Dynamic Spillover Effects of International Crude Oil Prices on Chinese Stock Markets Based on Information Technology

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Abstract. Oil is a strategic resource indispensable for the survival and development of a state, and plays an inestimable role in safeguarding international economic and social development. This paper mainly uses the computer technology in information technology, based on the construction of TVP-VAR model of the specific computer code, through the analysis of international crude oil price index and China's price index, input the relevant computer code instructions to get different lag, different time point impulse response diagram. The dynamic spillover effect of international crude oil price on Chinese stock market is analyzed. The empirical results show that: (1) there is a dynamic correlation between international crude oil prices and China's stock market by sector, and there is a lag in the impact of international crude oil price changes on industry stock yield. (2) The instability of international crude oil prices is a negative factor for stock yield, and has a negative impact on industry stock yield. (3) Different industries differ in their sensitivity to dynamic spillovers from international oil price changes and in the direction of their stock yield movements.

Keywords: TVP-VAR Model · WTI · Stock Yield

1 Introduction

As one of the world's major energy sources, oil is known as black gold and the blood of industry. In the energy consumption structure, oil usually occupies the first place, and oil and its additional industries account for a high proportion of the national economy. In 2016, China's oil and additional industries, excluding indirect contributions, accounted for 13% of annual GDP, and the actual contribution of oil to GDP was much larger than 13%. In addition, China is not a major oil producer, domestic oil supply is insufficient to meet its demand, and most of the oil depends on imports. According to the data, China has become the world's largest oil importer since 2018, with an external dependence of 70%. According to the proportion of oil in China's economy, and the degree of foreign dependence, the fluctuation of international oil prices is bound to have a tremendous impact on China's economy. The stock market is an important indicator of economic performance, and economic changes will be manifested in the stock price movement at the first time. In addition, information technology, as a representative of advanced

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productive forces, is widely used in the world and profoundly affects the economic structure and economic efficiency. Therefore, it is of certain research value and economic significance to use information technology to combine information management with the economic research of international crude oil price on stock market, and to calculate the spillover effect of international crude oil price on Chinese stock market by computer code model and simulation.

Various scholars have studied the dynamic spillover effects between international oil prices and stock markets in different ways. [1] examined the degree of volatility transmission between oil and stock markets in Europe and the United States at the industry level using a VAR-GARCH approach. His results show that there is a significant volatility spillover effect between oil and industry stock returns, and the spillover effect is unidirectional in Europe and bidirectional in the United States. Based on the VAR model and DCC-MGARCH model [6] analyzed the interaction between Chinese and international stock markets, as well as international commodity markets, including oil markets. It was concluded that the direct spillover effects of international commodity markets on the Chinese stock market have been on the rise. [2] investigated the spillover effects of oil prices and stock market volatility and shocks in BRICS countries over different time frames using multivariate ARMA-GARCH models and wavelet analysis. The empirical results show that oil prices and stock market prices are subject to their own volatility directly, and indirectly to other prices and wavelet-scale volatility.

Compared with the previous literature, the innovations of this paper are as follows: (1) In the context of the ongoing COVID-19 epidemic, international crude oil prices experienced the fourth plunge in the 21st century. In this paper, the COVID-19 epidemic in 2020 was selected as one of the important time points for the time-point impulse response plot. The time frame of the study includes the latest affairs. (2) In this paper, after selecting the industry indices from the Shenwan Industry Classification Index, we categorized the research subjects into oil-related industries, oil substitution industries, and oil consumption industries by using the distinction of [3](3) This paper adopts TVP-VAR model and uses MCMC algorithm through computer specific code to perform 10000 simulation calculations on the data in this paper. In addition, TVP-VAR model has the characteristics of time-varying parameters, which can better capture the relationship and characteristics of economic variables in different historical backgrounds. Therefore, the exploration of this paper can visualize the extent of the impact of international oil price changes on the stock market of different sectors.

2 Materials and Methods

2.1 Data Sources and Processing

The sample period of this paper was from January 2007 to December 2020, which was selected in consideration of the limited effectiveness of the securities market before the completion of the reform of the shareholder structure by the end of 2006. The classification indices of industries were selected from the Shenwan Industry Classification Index, and the monthly closing prices were chosen, and the industries were divided into oil-related industries, oil substitution industries, and oil consumption industries according to (Elyasiani, Mansur, Odusami 2011) as shown in Table 1. International crude oil

Table 1. VARIABLE DESCRIPTIONS.

Shenwan Industry Classification Index	Variable name	Variable symbol
Petroleum and petrochemicals Oil mining Coal mining	Oil-related industries	H1
Electricity Gas Non-ferrous Metals	Oil substitution industries	H2
Machinery and equipment Transportation Construction materials	Oil consumption industries	H3
	International crude oil prices	Y

prices were taken from the WTI (West Texas Intermediate) light crude oil price, a major pricing benchmark in the global oil market, and the data was obtained from the U.S. Energy Information Administration.

In order to eliminate the effect of heteroskedasticity, ensure the smoothness of the data and take into account the economic significance of each data sequence, the international crude oil price and indexes of various industries were processed by first taking logarithm and then differencing them. The international crude oil price variation rate and the stock yields by sector were obtained.

Computational equation: $R_{it} = \ln P_{it} - \ln P_{it-1}$.

where, P_{it} denotes the closing price of industry stock i in month t or the price of international crude oil in month t, and P_{it-1} denotes the closing price of industry stock i in month $t - 1$ or the price of international crude oil in month $t - 1$.

2.2 TVP-VAR Model Building

The Time-Varying Parameter Vector Autoregressive Model (TVP-VAR) proposed by [5], compared to the VAR model with fixed coefficients, does not have the assumption of homoskedasticity in its model assumptions. This assumption is in line with the actual situation and it features time-varying parameters that better capture the relationships and characteristics of the economic variables in different epochs, and assumes stochastic volatility. The TVP-VAR model is established as follows:

First of all, a standard SVAR model was defined:

$$Ay_t = F_1 y_{t-1} + \ldots + F_s y_{t-s} + \mu_t \quad t = s + 1, \ldots, n \tag{1}$$

where, y_t denotes a k * 1 dimensional observation vector, A denotes a k * k dimensional joint coefficient matrix; $F_1 \ldots F_s$ denote a k * k dimensional lag coefficient matrix, and the disturbance term μ_t denotes the k*1 dimensional structural impact, with $\mu_t \sim N(0, \sum)$. At the same time, it is assumed that the structural impact obeys recursive identification, which means that the coefficient matrix A is a lower triangular matrix. Thus, Eq. (1) can be organized in the following form:

$$y_t = B_t y_{t-1} + \ldots + B_s y_{t-s} + A^{-1} \sum \varepsilon_t,\ \varepsilon_t \sim N(0,\ \mathrm{I_k}),\ \mathrm{B_i} = \mathrm{A}^{-1}\mathrm{F_i},\ \mathrm{i} = \ldots \mathrm{s} \quad (2)$$

The line element in matrix B were straightened and rewritten as a K^2s*1 dimensional vector β, and $X_t = I_s \otimes (y_{t-1}, \ldots, y_{t\text{-}s})$ was defined, where ⊗ denotes the Kronecker product. Thus the model can be reduced to:

$$y_t = X_t\beta + A^{-1}\sum \varepsilon_t,\quad t = s + 1, \ldots n \quad (3)$$

The parameter estimation of this model was then extended to a TVP-VAR model by introducing time-varying characteristics, in the following form:

$$y_t = X_t\beta_t + A^{t-1}\sum_t \varepsilon_t,\ t = s + 1, \ldots n \quad (4)$$

where, the coefficient matrix β_t, the joint coefficient matrix A_t and the co-variance matrix $\sum$ t of random fluctuations all obey time-varying characteristics.

In order to reduce the complexity of the model estimation process and reduce the parameters to be estimated, the approach of [5] and [4] was used to straighten the non-0 and 1 elements of the lower triangular matrix A_t into column vectors, i.e., letting:

$$a_t = (a_{21}, a_{31}, a_{41}, \ldots, a_{kk-1}),\ h_t = (h_{1t}, \ldots, h_{kt}) \quad (5)$$

where, $h_{it} = \log \sigma_{it}^2,\ i = 1 \ldots k\ ;\ k = s + 1,\ \ldots, n$

Meanwhile, the parameters of Eq. (4) are assumed to obey the following random walk process:

$$\begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{\alpha t} \\ \mu_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \sum_\beta & 0 & 0 \\ 0 & 0 & \sum_\alpha & 0 \\ 0 & 0 & 0 & \sum_h \end{pmatrix}\right) \quad (6)$$

where, t = s + 1,... n.

2.3 Model Parameter Estimates

The sample data passed the ADF test and was found to be a stationary series. With the development of computer, Internet and other information technology, Markov chain Monte Carlo (MCMC) simulation technology enables Bayesstatistics to be applied to many complex problems in many fields. In this paper, the method is used to estimate the parameters, and 10000 valid samples are set. The selection of the optimal lag order is determined to be 4 order according to LR test. According to the model estimation results in Table 2, the Geweke diagnostic values, invalid factors and posterior means of the parameters could not reject the original hypothesis at 5% significance level. It indicates that the uncorrelated samples obtained by the MCMC algorithm could meet the need of posterior inferential statistics and that the model was well fitted.

Table 2. TVP-VAR MODEL PARAMETER ESTIMATION RESULTS.

Parameter	Mean	Standard deviation	95% confidence interval	Geweke test	Invalid factor
sb1	0.0226	0.0025	[0.0183,0.0283]	0.3120	7.9400
sb2	0.0229	0.0026	[0.0185,0.0287]	0.2060	9.4000
sa1	0.0721	0.0228	[0.0396,0.1276]	0.3470	55.0100
sa2	0.0657	0.0206	[0.0381,0.1151]	0.5620	58.2100
sh1	0.4924	0.0960	[0.3197,0.6883]	0.9130	38.5600
sh2	0.2734	0.0825	[0.1392,0.4629]	0.3850	56.5000

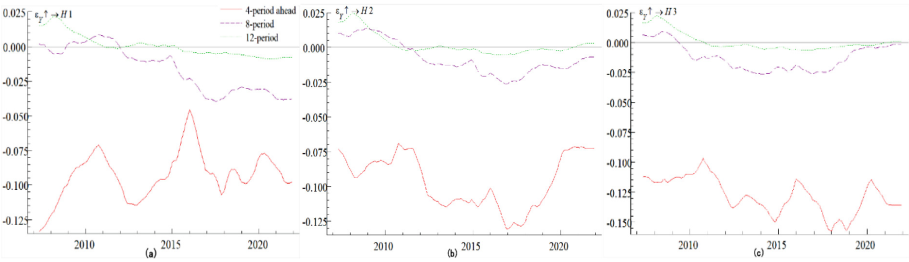

Fig. 1. Time-varying impulse response diagram.

3 Results and Discussion

3.1 Time-Varying Impulse Response Analysis

In Fig. 1, it can be seen from the direction of the impact that the international crude oil price presented a negative impact on oil-related industries, oil substitution industries, and oil consumption industries as a whole, except for a positive impact in the early period with lags of 8 and 12, but the impact interval was (0, 0.025), and the positive impact was not significant. During the whole sample period, international oil prices did not show a stable upward or downward trend, but have been fluctuating up and down in an unstable state. Since 2007, international crude oil prices have been affected by policy adjustments, economic changes, and changes in international relations due to the complex and unpredictable uncertainties of the international landscape.

However, according to the main trends, the sample period studied in this paper can be broadly divided into 4 phases. Phase 1 (2007–2009): 1. OPEC decided to cut production. 2. It coincided with the rapid development of the global economy, with strong demand for crude oil. 3. The Federal Reserve cut interest rates sharply, the dollar depreciated, and speculators were significantly speculative. Supported by these 3 factors, oil prices rose dynamically and reached a decade high. However, in October 2008, the financial crisis broke out, oil prices soared and then ushered in a plunge. Within less than 2 years, the price of oil has fluctuated dramatically. Phase 2 (2009–2014.6): The Federal Reserve carried out three times of quantitative easing (QE1, QE2, QE3), and the dollar exchange rate became lower, which supported oil prices notably. The global economy gradually recovered from the gloom of the financial crisis, oil prices showed an upward trend after falling into the trough, and stabilized in the high range of $90–120/barrel between 2011 and 2013. Phase 3 (2014.7–2015.6): Oil prices kept falling from the high level, and fell back to the range of $50–70/barrel again in 2015, returning to the oil price level of a decade ago. Phase 4 (2015.7–2022): Crude oil prices did not show high price levels, but continued to have a downward trend with fluctuations. In particular, in 2018 and 2020, the trade war between the United States and China saw the two countries impose tariffs on top of each other, which led to a succession of declines in global stock markets. Crude oil also saw a drop of close to 45% as a result of this. The year 2020 marked the beginning of the ongoing COVID-19 epidemic. The major oil exporters favored oil production cuts due to the fear of the long-term negative economic impact of the global spread of the COVID-19 epidemic, but the OPEC negotiations on production cuts failed, and Saudi Arabia increased production to start a price war, resulting in a plunge in international oil prices.

Through the above representations, the results of the impulse response plots in Figure (a)(b)(c) show that the international crude oil prices fluctuate significantly without any evident pattern. When the international crude oil tends to rise or fall significantly, the stock yields of the three industries do not vary significantly in the same or opposite direction with the crude oil price, but the impact merely remains negative. Thus, when the international crude oil price rises or falls, the stock yields in China by sector do not show rule-based movements immediately. It takes some time to transmit the movements of international crude oil prices to the stock market. However, the unstable international crude oil price is one of the adverse factors of stock yields. From the perspective of impact intensity, the negative impact intensity of the three industries with a lag of 4 periods was significantly higher than that with a lag of 8 and 12 periods, and the stock yield fluctuation of oil-related industries was the most significant. It indicated that the international crude oil price has a short-term time-sensitive effect on the stock market, but its long-term effect is not significant, while the oil-related industries are the most affected.

3.2 Time-Point Impulse Response Analysis

The three time points selected in this paper were April 2008 during the financial crisis, December 2014 during the dramatic increase in U.S. shale oil production, and March 2020 during the COVID-19 epidemic. The three time points represented typical periods of international crude oil price crashes in the sample period.

For oil-related industries and oil consumption industries, lower crude oil prices mean lower production and sales costs, which will lead to some increase in corporate profits and thus have a positive impact on the stock market. In the case of crude oil substitution industries, the reduced crude oil prices will lead to a shift in demand from the use of alternative energy sources such as electricity and gas to the use of crude oil. Thus, it may lead to lower profitability of the companies, which may have a negative impact on the stock market. At the time points chosen in this paper, especially during the COVID-19 epidemic and financial crisis, the global economy was severely hit and the entire stock market was in recession. In the context of the overall economic downturn, the oil-related

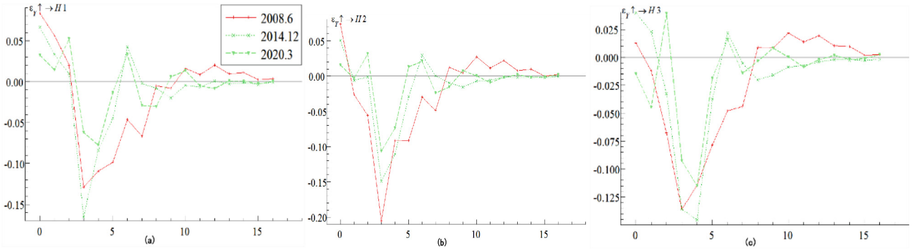

Fig. 2. Time-point impulse response diagram.

industries and oil substitution industries experienced negative stock yields because the increase in profits resulting from the decline in crude oil prices was not sufficient to offset the impact of the overall economic downturn. However, by comparing Figures (a) (b) and (c) in Fig. 2, we can see that the negative impact in Figure (b) was stronger than in Figure (a) and Figure (c), and that its minimum peak was the smallest. It indicates that the fall in crude oil prices has a dampening effect on the stock yields of oil substitution industries. According to the trend, the time-point impulse curves of all three industries gradually converged to near zero in the later stage. It suggested that the international crude oil price has a short-term time lag on the stock market, which is consistent with the analysis of the time-varying impulse response diagram.

4 Conclusions

4.1 Conclusions

In this paper, the following conclusions were drawn from the impulse response diagrams:

The time-varying impulse response diagram revealed that, firstly, the movements of international crude oil prices are dynamically correlated with the stock yields of oil-related industries, oil substitution industries and oil consumption industries. However, it takes time to transmit the impact of international crude oil price changes on the stock yield of the industry, and the stock yield of the industry will not show regular changes immediately with the changes of crude oil price, featuring a lag. Secondly, the instability of international crude oil prices is a negative factor for stock yields. Frequent fluctuations in international crude oil prices within a short time frame will have a negative impact on the stock markets of all three industries. Thirdly, the sensitivity to the dynamic spillover of international oil price changes varies across industries, with oil-related industries being the most affected by international crude oil price fluctuations.

The time-point impulse response diagram revealed that the stock yields of the industries differ in the direction of change in response to changes in international oil prices. When the price of crude oil falls, there is a positive impact on the stock yields of oil-related industries and oil consumption industries, while there is a negative impact on the stock yields of oil substitution industries.

4.2 Suggestions

Based on the above analysis and conclusions, the following recommendations were made from the macro policy perspective:

China should stabilize its domestic crude oil futures market and strive for the RMB pricing power of oil. In order not to become a victim of international oil price manipulation game, departments concerned should reinforce the management of the crude oil futures market, expand the storage capacity of crude oil futures delivery warehouses, accelerate the improvement of China's oil futures market, and guarantee that the futures play their roles in the pricing of crude oil trade.

China should develop the clean energy industry and accelerate economic transformation. The impact of international oil price fluctuations is a test of the tolerance of China's energy system and economic structure. Responsible departments should prioritize the development of renewable energy, adjust and optimize the energy industry structure and consumption structure, and mitigate the impact of falling oil prices on the progress of clean energy development.

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