Whether the Air Transport is Going through the Difficulties: Evidence from Dynamic Changes in Brent Oil Prices

Jianhui Li[1, *, †], Xiaohan Wang[2, †] and Zichun Wang[3, †]

[1] Department of finance, Nankai University, Tianjin, 300350, China

[2] School of Applied Statistics, Anhui University, Hefei, 230039, China

[3] School of Mathematics and Statistics, University of Glasgow, Glasgow, G12 8QQ, UK

† These authors contributed equally.

*Corresponding author: 2012047@mail.nankai.edu.cn

Abstract: In 2020, the outbreak of COVID-19 caused a sharp drop in international crude oil prices. The outbreak of the Russian Ukrainian conflict in 2022 has also had a great impact on the fluctuation of international crude oil prices. So far as an important source of energy, the fluctuation of crude oil price is associated with the entire financial market. Therefore, this paper try to find how the air transport industry will going through the dynamic changes of its main source of energy——crude oil. Then the data of Brent oil price and air transportation industry index are selected from six months earlier before the Russian Ukrainian conflict broke out, used for constructing VAR model and ARMA-GARCH model with their logarithmic sequences. Through testing and observing the constructed Var model and ARMA-GARCH model, find the impact of international crude oil price changes on the yield and volatility of air transportation industry, so that the air transport industry can acquire the initiative of energy source.

Keywords: Crude Oil Price, Air Transportation Industry, Var Model, ARMA-GARCH Model.

1. Introduction

The prices of crude oil play a significant role in the global, economy environment, oil exploration and other relevant activities. Crude oil itself is one of the world's primary fuel [1]. Crude oil has also derived many related market economy concepts, and all of these are vital in worldwide financial markets. Many researches have shown that the changes in crude oil prices would have great effects on the entire financial market. For instance, crude oil has been a commodity which is associated with inflation in markets. The parice of crude oil is of great importance for the economy and international oil prices may affect foreign exchange market in the long term.

In recent years, some events have a profound influence on crude oil prices. The line chart below shows the crude oil price these years. A suddenly decrease in the price happened in 2020 due to the outbreak of Covid-19 in 2020 and some other complicated reasons, which increased uncertainty in crude oil supply and demand. In 2022, the war between Russia and Ukraine broke out and some countries imposed certain trade sanctions on Russia, which reduced the global supply of oil and led to significant fluctuations in international crude oil prices (please see Figure 1).

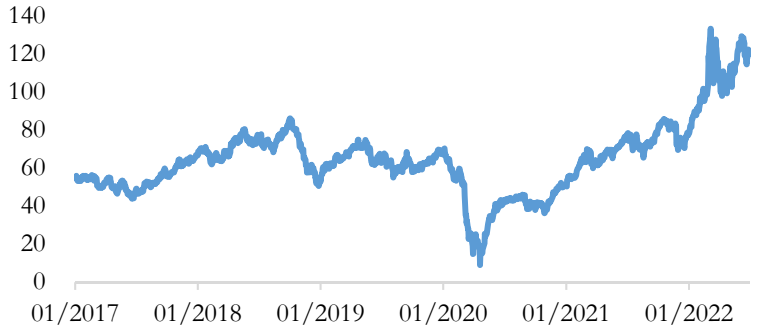

Fig.1 Crude oil price
Data Source: Federal Reserve Economic Data

As one of the most important energy sources for the air transport industry, changes in crude oil prices may affect the returns of the whole industry significantly. The air transport industry has become an indispensable mode of transport for travel and logistics activities due to its speed and comfort. With the economic development and the improvement of people's living standards, air transport services are playing an increasingly important role because of the efficiency of it.

The rest of this paper is organized are as follows: Part 2 is the literature review, which includes relevant research on impacts on crude oil prices of the war between Russia and Ukraine and the relationship between crude oil price and air transport industry, concluding with a summary of the literature review. Then it is followed by Part 3, which shows the data source and the models would be used for empirical analysis in the following part. After that, the fourth section will then construct Var model and ARMA-GARCHX model, respectively analyse the dynamic dependence, volatility and yield of the above relevant data's logarithmic series. The results of empirical analysis are used to demonstrate results of the empirical analysis that the impact of change in the price of crude oil on the profit of air transport industry, and finally to draw conclusions and give feasible and innovative suggestions for the future development of the Chinese air transport industry.

2. Literature Review

2.1 Studies related to the Russia-Ukraine war

Russia is abundant in energy and minerals and is an important energy producer and exporter around the whole world. The outbreak of Russia-Ukraine war has great effect on the global financial market. Tabash argues that knock-on effects have been caused by the Russia-Ukraine conflict all over the world. The price and the supply of major commodity markets have been deeply affected by the war, such as gold, silver, platinum, oil and gas [2]. Ahmed, M. Hasan and Kamal find that significant negative abnormal returns in European stocks happened as a result of the Russia-Ukraine crisis and these reactions continued after the event [3]. And in Nerlinger and Utz's research, coal, oil and gas firms generated comparably high abnormal returns than renewable energy, so the investors' assessment of green energy may not be affected greatly by the Russia-Ukraine conflict [4]. Petroleum intelligence weekly group points out that how highly the price of crude oil may finally go up will rely on a lot of factors, including the distance Russian troops have moved into Ukraine, whether Russia halts oil and gas flows to Europe and the US, the level of severity that energy flows get damaged in the conflict, and the sanctions are inflicted by the Western countries [5].

The conflict between Russia and Ukraine has changed the global energy supply in the short term and it is vital for China to attach great importance to energy security, regulate energy balance and accelerate energy transition. Yue, Zhang and Li argue that the conflict had a significant impact on international crude oil price volatility, but not on Chinese energy price volatility, and the cumulative price volatility in the international and Chinese crude oil markets during the Russia-Ukraine war was rapid and volatile, with a sustained effect [6].

2.2 Studies related to the relationship between crude oil price and air transport industry

For air transport industry, fuel expenditure takes up a large part of the gross costs. Therefore, airlines are exceptionally sensitive to changes in crude oil prices. Wensheng, Fernando and Ronald A mention that the increase of the oil price, the volatility of jet fuel price and the uncertainty of economic all have profound negative impact on stock returns of airlines both at firm level and at industry [7]. Kathiravan selects the performance of six airlines and and three crude oil markets between 1 January 2007 and 30 November 2018, finding that fluctuations in stock returns for most airlines were triggered by crude oil price [8]. Arif Billah Dar argues that in the short run some nexus may exist while there are no sustainable long-run nexus by using the methodology of wavelets and decomposing the aviation stocks and oil prices into different time horizons, so it is certain reasons that are not associated to the changes in crude oil price that resulted in sustainable long run movements in aviation stocks [9].

2.3 Review of the literature

Overall, the research on how the Russia-Ukraine war have effects on the price of crude oil and the relationship between crude oil price and air transport industry, but there is still relatively little research on the influence of the Russia-Ukraine war on the return of air transport industry because of the trade sanctions and other relevant factors that affect the crude oil price. It is difficult to predict the future development of Chinese air transport industry. Thus, this paper hopes to do more to fill the gaps in the research in this area and use empirical data to demonstrate the impact of the Russia-Ukraine war and long-term development of Chinese air transport industry.

3. Research Design

3.1 Data sources

In order to study the association between the fluctuation of crude oil price and the income and fluctuation of air transport industry, the Brent crude oil price data and the Air Transport industry index data were chosen from the "Choice Financial Terminal" and used in this paper. Both of the two selected data sets are from August 10, 2021 to August 11, 2022, which is also the time six months earlier when the Russian Ukrainian conflict broke out. Due to futures fluctuate more and change more, which makes it easier to identify its trend, the data is selected with the closing price of daily futures.

3.2 Unit root test

Since only the stationary time series have the significance of research, the price of Brent crude oil series and air transport industry index used in the paper need to do unit root test to verify whether they are stationary.

$$p_t = p_{t-1} + a_t \tag{1}$$

Define that random sequence $\{p_t\}$, t = 1,2,... is a unit root process, if the time series $\{p_t\}$ satisfies: $p_t = p_{t-1} + a_t$ (1), where p is a real number, it represents the starting value of the process, and $\{a_t\}$ is a white noise sequence, then p_t is called a random walk. Add a new factor μ to formula (1), where $\mu = E(p_t - p_{t-1})$, then formula (2) is called random walk with drift, and becomes nonstationary.

$$p_t = \mu + p_{t-1} + a_t \tag{2}$$

In order to check whether the sequence is stationary, set the original assumption H_0 as the sequence is nonstationary. The random walk with drift model is built as:

$$x_t = c_t + \beta x_{t-1} + \sum_{i=1}^{p-1} \varphi_i \Delta x_{t-i} + e_t \tag{3}$$

The process of unit root test used Augmented Dickey-Fuller test in formula (4). If the coefficient $\beta = 1$, there is a unit root, which means that the original assumption holds, the sequence is nonstationary. if $\beta \neq 1$, the original assumption was rejected, the sequence is stationary.

$$t = \frac{\hat{\beta} - 1}{standard\ deviation\ of\ \hat{\beta}} \tag{4}$$

It rejects the original assumption if the value of t in formula (4) is too large or if the obtained significance test statistic p value is less than 0.1, it rejects the original assumption, the sequence is stationary.

The result of ADF test in this part is shown at Table 1.

Table 1. ADF test

Variables	t-statistic	p-value
	Price	
Air transport	-3.107	0.1046
Brent	-2.175	0.5042
	Yield	
Air transport	-11.312	0.0000***
Brent	-11.619	0.0000***

3.3 VAR Model Setting

VAR model is used to predict the influence of international crude oil price changes on the return rate of air transportation industry. After judging whether each variable has stationarity, the VAR model is established as follow.

It is assumed that there are two time series intersections $\{y_{1t}, y_{2t}\}$, y_{1t} represents crude oil price and y_{2t} represents air transportation industry index, which are respectively used as explained variables of the two regression equations. And the explanatory variable is the p-order lag value of these two variables, forming a bivariate VAR (p) system:

$$\begin{cases} y_{1t} = \beta_{10} + \beta_{11} y_{1,t-1} + \cdots + \beta_{1p} y_{1,t-p} + \gamma_{11} y_{2,t-1} + \cdots + \gamma_{1p} y_{2,t-p} + \varepsilon_{1t} \\ y_{2t} = \beta_{20} + \beta_{21} y_{1,t-1} + \cdots + \beta_{2p} y_{1,t-p} + \gamma_{21} y_{2,t-1} + \cdots + \gamma_{2p} y_{2,t-p} + \varepsilon_{2t} \end{cases} \tag{5}$$

Write the above two equations (5) together and write them in matrix form in turn to get:

$$\begin{pmatrix} y_{1t} \\ y_{2t} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} \\ \beta_{21} \end{pmatrix} y_{1,t-1} + \cdots + \begin{pmatrix} \beta_{1p} \\ \beta_{2p} \end{pmatrix} y_{1,t-p} + \begin{pmatrix} \gamma_{11} \\ \gamma_{21} \end{pmatrix} y_{2,t-1} + \cdots + \begin{pmatrix} \gamma_{1p} \\ \gamma_{2p} \end{pmatrix} y_{2,t-p} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \tag{6}$$

Write the contemporaneous variables into column vectors, combine the corresponding coefficients into a matrix, and definite the corresponding coefficient matrix as $\Gamma_0, \Gamma_1, \cdots, \Gamma_p$:

$$y_t = \Gamma_0 + \Gamma_1 y_{t-1} + \cdots + \Gamma_p y_{t-p} + \varepsilon_t \tag{7}$$

The formula (7) is the VAR(p) model.

The Var model has been constructed in this part, then the following steps are the use of model.

Determine the order p of VAR model by using information criterion. This order cannot be too large or too small, if the order is too large, it will result in loss of degrees of freedom, which will directly affect the estimation accuracy of the model. However, if the lag order is too small, other problems will occur, and the validity of parameters will be affected due to insufficient information content [10]. The joint significance of the coefficients was tested by likelihood ratio (LR test), finding the minimum value and determine the order p to decide the maximum order of lag.

First, Before using VAR model for analysis, it is also necessary to check the stationarity of the model, which is a meaningful basic guarantee for all subsequent tests and analyses. If all the unit roots in pulse diagram are less than 1, which means all the Eigenvalues are in the unit circle, the VAR model is stable.

Second, Establish the impulse response function in which crude oil price and air transport yield are impulse variables and corresponding variables. Use impulse response function (formula (8)) to reflects the influence of an endogenous variable on its current value and future value after the influence on the error term.

The Impulse Response function (IRF):

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t{}'} = \psi_s \tag{8}$$

Formula (7) indicates the impact on the value $y_{i,t+s}$ of the i-th variable in the (t + s)-th period when the disturbance term ε_{jt} of the j-th variable in the t-th period is increased by one unit (while the disturbance terms of other variables and other periods are unchanged).

Observe the impulse response diagram to find the impact response and analyze the influence relationship between crude oil price and air transport yield.

3.4 ARMA-GARCHX Model Setting

ARMA model, also known as "autoregressive moving average model", is a common model to study stationary time series models, and its expression is as follow:

$$x_t = \phi_0 + \sum_{i=1}^{p} \phi_i x_{t-i} + a_t - \sum_{i=1}^{q} \theta_i a_{t-i} \tag{9}$$

This model can well analyze the linear part of the time series data, but the analysis of the nonlinear part of the data is not ideal. Therefore, for some financial market volatility problems, ARMA model cannot be used alone, and GARCH model needs to be further introduced for research. [11]

The mean equation of GARCH model is set as ARMA process to build the ARMA-GARCHX model, simultaneously forecasting the impact of international crude oil price change on the air transportation industry yield and volatility.

Observing the ACF, PACF and EACF diagram of the logarithmic return series, preliminarily estimate parameters p and q of the ARMA model.

Then output different parameter estimation results, and determine the relatively most suitable model according to AIC or BIC information criteria.

After the ARMA model is established, the mean equation has obtained, then it is necessary After the ARMA model is established to obtain the mean equation, it is necessary to test the residual of the model to test whether the residual of the model is a white noise sequence. to test whether the residual of the model is a white noise sequence. Extracts the residual sequence $\{a_t\}$. Using Ljung box test to check the residual, if the residual satisfies the white noise hypothesis, then the ARMA model is fully modeled; if it fails, the ARMA order must be modified to remodel.

The residual sequence of the AR model established above may have conditional heteroscedasticity. The arch effect test is required to determine whether the conditional heteroscedasticity really exists. Only the sequence with arch effect can establish the GARCH model. The existence of conditional heteroscedasticity can be shown in the diagrams or directly estimating the GARCH (or ARCH) model:

$$\sigma_t{}^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}{}^2 + \cdots + \alpha_q \varepsilon_{t-q}{}^2 + \gamma_1 \sigma_{t-1}{}^2 + \cdots + \gamma_p \sigma_{t-p}{}^2 \tag{10}$$

The GARCH(1,1) model is shown as follow:

$$\sigma_t{}^2 = \alpha_0 + \alpha a_{t-1}{}^2 + \gamma \sigma_{t-1}{}^2 + \beta b_t \tag{11}$$

The b_t represents Brent crude oil price.

After repeated model fitting and comparison, the orders of the autoregressive and moving average terms can be determined using the extended sample autocorrelation function (ESACF) [12], and according to AIC and BIC information criteria, choose the best GARCH model to fit the data set, and observe whether the parameters are significant. If there is conditional heteroscedasticity, GARCH model are constructed successfully.

4. Empirical results and analysis

4.1 VAR Model

Before using the VAR model, it is necessary to decide the maximum order of lag. With the help of Stata, results of the VAR model identification can be seen in Table 2, which lists many criteria that could be used to make the decision. According to the likelihood ratio test, the LR statistic is statistically significantly less than the critical value at lag 6, which means that the order of 6 is optimal for the VAR model.

Table 2. VAR model identification

Lag	LL	LR	df	p
0	1061.95			
1	1069.86	15.819	4	0.003
2	1071.68	3.6461	4	0.456
3	1073.23	3.095	4	0.542
4	1075.75	5.0453	4	0.283
5	1078.91	6.3214	4	0.176
6	1084.03	10.225*	4	0.037
7	1085.15	2.2456	4	0.691
8	1087.29	4.2854	4	0.369
9	1089.39	4.197	4	0.380
10	1091.64	4.5007	4	0.342
11	1094.44	5.6089	4	0.230
12	1095.6	2.3008	4	0.681

Stability of the VAR model is needed to be tested after fitting the data. As can be seen from Figure 2, all the eigenvalues lie inside the unit circle, indicating that the VAR model satisfies stability. Hence, the lag order of 6 is appropriate in this case.

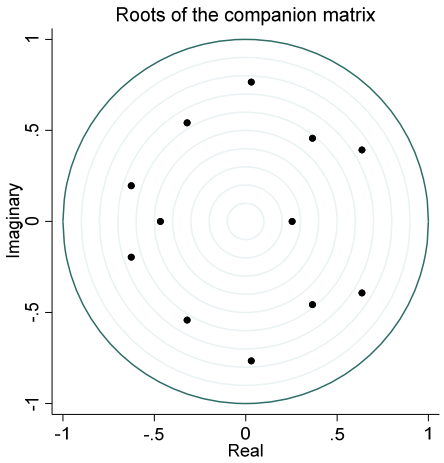

Fig.2 VAR stability

4.2 Impulse Response

To learn more about how changes in Brent oil price affect air transport industry yield, impulse response function is used in this section. Brent crude oil yield is regarded as the impulse variable and air transport industry yield is the response variable. The results are shown in Figure 3. In general, the changes in Brent oil price have short-term influence on air transport industry yield, and this effect is negative. That is to say, the increase of the Brent oil price might have negative net impact on air transport industry yield and cause the decrease of the air transport industry yield.

To be specific, when the Brent crude oil yield increases 1% at time 0, the air transport industry yield would consequently fluctuate around 0 in the following 10 periods, after which this effect weakened rapidly. However, it could be basically argued that the overall net effect is negative. What is more, the highest and second highest values of positive effect occur at time 0 and time 3, with the number becoming 0.3% and 0.1% respectively. Apart from this, the attenuation of the positive effect is obvious throughout the period, and the highest negative effect happens at time 5, with the absolute value of 0.3%. As a result, if the impulse of the Brent oil price sustains, the air transport industry yield would continue to decline in the future.

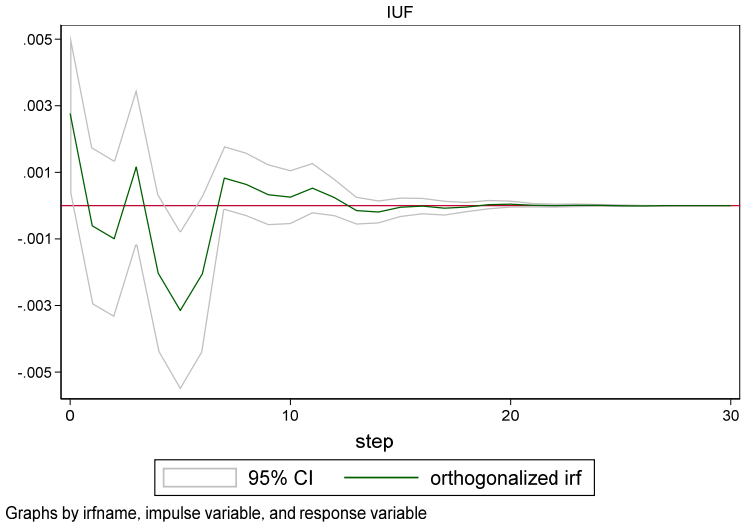

Fig.3 Impulse and response

4.3 ARMA Model Identification

When comes to using the ARMA-GARCHX model, it is of vital importance to identify the order of ARMA part for the air transport industry yield series at the beginning. And this could be done by using the PACF and ACF pairs, the results of which are shown in Figure 4.

As can be seen from the PACF plot, the first significant spike is at lag 28. Although there are two significant spikes thereafter, we have the tendency to choose the simplest model. Hence, AR (p) is of order 28. Additionally, ACF plot is used to confirm the order of MA term. Since there is no significant spike which lie outside the limits, the MA (q) part could be dropped in the following process of analysis.

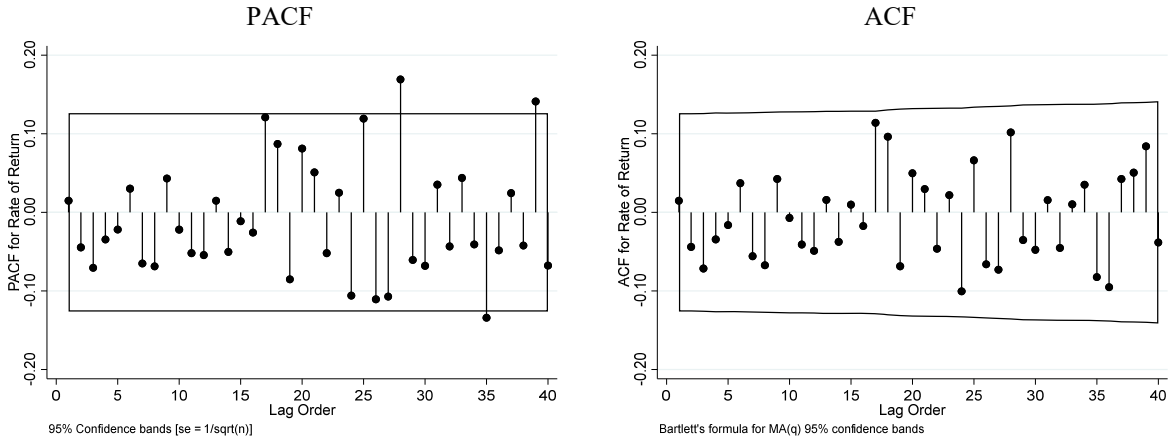

Fig.4 PACF and ACF

4.4 ARMA-GARCHX Model

To have better airline industry yield variance forecasting, the ARCH model is used to look at the patterns of yield volatility in the aviation industry. The results could be found in Figure 5. As can be seen from the plot that, the data fluctuate sharply at specific time period and less at another. Hence, there seems to have obvious volatility clustering existing in the air transport industry yield, which indicates a clear conditional heteroskedasticity. However, whether or not there is statistically significant autoregressive conditional heteroskedasticity is still needed to be judged by the following empirical testing.

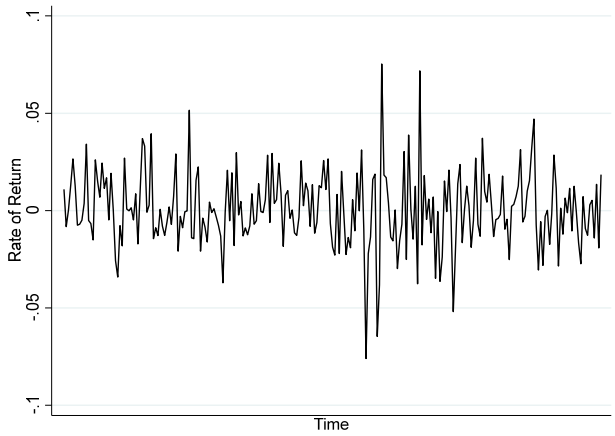

Fig.5 Yield trend

4.5 Estimation results

In this section, ARMA-GARCH model is used to investigate the impact of Brent oil price variations on air transport industry yield volatility. According to the result of the previous PACF plot, AR (28) term is also needed to be included in the model at first. However, due to the convergence issue of the maximum likelihood estimation, AR (28) part is eventually deleted from the model, and the final estimation results are shown in Table 3.

From the second and third lines of the table, it could be found that the p values for ARCH and GARCH terms are less than 0.01, which means at the significance level of 1%, they are statistically significant. This indicates that the air transport industry yield has obvious autoregressive conditional heteroskedasticity, and the GARCH model could be used to fit the data in this situation.

In addition, the estimation result of the external explanatory variable indicating that, at the 1% level, the coefficient of the Brent oil yield is statistically significant as well, because its p value nearly equals to 0, which is far less than 0.01. To be specific, the value of the coefficient is 51.026, which means that when the Brent crude oil yield increases 1 unit, the volatility of the air transport industry yield would rise correspondingly 51.026 units.

To sum up the above analysis, crude oil as one of the main fuels of air transportation, which could not be replaced in the near future, the changes in its price would have a dramatic influence upon the yield volatility in the aviation industry.

Table 3. ARMA-GARCHX estimation results

	Coefficient	Std. err	z	P>|z|
Brent	51.026	4.5477	11.22	0.000
ARCH, L1	-0.1132	0.0326	-3.48	0.001
GARCH, L1	1.0422	0.0149	70.11	0.000
Constant	-11.7841	0.4843	-24.33	0.000

5. Discussion

Previous studies concentrated on the impact on the air transport industry in the long run or the changes in the crude oil happened in the pass, while this research put more emphasis on the effect brought by events happened recently. The article analyzes the impact caused by the Russia-Ukraine war on the return and the volatility of the air transport industry. This essay focus on the recent events that have profound effects on the development of air transport industry. The results suggest that changes in crude oil price have effect on air transport industry yield in the short run, and this effect is negative.

Through the analysis of the current situation and prospects of air transport industry, this paper puts forward enlightenment and policy suggestions. Firstly, it is of great importance to further strengthen the cooperation between China and Russia in upstream oil and gas fields, which could help China seek better development in the future through cooperation to some degree. What's more, China could deepen international cooperation and promote the construction of futures market, developing renewable energy to ensure national oil security.

In addition, improve the ability of airlines to withstand risks would also be useful when being faced with unexpected events. And for investors, the future of the air transport industry is still unknown. Therefore, when choosing stocks in related industries, investors are supposed to be as careful as possible.

6. Conclusion

The object of this thesis is to study how the air transport industry in China has been impacted in the short run in the context of the Russia-Ukraine war and to forecast and make recommendations on the future direction and development of the air transport industry in China.

In this paper, VAR model and ARMA-GARCH model are mainly used to analyze and integrate relevant data, observe the dynamic dependence between crude oil prices and air transportation industry, and express the impact on China's relevant industries by studying the relationship between crude oil price return and industry fluctuations.

In the present day, the Russia-Ukraine war has brought great impact on the crude oil price, which has significantly affected the return and volatility of China's air transport industry. From the results of the data model analysis in this paper, crude oil is not alternative in the air transport industry in the near future, so the volatility of the yield in air transport industry might be influenced strongly. Looking ahead, how long the war may continue and what event may happen is not certain. Thus, China will have to actively respond to a series of actions and enhance the power of discourse in the relevant problem.

References

[1] Gao S, Lei Y. A new approach for crude oil price prediction based on stream learning. Geoscience Frontiers, 2017, 8(1): 183-187.

[2] Alam M, Tabash M I, Billah M, et al. The Impacts of the Russia–Ukraine Invasion on Global Markets and Commodities: A Dynamic Connectedness among G7 and BRIC Markets. Journal of Risk and Financial Management, 2022, 15(8): 352.

[3] Ahmed S, Hasan M M, Kamal M R. Russia–Ukraine crisis: The effects on the European stock market. European Financial Management, 2022.

[4] Nerlinger M, Utz S. The impact of the Russia-Ukraine conflict on the green energy transition–A capital market perspective. Swiss Finance Institute Research Paper, 2022 (22-49).

[5] PETROLEUM INTELLIGENCE WEEKLY GROUP. How High Could Ukraine Crisis Push Oil Prices? Petroleum intelligence weekly,2022,61(8).

[6] Yue Kaidi, Zhang Lijie, Li Yuchao. The impact of the Russia-Ukraine conflict on energy price volatility from the perspective of Internet's attention[J/OL]. Prices Monthly:1-11[2022-09-07]. http://kns.cnki.net/kcms/detail/36.1006.F.20220726.1226.004.html

[7] Kang W, de Gracia F P, Ratti R A. Economic uncertainty, oil prices, hedging and US stock returns of the airline industry. The North American Journal of Economics and Finance, 2021, 57: 101388.

[8] Kathiravan C. Relationship between crude oil price changes and airlines stock price: The case of Indian aviation industry. 670216917, 2019.

[9] Dar A B. On the Sustainable Nexus between Oil Prices and Aviation Stocks. Sustainable Operations and Computers, 2022, 3: 168-175.

[10] PAN Jing, LI Weng-fang. Research on the Dynamic Relationship between Education Level and Economic Growth Based on VAR Model. Special Economic Zone , 2022(07):137-140.

[11] Li Mingxuan, Yu Hanjun. Research on RMB exchange rate volatility based on ARMA—GARCH model. Times finance, 2020 (33): 1-3 + 8

[12] Liu H, Shi J. Applying ARMA–GARCH approaches to forecasting short-term electricity prices. Energy Economics, 2013, 37: 152-166.