as shown in (3.3).1) For *prod* (i.e. crude oil production), due to the high adjustment cost of crude oil production, the crude oil supply cannot make rapid adjustment to the demand change in the short term, and the impact of total economic demand, speculative futures and other specific demand shocks of crude oil market have no impact on the current crude oil production. 2) The crude oil supply shock and aggregate demand shock will have a certain impact on global economic activities in the current period, while the impact of futures speculation and other specific demand shocks have no impact on global economic activities in the current period. 3) The crude oil position data published by CFTC on Friday every week actually reflects the market position of last Tuesday, so the impact of oil price lags behind the change of futures position, that is, there is no impact on futures speculation. 4) The oil price fluctuations that cannot be explained by supply shocks, aggregate economic demand shocks and futures speculative stocks are specific demand shocks of other crude oil markets, and crude oil prices are sensitive to various structural shocks.

2.3 Spillover effect analysis based on DCC-GARCH model

DCC-GARCH model can be established by using the historical decomposition sequence of the real oil price change rate driven by the structural shocks obtained in the previous step, so as to explore the dynamic correlation between the international oil price fluctuations and the Chinese stock market returns under different shocks. If the residual of the yield of k assets (i.e.e_t) is an independent and identically distributed white noise process, obeying multivariate normal distribution of the time-varying conditional covariance matrix H_t and mean value of 0, the dynamic correlation structure of it is set as follows:

$$r_t = u_t + e_t \tag{4}$$

$$e_t|\Omega_{t-1} \sim N(0, H_t) \tag{5}$$

$$H_t = D_t R_t D_t, \ \ D_t = \text{diag}\left(\sqrt{h_{it}}\right) \tag{6}$$

$$h_{ii,t} = \omega_i + \sum_{p=1}^{P_i} \alpha_{ip} e_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{it-q} \tag{7}$$

$$Q_t = \left(1 - \sum_{m=1}^{M} \alpha_m - \sum_{n=1}^{N} \beta_n\right)\bar{Q} + \sum_{m=1}^{M} \alpha_m (\varepsilon_{t-m}\varepsilon'_{t-m}) + \sum_{n=1}^{N} \beta_n Q_{t-n} \tag{8}$$

Where$\bar{Q} = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_t \, \varepsilon'{}_t$is the unconditional variance matrix of standardized residuals?

$$R_t = (Q_t^*)^{-1} Q_t (Q_t^*)^{-1}, \ \ Q_t^* = diag(\sqrt{q_{11}}, \sqrt{q_{22}}, \cdots, \sqrt{q_{kk}} \tag{9}$$

R_t is the dynamic correlation coefficient matrix, $\varepsilon_t' = D_t^{-1} e_t$ is the normalized residual vector, $\bar{Q}$ is the unconditional variance matrix of the standard residual, The element in R_t is $\rho_{ij,t} = q_{ij,t}/\sqrt{q_{ii,t} q_{jj,t}}$, where the correlation coefficient matrix R_t is broken down, so Q_t^* is the diagonal matrix with diagonal element $\sqrt{q_{ii,t}}$. The elements of Q_t are$q_{ij,t}$,$q_{ii,t}$, $q_{jj,t}$. α_m And β_n are called the coefficient of DCC model (m and n are lag order).

3. Decomposition Of Oil Price Based On Four-variable SVAR Model

3.1 Impulse response analysis

Fig. 1 shows the impulse response of international oil price change rate to crude oil supply shock, economic aggregate demand shock, futures speculative shock and other specific demand structure shock of crude oil market with one standard deviation. The lag period is set as 24 months, and the dotted line represents the confidence interval of positive and negative two standard deviations calculated by 500 Monte Carlo simulations.

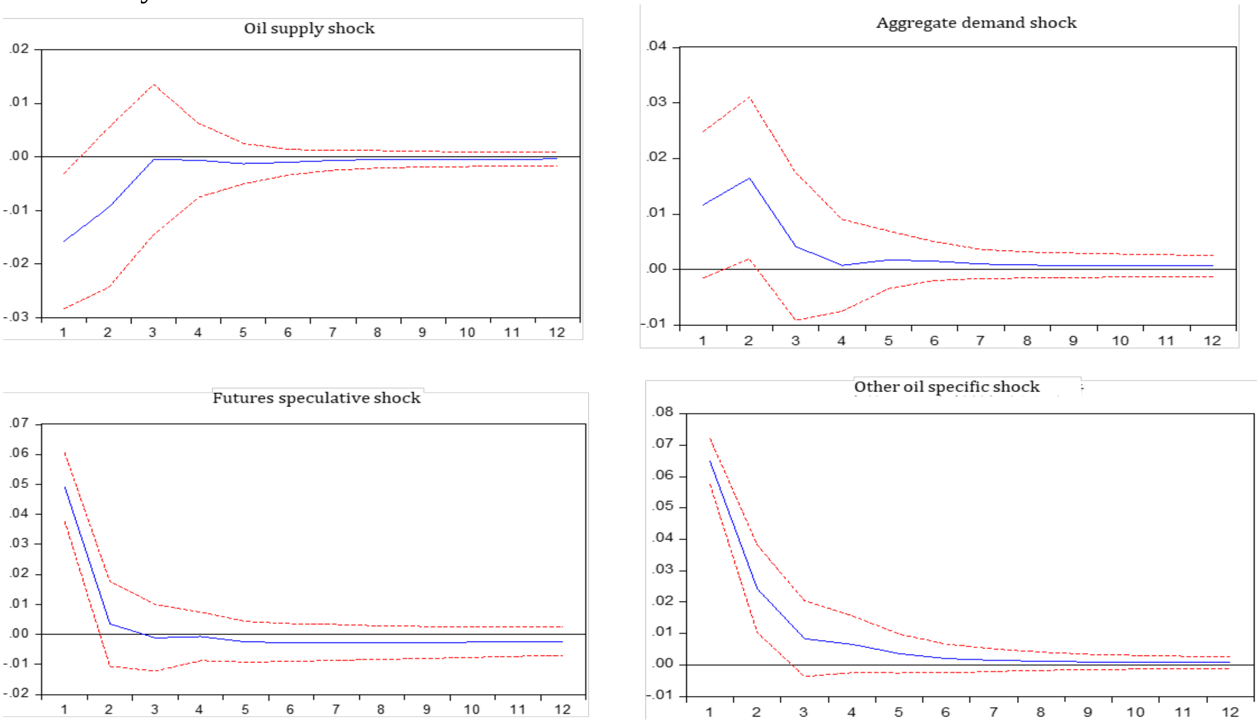


Fig.1 Impulse response of four structural shocks to the change rate of international oil price.

As to oil supply shock, in the first two periods, the absolute value of the response coefficient is the largest, which is -0.0157. In the third period, it tends to 0, but the response coefficients are all negative. On the whole, the sudden increase of crude oil supply leads to the oversupply of crude oil market, which leads to the decline of oil price, but the impact is weak, which shows that the impact of crude oil supply in the sample period is not the main reason for the fluctuation of oil price.

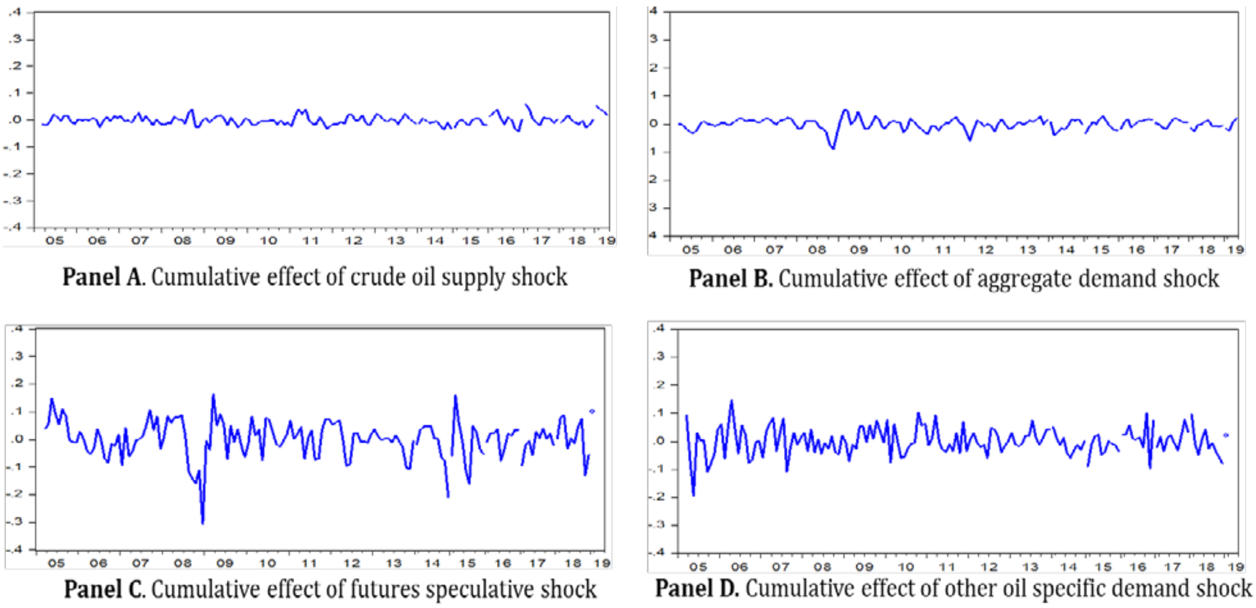
In the first three periods, the impact of total economic demand has a more significant positive impact on the rise of oil price, and it reaches the maximum in the second period, which is 0.0165, and gradually tends to 0 in the fourth period, with the sign keeping positive. Compared with the supply shock, the impact of the total demand shock is greater and the impact period is longer, showing that the activity of global economic activities can aggravate the fluctuation of oil price, and the more prosperous the economy is, the greater the demand for commodities such as crude oil, leading to an upward trend of oil price.

The impact of futures speculation only has a positive impact on the oil price volatility in the first period, the response coefficient is 0.0493, and the response coefficient tends to 0 from the second period, and has a negative impact from the third period. These phenomena deserve our attention, which shows that the impact of futures speculation can cause significant fluctuations in oil prices in the current period, but due to the lack of fundamental support, its impact duration is very short, and may reverse in the short term (three months later), causing oil prices to fall.

The international oil price always keeps a positive response to the other specific demand shock of crude oil markets, and the response coefficient reaches the maximum value of 0.0648 in the first period, then gradually decreases and tends to 0. Other specific demand shocks in the crude oil market reflect the preventive demand changes caused by the uncertainty of future oil supply shortage or price rises.

3.2 Historical decomposition results

Next, we use the historical decomposition method to estimate the cumulative effect of structural shocks on the changes of international oil prices, and use the obtained structural shock decomposition sequence to the subsequent study of spillover effects on international oil prices and China's stock market. The historical decomposition results are shown in Fig. 2.



Panel A. Cumulative effect of crude oil supply shock

Panel B. Cumulative effect of aggregate demand shock

Panel C. Cumulative effect of futures speculative shock

Panel D. Cumulative effect of other oil specific demand shock

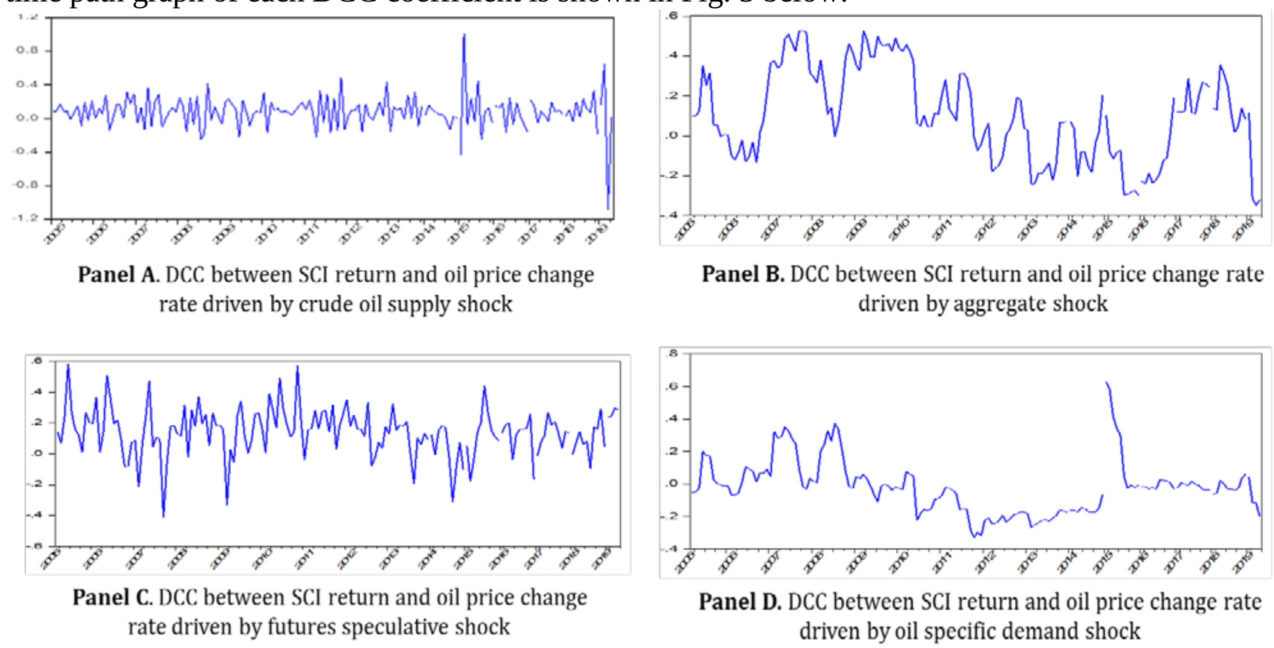
Fig.2. Historical decomposition results of international oil prices (March 2005 to June 2019).

4. Dynamic Relationship Between Oil Prices Driven By Different Shocks And China's Stock Market

The cumulative real oil price change rate series corresponding to crude oil supply shock, economic aggregate demand shock, futures speculative shock and other oil specific demand shocks are obtained by using the historical decomposition method. Next, the DCC-GARCH model is constructed with the return rate of Shanghai Composite Index and various industry indexes to study the linkage between oil price fluctuations caused by different sources of oil price shocks and China's stock market.

4.1 Spillover effect on the aggregate level

In order to observe the overall change of volatility spillover effect over time more intuitively, the time path graph of each DCC coefficient is shown in Fig. 3 below.



Panel A. DCC between SCI return and oil price change rate driven by crude oil supply shock

Panel B. DCC between SCI return and oil price change rate driven by aggregate shock

Panel C. DCC between SCI return and oil price change rate driven by futures speculative shock

Panel D. DCC between SCI return and oil price change rate driven by oil specific demand shock

Fig.3 Time path of DCC between SCI return and oil price change rates driven by different structural shocks (March 2005 to June 2019).

The results show that the correlation between oil price change and stock price return changes with time, and there are some differences in the spillover effects under different structural shocks.

As shown in Panel A, the average absolute value of DCC between oil price volatility driven by crude oil supply shock and SCI return is 0.15, which is positive under 71%, and fluctuates frequently. This shows that under the impact of crude oil supply, the oil price and the Shanghai composite index are in most cases positive linkage, and there will be reverse changes in some time periods.

In Panel B, the average level of the absolute value of DCC between the rate of change of oil price driven by the impact of total economic demand and the SCI return is 0.21, and it can be seen intuitively from the figure that from the beginning of 2007 to 2011, the DCC basically stabilized at a high positive level, reaching a maximum of 0.53, but from 2012 to 2016, the DCC coefficient fluctuated significantly between the positive and negative values. Through the study of historical events, it can be found that since 2007, the global economy has experienced a great depression, and the reduction of total economic demand has led to the decline of oil prices. At the same time, affected by the adverse economic environment, the poor operation of enterprises has led to the collective decline of stock prices. In this period of time, the oil price fluctuation has the same direction with the return rate of Shanghai stock index.

In Panel C, the average absolute value of DCC between the volatility of oil price driven by the futures speculative shock and SCI return is 0.17, which is positive in 85% of the cases, although it shows obvious volatility characteristics. It can be seen from this that the impact of financial speculation will basically lead to the same change trend of international oil price and Shanghai stock index. This is consistent with the research conclusions of many scholars, finding that due to the increased participation of financial institutions such as hedge funds in the crude oil market, speculative trading in the crude oil market increased, leading to the correlation between stocks and oil prices increased [19, 20]. Broadstock and Filis found that there is a positive correlation between the specific demand impact of the crude oil market and the NYSE index, and attributed it to the role of the crude oil market finance [21].

In Panel D, the average absolute value of DCC between oil price volatility driven by other oil specific demand shock and SCI return is 0.12, which is negative at 64%. Other specific demand shocks in the crude oil market are mainly reflected in the preventive demand of crude oil consumers due to their expectation of future oil supply shortage. Kilian and Park found that the positive preventive demand shocks leading to the rise of oil prices have negative effects on the stock yield [12].

4.2 Spillover effect on the industrial level

To observe the industrial level change of volatility spillover effect more intuitively, the time path graph of each DCC of ten industry indexes is shown in Fig.4 below.

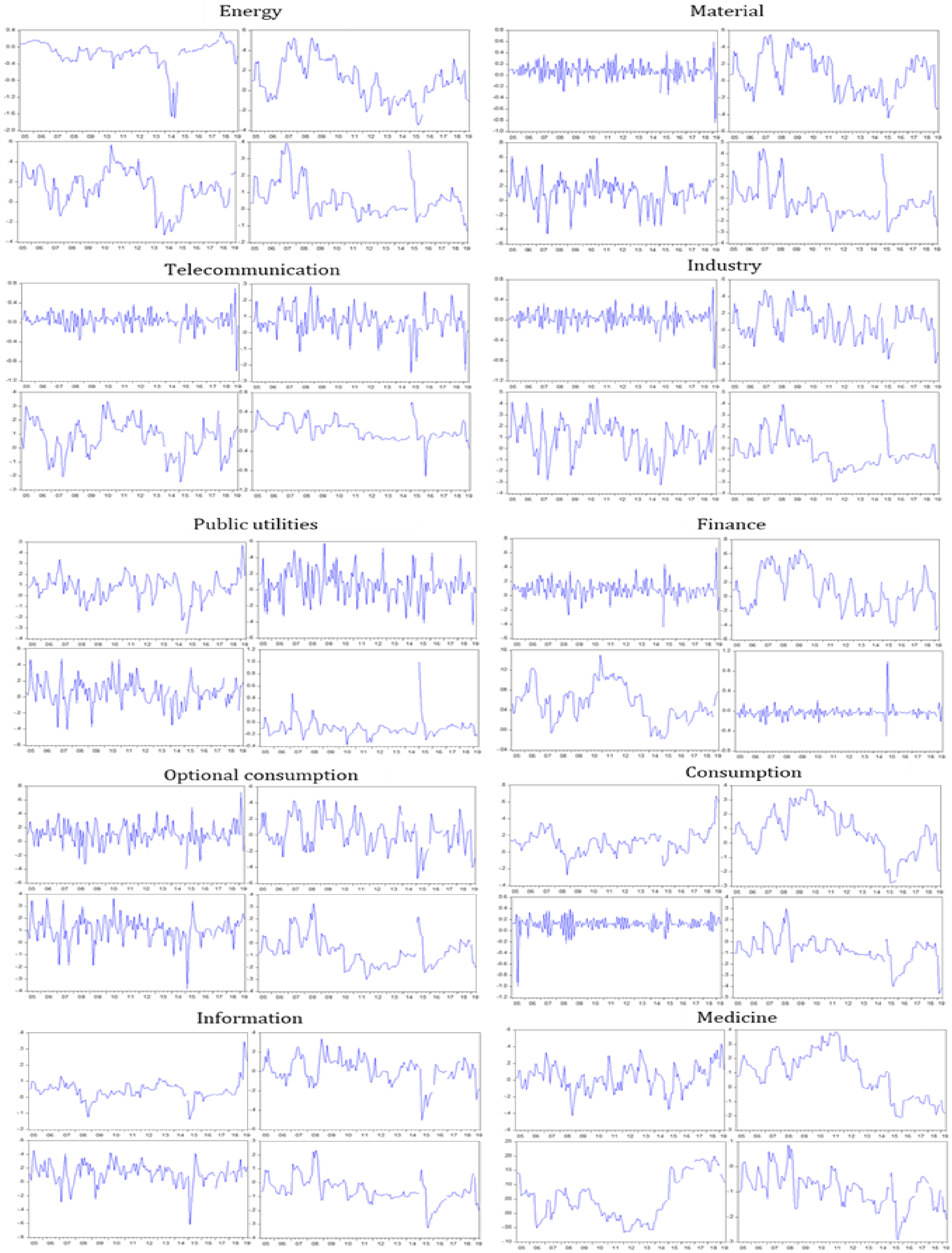


Fig.4 DCC coefficient time path chart by industry[a]

Notes: top left, top right, bottom left and bottom right are respectively based on the DCC coefficient time path of oil price and index yield of the industry driven by the structural shock of crude oil supply, total economic demand, futures speculation and other specific oil demand.

Considering the DCC of real oil price change driven by oil supply shock, it is worth noting that the response of index return rate of energy industry and other non-energy industries to oil price fluctuation driven by crude oil supply shock is obviously different: the DCC coefficient between index return rate of energy industry and oil price fluctuation driven by crude oil supply shock is characterized by low-frequency oscillation, which indicates that oil price fluctuation caused by crude oil shock can make a more stable impact on stock return rate of energy industry companies.

As to the DCC coefficient between oil price and index return driven by total economic demand fluctuates frequently in telecom, public and optional consumer industry, with no stable spillover effect. In other industries, such as energy, materials, consumer industries, etc., the DCC coefficient can maintain a relatively stable state for a certain period of time, and in most cases, the value is positive.

The DCC coefficients of oil price change rates driven by futures speculative shock in materials, public utilities, consumption and optional consumption industries show the characteristics of high-frequency fluctuations. Among these industries, finance is worthy of attention. The DCC coefficient of the financial industry is basically positive, which indicates that the fluctuation of oil price driven by the speculative impact of futures and the fluctuation of index return rate of the financial industry are rising and falling together. This is mainly because the financial institutions such as hedge funds in the financial industry participate in the trading of crude oil futures market in a large amount, and their fund performance is directly linked to the crude oil performance, so they are more than other industries it is a stable positive spillover effect.

The DCC of other oil specific demand shocks shows the trend characteristics of DCC coefficient in various industries similar to that of the Shanghai Composite Index despite the financial industry. This indicates that oil price fluctuations driven by specific demand shocks in other crude oil markets have a general impact on all industries, and there is no industry difference in the specific impact characteristics. For the financial industry, there is basically no significant impact.

5. Conclusion And Policy Implications

This paper constructs a four-variable SVAR model based on monthly oil price, oil supply, oil aggregate demand, futures speculative demand from January 2005 to June 2019. The purpose of this study is to examine the dynamic correlation of different factor-driven oil price and Chinese stock returns from the aggregate and industrial level. The conclusions are presented as follows.

Firstly, the impulse response analysis of different structural shocks to crude oil price shows that the positive crude oil supply shock will lead to the decline of international oil price, while the positive economic aggregate demand shock will lead to the rise of international oil price. Noteworthily, the positive futures speculative shock will only stimulate the sharp rise of oil price in a short period of time, but due to the lack of support of economic fundamentals, the oil price will reverse in the later period.

Secondly, from the perspective of the aggregate level of the stock market, the correlation between the change of oil price and the return on stock price changes over time, and there are some differences in the spillover effects under different structural shocks: 1) in most cases, the oil price volatility driven by the crude oil supply shock and the return on the Shanghai composite index are positively linked, which is the main reason It is caused by China's highly dependent energy consumption structure on coal and the predictability of supply shock; 2) the oil price fluctuation driven by the impact of total economic demand has a positive impact on the return rate of Shanghai stock index, but it will also show different characteristics in different stages; 3) the impact of financial speculation will basically lead to the change of international oil price and Shanghai Composite Index in the same direction; 4) the impact of other specific demand shocks of crude oil is more complex, among which the positive preventive demand shocks lead to the rise of oil price has a negative effect on the yield of Shanghai Composite Index.

Thirdly, from the perspective of industrial level, different structural shock sources and industry differences will affect the correlation between oil price volatility and stock return: 1) the DCC coefficient between energy industry index return and oil price volatility driven by crude oil supply shock is characterized by low-frequency oscillation, which indicates that oil price volatility caused by crude oil shock can cause relatively high stock return of energy industry companies; 2) The fluctuation of oil price driven by the impact of total economic demand has a positive impact on the index returns of energy, materials, consumption and other seven industries to some extent; 3) there is a significant rising and falling phenomenon between the fluctuation of oil price driven by the speculative impact of futures and the fluctuation of index returns of financial industry, which is mainly due to the large participation of financial institutions in the futures market, the fund performance is directly linked to the crude oil performance; 4) Oil price fluctuations driven by specific demand shocks in other crude oil markets have a general impact on all industries, while there is basically no significant impact on financial industry.

The study of this paper has the following implications for the economic development. On one hand, we need to increase strategic oil reservations to ensure the safety of oil supply. *Belt and Road Strategy* should be used to expand the source of oil imports, open up the transportation routes to the west to ensure the stability and safety of oil transportation, and get rid of the dependence of Malacca Strait as the main oil transportation channel for a long time. At the same time, it is also necessary to vigorously develop the oil industry in China, transforming and adjusting the structure, in order to expand the strategic oil reserve capacity, and adhere to technological innovation to deal with market risks. On the other hand, the government should adhere to the principle of macro prudence, establish a risk buffer mechanism between the oil market, the stock market and other domestic markets. In the meantime, strengthen systematic risk prevention and improve crisis response capacity by improving market macro prudence supervision tools.

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