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Volatility and Asymmetric Effect of Crude Oil Options on Crude Oil Market: Empirical Evidence from China

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Abstract

Based on daily data, this paper uses the GARCH model family to empirically study the impact of crude oil option launch on the volatility and asymmetric leverage effect of crude oil futures market variables (futures price, trading volume, open interest, inventory).The conclusion is as follows: Regardless of the impact of the COVID-19, the launch of crude oil options has a long-term volatility impact on price, open interest and inventory volatility in addition to trading volume, and only has a long-term volatility impact on prices under the influence of COVID-19.Regardless of whether the impact of COVID-19 is considered, the launch of crude oil options has intensified the volatility of price yield, reduced the volatility of trading volume, open interest and inventory, and Considering COVID-19 influence, the volatility of crude oil futures prices yield has weakened, and the degree of weakening of trading volume fluctuations has decreased. Regardless of the impact of COVID-19, crude oil futures prices, trading volume, open interest, and inventory volatility all have negative asymmetric leverage effects, and the impact of bearish news is greater than the impact of bullish news. Considering the introduction of crude oil options under the influence of COVID-19: the fluctuation of crude oil futures prices yield has changed from negative asymmetry to positive asymmetric leverage effect. The asymmetric leverage effect of negative fluctuations in crude oil futures trading volume becomes smaller and decreases less than the leverage effect without considering the impact of COVID-19 after the listing of crude oil options. Fluctuations in open interest and inventory have weakened the negative asymmetric leverage effect after the launch of crude oil options. Finally, relevant policy suggestions are given for the construction of the domestic options market.

Keywords: crude oil options, GARCH model family, volatility,asymmetry, leverage effect

1. Introduction

The foreign options market developed relatively early, and options trading appeared in the European and American markets in the eighteenth century, and then in the early seventies of the twentieth century, after the Chicago Board Options Exchange in the United States adopted standardized option contracts, the overseas options market has developed rapidly.

Although the domestic futures market has undergone more than 30 years of development, the launch of options is relatively late. China's first option variety 50ETF was listed on the Shanghai Stock Exchange on February 9, 2015. The listing of commodity options is even later, the soybean meal option listed on March 31, 2017 is the first commodity option in China, and then there are more than 20 varieties of domestic commodity options listed by 2022, and the launch of commodity options has strongly promoted the development of the domestic futures market.

Domestic crude oil futures as the first international commodity futures listed on March 26, 2018, the launch of crude oil futures for the internationalization of domestic commodity futures is of great significance, after more than three years of development, on June 21, 2021, the domestic crude oil futures market ushered in crude oil options. Crude oil options is the first batch of international options denominated in RMB, the listing of crude oil options has improved the structure of the domestic crude oil market, improved the price discovery efficiency of the crude oil futures market, It enriches the hedging tools of oil enterprises and improves the risk management methods of enterprises in the crude oil industry chain.

In order to further study the role and impact of crude oil option launch on crude oil futures market, we use GARCH model family to make an empirical analysis of the comprehensive impact of crude oil options on the volatility of crude oil futures market before and after the launch of crude oil options, hoping to find the impact and limitations of crude oil option launch on the crude oil futures market, and provide valuable suggestions for the further development of commodity options market in China.

2. Literature Review

There are many research literature on options at home and abroad, among which most of the research on the impact of option launch on the underlying asset market is concentrated in the capital market, and relatively few studies on the commodity market. There are also large differences in the results of domestic and foreign literature research.

Some foreign literature studies find that the introduction of options reduces the volatility of the underlying market. For example, Roll (1977) found that the introduction and trading of options can reduce the volatility of the underlying spot market, possibly because the introduction of options can prompt investors with a lot of information to move their funds to the options market. Hakansson（1982） found that the volatility of the underlying spot market was significantly reduced after the introduction of options. The introduction of options will increase investors' choice strategy set, improve investors' risk-return opportunities, thereby enhancing the effectiveness of the market and changing the state of incomplete financial markets. Damodaran and subrahmanyam (1992) studied the options and spot markets in the United States and found that the introduction and trading of options played a certain role in restraining the volatility of the underlying spot market. Kumar et al. (1995) found that after the listing of stock index options on the Tokyo Stock Exchange, the volatility and trading volume of the underlying index decreased. Kumar et al. (1998) found that the introduction of stock options in the United States improved the quality of the spot stock market while reducing the volatility of the underlying stock market. Wang et al. (2009) found that stock index options trading in the Hong Kong market reduced the volatility of the H-share market. Bhaumik and Bose (2009) found that in the Indian financial market, the underlying market volatility after the launch of options decreases. Liu (2009) used the method of controlling variables to find that the introduction of S&P100 stock index options suppressed the volatility of the underlying stock, but had no significant impact on the price and overall systemic risk of the financial market, and stock index option trading was not the cause of abnormal fluctuations in the underlying stock market. Galloway and Miller (2010) found that the introduction of stock index options does not exacerbate the volatility of the stock index futures market, and the trading of options plays a certain role in restraining the volatility of the spot market .

Some foreign literature studies find that the introduction of options enhances the volatility of the underlying market. For example, Robbani et al. (2005) using the GARCH model found that after the introduction of Dow Jones index options, the volatility of the 30 underlying stocks by the Dow Jones index increased significantly. Filis (2007, 2011) found that the introduction of Greek stock options on the Greek stock market increased the volatility of the underlying market, while the Greek market became more efficient. Han (2014) found that in the early days of the listing of Hong Kong Hang Seng Index options, the options market increased the volatility of the spot market, and in the long run, as the market stabilized, options gradually weakened the volatility of the spot market.

Some foreign literature studies find that the introduction of options has no obvious impact on the underlying market volatility. For example, Kabirm (1999) found that in the Dutch financial market, after options are issued and listed, the volatility of the underlying market does not change significantly .Antoniou and Koutmos (2004) using the GARCH model found that the Nikkei 225 index and the German DAX index did not experience significant fluctuations after they were listed as underlying market stock index options. Mazouz (2004) conducted a study on the impact of CBOE options listings on stock volatility and found that options listings did not have a significant impact on the volatility of the underlying stock. Using the GARCH cluster model as an empirical analysis tool, Floros and Vougas (2006) found that the listing of stock index futures has a limited impact on the underlying market volatility and cannot be accurately judged in an economic sense.

There are also some foreign literature that believes that the impact of the introduction of options on the underlying market can only be determined in combination with relevant circumstances, for example, Ma and Rao (1988) found that it is not possible to say that the introduction of options increases or decreases the volatility of the spot market, and the specific characteristics of the impact depend on the operation of the underlying spot market itself, if the underlying spot market itself is sufficient and effective, then the launch of options will further enhance the effectiveness of the market and reduce market volatility, Conversely, it will increase market volatility. Ronel (1995) found that the impact of the introduction of options on the underlying spot market has a certain abrupt effect, because it is difficult to directly study the impact of options on the spot market regardless of the impact of the market as a whole. Because if the financial market is incomplete and inadequate, the impact of the introduction of financial derivatives on the spot market will show discreteness and jumping, and lack smoothness characteristics.

From the perspective of domestic literature, some literature studies find that the introduction of options reduces the volatility of the underlying market. Some literature studies on the launch of options on the S&P 100 index in the United

States believe that the volatility of the underlying index has decreased, such as Liu (2017), Sheng and Feng (2018). Some literature uses a variety of measurement methods to study the launch of domestic SSE 50 index options, and all think that the volatility of the underlying index has decreased, such as Wu (2015), Li (2016), Su and Wang (2016), Zhang and Song (2016), Mao (2017), Zhang (2018), etc. Some literature has studied the impact of the launch of domestic commodity futures options on the commodity futures market, and the study think that the introduction of commodity options reduces the volatility of the underlying commodity futures, for example, Jiao (2018) uses the GARCH family model to find that the introduction of sugar options and soybean meal inhibits the volatility of the underlying futures market price to a certain extent, and improves the efficiency of the underlying market information processing, while the leverage effect in the sugar futures market is improved. Tu (2018) found that with the listing of soybean meal options, the volatility and asymmetry of the underlying futures market price have been reduced. Wang (2020) found that after the introduction of sugar and copper options, the overall volatility and asymmetry of the underlying futures market price have been reduced, and the information processing efficiency has been improved. Luo (2022) found that the listing of natural rubber commodity options can reduce the price volatility of the underlying futures market.

From the perspective of domestic literature, some literature studies think that the introduction of options enhances the underlying market volatility. Some use a variety of measurement methods to study the launch of options such as domestic and foreign stock indexes, and think that the volatility of the underlying index has increased, such as Xiong (2011) used the multi-GARCH model to find that after the introduction of KOSPI200 stock index options, the volatility of the KOSPI200 index market and the index futures market was amplified. Wang (2013) found that the listing of KOSPI200 stock index options in South Korea enhanced the volatility of the yield of the underlying spot index. Zhao and Sun (2015) use the Agent experimental simulation method to find that the introduction of stock index options in China has aggravated the volatility of the underlying stock market .Liu et al. (2017) used the GARCH class model and found that the volatility of the underlying index increased after the launch of domestic 50 ETF options, and bad news would aggravate the volatility of the underlying market, while the leverage effect increased .There are relatively few studies on the introduction of commodity options to enhance the volatility of the underlying market, only Liu and Zuo (2022) found that there is a fluctuation agglomeration in the cotton futures price yield series, and regardless of COVID-19 epidemic, the introduction of cotton options will not only increase the volatility of cotton futures yields, but also reduce the overall volatility and asymmetry of the cotton futures market.

From the perspective of domestic literature, some literature studies think that the introduction of options has no obvious impact on the underlying market volatility. For example, Guo (2014) studied nine typical stock index options around the world, believing that the impact of the launch of options on the underlying market volatility is irregular and may be caused by other reasons.Fan (2015) found that the launch of 50 ETF options had no significant impact on the volatility of the underlying index. Zhang (2016) found that the launch of 50 ETF options had no significant impact on the volatility of the underlying constituents. There are relatively few studies on the launch of commodity options that have no impact on the underlying market volatility, only Guo et al. (2021) found from the daily data that the price fluctuation of sugar futures after the listing of sugar options did not change significantly, but from the 5-minute high-frequency data, the "glitch" phenomenon of the sugar futures market after the listing of sugar options has been alleviated, indicating that options have played a role in suppressing short-term irrational fluctuations in futures trading.

In summary, most of the research literature at home and abroad on the impact of option launch on the underlying asset is about the impact of option introduction on the underlying stock index or stock volatility in the domestic and foreign stock markets, and the research conclusions are diverse. There are relatively few studies on the impact of commodity futures options on the volatility of commodity futures, most of the research methods use various ARCH, GARCH and other methods, from the existing literature, the impact of the introduction of commodity options on the underlying futures is focused on the impact on the volatility of commodity futures price univariate, the current research on the impact of crude oil options on crude oil futures and the impact on multiple variables is still a blank. Therefore, in this paper, the GARCH model family method is used to study the impact of crude oil option introduction on the volatility and asymmetric leverage effect of micro variables (futures price, trading volume, open interest, inventory) in the crude oil futures market, hoping to obtain valuable conclusions and provide valuable references for the development of China's futures market.

3. Methodology

3.1 GARCH Model Setting for Variable Fluctuations in Crude Oil Futures

Engle (1982) proposed the Autoregressive Conditional Heteroskedastic (ARCH) model when studying inflation, and Bollerslev (1986) proposed the GARCH model based on the ARCH model, which can be generalized to allow conditional variance to affect yields. Therefore, the GARCH (q,p) model variance equation for fluctuations in crude oil futures variables (price, trading volume, open interest, inventory) can be set as follows:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \qquad (1)$$

where p is the order of the ARCH term and q is the order of the GARCH term, p>0, q≥0， $\alpha_0 > 0, \alpha_i \geq 0, \beta_j \geq 0$, $\sum_{i=1}^{p} \alpha_i + \sum_{j=1}^{q} \beta_j < 1$. The model reflects that the current volatility of crude oil futures related indicators is affected by the previous volatility information，when $\sum_{i=1}^{p} \alpha_i + \sum_{j=1}^{q} \beta_j$ value is closer to 1, the longer the information shock affects volatility.

In order to further study the impact of crude oil options on the volatility of the crude oil futures market, we introduce dummy variables in the GARCH(q,p) model of crude oil futures variables (price, trading volume, open interest, inventory), and the model settings for introducing dummy variables are as follows:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \lambda_1 D_1 \qquad (2)$$

where D1 is a dummy variable，$D_1 = \begin{cases} 0 & \textit{Before the launch of crude oil options} \\ 1 & \textit{After the launch of crude oil options} \end{cases}$ ， λ_1 is the coefficient of the dummy variable，when $\lambda_1 > 0$, indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has intensified. When $\lambda_1 < 0$, indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has reduced. When $\lambda_1 = 0$, shows that the fluctuations of price yield, trading volume, open interest and inventory changes of crude oil futures variables have not changed significantly.

Since COVID-19 epidemic has occurred before the launch of crude oil options, considering the impact of the epidemic on the fluctuation of crude oil futures market variables, we analyze the impact of the epidemic on the fluctuation of crude oil futures market before the launch of options, introduce the dummy variable D2 to add the model (1), and compare and analyze the impact of the epidemic on the crude oil market before the launch of crude oil options, the model is set as follows:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \lambda_2 D_2 \qquad (3)$$

Where $D_2 = \begin{cases} 0 & \textit{Before COVID–19 epidemic} \\ 1 & \textit{From the onset of COVID–19 epidemic to before the introduction of crude oil options} \end{cases}$, λ_2 is the coefficient of the dummy variable，where $\lambda_2 > 0$ ， indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has intensified. Where $\lambda_2 < 0$, indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has reduced. Where $\lambda_2 = 0$, shows that the fluctuations of price yield, trading volume, open interest and inventory changes of crude oil futures variables have not changed significantly.

Considering the impact of the COVID-19 epidemic, in order to more accurately distinguish the impact of crude oil option launch on the volatility of crude oil futures market, and Compare the post- epidemic to the pre-launch and post-launch of crude oil options, we introduce the dummy variable D3 to the model (1), and the model is set as follows:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \lambda_3 D_3 \tag{4}$$

Where $D_3 = \begin{cases} 0 & \text{From the aftermath of the COVID–19 to before crude oil options were introduced} \\ 1 & \text{After the launch of crude oil options} \end{cases}$, λ_3 is the coefficient of the dummy variable, when $\lambda_3 > 0$, indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has intensified. Where $\lambda_3 < 0$, indicates that the volatility of price yield, trading volume, open interest and inventory changes in crude oil futures variables has reduced. Where $\lambda_3 = 0$, shows that the fluctuations of price yield, trading volume, open interest and inventory changes of crude oil futures variables have not changed significantly.

3.2 Asymmetric EGARCH Model Setting of Variable Fluctuations in Crude Oil Futures

Asymmetric leverage effect reflects the unidirectional nature of volatility transmission, or a certain degree of risk attitude difference, leverage effect can be achieved by introducing a certain asymmetry in the GARCH model, because the asymmetry of market fluctuations and reactions has a variety of structural forms and representation methods, and there are some generalized forms of GARCH models, such as EGARCH models, which are widely used. According to the EGARCH model proposed by Nelson (1991), we set the conditional variance equation for fluctuations in crude oil futures variables (price, trading volume, open interest, and inventory) as:

$$\ln \sigma_t^2 = \omega + \beta \ln \sigma_{t-1}^2 + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \tag{5}$$

Good news $(\varepsilon_t > 0)$ and bad news $(\varepsilon_t < 0)$ have different effects on conditional variance, The good news impact factor is $\alpha + \gamma$, The impact factor of bad news is $\alpha - \gamma$. if $\gamma \neq 0$, The impact response has asymmetry and leverage effect. If $\gamma < 0$, Bearish news has a greater impact on volatility than bullish news. If $\gamma > 0$, Then the impact of bullish news on volatility is greater than the impact of bearish news. If $\gamma = 0$, There is no asymmetry and leverage. We define the function as follows:

$$f\left(\frac{\varepsilon_t}{\sigma_t}\right) = \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \tag{6}$$

then $f(\bullet)$ is the information impact curve.

Based on the basic EGARCH model form, our multi-order equation of variance for the multi-order form of EGARCH model fluctuations in crude oil futures variables (price, trading volume, open interest and inventory) can be set as follows:

$$\ln \sigma_t^2 = \omega + \sum_{j=1}^{p} \beta_j \ln \sigma_{t-j}^2 + \sum_{i=1}^{q} \left(\alpha_i \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \gamma_i \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right) \tag{7}$$

Good news $(\varepsilon_t > 0)$ and bad news $(\varepsilon_t < 0)$ have different effects on conditional variance, The good news impact factor is $\sum_{i=1}^{q}(\alpha_i+\gamma_i)$, The impact factor of bad news is $\sum_{i=1}^{q}(\alpha_i-\gamma_i)$, if $\sum_{i=1}^{q}\gamma_i \neq 0$, There is a leverage effect, if $\sum_{i=1}^{q}\gamma_i = 0$, There is no leverage effect.

4. Empirical Analysis

4.1 Variable Selection and Data Processing

4.1.1 Selection and Description of Variables

Taking the international crude oil futures listed on March 26, 2018 as the research target, the crude oil futures price, trading volume, open interest and inventory variable indicators are selected. The crude oil futures price selects the daily closing price of the active contract with the largest trading volume and links it into a continuous price time series, the trading volume indicator selects the total daily trading volume of crude oil futures contracts, the open interest indicator selects the daily open interest of the active contract, and the inventory indicator selects the daily inventory of crude oil futures. Time range 2018.3.26-2022.9.22. There are 1095 valid data excluding holidays. Source: Shanghai International Energy Exchange Center. Among them, crude oil inventories were not available in the early stage of crude oil futures listing, that is, crude oil inventories were 0 during the period of 2018.3.26-2018.6.25, and 1 was used to make up for research needs.

The selected data is logarithmically processed, where the crude oil futures price yield is the first-order difference of the logarithm of the crude oil futures price, that is: $R_t = D\ln P_t = \ln P_t - \ln P_{t-1}$, where R_t is the yield of crude oil futures price on t day, P_t is the price of crude oil futures on t day, P_{t-1} is the t-1 day crude oil futures price.

Similarly, the logarithmic first-order difference treatment is done for the trading volume, open interest and inventory of crude oil futures, and the trading volume, open interest and inventory fluctuation indicators are obtained respectively as follows: $D\ln Q_t = \ln Q_t - \ln Q_{t-1}$、 $D\ln I_t = \ln I_t - \ln I_{t-1}$、 $D\ln S_t = \ln S_t - \ln S_{t-1}$, Among them, Q, I, and S represent the trading volume, open interest, and inventory of crude oil futures, respectively.

4.1.2 Times Series Plots of Variables and Basic Judgments

The following is a logarithmic first-order difference series chart for each variable:

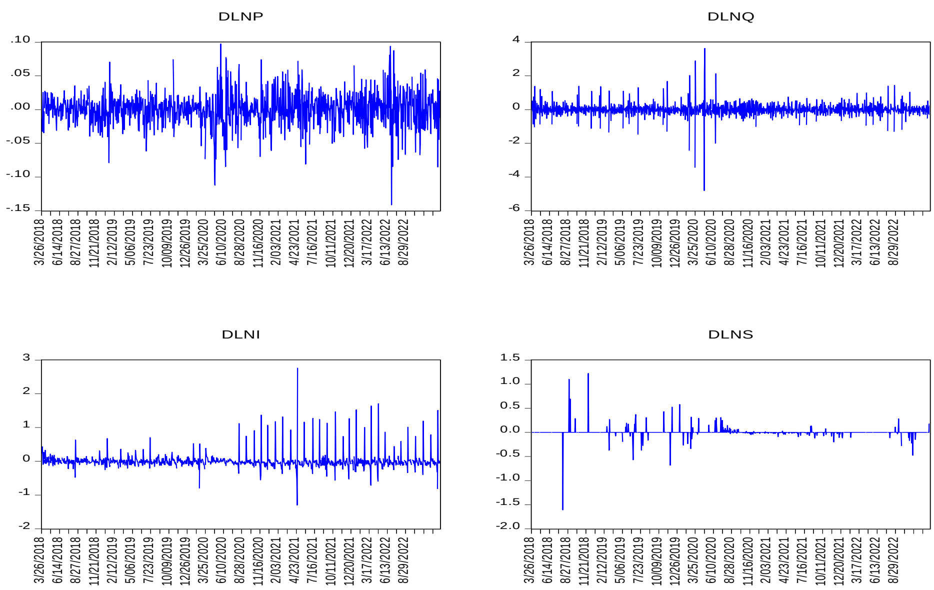

Figure 1. Logarithmic first-order difference chart of crude oil futures price, trading volume, open interest and inventory

As can be seen from the above figure, the crude oil futures price and trading volume, open interest, and inventory logarithmic first-order difference fluctuation chart all show fluctuation agglomeration effect. Therefore, it can be judged that there may be heteroscedasticity in the logarithmic first-order difference sequence of crude oil futures price and trading volume, open interest and inventory. Taking the listing of crude oil options on June 21, 2021 as the time dividing point, for the crude oil futures price yield, there is no significant change in the volatility before and after the listing of crude oil options, and even there is an increase in volatility in individual time periods, which may be related to the impact of the COVID-19 epidemic. From the perspective of trading volume, open interest and inventory fluctuations, the volatility of the three before and after the launch of crude oil options has changed greatly, and all show a decrease in volatility after the launch of crude oil options.

Since the COVID-19 epidemic already existed when crude oil options were launched, the domestic epidemic first appeared at the end of 2019, the World Health Organization set the time point of the global pandemic as 2020.3.11, therefore, we use the view of the World Health Organization to determine the time point of the epidemic, in order to better analyze the impact of crude oil options launch on the volatility of crude oil futures market, we will divide the selected samples into the following situations: full sample (2018.3.36-2022.9.22), Before the outbreak of the COVID-19 epidemic (2018.3.26-2020.3.11), after the outbreak of the COVID-19 epidemic to before the launch of crude oil options (2020.3.11-2021.6.21), before the launch of crude oil options (2018.3.26-2022.9.22), after the launch of crude oil options (2021.6.21-2022.9.22). Descriptive statistics in several cases are given(appendix table1).

As can be seen from the appendix table1, the kurtosis values of all samples are greater than 3 in several cases, and the skewness values are partly greater than 0 and some are less than 0, indicating that each index shows the characteristics of Excess Kurtosis Fat tails and some showing the distribution characteristics of long left trailing tail and some long right trailing. At a significance level of 1%, the JB statistic rejects the normal distribution hypothesis, indicating that the normal distribution is not satisfied for each series in several cases.

From the perspective of standard deviation, the fluctuation of crude oil price yield and open interest fluctuation after the launch of crude oil options is slightly larger than that before the launch of crude oil options, and there is no significant change, while the trading volume and inventory fluctuations of crude oil futures become smaller after the launch of crude oil options, and there are significant changes. Since the COVID-19 epidemic has occurred more than a year when crude oil options were launched, the emergence of the epidemic has a greater impact on the volatility of the crude oil futures market, compared with the pre-epidemic and before crude oil options launch in post-epidemic, crude oil futures prices and open interest have increased volatility, and crude oil trading volume and inventory fluctuations have weakened.

During the epidemic, before and after the launch of crude oil options, we compare the two time periods after the outbreak of the epidemic to before the launch of crude oil options and after the launch of crude oil options, in these two time periods the epidemic has an impact on the crude oil futures market, comparing the impact of crude oil options before and after the launch of crude oil options in these two time periods can be seen: after the launch of crude oil options, in addition to the fluctuation of crude oil futures inventory fluctuations are not significant, crude oil futures price yield fluctuations, trading volume fluctuations, Open interest volatility has decreased compared to the outbreak of the epidemic and before the launch of crude oil options.

Therefore, from the daily data, the listing of crude oil options has a certain impact on the volatility of the crude oil futures market, without considering the epidemic, although the fluctuation of crude oil futures prices and Open interest has not changed much, but the trading volume and inventory fluctuations of crude oil futures have weakened significantly. Considering the impact of the epidemic, before and after the outbreak of the epidemic, the fluctuation of crude oil futures prices and open interests has increased, and the fluctuation of trading volume and inventory has weakened. Considering that during the epidemic period, the introduction of crude oil options has reduced the fluctuation of price yield, trading volume and open interest volume in the crude oil futures market, and the inventory fluctuation has increased. The above descriptive statistics describe to a certain extent the impact of crude oil option launch on the volatility of crude oil futures market, and the specific degree of impact requires further model empirical analysis.

4.2 Related Test

4.2.1 Unit Root Test for Data Stationarity

We test the stationarity of the selected crude oil futures price, trading volume, open interest and inventory logarithmic first-order difference sequence under three conditions, and we use the commonly used unit root test ADF test method below, and the test results are given (appendix table 2).

Through appendix table 2 the unit root ADF test results, it can be seen that under the significance levels of 1%, 5% and 10%, the crude oil futures price, trading volume, open interest, and inventory logarithmic first-order difference sequence are stable under several circumstances, and ARMA model can be used for subsequent model empirical analysis.

4.2.2 ARCH Effect Test

Determine the order of each ARMA model according to the autocorrelation and partial autocorrelation function graphs of crude oil futures price, trading volume, open interest, and inventory logarithmic first-order difference series (limited in length, specific graphs omitted).Through the graph of crude oil futures price yield autocorrelation and partial autocorrelation function, it can be seen that there is no phenomenon of one side tailing and the other truncating, and there is a certain tailing phenomenon in both graphs, and ARMA model can be considered. According to AIC, SC and other information criteria, the lagging order is determined, and the final ARMA model of crude oil futures price yield is ARMA(1,1).Through the graph of the logarithmic first-order difference sequence of crude oil futures trading volume, the second-order truncation of the partial autocorrelation coefficient and the second-order truncation of the autocorrelation coefficient can be determined, and the ARMA model of the logarithmic first-order difference sequence of crude oil futures trading volume can be determined to be ARMA(2,2). Through the graph of the logarithmic first-order difference sequence autocorrelation and partial autocorrelation function of crude oil futures open interest, it can be seen that the partial autocorrelation coefficient and autocorrelation coefficient are truncated, and the ARMA model of the logarithmic first-order difference sequence of crude oil futures open interest can be determined to be ARMA(17,1). Through the graph of the logarithmic first-order difference sequence autocorrelation and partial autocorrelation function of crude oil futures inventory, it can be seen that there is no phenomenon of one side trailing and one side truncating, and there is a certain trailing phenomenon in both figures, and the lagging order is determined according to AIC, SC and other information criteria, and finally the ARMA model of the logarithmic first-order difference sequence of crude oil futures inventory is ARMA(1,1).

Then the ARCH effect test is carried out, that is, the square of the residuals of the crude oil futures price, trading volume, open interest, inventory logarithmic first-order difference series: ARMA(1,1), ARMA(2,2), ARMA(17,1), ARMA(1,1) is made autocorrelation test. According to AIC, SC and other information criteria, the best lag order of each ARCH model is determined, which is 3, 3, 2, and 17 respectively, and the specific test results are as follows:

Table 1. ARCH effect test results of each ARMA model

Model	F-statistic	Prob.	nR^2	Prob.
Futures price yield ARMA（1,1）	47.34952	0	126.0934	0
Trading volume ARMA（2,2）	12.80958	0	37.25314	0
Open interest ARMA（1,1）	38.76416	0	72.57511	0
Inventory ARMA（1,1）	5.494040	0	87.28783	0

Note：where n represents the number of observations， R^2 indicates goodness-of-fit.

As can be seen from the table, the P value corresponding to the F statistic and the chi-square statistic in the four cases is 0, indicating that there is an ARCH effect in the first-order difference order of crude oil futures price, trading volume, open interest and inventory logarithm.

4.3 An Empirical Analysis of the Impact of Introduction of Crude Oil Options in the Whole Sample

Since the residuals of the ARMA model of the logarithmic difference sequence of the crude oil futures variables have ARCH effect, we empirically estimate the logarithmic difference sequence fluctuation GARCH model of each variable, and first determine the best lag order of the GARCH model according to AIC, SC and other information criteria (limited to length, specific test omitted), we can know the price yield, trading volume, open interest and inventory fluctuations models are all GARCH(1,1) models.

4.3.1 GARCH model estimation with the addition of dummy variable D1

Considering the changes in the volatility of crude oil futures-related variables before and after the launch of crude oil options, the GARCH(1,1) model of crude oil futures price yield, trading volume, open interest and inventory fluctuations added to the dummy variable D1 is estimated, and the results are as follows:

Table 2. GARCH(1,1) model estimates added to the dummy variable D1

Model	Variable	Coefficient	Std. Error	z-Statistic	Prob.
GARCH(1,1) model estimate of crude oil futures price yield	C1	2.14E-05	5.28E-06	4.057299	0.0000
	α_1	0.136699	0.020244	6.752437	0.0000
	β_1	0.823153	0.023173	35.52229	0.0000
	λ_1	2.39E-05	9.30E-06	2.571687	0.0101
GARCH(1,1) model estimates of Crude oil futures volume fluctuation	C2	0.085901	0.006126	14.02194	0.0000
	α_2	0.320298	0.035080	9.130391	0.0000
	β_2	0.127132	0.049989	2.543166	0.0110
	λ_2	-0.033908	0.003666	-9.248481	0.0000
GARCH(1,1) model estimate of crude oil futures open interest	C3	0.279850	1.230796	0.227373	0.8201
	α_3	0.041120	0.162885	0.252446	0.8007
	β_3	0.672422	0.152764	4.401714	0.0000
	λ_3	-0.014358	0.054816	-0.261934	0.7934
GARCH(1,1) model estimate of crude oil futures inventories	C4	0.003418	0.000367	9.310708	0.0000
	α_4	0.039909	0.006527	6.114810	0.0000
	β_4	0.781427	0.021297	36.69207	0.0000
	λ_4	-0.003079	0.000332	-9.277133	0.0000

Note: where C is a constant term, α is the ARCH term coefficient, β is the GARCH term coefficient, λ is a dumb variable coefficient, the following is similar.

The ARCH effect test is carried out on the GARCH(1,1) model of the fluctuation of each variable of crude oil futures added to the dummy variable D1, and the results are as follows:

Table 3. GARCH(1,1) model ARCH effect test with dummy variable D1

Crude Oil Futures Price Yield GARCH(1,1) Model ARCH Effect Test	F-statistic	0.452395	Prob. F(1,1090)	0.5013
	Obs*R-squared	0.453037	Prob. Chi-Square(1)	0.5009
GARCH(1,1) model ARCH effect test for crude oil futures volume fluctuations	F-statistic	0.067408	Prob. F(1,1090)	0.7952
	Obs*R-squared	0.067527	Prob. Chi-Square(1)	0.7950
GARCH(1,1) model ARCH effect test for fluctuations in crude oil futures open interest	F-statistic	1.437436	Prob. F(10,1056)	0.1584
	Obs*R-squared	14.32904	Prob. Chi-Square(10)	0.1585
GARCH(1,1) model ARCH effect test for crude oil futures inventory fluctuations	F-statistic	0.084695	Prob. F(1,1090)	0.7711
	Obs*R-squared	0.084843	Prob. Chi-Square(1)	0.7708

From the above ARCH effect test results, it can be seen that the test statistics are not significant, and the P values are greater than 10%, indicating that the model is effectively fitted to the conditional heteroscedasticity of the residual sequence, indicating that the setting of each GARCH model introduced into the dummy variable D1 is valid, and the conclusions are as follows:

For the GARCH(1,1) model estimation of the price yield of crude oil futures added to the dummy variable, the ARCH and GARCH coefficient α_1、β_1 are significantly greater than 0, which shows that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. $\alpha_1 + \beta_1$ =0.9599, close to 1, shows that the information shock has a long-term volatility impact on the price yield of crude oil futures.ARCH coefficient α_1 is small, indicating that the impact of new information on the volatility of crude oil futures prices is small, and the speed of digesting new information is slow. Among them, the GARCH coefficient β_1 is large, indicating that the impact of historical information is large. The dummy variable λ_1 coefficient is greater than 0 and significant at the 1% level, indicating that the volatility of crude oil futures price yields has been exacerbated after the introduction of crude oil options, and the degree of exacerbation is limited due to the relatively small coefficient value.

For the GARCH(1,1) model estimation of the trading volume of crude oil futures added to the dummy variable D1, the ARCH and GARCH coefficient α_1、β_1 are significantly greater than 0，which shows that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. $\alpha_2 + \beta_2 = 0.4474$，which shows that the information shock has a short-term volatility impact on the fluctuation of crude oil futures trading volume. Among them, the ARCH term coefficient α_2 is large, indicating that the new information has a greater impact on the volatility of crude oil futures trading volume, and the speed of digesting new information is faster. The GARCH coefficient β_2 is small, indicating that the impact of historical information is small. The dummy variable coefficient λ_2 is negative and significant at the 1% level, indicating that the volatility of crude oil futures trading volume fluctuations has been reduced after the introduction of crude oil options, and the degree of reduction is limited due to the relatively small coefficient value.

For the GARCH(1,1) model estimation of the open interest of crude oil futures added to the dummy variable D1, the ARCH and GARCH coefficient α_3、β_3 are significantly greater than 0，which shows that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. $\alpha_3 + \beta_3 = 0.7135$,which shows that the information shock has a long-term volatility impact on the fluctuation of crude oil open interest. Among them, the ARCH α_3 term coefficient is small and not significant, indicating that the impact of new information on the volatility of crude oil futures open interest is small, and the speed of digesting new information is slow. The GARCH coefficient β_3 is large, indicating that the impact of historical information is large. The dummy variable coefficient λ_3 is negative and not significant, indicating that the volatility of crude oil futures open interest fluctuations has been reduced after the introduction of crude oil options, and the degree of reduction is limited because the coefficient value is relatively small.

For the GARCH(1,1) model estimation of the inventory of crude oil futures added to the dummy variable D1, the ARCH and GARCH coefficient α_4、β_4 are significantly greater than 0，which shows that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. $\alpha_4 + \beta_4 = 0.8213$, which shows that the information shock has a long-term volatility impact on the fluctuation of crude oil futures inventory. Among them, the ARCH term coefficient α_4 is small, indicating that the impact of new information on the volatility of crude oil futures inventory is small, and the speed of digesting new information is slow. The GARCH coefficient β_4 is large, indicating that the impact of historical information is large. The dummy variable coefficient λ_4 is negative and significant at the 1% level, indicating that the volatility of crude oil futures inventory fluctuations has been reduced after the introduction of crude oil options, and the degree of reduction is limited due to the relatively small coefficient value.

4.3.2 GARCH Model Estimates Before and After the Listing of Crude Oil Options

In order to further analyze the information processing speed of the impact of information shock on the fluctuation of crude oil futures variables, the GARCH model before and after the listing of crude oil futures was compared and analyzed. The empirical results are as follows:

Table 4. GARCH estimate of crude oil futures variable fluctuations before and after the listing of crude oil options

Modle	Coefficient	Before the listing of crude oil options				After the listing of crude oil options			
Crude Oil	Variable	Coefficient	Std. Error	z-Statistic	Prob.	Coefficient	Std. Error	z-Statistic	Prob.
Futures Price	C1	2.11E-05	5.83E-06	3.617645	0.0003	4.86E-05	2.13E-05	2.281014	0.0225
Yield	α_1	0.155659	0.026591	5.853876	0.0000	0.090057	0.029769	3.025180	0.0025
GARCH(1,1)	β_1	0.811522	0.027031	30.02160	0.0000	0.849876	0.049565	17.14673	0.0000
Crude Oil	C2	0.051390	0.015808	3.250963	0.0012	0.100392	0.097412	1.030591	0.3027
Futures trading Volume	α_2	0.254575	0.105371	2.415988	0.0157	0.150000	0.142168	1.055090	0.2914
GARCH(1,1)	β_2	0.336003	0.156946	2.140887	0.0323	0.600000	0.373202	1.607707	0.1079
Crude Oil Futures open	C3	0.016412	0.003283	4.998375	0.0000	0.027516	0.007613	3.614167	0.0003
interest	α_3	0.031106	0.011592	2.683404	0.0073	0.142223	0.070123	2.028200	0.0425
GARCH(1,1)	β_3	0.480186	0.093731	5.123046	0.0000	0.505033	0.031621	15.97146	0.0000
Crude oil futures inventory	C4	0.000325	1.37E-05	23.79113	0.0000	8.26E-06	6.34E-07	13.02145	0.0000
GARCH(1,1)	α_4	0.008344	0.000754	11.07083	0.0000	0.073686	0.005697	12.93519	0.0000
	β_4	0.965475	0.001633	591.2176	0.0000	0.914170	0.003576	255.6538	0.0000

From the GARCH estimation results of crude oil futures variable fluctuations before and after the introduction of crude oil options in the above table, the following conclusions can be drawn.

The values （$\alpha_1+\beta_1$）in the GARCH(1,1) model estimation results for crude oil futures price yields fluctuations before and after the launch of crude oil options are 0.9731, 0.9400 respectively, there is a slight weakening, indicating that the impact of information on the volatility of crude oil futures price yields is slightly weakening, that is, the long-term memory of volatility is slightly weakened, and the value α_1 has weakened, the value β_1 has strengthened, indicating that after the launch of crude oil options, the impact of new market information is weakening, and the impact on the volatility of crude oil futures prices is weakening. The rate of absorption of new information is decreasing, while the impact of historical information on volatility is increasing, indicating that the speed of processing information in the crude oil futures price market has decreased after the introduction of crude oil options.

The values （$\alpha_2+\beta_2$） in the GARCH(1,1) model estimation results for crude oil futures trading volume fluctuations before and after the launch of crude oil options are 0.5906, 0.7500 respectively, there is a certain enhancement, indicating that the impact of information on the volatility of crude oil futures trading volume is increasing, that is, the long-term memory of fluctuations has been enhanced to a certain extent, and the value α_2 has weakened, and the value β_2 has been enhanced, indicating that after the launch of crude oil options, the impact of new market information is weakening, and the impact on the volatility of crude oil futures trading volume is weakening. The speed of absorbing new information is weakening, while the impact of historical information on volatility is increasing, indicating that after the launch of crude oil options, the speed of processing information in the crude oil futures volume market has generally increased.

The values ($\alpha_3+\beta_3$) in the estimation results of the GARCH(1,1) model of crude oil futures open interest fluctuations before and after the launch of crude oil options are 0.5112, 0.6472 respectively, which has a certain strengthening, indicating that the impact of information on the volatility of crude oil futures open interest is increasing, that is, the long-term memory of fluctuations has been enhanced to a certain extent, and the value α_3, β_3 has been enhanced, indicating that after the launch of crude oil options, the impact of new market information is increasing, and the impact on the volatility of crude oil futures open interest is increasing. The speed of absorbing new information is increasing, and the impact of historical information on volatility is also increasing, indicating that after the introduction of crude oil options, the speed of processing information on open interest in the crude oil futures market has increased.

The values ($\alpha_4 + \beta_4$) in the estimation results of the GARCH(1,1) model of crude oil futures inventory fluctuations before and after the launch of crude oil options are 0.9738, 0.9879 respectively, which has a certain strengthening, indicating that the impact of information on the volatility of crude oil futures inventories is increasing, that is, the long-term memory of fluctuations has been enhanced to a certain extent, and the value α_4 has been enhanced, and the value β_4 has weakened, indicating that after the launch of crude oil options, the impact of new market information is increasing, and the impact on the volatility of crude oil futures inventories is increasing. The speed of absorbing new information is increasing, while the impact of historical information on volatility is decreasing, indicating that the speed of processing information in the crude oil futures inventory market has increased after the introduction of crude oil options.

4.4 Analysis of the Impact of the COVID-19 on the Volatility of Crude Oil Futures Variables before the Introduction of Crude Oil Options

From above analysis, it can be seen that simply considering the impact of crude oil options on the fluctuation of crude oil futures market before and after the launch of crude oil options, the impact of option launch on the fluctuation of crude oil futures micro market indicators (futures price, trading volume, open interest, inventory) is limited, which only has a weakened impact on the fluctuation of futures trading volume and inventory, and has an enhanced impact on the fluctuation of futures price and open interest.

The reason for this phenomenon may be due to the impact of the COVID-19 epidemic, we analyze the fluctuation of crude oil futures market variables before and after the emergence of the COVID-19 epidemic. We added the dummy variable D2 to the GARCH model of the crude oil futures market variables (futures price, trading volume, open interest, inventory), that is, the D2 value was 0 before the COVID-19 outbreak, and the D2 value was 1 after the COVID-19 outbreak and before the launch of crude oil options. First of all, we determine the form of ARMA of each variable, and determine the order of each ARMA model according to the autocorrelation and partial autocorrelation function graphs of crude oil futures prices, trading volume, open interest, and inventory logarithmic first-order difference series (limited in length, specific graphs omitted). After testing, the crude oil futures price, trading volume, open interest, and inventory logarithmic first-order difference sequence before the launch of the option are as follows: ARMA(1,1), ARMA(2,2), ARMA(17,1), ARMA(1,1) (limited in length, specific test omitted). Then the GARCH model is estimated again, and the specific results are as follows:

Table 5. GARCH(1,1) model estimation with dummy variable D2

Model	α	β	λ	$\alpha + \beta$
GARCH(1,1) model estimate of crude oil	0.160803	0.778098	2.20E-05	
futures price yield	(0.0000)	(0.0000)	(0.0720)	0.9389
GARCH(1,1) model estimate of Crude oil	0.478664	0.103913	-0.056796	
futures trading volume fluctuation	(0.0000)	(0.0242)	(0.0000)	0.5826
GARCH(1,1) model estimate of crude oil	0.070560	0.256024	-0.006588	
futures open interest	(0.0041)	(0.0000)	(0.0054)	0.3266
GARCH(1,1) Model Estimate of Crude Oil	0.009219	0.953421	-0.000790	
Futures Inventories	(0.0000)	(0.0000)	(0.0000)	0.9626

Note: The values in parentheses in the table are p-values, λ is dummy variable coefficients, and the following are similar. The ARCH effect test was carried out on the above-mentioned GARCH (1,1) model of fluctuations of crude oil futures variables with dummy variable D2, and the results were all tested, and each model effectively fitted the conditional heteroscedasticity of the residual sequence, indicating that the setting of each GARCH model introduced into the dummy variable D2 was valid (limited in space, specific test results omitted).

Based on the above test results, the following conclusions can be obtained:

For the GARCH(1,1) model estimation of crude oil futures price yield added to the dummy variable D2, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and satisfies the characteristics of the volatility cluster. The sum of α and β is 0.9389, close to 1, indicating that the information shock has a long-term volatility impact on the price yield of crude oil futures. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures price yields is small, and the speed of digesting new information is slow. A large GARCH coefficient β indicates that the impact of historical information is large. The dummy variable coefficient λ is greater than 0, significant at the 10% level, and the COVID-19 epidemic has increased volatility of crude oil futures price yields.

For the GARCH(1,1) model estimation of crude oil trading volume added to the dummy variable D2, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and satisfies the characteristics of the volatility cluster. The sum of α and β is 0.5826, indicating that the information shock has a short-term volatility impact on the fluctuation of crude oil futures trading volume. The ARCH term coefficient α is large, indicating that the new information has a greater impact on the volatility of crude oil futures trading volume, and the speed of digesting new information is faster. The GARCH coefficient β is small, indicating that the impact of historical information is small. The dummy variable coefficient λ is negative and significant at the 1% level, indicating that the volatility of crude oil futures trading volume fluctuations has been reduced after the emergence of the COVID-19 epidemic, and the degree of reduction is limited due to the relatively small coefficient value.

For the GARCH (1,1) model estimation of crude oil open interest added to the dummy variable D2, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.3266, indicating that the information shock has a short-term volatility impact on the volatility of crude oil futures open interest. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures open interest is small, and the speed of digesting new information is slow. The GARCH coefficient β is large, indicating that the impact of historical information is large. The dummy variable coefficient λ is negative and significant at the 1% level, indicating that the volatility of crude oil futures open interest fluctuations has been reduced after the emergence of the COVID-19 epidemic, and the degree of reduction is limited due to the relatively small coefficient value.

For the estimation results of the GARCH(1,1) model of crude oil futures inventory fluctuation with the addition of the dummy variable D2, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.9626, indicating that the information shock has a long-term volatility impact on the volatility of crude oil futures inventory. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures inventory is small, and the speed of digesting new information is slow. The GARCH coefficient β is large, indicating that the impact of historical information is large. The dummy variable coefficient λ is negative and significant at the 1% level, indicating that the volatility of crude oil futures inventory fluctuations has been reduced after the emergence of the COVID-19 epidemic, and the degree of reduction is limited due to the relatively small coefficient value.

In summary, before the listing of crude oil options, the emergence of the COVID-19 epidemic had a certain impact on the fluctuation of crude oil futures market variables, which enhanced the fluctuation of crude oil futures price yields to a certain extent, and reduced the trading volume, open interest and inventory volatility of crude oil futures.

4.5 An Empirical Analysis of the Impact of Crude Oil Options Listing after the Emergence of the COVID-19

From the above analysis, it can be seen that the emergence of the COVID-19 epidemic has a certain impact on the volatility of various variables in the crude oil futures market, in order to study more deeply the impact of crude oil options before and after the listing of crude oil options on the volatility of crude oil futures market variables, we analyze the impact of crude oil options after the emergence of the COVID-19 epidemic on the volatility of crude oil futures market variables, we add dummy variable D3 to the GARCH model of crude oil futures market variables (futures price, trading volume, open interest, inventory), That is, when the D3 value is 0 after the outbreak of the COVID-19 epidemic and before the listing of crude oil options, and the D3 value is 1 after the listing of crude oil options, the GARCH model is then estimated. Firstly, the order of each ARMA model is determined according to the autocorrelation and partial autocorrelation function graphs of the first-order differential sequence of crude oil futures price, trading volume, open interest and inventory logarithm (limited in length, specific images omitted). After testing, the first order difference series of crude oil futures price, trading volume, open interest and inventory logarithm are obtained by each ARMA model: ARMA(1,1), ARMA(3,1), ARMA(17,2), ARMA(1,1) (limited in length, specific test omitted).

The GARCH(1,1) model estimates for each market variable of crude oil futures added to the dummy variable D3 are shown in the table below.

Table 6. Estimation results of each GARCH(1,1) model added to the dummy variable D3

Model	α	β	λ	$\alpha + \beta$
GARCH(1,1) model estimate of crude oil futures price yield	0.113365 （0.0000）	0.830853 （0.0000）	1.15E-05 （0.2756）	0.9442
GARCH(1,1) model estimate of Crude oil futures trading volume fluctuation	0.087589 （0.087589）	0.343375 （0.4421）	-0.012851 （0.2727）	0.4310
GARCH(1,1) model estimate of crude oil futures open interest	0.046058 （0.0000）	0.510236 （0.0000）	-0.007183 （0.0000）	0.5563
GARCH(1,1) Model Estimate of Crude Oil Futures Inventories	0.053650 （0.2517）	0.402852 （0.0681）	-0.000863 （0.0685）	0.4565

Note: The above GARCH(1,1) models of crude oil futures variables added to the dummy variable D3 were tested for ARCH effect in two time intervals, and each model effectively fit the conditional heteroscedasticity of the residual sequence, indicating that the setting of each GARCH model introduced into the dummy variable D3 is valid (limited in space, specific test results omitted).

From the above estimates, it can be seen that:

For the estimation of GARCH(1,1) model of crude oil futures price yield added to the dummy variable D3, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.9442, close to 1, indicating that the information shock has a long-term volatility impact on crude oil futures price yield. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures prices yield is small, and the speed of digesting new information is slow. A large GARCH coefficient β indicates that the impact of historical information is large. The dummy variable coefficient λ value is 1.15E-05, which is not significant, indicating that after the outbreak of the COVID-19 epidemic, compared before with after the introduction of crude oil options, the volatility of crude oil futures price yields has not increased significantly.

For the estimation of GARCH(1,1) model of crude oil futures trading volume added to the dummy variable D3, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.4310, indicating that the information shock has a short-term volatility impact on the fluctuation of crude oil futures trading volume. The ARCH term coefficient α is large, indicating that the new information has a greater impact on the volatility of crude oil futures trading volume, and the speed of digesting new information is faster. The GARCH coefficient β is small, indicating that the impact of historical information is small. The dummy variable coefficient λ is -0.0129, indicating that after the outbreak of the COVID-19 epidemic, the volatility of crude oil futures trading volume has been reduced after the introduction of crude oil options, and the degree of impact is limited because the coefficient values are not significant enough.

For the estimation of GARCH(1,1) model of crude oil futures open interest added to the dummy variable D3, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.5563, indicating that the information shock has a short-term volatility impact on the fluctuation of crude oil futures open interest. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures open interest is small, and the speed of digesting new information is slow. The GARCH coefficient β is large, indicating that the impact of historical information is large. The dummy variable coefficient λ is -0.0071 and is significant at the 1% level, indicating that after the outbreak of the COVID-19 epidemic, the introduction of crude oil options has reduced the volatility of crude oil futures open interest, and the degree of reduction is limited due to the relatively small coefficient value.

For the estimation of GARCH(1,1) model of crude oil futures repertory added to the dummy variable D3, the ARCH term α and GARCH term coefficient β are significantly greater than 0, indicating that the volatility of the previous period has a positive impact on the current period and meets the characteristics of the volatility cluster. The sum of α and β is 0.4565，indicating that the information shock has a short-term volatility impact on the fluctuation of crude oil futures repertory. The ARCH term coefficient α is small, indicating that the impact of new information on the volatility of crude oil futures repertory is small, and the speed of digesting new information is slow. The GARCH coefficient β is large, indicating that the impact of historical information is large. The dummy variable coefficient λ is -0.0009 and is significant at the 10% level, indicating that the introduction of crude oil options has reduced the volatility of crude oil futures inventory fluctuations after the outbreak of the COVID-19 epidemic. The small value of the coefficient indicates that the extent of the impact is limited.

In summary, the listing of crude oil options after the emergence of the COVID-19 epidemic has a certain impact on the fluctuation of crude oil futures market variables, which has enhanced the volatility of crude oil futures price yield to a certain extent, and reduced the trading volume, open interest and inventory volatility of crude oil futures. Compared with the fluctuation of crude oil futures market variables caused by the COVID-19 epidemic before the launch of crude oil options, the volatility of crude oil futures price yield is weakened, the degree of weakening of trading volume fluctuation is reduced, and the reduction in open interest and inventory volatility is not obvious.

4.6 EGARCH Model Estimation of Asymmetric Fluctuations before and after the Launch of Crude Oil Options

The above we have compared and analyzed the fluctuations of various variables in the crude oil futures market by the listing of crude oil options in the whole sample, the fluctuations of various variables in the crude oil futures market by the outbreak of the COVID-19 epidemic before the listing of crude oil options, and the fluctuation of various variables in the crude oil futures market before and after the listing of crude oil options after the COVID-19 outbreak of the GARCH model. The following uses the EGARCH model to estimate and analyze the asymmetric leverage effect changes of crude oil futures market variable fluctuations before and after the listing of crude oil options.

4.6.1 EGARCH Model Estimation under the Full Sample

The following analysis in the full sample range, crude oil futures market fluctuation asymmetric leverage effect EGARCH model estimate, in order to be consistent with the aforementioned estimated GARCH(1,1) model, below we use EGARCH(1,1) model for empirical estimation, the specific estimation results are shown in the following table:

Table 7. Estimation of EGARCH model under the full sample

Model	Variable	Coefficient	Std. Error	z-Statistic	Prob.
EGARCH(1,1) model	ω_1	-0.651748	0.104314	-6.247921	0.0000
estimate of Crude oil futures	α_1	0.292036	0.032882	8.881334	0.0000
price yield	γ_1	-0.043791	0.016463	-2.660019	0.0078
	β_1	0.943225	0.012174	77.48045	0.0000
EGARCH(1,1) model	ω_2	-2.478837	0.132023	-18.77585	0.0000
estimate of Crude oil futures	α_2	0.777517	0.097628	7.964050	0.0000
trading volume	γ_2	-0.151041	0.057717	-2.616935	0.0089
	β_2	0.122633	0.052942	2.316370	0.0205
EGARCH(1,1) model	ω_2	-1.731656	0.088058	-19.66501	0.0000
estimate of Crude oil futures	α_3	0.761396	0.041940	18.15428	0.0000
open interest	γ_3	-0.741199	0.040628	-18.24332	0.0000
	β_3	0.708768	0.018995	37.31414	0.0000
EGARCH(1,1) Model	ω_4	-7.041530	0.434867	-16.19236	0.0000
estimate of Crude Oil	α_4	0.065356	0.014285	4.575286	0.0000
Futures Inventory	γ_4	-0.016708	0.004086	-4.088777	0.0000
	β_4	0.313502	0.035848	8.745220	0.0000

Note：where ω is constant，α , β , γ is coefficient，and the following are similar.

The ARCH effect test is carried out on the EGARCH(1,1) model of each variable of crude oil futures mentioned above, and the results are as follows:

Table 8. ARCH effect Test of EGARCH(1,1) model under the whole sample

Crude Oil Futures Price Yield EGARCH(1,1)	F-statistic	0.329302	Prob. F(1,1090)	0.5662
Model ARCH Effect Test	Obs*R-squared	0.329806	Prob. Chi-Square(1)	0.5658
Crude oil futures trading volume EGARCH(1,1)	F-statistic	0.106102	Prob. F(1,1089)	0.7447
model ARCH effect test	Obs*R-squared	0.106287	Prob. Chi-Square(1)	0.7444
Crude oil futures open interest EGARCH(1,1)	F-statistic	0.017440	Prob. F(1,1074)	0.8950
model ARCH effect test	Obs*R-squared	0.017472	Prob. Chi-Square(1)	0.8948
Crude oil futures inventory EGARCH(1,1)	F-statistic	0.009012	Prob. F(1,1090)	0.9244
model ARCH effect test	Obs*R-squared	0.009029	Prob. Chi-Square(1)	0.9243

From the above ARCH effect test results, it can be seen that the test statistics are not significant, and the corresponding P values are greater than 10%, indicating that the models are effectively fitted to the conditional heteroscedasticity of the residual sequence, indicating that the settings of each EGARCH model are valid, and the conclusions are obtained according to the above test results as follows:

The asymmetric coefficient of crude oil futures price yield fluctuation in the EGARCH model is -0.0438, indicating that there is a weak negative asymmetric leverage effect in the series, and the influence of bearish news is greater than the influence of bullish news. The bullish news had a 0.2482 times ($\alpha_1 + \gamma_1$) impact on the fluctuation of crude oil futures price yield. Bearish news has a 0.3358 times ($\alpha_1 - \gamma_1$) impact on the volatility of crude oil futures price yield.

The asymmetric coefficient in the EGARCH model of crude oil futures trading volume fluctuation is -0.1510, indicating that there is a negative asymmetric leverage effect in the series, and the influence of bearish news is greater than the influence of bullish news. The bullish news had a 0.6265 times ($\alpha_1 + \gamma_1$) impact on the fluctuation of crude oil futures trading volume. Bearish news has a 0.9286 times ($\alpha_1 - \gamma_1$) impact on the volatility of crude oil futures trading volume.

The asymmetric coefficient of crude oil futures open interest fluctuation in the EGARCH model is -0.7412, indicating that there is a negative strong asymmetric leverage effect in the series, and the impact of bearish news is much greater than the impact of bullish news. The bullish news has a +0.0202 times ($\alpha_1 + \gamma_1$) impact on the fluctuation of crude oil futures positions. Bearish news has a 1.5026 times ($\alpha_1 - \gamma_1$) impact on the volatility of crude oil futures positions.

The asymmetric coefficient in the EGARCH model of crude oil futures inventory fluctuation is -0.0167, indicating that there is a weak negative asymmetric leverage effect in the series, and the impact of bearish news is slightly greater than the impact of bullish news. The bullish news had a 0.0486 times ($\alpha_1 + \gamma_1$) impact on the volatility of crude oil futures inventories. Bearish news has a 0.0821 times ($\alpha_1 - \gamma_1$) impact on the volatility of crude oil futures inventories, and the long-short factors have a small impact on it.

4.6.2 Comparative Analysis of EGARCH Model Estimates before and after the Launch of Crude Oil Options

In order to further analyze the improvement of the asymmetric leverage effect of crude oil futures market variable fluctuations after the launch of crude oil options, we compare and analyze the estimation of EGARCH model of crude oil futures market variables before and after the launch of crude oil options.

Due to the impact of the COVID-19 epidemic, we consider the impact of asymmetric leverage effect on the fluctuation of relevant variables in the crude oil futures market after the launch of crude oil options after the emergence of the COVID-19 epidemic, and the impact of asymmetric leverage effect on the fluctuation of relevant variables in the crude oil futures market after the launch of crude oil options without considering the COVID-19 epidemic.

We consider that after the emergence of the COVID-19 epidemic, we respectively compared and analyzed the estimation of crude oil futures market variables before and after the launch of crude oil options after the emergence of the COVID-19 epidemic (the specific test results are limited to space omission), and the specific model adopts the ARMA model form and EGARCH model form of each variable before and after the launch of crude oil options after the COVID-19 epidemic.

Regardless of the impact of the COVID-19 epidemic, the EGARCH(1,1) model estimation on the fluctuation of crude oil futures-related variables before and after the launch of crude oil options is compared and analyzed (specific test results are limited to space omission), and the specific model adopts the ARMA model form and EGARCH(1,1) model form of each variable in the time interval before and after the introduction of crude oil options. The comparison results of the specific model parameter estimation are shown in the following table:

Table 9. Comparison of EGARCH(1,1) model estimates before and after crude oil option listing

Model	Time interval	α	γ	$\alpha+\gamma$	$\alpha-\gamma$
Crude oil futures price yield EGARCH(1,1) model estimates	Before crude oil options are listed	0.316721（0.0000）	-0.090648（0.0001）	0.2261	0.4074
	Before the listing of crude oil options after the emergence of the epidemic	0.276445（0.0030）	-0.096562（0.0348）	0.1799	0.3730
	After the listing of crude oil options	0.164797 (0.0092)	0.067826 (0.0577)	0.2326	0.0970
Crude oil futures trading volume EGARCH(1,1) model estimates	Before crude oil options are listed	0.091748（0.0001）	-0.304406（0.0007）	-0.2127	0.3962
	Before the listing of crude oil options after the emergence of the epidemic	0.400186 (0.0000)	0.192100（0.0048）	0.5923	0.2081
	After the listing of crude oil options	0.037693 (0.0018)	-0.174874 (0.0039)	-0.1372	0.2126
Crude oil futures open interest EGARCH(1,1) model estimates	Before crude oil options are listed	0.880069（0.0000）	-0.576220（0.0000）	0.3038	1.4563
	Before the listing of crude oil options after the emergence of the epidemic	1.085159 (0.0000)	-0.898973 (0.0000)	0.1862	1.9841
	After the listing of crude oil options	0.697222 (0.0000)	-0.655873 (0.0000)	0.0413	1.3531
Crude Oil Futures Inventory EGARCH(1,1) Model estimates	Before crude oil options are listed	-0.076418（0.0255）	-0.161694（0.0000）	-0.2381	0.0853
	Before the listing of crude oil options after the emergence of the epidemic	0.528688（0.0003）	-0.301388（0.0007）	0.2272	0.8301
	After the listing of crude oil options	-1.053832（0.0000）	-0.150527（0.0002）	-1.2044	-0.9033

As can be seen from the above table results, the estimation parameters of each EGARCH(1,1) model before and after the listing of crude oil options are significant at the level of 10%, and we compare and analyze the above parameters as follows:

4.6.3 Comparison of Asymmetric Leverage Effects of Crude Oil Futures Price Yield Fluctuations before and after the Launch of Crude Oil Options

In both cases of whether to consider the impact of the COVID-19 epidemic, there were $\gamma < 0$ and $\alpha+\gamma < \alpha-\gamma$ before the launch of the crude oil option and the results were the same as the results of the full sample analysis, and the impact of the negative news was greater than the impact of the bullish news. There were $\gamma > 0$ and $\alpha+\gamma > \alpha-\gamma$ after the launch of crude oil options, the impact of bullish news is greater than the impact of bearish news.

It shows that the asymmetric leverage effect has changed before and after the launch of crude oil options under the influence of the COVID-19 epidemic, and has changed from negative asymmetry to positive asymmetry, because the value $|\gamma|$ is basically the same before the launch of crude oil options regardless of whether the epidemic is COVID-19 considered, and slightly smaller after the listing of crude oil options, indicating that the asymmetric leverage effect of crude oil futures price yield fluctuations is slightly smaller after the listing of crude oil options. Due to the small values $\alpha+\gamma, \alpha-\gamma$ before and after the introduction of crude oil options, the positive and negative asymmetry is not obvious.

In order to more intuitively observe the asymmetric leverage effect caused by the information shock, the following information impact curve of crude oil futures price yield fluctuations before the launch of crude oil options, before the launch of crude oil options after the emergence of the COVID-19 epidemic, and after the launch of crude oil options is as follows:

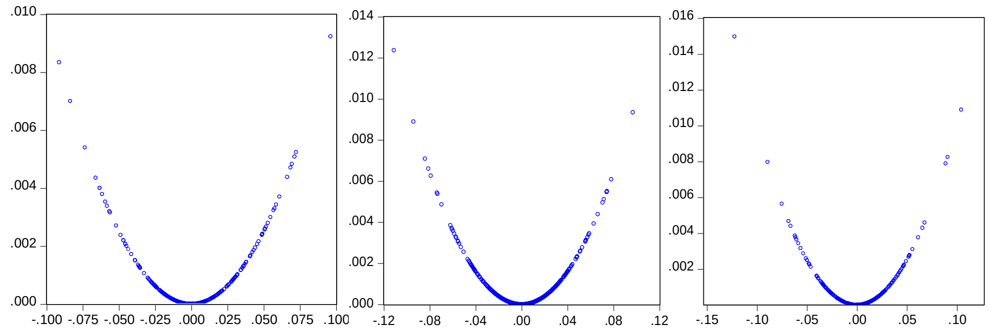

Figure 2. Crude oil futures price yield information impact curve

From the above crude oil futures price yield information impact curve, it can be seen that regardless of the impact of the COVID-19 epidemic, there is a certain asymmetry before and after the launch of crude oil options, the asymmetry has turned from negative to positive, and the degree of asymmetric leverage effect is not significant. It can be seen that the COVID-19 epidemic has an impact on the asymmetric leverage effect of crude oil futures price yield fluctuations before and after the launch of crude oil options, but it is not obvious enough.

4.6.4 Comparison of Asymmetric Leverage Effects of Crude Oil Futures Trading Volume Fluctuations before and after the Launch of Crude Oil Options

Regardless of the impact of the COVID-19 epidemic, there were $\gamma < 0$ and $\alpha + \gamma < \alpha - \gamma$ before and after the launch of the crude oil option and the results are the same as the results of the full sample analysis, the impact of bearish news is greater than the impact of bullish news, and the asymmetry before and after the launch of crude oil options is negative, and the symmetry has weakened.

Considering the impact of the COVID-19 epidemic, there were $\gamma > 0$ and $\alpha + \gamma > \alpha - \gamma$ before the launch of crude oil options after the emergence of the COVID-19 epidemic, and the results are contrary to the results of the full sample analysis, the impact of bullish news is greater than the impact of bearish news, and there were $\gamma < 0$ and $\alpha + \gamma < \alpha - \gamma$ after the launch of crude oil options, the impact of bearish news is greater than the impact of bullish news.

It shows that under the influence of the COVID-19 epidemic, the asymmetric leverage effect of crude oil futures variables have changed before and after the listing of crude oil options after the emergence of the COVID-19 epidemic, from positive asymmetry to negative asymmetry. Since the value $|\gamma|$ becomes smaller after the listing of crude oil options, it indicates that the asymmetric leverage effect of crude oil futures trading volume fluctuations after the listing of crude oil options after the emergence of the COVID-19 epidemic becomes smaller and decreases less than the leverage effect without considering the impact of the COVID-19 epidemic.

In order to more intuitively observe the asymmetric leverage effect generated by the information shock, the following information impact curve of crude oil futures trading volume fluctuations before the launch of crude oil options, before the launch of crude oil options after the emergence of the COVID-19 epidemic, and after the launch of crude oil options is as follows:

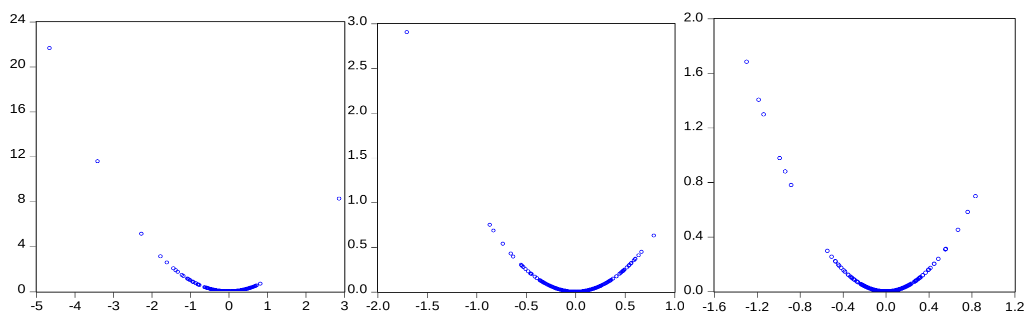

Figure 3. Crude oil futures trading volume information impact curve

From the above crude oil futures trading volume information impact curve, it can be seen that there is a certain negative asymmetry before and after the launch of crude oil options without considering the impact of the epidemic, and the asymmetric leverage effect is weakened after the launch of crude oil options. After the emergence of the epidemic, there was a certain asymmetry before and after the launch of crude oil options, the asymmetry turned from positive to negative, and the degree of asymmetric leverage effect weakened. It can be seen that the epidemic has a certain impact on the asymmetric leverage effect of crude oil futures trading volume fluctuations before the launch of crude oil options.

4.6.5 Comparison of Asymmetric Leverage Effects of Fluctuations in Crude Oil Futures Open Interest before and after the Launch of Crude Oil Options

Regardless of whether the impact of the COVID-19 epidemic is considered, there are $\gamma < 0$ and $\alpha + \gamma < \alpha - \gamma$ before and after the launch of crude oil options, and the results are the same as the results of the full sample analysis, and the impact of bearish news is greater than the impact of bullish news.

Regardless of the impact of the COVID-19 epidemic, because the values of $\alpha + \gamma$ and $\alpha - \gamma$ have become smaller after the listing of crude oil options, it shows that the impact of bullish news and the impact of bearish news have become smaller. Since the value $|\gamma|$ becomes smaller after the listing of crude oil options, it indicates that the asymmetric leverage effect of crude oil futures open interest fluctuations is slightly larger after the listing of crude oil options without considering the impact of the epidemic. Considering the impact of the epidemic, the impact of bullish news and bearish news has become smaller, and the asymmetric leverage effect has become slightly smaller after the listing of crude oil options.

In order to more intuitively observe the asymmetric leverage effect generated by the information shock, the following information impact curves of crude oil futures open interest fluctuations before the launch of crude oil options, before the launch of crude oil options after the emergence of the epidemic, and after the launch of crude oil options are as follows:

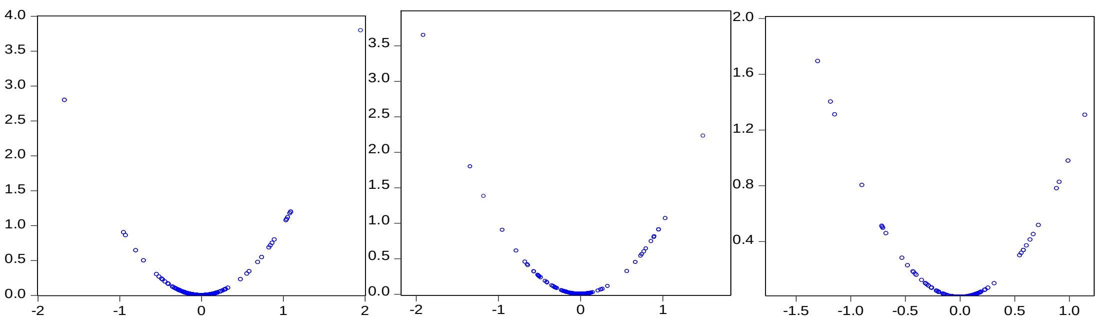

Figure 4. Crude oil futures open interest information impact curve

From the above information impact curve, it can be seen that regardless of the impact of the epidemic, there is a certain negative asymmetry before and after the launch of crude oil options, and the asymmetric leverage effect after the launch of crude oil options is slightly larger without considering the impact of the epidemic. Considering the impact of the epidemic, the asymmetric leverage effect of crude oil futures open interest fluctuations after the launch of crude oil options has become slightly smaller. Therefore, the epidemic has a certain impact on the leverage effect of fluctuations in crude oil futures open interest after the launch of crude oil options.

4.6.5.1 Comparison of Asymmetric Leverage Effects of Crude Oil Futures Inventory Fluctuations before and after the Launch of Crude Oil Options

Regardless of whether the impact of the epidemic is considered, there are $\gamma < 0$ and $\alpha + \gamma < \alpha - \gamma$ before and after the launch of crude oil options, and the results are the same as the results of the full sample analysis, and the impact of bearish news is greater than the impact of bullish news. Regardless of whether the impact of the epidemic is considered, the value $\alpha + \gamma$ and $\alpha - \gamma$ after the launch of crude oil options has become smaller, indicating that the impact of bullish news and the impact of bearish news have become smaller.

The value $|\gamma|$ is slightly smaller after the listing of crude oil options, but the degree of reduction is slightly greater under the influence of the epidemic, indicating that the asymmetric leverage effect of crude oil futures inventory fluctuations becomes smaller after the listing of crude oil options, regardless of the impact of the epidemic.

In order to more intuitively observe the asymmetric leverage effect generated by the information shock, the following information impact curves of crude oil futures inventory fluctuations before the launch of crude oil options, before the launch of crude oil options after the emergence of the epidemic, and after the launch of crude oil options are as follows:

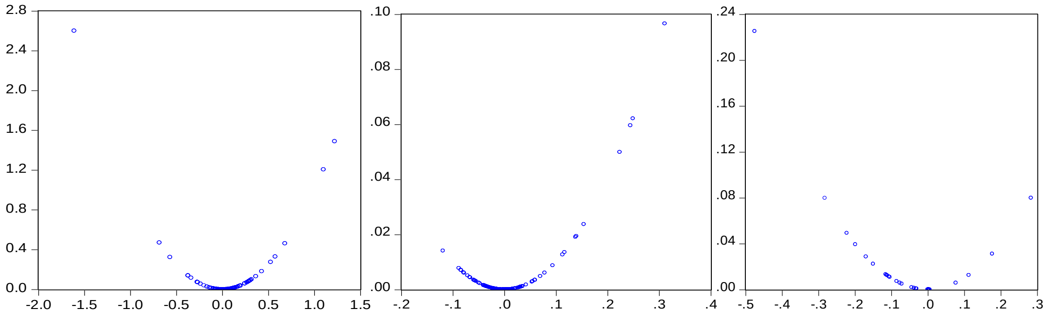

Figure 5. Crude oil futures inventory information impact curve

From the above information impact curve, it can be seen that regardless of the impact of the epidemic, there is a certain negative asymmetry before and after the launch of crude oil options, and the asymmetric leverage effect weakens after the launch of crude oil options.

5. Conclusion

This paper uses the GARCH class model to empirically study the impact of crude oil option listing on the volatility and asymmetric leverage effect of crude oil futures market variables (price, trading volume, open interest, inventory). The following conclusions were drawn:

First, from the perspective of the full sample range without considering the impact of the epidemic, the information shock after the launch of crude oil options has a long-term volatility impact on crude oil futures price yield, open interest and inventory fluctuations, and has a short-term volatility impact on trading volume. The launch of crude oil options has aggravated the volatility of crude oil futures price yield, reduced trading volume, open interest and inventory volatility. After the launch of crude oil options, the speed of processing information in the crude oil futures price market has decreased, while the speed of processing information on trading volume, open interest and inventory market has increased.

Second, considering the impact of the epidemic on the crude oil futures market, the information shock has a long-term volatility impact on the price yield and inventory fluctuations of crude oil futures, and has a short-term volatility impact on the fluctuation of trading volume and open interest. The emergence of the epidemic has increased the volatility of crude oil futures price yield, reduced the volatility of crude oil futures trading volume, open interest, and inventory fluctuations, and the degree of reduction of all three is limited.

Third, considering the impact of the launch of crude oil options on the crude oil futures market after the outbreak of the epidemic, the information shock has a long-term volatility impact on the price yield of crude oil futures, and has a short-term impact on trading volume, open interest and inventory. After the emergence of the epidemic, the launch of crude oil options has a certain impact on the fluctuation of crude oil futures market variables, which has enhanced the volatility of crude oil futures price yield to a certain extent, and reduced the trading volume, open interest and inventory volatility of crude oil futures. Compared with the fluctuation of crude oil futures market variables caused by the epidemic before the launch of crude oil options, the volatility of crude oil futures price yield is weakened, the degree of weakening of trading volume fluctuation is reduced, and the reduction in open interest and inventory volatility is not obvious.

Fourth, for the asymmetric leverage effect, without considering the impact of the epidemic, there is a negative asymmetric leverage effect on crude oil futures price yield, trading volume, open interest, and inventory volatility, and the impact of bearish news is greater than the impact of bullish news, among which the negative leverage effect of trading volume and open interest fluctuation is larger. Considering the impact of the epidemic, the asymmetric leverage effect of crude oil futures price yield fluctuations before and after the launch of crude oil options has changed, and all have changed from negative asymmetry to positive asymmetric leverage effect. Considering that there is a certain negative asymmetry in the fluctuation of trading volume before and after the launch of crude oil options under the influence of the epidemic, the asymmetric leverage effect of crude oil futures trading volume fluctuation after the emergence of the epidemic becomes smaller and the reduction is smaller than the leverage effect without considering the impact of the epidemic. Regardless of whether the impact of the epidemic is considered, there is a certain negative asymmetry in the fluctuation of open interest before and after the launch of crude oil options, and the asymmetric leverage effect after the launch of crude oil options becomes slightly larger regardless of the impact of the epidemic. Considering the impact of the epidemic, the asymmetric leverage effect of crude oil futures open interest fluctuations after the launch of crude oil options has been slightly weakened. Regardless of whether the impact of the epidemic is considered, there is a certain negative asymmetry in inventory fluctuations before and after the launch of crude oil options, and the asymmetric leverage effect is weakened after the launch of crude oil options.

In summary, the introduction of crude oil options has a certain impact on the volatility and asymmetric leverage effect of micro variables in the crude oil futures market, in order to better play the role of commodity options such as crude oil option, it is recommended as follows:

First, improve investor education in various forms

Due to the late launch of commodity options such as crude oil options, as a new trading variety in the futures market, investors have limited understanding of them, and the pricing of commodity options is more complex, applied to complex option pricing models, etc., increasing the difficulty of investors to participate in the transaction, exchanges and other institutions can carry out online or offline and other forms of investor education, improve investors' cognitive level, and continuously expand the scale of investor participation.

Second, constantly enrich the variety of commodity futures options

From the current point of view, the domestic commodity market has launched some commodity option varieties, from the number of which is still relatively small, in order to meet the hedging and investment needs of investors, as much as possible to launch as many existing commodity futures options as possible, to ensure the healthy development of the futures market. In addition, for a single variety of commodity options, you can also consider launching mini options with small contracts to activate the market and meet the diversified needs of the market.

Third, to meet the needs of internationalization and constantly improve relevant rules

As domestic commodity options are an innovative variety, they are constantly evolving. Relatively speaking, the threshold for participation in some varieties such as crude oil options is relatively high, and it can be considered to appropriately lower the threshold for investor participation with the development of the market. In addition, for some listed commodity option varieties, according to the needs of market development and internationalization, appropriately improve the relevant trading rules, such as the current market maker system of commodity options to gradually deregulate and achieve self-price adjustment, etc., which is more conducive to activating the market and attracting more international investors to enter the domestic market.

Fourth, continuously improve and upgrade the technical facilities and level of the commodity options market

Due to the complexity of the pricing of crude oil and other commodity options, the technical facilities and technical level of option trading are high, and for the settlement of options, the management of margin must also consider market price fluctuations and volatility, and it is necessary to upgrade the original clearing system. Investors need option trading software to be able to provide a variety of trading strategies according to the option pricing model, and need to be simple to operate, improve the convenience of investors to participate in options, which requires exchanges and brokerage companies to continuously improve the technical level of option trading and continuously improve technical facilities.

Fifth, strengthen supervision within the regulatory framework of the Futures Law

The promulgation of the Futures Law regulates the development of China's futures market, due to the complexity of option pricing and trading, the option trading market may have some risks, such as professional investors using professional advantages may cause excessive speculation on the option trading market, so within the framework of the Futures Law, strengthen the supervision of excessive speculation and other damage market behaviors, to ensure the stable operation of the futures and options market.

By studying the impact of crude oil option launch on the volatility of crude oil futures market, it can be seen that the launch of crude oil options does have a certain impact on the volatility of crude oil futures market price, volume, Interests, inventory, etc., and due to the impact of the COVID-19 epidemic, the launch of crude oil options has a more complex effect on the crude oil futures market. In order to further study the role of crude oil options on the crude oil futures market, in the future, a variety of frequency crude oil option data can be used to study the discovery effect of crude oil options on crude oil futures prices and the impact of options on the spot and futures market, so as to better reveal the operation law of the crude oil market.

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Apendix

Table 1. Descriptive statistics for each variable in the crude oil futures market

Time interval	Variable	mean	median	maximum	minimum	Standard Deviation	skewness	kurtosis	Jarque-Bera
full sample	DLNP	0.0004	0.0009	0.0973	-0.1413	0.0247	-0.2739	5.6121	324.6937
	DLNQ	0.0014	-0.0076	3.6359	-4.8023	0.4257	-0.7731	31.1661	36271.51
	DLNI	0.0022	-0.022	2.7705	-1.2985	0.2358	4.3476	37.0827	56397.28
	DLNS	0.0014	0.0000	1.2240	-1.6094	0.0965	-0.8378	120.6431	630996.4
Before the outbreak of the COVID-19 epidemic	DLNP1	-0.0007	0.0006	0.0746	-0.0945	0.0187	-0.5908	5.8448	187.8059
	DLNQ1	-0.0040	0.0010	2.8867	-4.8028	0.4995	-1.9321	29.6210	14321.49
	DLNI1	0.0054	-0.0060	0.7030	-0.8041	0.1208	0.9583	14.0886	2506.218
	DLNS1	0.0037	0.0000	1.2240	-1.6094	0.1371	-0.7049	67.9676	83575.88
after the outbreak of the COVID-19 epidemic to before the launch of crude oil options	DLNP2	0.0012	0.0002	0.0973	-0.11203	0.0286	-0.06204	4.2391	20.0304
	DLNQ2	0.0116	-0.0189	3.6359	-1.99432	0.3971	2.435232	28.32136	8588.20
	DLNI2	0.0006	-0.0340	2.7705	-1.29848	0.3018	4.270027	32.7037	12338.51
	DLNS2	0.0051	0.0000	0.3078	-0.11851	0.0444	3.929024	23.7226	6344.327
before the launch of crude oil options	DLNP3	0.0001	0.0005	0.0973	-0.112	0.0231	-0.1834	5.4447	199.8818
	DLNQ3	0.0022	-0.0039	3.6359	-4.8028	0.4616	-0.8801	30.7746	25333.40
	DLNI3	0.0035	-0.0177	2.7705	-1.2985	0.2115	4.9666	53.9976	88293.52
	DLNS3	0.0043	0.0000	1.2240	-1.6094	0.1102	-0.7317	98.6766	299482.7
after the launch of crude oil options	DLNP4	0.0013	0.0032	0.0938	-0.1413	0.0283	-0.4218	5.4036	83.5452
	DLNQ4	-0.0006	-0.0200	1.4354	-1.3179	0.3175	0.2485	7.7489	293.5386
	DLNI4	-0.0012	-0.0354	1.7093	-0.8201	0.2889	3.4517	19.0652	3936.493
	DLNS4	-0.0058	0.0000	0.2828	-0.4747	0.0459	-4.1544	49.732	29006.29

Note: P represents the domestic crude oil futures price, Q represents trading volume, I represents Open interest and S represents inventory. LN represents the logarithm and D represents the first-order difference, and the following are similar.

Table 2. ADF unit root test results

Time interval	Variable	Augmented Dickey-Fuller test statistic	Test type (c,t,n)	1% level	5% level	10% level	Durbin-Watson stat	whether or not stable
full sample	DLNP	-32.93544	(0,0,0)	-2.567079	-1.941113	-1.616504	1.999836	Yes
	DLNQ	-18.29238	(0,0,0)	-2.567093	-1.941115	-1.616503	1.995965	Yes
	DLNI	-16.93522	(0,0,0)	-2.567111	-1.941117	-1.616501	2.006764	Yes
	DLNS	-32.04102	(0,0,0)	-2.567079	-1.941113	-1.616504	2.000363	Yes
Before the outbreak of the COVID-19 epidemic	DLNP1	-18.56621	(0,0,0)	-2.569850	-1.941493	-1.616251	1.943869	Yes
	DLNQ1	-15.07686	(0,0,0)	-2.569881	-1.941497	-1.616248	1.988120	Yes
	DLNI1	-9.715901	(0,0,0)	-2.569923	-1.941503	-1.616244	2.003094	Yes
	DLNS1	-11.37881	(0,0,0)	-2.569871	-1.941496	-1.616249	2.000889	Yes
after the outbreak of the COVID-19 epidemic to before the launch of crude oil options	DLNP2	-17.93674	(0,0,0)	-2.572467	-1.941853	-1.616013	2.032191	Yes
	DLNQ2	-16.91655	(0,0,0)	-2.572516	-1.941860	-1.616008	2.028534	Yes
	DLNI2	-20.69990	(0,0,0)	-2.572467	-1.941853	-1.616013	2.035017	Yes
	DLNS2	-6.486517	(0,0,0)	-2.572516	-1.941860	-1.616008	2.031327	Yes
before the launch of crude oil options	DLNP3	-25.93189	(0,0,0)	-2.567915	-1.941227	-1.616428	2.002805	Yes
	DLNQ3	-19.40630	(0,0,0)	-2.567930	-1.941230	-1.616426	2.018717	Yes
	DLNI3	-31.88076	(0,0,0)	-2.567915	-1.941227	-1.616428	2.021360	Yes
	DLNS3	-27.09199	(0,0,0)	-2.567915	-1.941227	-1.616428	2.000248	Yes
after the launch of crude oil options	DLNP4	-19.66720	(0,0,0)	-2.572492	-1.941857	-1.616011	1.993776	Yes
	DLNQ4	-14.13100	(0,0,0)	-2.572566	-1.941867	-1.616004	2.040774	Yes
	DLNI4	-15.59034	(0,0,0)	-2.572516	-1.941860	-1.616008	2.032976	Yes
	DLNS4	-17.35109	(0,0,0)	-2.572492	-1.941857	-1.616011	2.000677	Yes

Note:D represents the first-order difference. C represents the intercept, t represents the time trend, n represents the order of lag, and the following are similar.