The Impact of Normalized Covid-19 Pandemic on Tesla's Yield and Volatility

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Abstract. COVID-19 has been going on for almost three years now and has had a significant impact on people's daily lives, industry, agriculture, etc. Meanwhile, the financial markets have been very turbulent due to the epidemic, and many inventors were also nervous as a result. Electric vehicles which are the fastest growing industry in recent years have attracted a considerable range of attention. Therefore, this paper selects Tesla which is one of the largest electric vehicle companies as the research subject. Also, this essay intercepts a lot of data, including Tesla stock market closing price, new daily confirmed cases of China, and new daily confirmed cases overseas and uses impulse response and ARMA-GARCH model, to study how Tesla's yield and volatility have been affected by the normalized Covid-19, and to make a prediction about the future development of Tesla. Moreover, some suggestions are given to the investors and policy makers to help them to make a better decision.

Keywords: COVID-19; Tesla; yield; volatility; ARMA-GARCH model.

1. Introduction

Harper mentioned that COVID-19 has ravaged the world, killing thousands of people, crippling businesses, and sealing off borders of many countries in the world which has caused never-before-seen devastation to people across the globe [1]. Also, the impacts of COVID-19 in daily life are extensive and have far-reaching consequences. For example, economically, the epidemic slowed the manufacturing of essential goods, disrupted the supply chain of products, caused poor cash flow in the market, and significantly slowed revenue growth [2]. In addition, cars became necessary many years ago for almost every household as people's quality of life improved. Traveling by car became the first choice for many people. However, in recent years, with the increasing environmental pollution and the strengthening of people's awareness of environmental protection, a considerable amount of people is choosing new energy vehicles that are more environmentally friendly. Therefore, the essay chooses Tesla Ltd. as the research object. Tesla was founded in 2003 and is dedicated to the development of new energy vehicles. The company has a range of products, for example, model S, which is one of the best all-electric cars in the world, model X in 2015, model 3, which is a low-price, high-volume electric car; and model Y, which is an SUV [3]. Moreover, Tesla's stock price increased dramatically from 2019 to 2021. This may be due to its sales policy and the performance of the car itself. The vehicle could be done to meet the different needs of the users and be affordable for many people since its battery costs are low but have excellent efficiency. Meanwhile, People are becoming increasingly aware of environmental protection, and international organizations are developing policies to protect the environment, with the goal of achieving sustainable development. Also, in 2020, the Tesla industry developed its ventilator to deal with this epidemic and made a significant contribution to the health of humanity. These may also be the reason why the industry is widespread.

The worldwide prices of raw commodities, such as metals, plunged worldwide as the Chinese industries stopped manufacturing, causing a significant slowdown in a number of metal-producing economies. [4]. China, as Tesla's primary production and sales base, has a substantial impact on Tesla's development. Meanwhile, other countries also play an essential role in Tesla's products against a recession. By way of illustration, Tesla is a high-technology company; its cars are equipped with a reasonable amount of high-tech accessories, but the manufacturing of these accessories may not proceed normally, giving rise to the shortage of various parts. In 2020, Tesla closed its factories in Shanghai, California, and New York [5]. And its stock price may reach an all-time low.

Furthermore, the industry laid off amounts of employees that were affected by COVID-19. And in 2022, Tesla closed the factory that was in Shanghai, which is one of the largest in the world. Tesla's irreplaceability can be seen in the number of cars it produces in its Shanghai factory. Many Tesla shareholders are concerned about whether they will be able to respond effectively to the crisis. However, Wen who is a researcher mentioned that the sales of electric vehicles might be reduced in the short term, while the sales may also be increased in the long run, especially for large passenger EV models [6]. In addition, Junyang found that although many industries were affected by COVID-19 in 2020, the Tesla industry is profitable and even set a new top sales volume and net income in that challenging year [7]. Meanwhile, it also could be found that investors could receive more money from Tesla's stock after 2020, and many investors may have more confidence in the company and have a positive attitude. This also shows that this company has excellent growth potential.

A market or securities is said to be experiencing volatility when there are instances when price changes are without no signs and are occasionally abrupt [8]. Volatility may be considered by people when there are some difficulties, such as a drop in the price of the stock market or a drop in house prices, etc. Also, some companies may make a professional analysis for its dropping reasons. However, their prices could increase immediately when they reach their lowest. Volatility is also a term often used when doing analytical experiments, because the data generally selected for experiments are constantly changing, and such data are more worthy of an investigation into their causes. This is especially true for large global companies like Tesla. Then, as for the yield, in the world of finance, yield refers to the specific amount gained on securities over a specific time frame. Some dividends or interest received on debt or equity are included in it, as appropriate. It is often represented as an annual percentage and depends on two sides which are the face value or current market value of the investment of a specific company [9]. Meanwhile, it is known that generating profits is the description of return on business investment. Many people are interested in firm value, especially some researchers and inventors. Sucuahi and Cambarihan said that many inventors often look at the profitability of a company and profitability is positively correlated with the growth of the company [10]. People are also interested in an industry's stock price since they earn a considerable range of money from buying the stock of a company. The economic data of a company also play an important role in determining inventors' decisions. It may be a fact that when the economy performs well, inventors will show their positive sides, and the stock may be sold out faster, which is a good market performance. Moreover, job reports, GDP, and the sales of a company may also determine market performance and affect its volatility. Like other electric car industries worldwide, COVID-19 may have a serious impact on its stock price and sales, and some of them may be closed since they may need more workers to manufacture some parts for automobiles. However, the Tesla industry may depend on more high technology so that it can help them save money and their market may be more stable.

The literature that is used in this paper is relatively new and representative. However, the aspects considered in some literatures are incomplete and the amount of data is relatively small. Although a lot of literature has been conducted on Tesla in the case of the epidemic, such as the transformation, the future of the company, and so on. The impact of the epidemic on a high-tech industry like Tesla is stated. However, very little has been done to get into a deeper and more detailed study, especially on the impact of the Chinese epidemic and overseas epidemic on Tesla's return and volatility, and whether there is a positive or negative relationship between the Chinese epidemic and overseas epidemic and Tesla's yield rate and volatility. Therefore, this paper hopes to do more research in this area mentioned above to fill the gaps and it will use empirical data to demonstrate the impact of COVID-19 on Tesla's global yield rate and volatility.

The following parts of this paper will be organized as follows: Part 2 is research design, including data sources, ADF test, VAR model, and ARMA-GARCH model; Part 3 is empirical results and analysis which are composed of four parts (VAR model, impulse results, PACF fixed-order and ACF fixed-order, and ARMA-GARCHX estimation results, respectively). Part4 is the discussion and part 5 is the conclusion.

2. Research design

2.1 Data Source

The data for this paper are all obtained from Choice financial terminals [11], a search engine, to find the closing price of Tesla Inc. from January 24, 2020, to the present, as well as the amount of confirmed cases of COVID-19 in China and the number of confirmed cases in countries other than China for the same time period. Using these data to analyze their relationship, as a data source basis for empirical analysis to study the impact of COVID-19 on Tesla's yield rate and volatility.

2.2 ADF Test

The first step after the model construction is to do a unit root test on the model that is discussed. Then, there is an ADF test in Stata to verify the smoothness of the data. It is known that the null hypothesis is not smooth. From table 1, it can be seen that the p-value of the logarithmic series of Tesla's closing price is not stationary since its p-value is larger than 0.1, which means that the null hypothesis ought to be accepted. However, the p-values for the logarithmic series of Tesla's yield, new daily confirmed cases of China, and new daily confirmed cases overseas are less than 0.1, Therefore, the null hypothesis can be rejected. Meanwhile, after that, the steps have nothing with the logarithmic series of Tesla's closing price.

Table 1. ADF test

Variables	t-statistic	p-value
Tesla, closing price	-1.7600	0.7239
Tesla, yield	-17.350	0.0000***
New daily confirmed cases		
China	-3.8510	0.0142**
Overseas	-6.2580	0.0000***

2.3 VAR Model

The VAR model was proposed in 1980 by Sims. To assess the dynamic relationship between the joint endogenous variables, this model is frequently utilized. It is achieved by autoregression of all current period variables in the model on a number of period lags of all variables. The most important step is that we use the VAR model setting is to determine the number of steps(p). Then, VAR (3) where p equals 3 can be shown that:

$$Y_t = \alpha_1 + \phi_{11}Y_{t-1} + \cdots + \phi_{1p}Y_{t-p} + \beta_{11}X_{t-1} + \cdots + \beta_{1p}X_{t-p} + \delta_{11}Z_{t-1} + \cdots + \delta_{1p}Z_{t-p} + e_{1t} \quad (1)$$

$$X_t = \alpha_1 + \phi_{21}Y_{t-1} + \cdots + \phi_{2p}Y_{t-p} + \beta_{21}X_{t-1} + \cdots + \beta_{2p}X_{t-p} + \delta_{21}Z_{t-1} + \cdots + \delta_{2p}Z_{t-p} + e_{2t} \quad (2)$$

$$Z_t = \alpha_1 + \phi_{31}Y_{t-1} + \cdots + \phi_{3p}Y_{t-p} + \beta_{31}X_{t-1} + \cdots + \beta_{3p}X_{t-p} + \delta_{31}Z_{t-1} + \cdots + \delta_{3p}Z_{t-p} + e_{3t} \quad (3)$$

Meanwhile, the VAR model can be expressed by another way:

$$X_t = \sum_{i=1}^{p} \Pi_i X_{i-1} + U_t \quad (4)$$

Among the function above, X_t is a time series column vector of N×1, U_t is the random error column vector, U_t~IND (0, Ω). Moreover, the number of variables that have an interaction(N) needs to be determined before building the VAR model. It is also necessary to determine how many lagged variables are needed to explain clearly the endogenous variables(k) that have an inter-influence

relationship (No matter k is too large or too small, it will have a negative effect on estimation of the model parameters). In this paper, N equals to 3 (logarithmic series of Tesla's yield, new daily confirmed cases of China, and new daily confirmed cases of overseas, respectively). Then, finding the number of steps of this data. In addition, there are some methods to confirm the maximum lag order. The function of the LR likelihood method can be expressed:

$$\begin{gathered} LR = -2(\log L_k - \log L_{k+1}) \\ LR \sim \chi^2_{(N^2)} \text{ (Gradual obedience)} \end{gathered} \tag{5}$$

This method can be used when the sample size is enough large. The other two approaches are AIC statistics method and SC statistics method. After the VAR model is built, it is necessary to test whether the VAR system is stable. If all eigenvalues of the coefficient matrix are inside the unit circle, then it is a smooth process.

2.4 ARMA-GARCH Model

2.4.1 Model specification: ARMA

$$x_t = \phi_0 + \sum_{i=1}^{p} \phi_i \, x_{t-i} + a_t - \sum_{i=1}^{q} \theta_i \, a_{t-i} \tag{6}$$

From the above function, $\{a_t\}$ is a white noise sequence, p and q are non-negative integers. $\phi_0 + \sum_{i=1}^{p} \phi_i \, x_{t-i}$ represents the AR(p) model and $a_t - \sum_{i=1}^{q} \theta_i \, a_{t-i}$ that uses both past realizations and past perturbations to predict the future. In this paper, AR model uses the Tesla's yield rate to make a prediction, the error term is used by the MA model.

2.4.2 Model specification: GARCH

GARCH model was proposed by Bollerslev and this model is more accurate than the ARCH model. Also, GARCH model is used to reduce the number of parameters. The GARCH (p, q) is as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2 + \gamma_1 \sigma_{t-1}^2 + \ldots + \gamma_p \sigma_{t-p}^2 \tag{7}$$

$\alpha_1 \varepsilon_{t-1}^2 + \ldots + \alpha_q \varepsilon_{t-q}^2$ represents the ARCH(p) model and $\gamma_1 \sigma_{t-1}^2 + \ldots + \gamma_p \sigma_{t-p}^2$ represents the GARCH model. Moreover, σ_t^2 is the self-regression part. Also, if σ_{t-1}^2 is introduced as an explanatory variable, the higher-order ARCH model(p) can be reduced to a GARCH (1,1) model.

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2 + \beta C_t \tag{8}$$

C_t is an external explanatory variable which is confirmed cases including two parts (China and overseas, respectively). As for the ARMA-GARCH model, it can simultaneously forecast the yield rate and volatility. This paper let log China additions and log overseas additions as external explanatory variables.

As for the degree of ar, it can be recognized by the PACF fixed-order method. The degree of ma can be confirmed by the ACF fixed-order method.

3. Empirical Results and Analysis

3.1 VAR Model

To confirm the step(p), from the table2, it is necessary to see which the number of lags has the most "*". It can be seen that the lag of 6 may be good for this step. However, Since the sample size

is large enough, the order can be appropriately large. Then, it may be better to use LR likelihood method to define p. So, from this method, p may equal 10 since lag of 10 has the most "*" after lag of 6.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-1146.12				.011642	4.0605	4.06948	4.0835
1	-387.138	1518	9	0.000	.000822	1.41038	1.44628	1.50237
2	-272.895	228.49	9	0.000	.000567	1.0385	1.10133	1.19947
3	-235.673	74.445	9	0.000	.000513	.938773	1.02852	1.16873*
4	-218.169	35.007	9	0.000	.000498	.908726	1.0254	1.20767
5	-196.971	42.396	9	0.000	.000477	.865623	1.00923*	1.23356
6	-183.596	26.751	9	0.002	.00047*	.850161*	1.02069	1.28709
7	-177.635	11.922	9	0.218	.000475	.8609	1.05835	1.36681
8	-174.765	5.7397	9	0.766	.000485	.882562	1.10694	1.45746
9	-165.664	18.201	9	0.033	.000485	.882207	1.13351	1.5261
10	-156.297	18.735*	9	0.028	.000484	.880908	1.15914	1.59379
11	-153.84	4.9134	9	0.842	.000496	.904029	1.20918	1.6859
12	-150.929	5.8223	9	0.758	.000507	.925545	1.25763	1.7764

After that, it is need to test whether VAR model is stable. From the figure 1, it can be seen that all eigenvalues are within the unit circle although some points on the edge of the unit circle. Therefore, the process is stable.

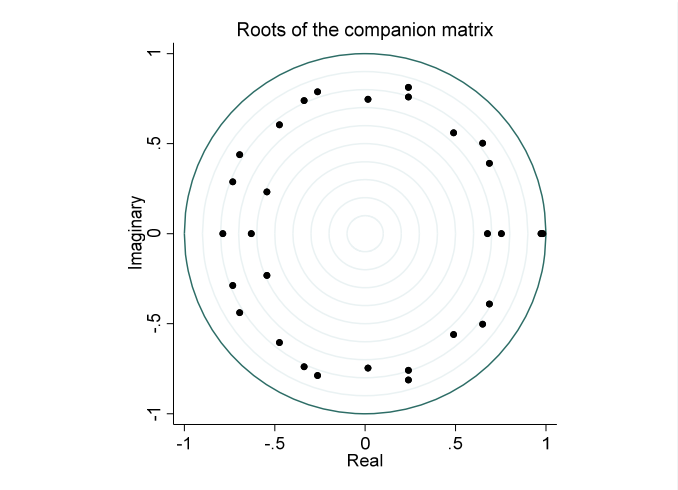

Fig. 1 Unit circle test

3.2 Impulse Response

The last step of VAR model setting is to plot the impulse response function of the VAR model and IRF describes the response of the endogenous variables to changes in the error term in the VAR model. It can help this article for a comprehensive analysis.

Impulse variable: new daily confirmed cases, China Impulse variable: new daily confirmed cases, overseas

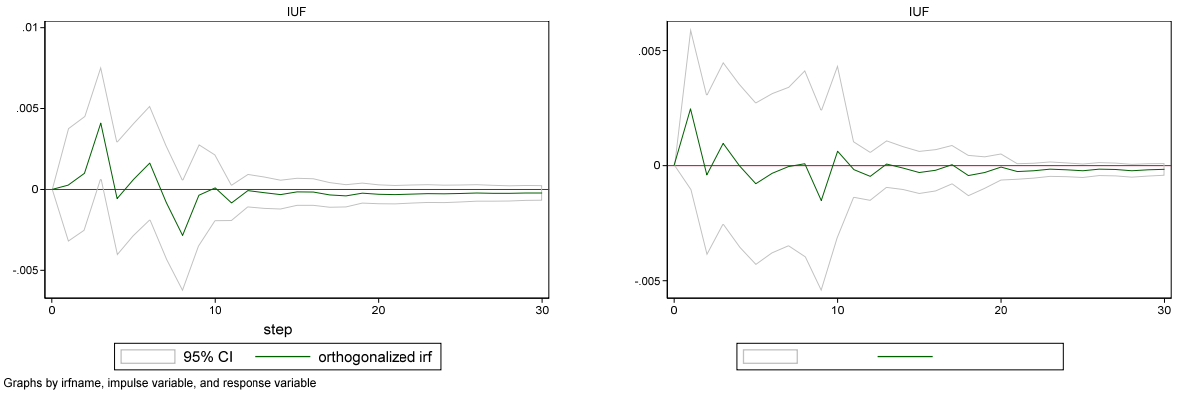

Fig. 2 Impulse and response

From the figure 2, it can be noticed that there is a considerable amount of dropping trends. It may due to COVID-19 in 2020 triggered turmoil in the financial markets and many investors are in a panic in the shortage. Hence, the risk aversion of funds leads to a massive "flight" of capital from the financial markets, many indices decline sharply. There is a plot about performance of major U.S. stock market indicates from January 2020 to March 2021.

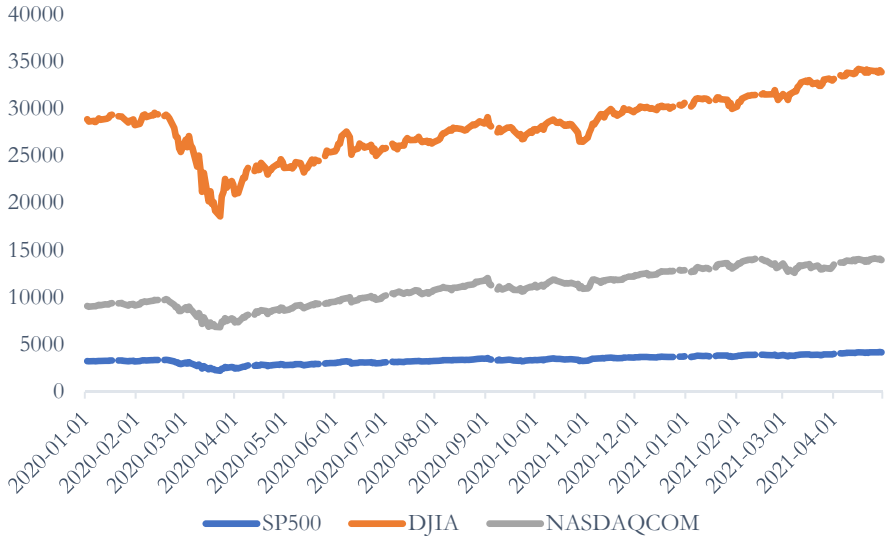

Fig. 3 Performance of major U.S. stock market indices since January 2020

From Figure 3, it can be seen that the stock price is very close to its minimum (around April 2020) after the serious falling. Then, after the market digested the panic, it started to surge again in a short period of time. However, in the long run, whether this effect exists, this needs to have a further verification.

According to China may be one of the largest markets for Tesla, and the policies implemented by the Chinese government are different from those of other countries. Thus, the investors will think differently. That is also why this paper uses the number of daily new diagnoses in China and number of new diagnoses overseas.

Moreover, from the results of impulse response, no matter the new daily confirmed cases of China or the new daily confirmed cases overseas have less of an impact on the Tesla's yield rate. And the positive and negative effects almost cancel each other out. In terms of the time effect, the shock in period when t equals to 0 decays to 0 after 10 periods.

From the information that is mentioned above. In the perennially popular of COVID-19 environment, investor panic is no longer as severe, and the impact on Tesla's yield rate is no longer as significant in quantitative terms.

3.3 PACF fixed-order and ACF fixed-order

PACF fixed order method can be used to confirm the degree of ar in the ARMA-GARCH model and ACF fixed order method can be used to confirm the degree of ma in the ARMA-GARCH model.

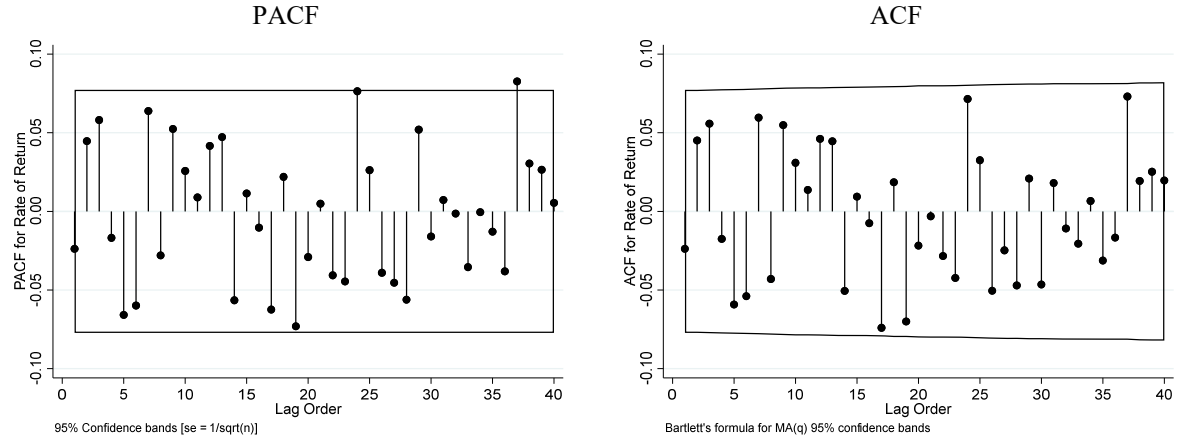

Fig. 4 PACF and ACF

From Figure 4 of the PACF plot, the first part beyond the x-axis is 37, so the degree of AR(p) is 37. Then, as for the ACF plot, all points are within the box, so the degree of ma(q) do not exist.

3.4 ARMA-GARCHX estimation results

The ARCH model is used to notice the characteristics of semiconductor return volatility since this paper need to better predict the variance of future semiconductor returns. The results are as follows.

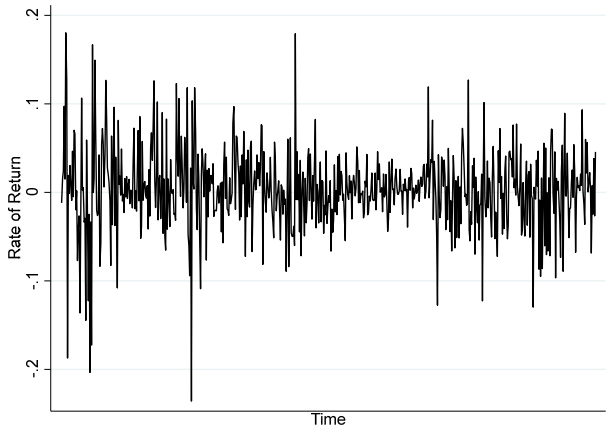

Fig. 5 Yield trend

From Figure 5, it can basically conclude that there is aggregation of Tesla's returns rate since most of lines are around 0, but the significance of the effect needs further empirical testing.

Then, from the results of Table 3, both the ARCH term and the GARCH term of the model are significant since all the p-values are led than 0.1. It indicates that there is statistically significant conditional heteroskedasticity in Tesla's yield rate and satisfies the basic condition of GARCH model. The first table of Table 3 may present the relationship between the new daily confirmed cases in China and the Tesla's yield rate. The other may be the relationship between the new daily confirmed cases overseas and the Tesla's yield rate. In addition, from the external explanatory variables, a 1% increase in the number of new daily confirmed cases in China may be associated with a 0.3079 unit increase in the volatility of Tesla's yield rate. Also, the coefficient is significant at the 1% level which may indicate that the epidemic in China has a significant positive effect on the volatility of Tesla. However, the epidemic overseas do not have this effect.

Table 3. ARMA-GARCH estimation results

	(1)			(2)		
	Coefficient	Std. err	p>|Z|	Coefficient	Std. err	p>|Z|
Mean equation						
AR, L37	0.0653	0.0353	0.0640	0.0833	0.0391	0.0330
Constant	0.0036	0.0016	0.0330	0.0037	0.0017	0.0360
Variance equation						
New daily confirmed cases						
China	0.3079	0.0757	0.0000			
Overseas				-0.2266	0.0432	0.0000
GARCH (1, 1)						
ARCH, L1	0.0891	0.0150	0.0000	0.0830	0.0169	0.0000
GARCH, L1	0.8841	0.0183	0.0000	0.8921	0.0204	0.0000
Constant	-11.0492	0.3976	0.0000	-6.9936	0.5184	0.0000

4. Discussion

This paper discussed the effect of COVID-19 on the Tesla's yield rate as many papers do and the conclusion about the short-term impact of the outbreak on Tesla's yield of this paper is as same as other paper. However, in the long term, this paper indicates the relationship between the COVID-19 in China or overseas and Tesla's yield rate. It May be more accurate. Also, many paper may find the epidemic have an influence on the volatility of Tesla, but they may not discuss this question from two sides (China and overseas, respectively) and find whether COVID-19 from these two parts has positive or negative effects on Tesla's volatility. Moreover, it can be learned from this paper that when doing another research, it can be considered from various aspects and consider some cultural differences. Although some policies has been designed to deal with COVID-19 by the governments, the effect of these policies may limit the Tesla's market in the short term. In the long term, it may have less effect on the Tesla's yield rate. Also, the governments need to publish more policy to protect the rights of inventors and try to eliminate their worries. From the conclusion of this paper, the inventors may be more confident to invest on Tesla since the return rate may be increasing. If the inventors want to invest in China's Tesla market, they should know that the greater the risk the greater the reward.

5. Conclusion

The object of this paper is to study Tesla's yield rate and volatility in a prolonged period affected by COVID-19 and give the explanation from both Chinese and overseas outbreaks and also make a prediction. Meanwhile, it offers some suggestions for the investors and policy makers.

In conclusion, from the results of impulse response method, Tesla's yield rate may be affected by COVID-19 in the short term, while the impact will be less in the long run. From ARCH-GARCH model, the volatility of Tesla is positively influenced by the epidemic in China. To be more specific, increased volatility of Tesla's earnings as the number of new daily confirmed cases of COVID-19 in China increases. Then, the volatility of Tesla is positively influenced by the epidemic overseas. In today's huge electric vehicle market, Tesla, as one of the leading electric vehicle companies, still has a lot of potential for growth. The electric cars may substitute the gasoline cars as the main means of transportation for people in the future.

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