Automobile Industry in the Long-term Uncertain Market: an Empirical Analysis

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Abstract. The automobile industry has been largely affected since the outbreak of the Russo-Ukrainian War, which is reflected by the crude oil price. In order to see the long-term effect of the oil price fluctuation on the auto industry, this paper analyzes changes in oil price and the rates of return of the automobile industry and new power automobile industry in specific. This research builds a VAR model and an ARMA-GARCH model to analyze the relationship between the stock price of automobile industry and the crude oil price from June 2021 to July 2022. Finally, the paper finds that rising oil prices have a negative net impact on the returns of the entire auto industry, but a positive impact on the returns of the new energy vehicle industry, and changes in oil prices have a positive impact on the volatility of the entire auto industry but no significant impact on the volatility of the new energy vehicle industry.

Keywords: Automobile Industry, New Power Automobile, Oil Price Fluctuation, Russo-Ukrainian War.

1. Introduction

Russia attacked Ukraine on February 24, 2022, intensifying the Russo-Ukrainian War that began in 2014. The Russo-Ukrainian War has resulted in financial sanctions, rising inflation, and supply-chain disruptions [1]. Crude oil price also increased dramatically in the globe. Rising oil prices induced by the invasion of Ukraine, according to Global Witness, Greenpeace USA, and Oil Change International, would generate a windfall of $37 to $126 billion for the United States upstream oil and gas industry in 2022 alone [2].

As gasoline is a petroleum-based product, change in crude oil price affects vehicle demand and consumers' vehicle-buying patterns [3]. In general, increasing crude oil prices is negatively related to the automobile demand and production. In the literature investigates the India market under the present trend of increasing crude oil prices, data on crude oil prices, car sales, and production are collected during a twenty-year period, and basic correlation analysis and multiple regression findings reveal that a rise in crude oil price has a negative influence on sales quantity in the Indian market [4].

However, some literatures found that the impact of oil price is somewhat different in different countries. A comparison has been made among Japan, the United States, and Germany by analyzing the stock return data of car companies and crude oil price changes from 1982 to 2007. It is determined that while the general market's sensitivity to crude oil price grows, Japanese firms demonstrate no additional sensitivity at all. German enterprises are sensitive, and both American and German corporations have gotten more sensitive in recent years [5]. And, the markets do not respond right away; instead, they need time to integrate changes in crude oil prices.

Additionally, in recent years, many nations have established measures to encourage customers toward more fuel-efficient automobiles in order to solve environmental problems and lessen reliance on imported oil. Thus, manufacturers have invested extensively in engine and transmission technology, creating many product alternatives that improve fuel economy and cut carbon emissions at a price premium. Consumers were expected to invest in these technologies since improved fuel economy would result in cheaper operational expenses. The literature indicates that fuel costs could drastically alter the investment for customers, and the demand for these technologies is expected to diminish if the oil price decreases [6]. On the other hand, the rising oil price might lead to the increasing demand for the new energy automobile.

All of these findings demonstrate the complexities of analyzing the car business following an oil shock, which encourages further investigation into any potential issues regarding the performance of the global automobile sector. Relying on this premise, this article seeks to identify more relevant links between the car industries and oil price fluctuations, with a focus on the new power automobile sector in the face of uncertainty.

This paper researches the long-term effect of crude oil price fluctuation on the automobile industry after a sudden shock. To begin with, the study focuses on the price value, which influences the return of the stock of the whole vehicle business, and the new power automobile sector. The study develops a VAR model, resulting in a system that includes all three variables: crude oil price, automotive industry rate of return, and new power automobile industry rate of return. In addition, the study generates an impulse response graph to represent these system interactions, demonstrating the model's usefulness. The study's last component focuses on stock price volatility, which communicates the danger of the stock price and the industry and constructs an ARMA-GARCH model. The research focuses the GARCH part's outcome and offers conclusions based on model performance based on the conditional heteroscedasticity observed in the stock price series.

2. Research Design

2.1 Data Source

Data of crude oil price is indicated by West Texas Intermediate (WTI) price. And, the indices of the automobile industry and new power automobile industry are caculated by the stock prices. All these data are from the Choice financial terminal [7].

This paper matched the stock prices of the automobile industry and new power automobile industry with the WTI price according to the date from 6/1/2021 to 7/31/2022. Since the stock price only changes in the trading days, some of WTI prices in the non-trading day were omitted.

2.2 Rate of Return

This study traces the price changes and the rate of return by using the logarithmic term, which is calculated as:

$$return_t = \frac{price_t - price_{t-1}}{price_{t-1}} \tag{1}$$

$$\text{logprice}_t = \log(1 + price_t) \tag{2}$$

$$\text{logreturn}_t = \log(1 + return_t) \tag{3}$$

2.3 Unit Root Test

To determine if a time series is stationary, a unit root test (process) is employed. The majority of time series quantification is based on the assumption that the time series is stationary. As a result, the stationarity condition of the data must be examined before the research is conducted. If any series is not stationary, this study must investigate potential solutions to enhance the outcomes. During this process, the time series b_t is usually expressed in the following way:

$$b_t = c_t + \beta b_{t-1} + \sum_{i=1}^{p-1} \phi_i \, \Delta b_{t-i} + \varepsilon_t \tag{4}$$

The null hypothesis of the test is that the coefficient $\beta = 1$, whereas the alternative hypothesis is that the coefficient $\beta < 1$. The null hypothesis indicates that the series has a unit root and is not stationary while the alternative one suggests that it is stationary.

Table 1 presents the results of the unit root test of stock prices as well as the rates of return:

Table 1. ADF test

Variables	t-statistic	p-value
	Price	
Automobile	-1.535	0.8167
New power automobile	-2.055	0.5709
Crude oil	-2.531	0.3125
	Rate of return	
Automobile	-10.914	0.0000***
New power automobile	-10.192	0.0000***
Crude oil	-12.734	0.0000***

According to the results, the logarithm series of price does not fare well in the stationarity test, since all indices are not statistically stationary under 95% confidence intervals. However, the improvement is apparent when using the logarithm series of the rate of return: Under 99% confidence intervals, all logarithmic series of returns from the automotive and new power automobile industries, as well as crude oil, are notably stagnant. Based on the findings, the following models might be constructed using these stationary series.

2.4 VAR Model Specification

Sims formally presented the Vector Autoregression Model (VAR) in 1980 [8]. This is a well-known and very powerful statistical model employed to study the relationship between several time series when they evolve through time. Based on the assumption that each parameter is influenced by the rest of the group, a VAR model integrates these variables into a single system and forecasts this multivariate time series as a whole, rather than developing separate models for each element, as an ARMAX model does.

Assume two time series variables (b_1, b_2) are used as explained variables in the two regression equations, and the p-order lag values of (b_1, b_2) are the explanatory variables, resulting in a bivariate VAR(p) system.:

$$b_{1t} = \beta_{10} + \beta_{11} b_{1,t-1} + \cdots + \beta_{1p} b_{1,t-p} + \gamma_{11} b_{2,t-1} + \gamma_{1p} b_{2,t-p} + \varepsilon_{1t} \tag{5}$$

$$b_{2t} = \beta_{20} + \beta_{21} b_{1,t-1} + \cdots + \beta_{2p} b_{1,t-p} + \gamma_{21} b_{2,t-1} + \gamma_{2p} b_{2,t-p} + \varepsilon_{2t} \tag{6}$$

It can be expressed as a vector group in the following way:

$$b_t = \begin{pmatrix} \beta_{10} \\ \beta_{20} \end{pmatrix} + \begin{pmatrix} \beta_{11} & \gamma_{11} \\ \beta_{21} & \gamma_{21} \end{pmatrix} b_{t-1} + \cdots + \begin{pmatrix} \beta_{1p} & \gamma_{1p} \\ \beta_{2p} & \gamma_{2p} \end{pmatrix} b_{t-p} + \varepsilon_t \tag{7}$$

In this case with three variables, the system can be written as:

$$b_t = \Gamma_0 + \Gamma_1 b_{t-1} + \cdots + \Gamma_p b_{t-p} + \varepsilon_t \tag{8}$$

where $b_t = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix}$, $\Gamma_0 = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \end{pmatrix}$, $\varepsilon_t = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix}$, $\Gamma_1 = \begin{pmatrix} \beta_{11} & \gamma_{11} & \lambda_{11} \\ \beta_{21} & \gamma_{21} & \lambda_{21} \\ \beta_{31} & \gamma_{31} & \lambda_{31} \end{pmatrix}$, … , $\Gamma_p = \begin{pmatrix} \beta_{1p} & \gamma_{1p} & \lambda_{1p} \\ \beta_{2p} & \gamma_{2p} & \lambda_{2p} \\ \beta_{3p} & \gamma_{3p} & \lambda_{3p} \end{pmatrix}$.

2.5 ARMA-GARCH Model Specification

Prior to the release of Engle's Autoregressive Conditional Heteroskedasticity (ARCH) model in 1982, economists performed the majority of their research on the premise that the variance of a series is constant, does not fluctuate greatly, and follows the stochastic process rule [9]. However, in the real world, where variation represents asset risk, it is common for the variance to change over time since it is hard to keep track of everything. Given a high variance in the previous period, the ARCH model predicts that the variance in the current period would be high. This is known as autoregressive reasoning, and it is comparable to the AR model for anticipating future variance. In general, an ARCH(p) model can be shown as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \delta_{t-1}^2 + \cdots + \alpha_p \delta_{t-p}^2 \tag{9}$$

where σ_t is the forecast variance in period t, δ_t is the actual variance in period t, and α_0 is a constant.

In 1986, Bollerslev refined the ARCH model by combining the GARCH term and the original model, which becomes the most foundational and strong model in time series analysis. This process is analogous to how an AR model becomes an ARMA model, and it can minimize the number of coefficients to be calculated in the ARCH model. A GARCH (p, q) model can be written as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \delta_{t-1}^2 + \cdots + \alpha_p \delta_{t-p}^2 + \beta_1 \sigma_{t-1}^2 + \cdots + \beta_p \sigma_{t-q}^2 \tag{10}$$

An ARMA-GRACH model is built to assess variability in order to concentrate on the risk. An ARMA-GARCH model consists of two value and variance equations. The GARCH section should be prioritized when determining market risk although the value is also examined in the VAR portion.

3. Empirical Result

3.1 VAR Order Selection

In this section, the paper incorporates three stationary series into our Vector Autoregression system: the logarithmic rate of return on crude oil, the automobile industry, and the new power automobile industry. Firstly, Stata's multiple VARSOC selection-order criteria are utilized to find the acceptable order p in this $VAR(p)$ model. Table 2 shows the outcome, which indicates that a VAR with 10 orders can be considered.

The likelihood ratio (LR) column in Table 2 evaluates the degree of fit of two competing statistical models according to the likelihood ratio. If the constraint, or the null hypothesis, is justified by the observations, the two likelihoods must not deviate beyond the sampling error. In this case, lag 10 shows that the likelihood to the null hypothesis is not significantly different from one, which indicates VAR (10) is valid.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	1895.48				1.5e-10	-14.1230	-14.1068*	-14.0828*
1	1906.81	22.6630	9	0.007	1.5e-10	-14.1404	-14.0758	-13.9796
2	1916.81	20.0100	9	0.018	1.4e-10*	-14.1479*	-14.0348	-13.8665
3	1921.34	9.0468	9	0.433	1.5e-10	-14.1145	-13.9530	-13.7125
4	1922.88	3.0926	9	0.961	1.6e-10	-14.0588	-13.8489	-13.5363
5	1925.72	5.6747	9	0.772	1.6e-10	-14.0128	-13.7545	-13.3697
6	1934.04	16.6460	9	0.055	1.7e-10	-14.0078	-13.7010	-13.2440
7	1937.97	7.8500	9	0.549	1.7e-10	-13.9699	-13.6147	-13.0856
8	1941.68	7.4218	9	0.593	1.8e-10	-13.9304	-13.5268	-12.9255
9	1947.67	11.9900	9	0.214	1.8e-10	-13.9080	-13.4560	-12.7825
10	1958.84	22.3270*	9	0.008	1.8e-10	-13.9242	-13.4237	-12.6780
11	1966.20	14.7140	9	0.099	1.8e-10	-13.9119	-13.3630	-12.5452
12	1972.61	12.8310	9	0.170	1.9e-10	-13.8926	-13.2952	-12.4053

3.2 Stability Condition of VAR Estimates

In this work, the varstable tool in Stata is used to test the eigenvalue stability criterion after estimation of the parameters of a vector autoregression, that would construct a unit circle to demonstrate overall outcome after creating the VAR (10) model. The VAR estimates are stable if all of the dots indicating the eigenvalues are inside the unit circle. Figure 1 depicts the plot result, indicating a satisfied stability condition.

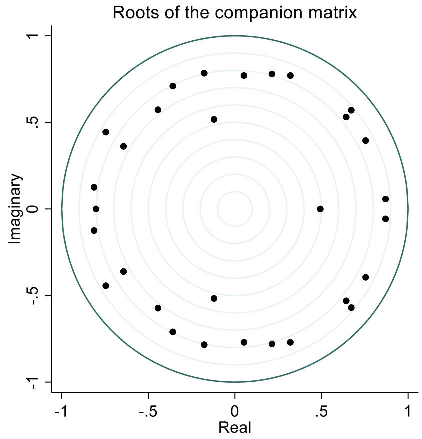

Figure 1. VAR stability

3.3 Impulse Response Graph of the VAR model

Figure 2 depicts the impulse response results of the car and new power vehicle industries' rate of return. From the standpoint of automobiles, it can be seen that one unit of oil price shock in the current era has a negative net effect on the whole vehicle sector in the future period. The current shock, in particular, will have three big negative impacts in the future, each with a size of roughly 0.25%.

According to the pulse graph with the new energy vehicle yield as the response variable, the net effect of a unit of oil price rise on the new power vehicle industry at t=0 is positive. The present era had the greatest beneficial influence, with a magnitude of roughly 0.25%.

Based on the above study, it is possible to infer that, while new energy cars are replacements for traditional fuel vehicles, the present market reaction indicates that they cannot totally replace fuel vehicles. This paper's estimation findings give empirical proof for this proposition.

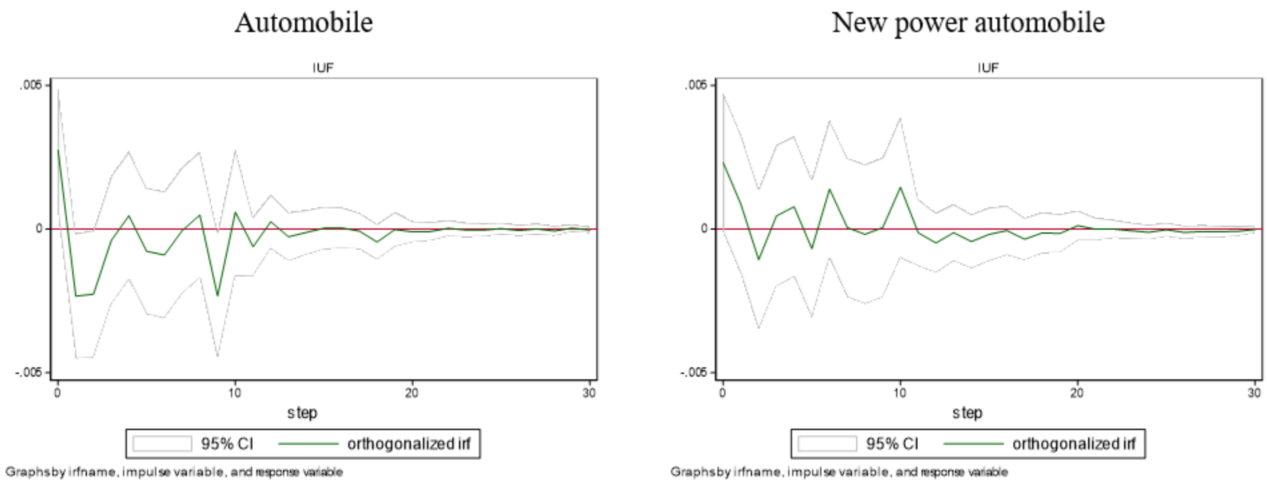

Figure 2. Impulse and response

3.4 ARMA Order Selection

To construct an ARMA-GARCH model, the research first identifies the appropriate AR and MA components of the car and new energy automobile industries. Figure 3 shows the Stata's outcome of the partial autocorrelation plot (PACF plot). The black rectangle is used to determine the statistically significant term in the AR model, and it can be shown that the lag 3 term of the original series of automobile parts and the lag 1 term of the original series of new power car components may have a substantial influence on the present data. This demonstrates that the AR model is attainable when the order is 3 for automobiles and 1 for new power automobiles.

In this work, the Autocorrelation Plot (ACF Plot) on the right in Figure 3 is utilized to calculate the MA model of the series. The result shows that the order of the MA model is 3 for automobiles and 1 for new power automobiles.

Finally, the paper finds that the best ARMA word for the vehicle sector is ARMA (3,3), while the best ARMA term for the new power automobile sector is ARMA (1,1).

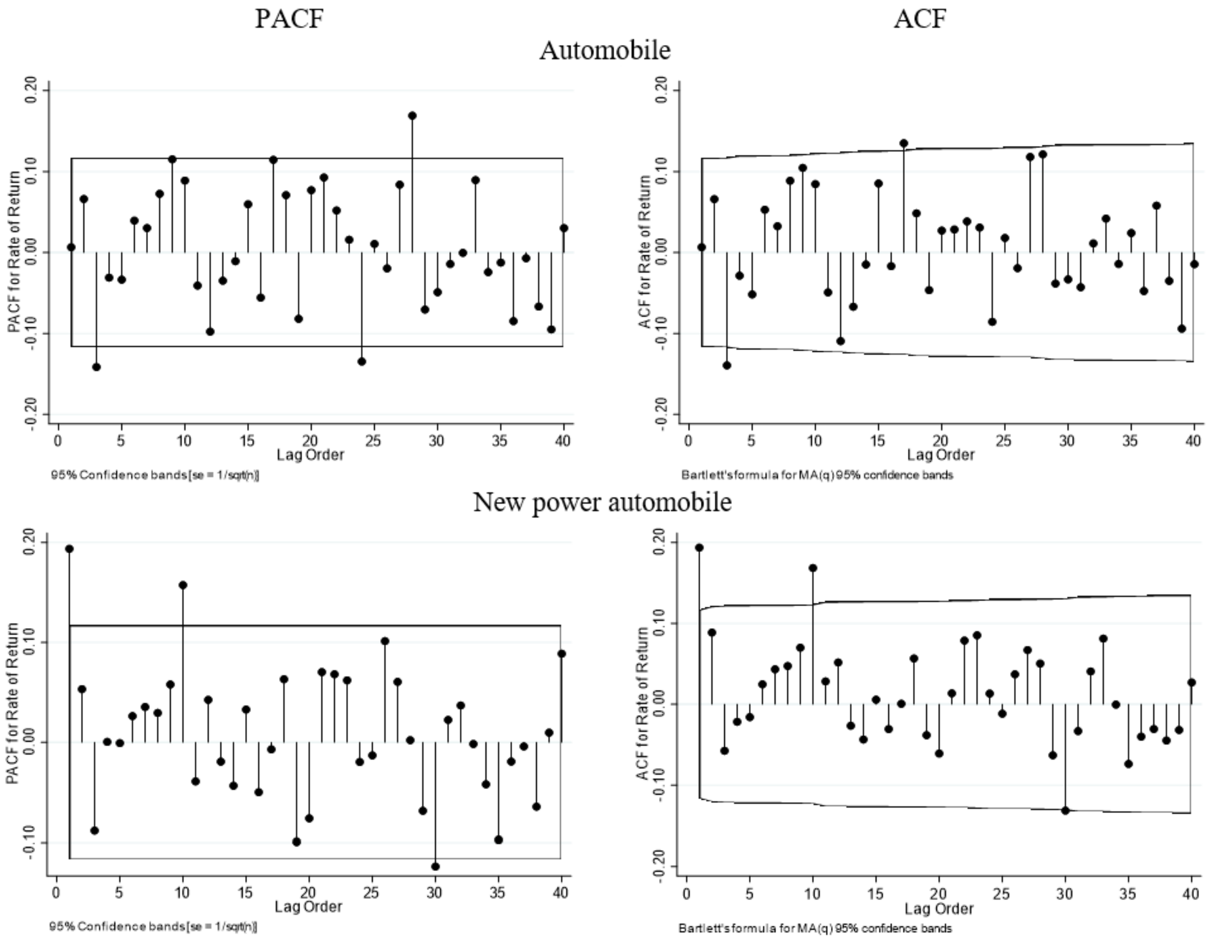

Figure 3. PACF and ACF

3.5 ARMA-GARCH Model Result

The ARCH-GARCH model of the returns of the auto industry and the new energy vehicle industry are both significant, indicating that there is statistically significant conditional heteroskedasticity and GARCH modeling can be performed, according to the estimation results of the ARMA-GARCH model presented in Table 3 below.

According to the estimation findings in column (1), the logarithmic term of the return in crude oil increases by one unit, and the volatility of the return of the car sector increases by 3.9856 units, with the coefficient significant at the 5% level. According to the findings in column (2), crude oil price fluctuations have no significant impact on the volatility of profitability in the new energy vehicle industry.

Table 3. ARMA-GARCH estimation results

Variables	(1) Automobile		(2) New power automobile	
	Coefficient	Std. err	Coefficient	Std. err
Crude oil	3.9856**	1.5939	4.9747	9.6587
ARCH (-1)	-0.0739**	0.0291	0.3389***	0.0844
GARCH (-1)	-0.6815***	0.1408	0.3783***	0.1457
Constant	-7.2553***	0.1083	-8.9649***	0.3904

4. Discussion

This paper examines the influence of the oil price changes on the returns on the vehicle industry and the fuel efficiency division. The results show that the rising oil price might lead to a decreasing trend in the automobile industry, but the impact of the new energy automobile part could be positive according to the impulse response and could be not significant according to the ARMA-GARCH model. Compared with the investigation of the Indian market, the general trend of the automobile is consistent even though the methodology the literature uses is not the same [4]. Changes in oil price increase the costs of traditional cars, and the demand and production of traditional vehicles will decrease.

Regarding the new energy vehicles, some literature indicates that the fuel cost will dramatically influence the customers' choices between the traditional cars and the new ones, so the demand and production of new energy automobiles will increase responding to the rising oil price [6]. However, in this research, even though the impulse response graph shows that there is a positive relationship between these two, the size of the impact is not significant. In addition, according to the ARMA-GARCH model, the new energy automobile industry is hardly affected by oil prices.

Some explanations for the little influence of the new energy automobile industry could be that these cars are more sensitive to the supplies of the metals and the improvements in technology. According to Ford Motor Company, a suite of battery materials, including lithium, nickel, and cobalt, that are largely obtained and processed outside of the United States, are facing significant supply shortages and unpredictable pricing, among other supply chain constraints. This will cause issues for Ford, which is attempting to fulfill the increasing demand for electric vehicles [10].

Based on this research, the investor can get some insights into the overall trend of the automobile industry, but something that needs to pay attention to is that different countries and different places have different patterns. Some countries might be more sensitive to oil price changes because they rely on imports, and some will be less sensitive than others. In addition to that, the investors need to take many other factors into consideration like the cost of the materials and the technological improvements.

5. Conclusion

In a short period of time after the outbreak of the Russian-Ukrainian conflict, along with the skyrocketing oil price, the entire financial market in China fluctuated violently in a short period of time and fell rapidly. But over time, the stock indexes have basically returned to their pre-Russian-Ukrainian levels. This situation shows that the Russian-Ukrainian conflict is more inclined to a short-term shock to the entire financial market. In the medium and long term, the financial market reflects its fundamentals more than a short-term shock.

When concerning the auto industry, the increase in oil prices is a huge negative for the traditional fuel vehicle industry, which is consistent with other literatures. Because new energy vehicles are a replacement for old fuel vehicles, oil prices fluctuations have minimal influence on vehicle costs, despite rising customer demand for electric vehicles. At the same time when considering the oil price fluctuation, investors are expected to pay attention to the sensitivity of the market and other factors like material cost and technology.

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