The impact of brake failure rights protection event on Tesla Motors: stock prediction based on ARIMA model

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Abstract. On April 19, 2021, the Shanghai Auto Show witnessed a rights protection incident involving Tesla's brake failure. The arrogant official response has eroded consumer trust and had a detrimental impact on Tesla's operational performance. This article employs the ARIMA model to analyze Tesla's stock price data, selecting data from a year prior to and following the incident. The forecast findings are analyzed to determine the impact of the event on Tesla's stock prices, followed by advice for investors on decision-making. According to this article, Tesla's stock prices were significantly negatively impacted by the rights protection incident. Meanwhile, policy lags and the absence of a weak efficient market could be blamed for the notable shift in stock price that occurred only starting on the seventh day of the event. This suggests that investors could leverage the interval of time between the occurrence of the event and the occurrence of stock price variations to their advantage when managing their investments.

1 Introduction

Tesla, as a publicly traded company specializing in automobiles, is known for its four super factories, providing ultra-high production capacity. It has successively launched four models in the Model series and offers various charging services for its new energy vehicles. The innovative energy model and structural design of automobiles have led to a continuous increase in sales. However, Tesla's development history is also marked by constant controversy.

Since 2021, Tesla has faced multiple major accidents [1]. In January 2021, a Tesla Model 3 car, purchased just six days earlier, experienced a circuit malfunction while using Tesla's official supercharging station. On May 3rd, a Tesla car crashed into a wall in an underground parking lot in Guangzhou, China, and the airbags did not deploy. The continuous occurrence of accidents has heightened consumer concerns about Tesla's safety [2,3].

In April 2021, a car owner staged a "roof protection" incident at the Shanghai Auto Show, further thrusting Tesla into the forefront of public opinion. On April 19, 2021, during the first Media Day of the exhibition, a Tesla owner stood on the roof of a Tesla car, shouting "Tesla brake failure" to assert her rights, drawing a crowd of media and onlookers. The white T-shirt she wore had the words "brake failure" printed on it. According to media reports, the car owner's father failed to brake while driving the Tesla Model 3, causing a rear-end collision that nearly resulted in the death of her entire family [1]. What further fueled her anger was Tesla's manufacturer refusing to return the car and provide compensation. This led her to choose the extreme measure of standing on the roof of the car at the show to protect her rights. Subsequently, various critical voices about Tesla surfaced on the internet [2].

Research indicates that when companies experience a black swan event, external investors tend to adopt a bearish stance on the company's stock [4]. Simultaneously, existing shareholders and other stakeholders may harbor doubts about the company's corporate governance capabilities, thereby influencing corresponding investment decisions [5]. Consequently, companies should actively respond by sending positive signals to the market [5].

However, Tesla Vice President Tao Lin emphasized in response to media inquiries that "all the public opinion was caused by this lady." Tesla's insincere crisis PR, haughty reactions from upper management, and slow fixes were the catalyst for a crisis of consumer trust, resulting in a sharp decline in Tesla's market share. Only 25,845 cars were traded in Tesla China in the first quarter following the incident, a 27% drop from the prior quarter. Among these, only 6,264 copies of the Model 3 involved in this rights protection event were sold, a significant drop of around 75% from the previous period.

Previous research has primarily focused on the series of public opinion impacts caused by Tesla's inappropriate public relations strategy, undermining consumer confidence and leading to a sharp drop in sales, thereby affecting short-term business indicators [6]. As a listed company, stock information theory determines that the volatility of stock prices can better reflect the fundamental impact on Tesla [7]. To fill the gap, this article will compare the differences between stock fluctuations and predicted values after the roof rights protection event, analyze whether the event has an impact on Tesla's stock prices and the degree of impact,

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and provide decision-making recommendations to investors.

The remaining part of this article is structured as follows: Section 2 will introduce the data sources and model design. Section 3 will comprehensively discuss the ARIMA model and its results. Firstly, it will explain the basis for determining the order of the ARIMA model, and then analyze and explain the stock prediction results based on the time series background. The discussion on the implications of this study for investor investment decisions and how policymakers can understand the research findings will be presented in Section 4. Finally, Section 5 will briefly reiterate the main conclusions of this article.

2 Research methods and model design

2.1 Data sources

Investing is one of the authoritative stock data query websites in China, so this paper used this website to collect the Tesla stock price information needed for our research [8]. This study collected the closing price data of Tesla stock on each trading day from April 19, 2020, to April 19, 2022, covering one year before and after the "Roof Rights Protection" event. There are a total of 505 sets of data per day and 105 sets of data per week.

2.2 Model design

The ARIMA model is developed based on the ARMA model [9]. Unlike the ARMA model used for modeling stationary time series, ARIMA can be employed to model non-stationary time series by performing differencing on non-stationary sequences [10]. The ARIMA (p, d, q) model is denoted as:

$$\begin{cases} \Phi(B)\nabla^d x_t = c + \Theta(B)\varepsilon_t \\ E(\varepsilon_t) = 0, Var(\varepsilon_t) = \sigma_t^2, E(\varepsilon_t \varepsilon_u) = 0, u \neq t \\ E(x_u \varepsilon_t) = 0, \forall u < t \end{cases} \quad (1)$$

In equation (1), $\nabla^d = (1-B)^d$ 、 $\Phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \ldots \phi_p B^p$ is the autoregressive coefficient polynomial of the stationary reversible ARMA (p, q) model; D in the model is the order of the difference; $\Theta(B) = 1 - \theta_1 B - \ldots - \theta_q B^q$ is the moving smoothing coefficient polynomial of the stationary reversible ARMA (p, q) model; $\{\varepsilon_t\}$ is a zero mean white noise sequence.

2.3 Augmented Dickey Fuller test

After summarizing and formatting data in Excel, use Stata MP 16 software to process the sequence. Perform stationarity tests on the daily and weekly sequences of Tesla's stock closing price. ADF (Augmented Dickey Fuller test), also known as unit root test, determines whether a time series has a unit root [11]. A time series without a unit root is stationary, while a time series with a unit root is non-stationary [11]. The null hypothesis of the ADF test has a unit root. If the p-value obtained is less than a confidence level of 5%, it indicates that there is at least 95% confidence that the time series is stationary. If the sequence is not stationary, perform natural logarithmic transformation and differencing on the sequence until it is stationary and can pass the ADF test.

Table 1 Weak stationarity test

	t (Test Statistic)	MacKinnon approximate p-value for Z(t)
	Daily	
Ln index	-1.523	0.8212
1st order difference	-11.675	0.0000
2nd order difference	-21.478	0.0000
	Weekly	
Ln index	-1.652	0.7713
1st order difference	-5.640	0.0000
2nd order difference	-8.655	0.0000

Table 1 shows that the second-order differenced sequences are stationary because the p-values for both the daily and weekly sequences are 0.000, which is less than 0.05.

2.4 Establishment of ARIMA model

After obtaining a stable time series, follow the three steps for modeling and prediction:

1) Model ordering and fitting: Determine the model parameters p (autoregressive order), d (number of differences required to transform the original time series into a stationary time series), and q (moving average order) based on the ACF and PACF plots [11,12]. Select the optimal parameters to fit the model. Try to start with smaller parameters and gradually increase them if the goodness of fit is poor.

2) Perform a residual test on the fitting model to ensure that the residuals conform to the assumption of white noise and validate the effectiveness of the model [10,11].

3) Prediction: After establishing the model, predict Tesla's stock price for the next 9 days and two weeks, respectively. Analyze the deviation between the predicted and actual values on different trading days under daily and weekly forecasts, as well as the reasons.

3 Empirical results and analysis

3.1 Order determination

As the model order obtained from the first-order differenced sequence of the stock price was too high, there is a risk of non-convergence in residual sequences, which could affect the goodness of fit of the model [10]. Therefore, although the first-order differenced sequences of daily and weekly degrees satisfy the condition of sequence stationarity (p, q), this study chooses the p, q values from second-order differenced sequences to determine the order. According to Table 1, the p-value of the 2nd order differenced sequence of Tesla's stock

closing price is less than the significance level of 0.05, hence rejecting the null hypothesis. Therefore, this sequence is considered to be a white noise sequence at a 95% confidence interval, and the model is effective. The difference order is 2, which is obtained from part 2.3.

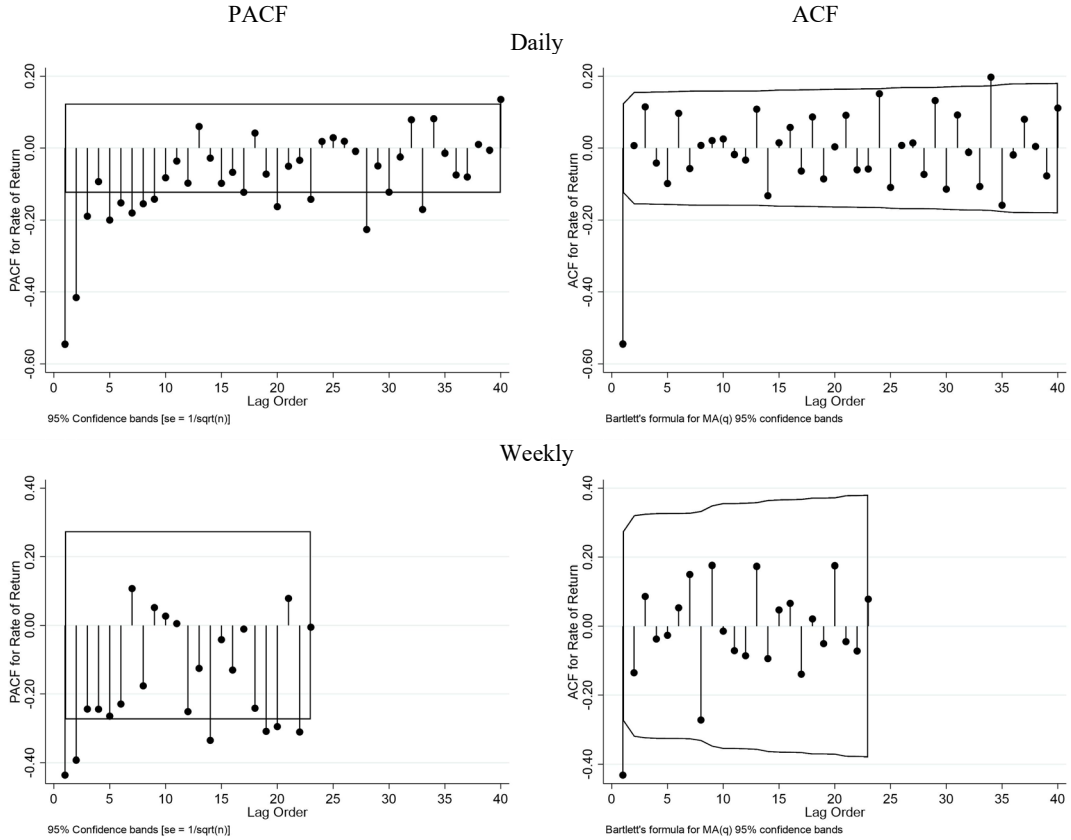

Fig. 1. ARMA (p, q) identification

Photo credit: Original

For the daily second-order differenced sequence, set p=9 and q=1 to establish a model and predict Tesla's closing price for the next 9 trading days. For the weekly second-order differenced sequence, set p=2 and q=1 to establish a model and predict Tesla's closing price for the next two weeks. To verify the accuracy of the model fitting, residual testing was performed on the prediction results. The initial assumption was that the residual sequence of the model was a white noise sequence, with a significance level of 0.1. The test results are shown in Table 2.

Table 2 Residual test

Model	Portmanteau (Q) statistic	Prob > chi2
Daily-ARIMA(9,2,1)	43.7690	0.3146
Weekly-ARIMA(2,2,1)	23.1027	0.9851

The P-value of Daily ARIMA (9,2,1) is 0.3146, which is greater than the significance level of 0.1. The P-value of Weekly ARIMA (2,2,1) is 0.9851, also greater than the significance level of 0.1. Therefore, this part accepts the null hypothesis that the residual sequence is white noise. The residuals of the daily and weekly sequence prediction models established using ARIMA conform to the assumption of white noise, indicating the effectiveness of the model.

3.2 Results and explanation

Draw trend charts of Tesla's stock closing price based on the predicted results.

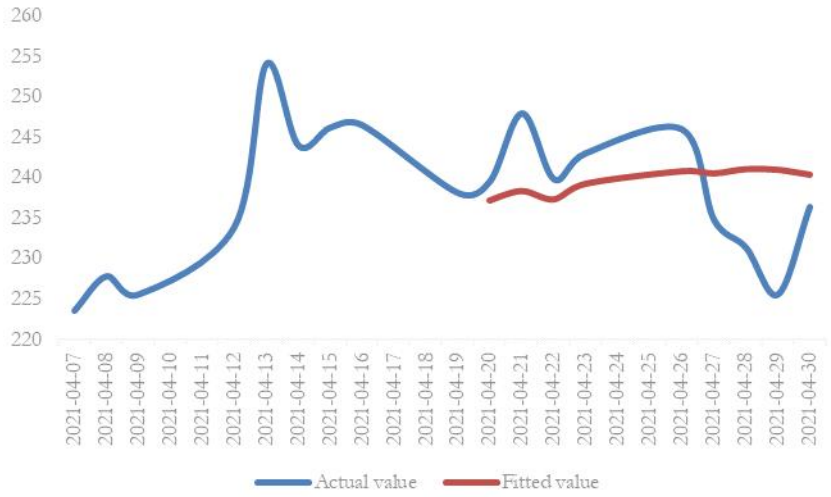

Fig. 2. Actual value and fitted value, daily

Photo credit: Original

As shown in Figure 2, under the daily and weekly models, with the event date of April 19, 2021, as the time node, there was no significant deviation between the predicted and actual values of Tesla's stock closing price from April 20, 2021, to April 25, 2021. However, starting from April 26, 2021, there was a significant deviation between the predicted and actual values of Tesla's stock closing price. From April 20, 2021, to April 25, 2021, the daily forecast of Tesla's stock closing price fluctuated almost in the same direction as the actual value, but the amplitude was relatively small, consistently within the range of 235-240. From April 26, 2021, to April 29, 2021, the predicted value remained almost at a level, while the actual value plummeted from 245 to 225. The weekly predicted value and actual value curve are smoother compared to the daily value, but there is also a significant deviation in almost the same time period. This indicates that the "roof rights protection" incident at the Shanghai Auto Show had a significant negative impact on Tesla's stock price, and this impact suddenly became apparent 7 days after the incident occurred.

There are several reasons why Tesla's stock has lagged behind in responding to the rights protection incident. Firstly, there is a policy lag effect in stock price fluctuations [13]. When a specific event occurs that will affect the stock price, the stock market cannot immediately adjust the stock price due to the influence of laws, regulations, and local policies [13]. The time difference between the time when the event occurred and the time when the stock price was adjusted accordingly is known as the policy lag. The reasons for delayed stock price fluctuations can also be analyzed from the perspective of market efficiency [7]. Research has shown that the lower the efficiency of the market, the more difficult it is for securities prices to accurately and quickly reflect changes in the intrinsic value of securities [14]. In a weakly efficient market, stock prices can fully reflect all historical information; that is, future trends in stock prices are independent of past events [15]. Mo Yixian and Zhou Lemin used an autocorrelation regression model to verify that historical information in today's era still has an impact on current stock returns, and the market has not yet reached weak efficiency [16]. This explains why the rights protection incident that occurred on April 19, 2021, still has an impact on stock prices from April 26, 2021, onwards.

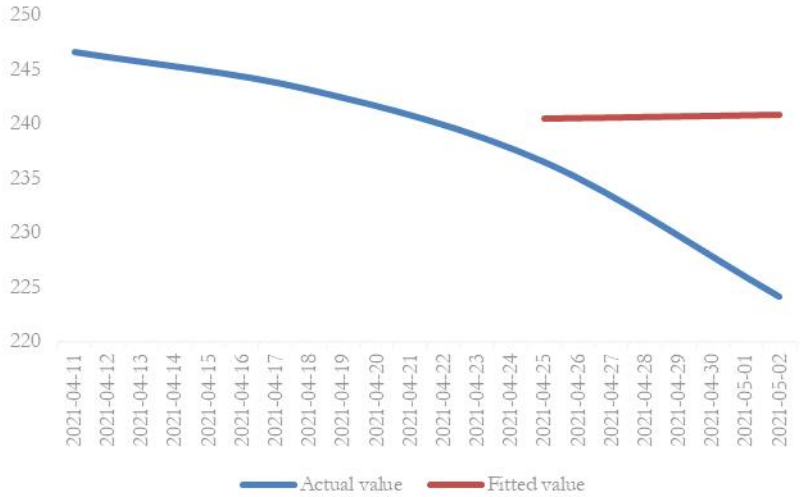

Fig. 3. Actual value and fitted value, Weekly
Photo credit: Original

4 Conclusion

This article aims to study the impact of the rights protection incident involving a Tesla car owner at the Shanghai Auto Show on Tesla's stock price and provide recommendations for investor decision-making by analyzing the reasons for stock price changes. The article primarily uses the ARIMA model to process relevant data, employing daily and weekly Tesla stock closing price sequences to predict the short-term trend of stock price changes. The prediction results indicate that within about 7 days of the event, stock prices were not significantly affected. However, after 7 days, there was a sharp decline in stock prices. This suggests that the rights protection incident has a significant negative impact on Tesla's stock price. Meanwhile, the delayed response of stock prices may be related to policy delays and the stock market not achieving weak efficiency.

While existing research mainly discusses the impact of Tesla's public relations errors on consumer confidence, the decline in business performance, and the negative effects on brand reputation, this article focuses on the impact on its stock price fluctuations. The ARIMA model used in this study has limitations in fitting accuracy when establishing high-order models. Therefore, this method can only study the short-term impact of the event. To compensate for limitations, future research can focus on whether the rights protection event has a long-term impact on Tesla's stock price.

Tesla Motors has been facing numerous vehicle safety and after-sales issues in recent years. An uncompromising and arrogant attitude will not only worsen the trust relationship between the brand and consumers, affecting the business performance of the enterprise, but also cause investors to lose confidence, which is not conducive to Tesla's long-term development. Therefore, only by maintaining a positive attitude towards consumers and actively investigating and resolving after-sales issues can the brand's image be restored in front of the public and investor confidence be regained.

Investors can utilize the time difference between public information disclosure and stock price changes to manage their investments. On the one hand, they should closely monitor relevant news and make rational decisions based on public opinion and personal experience. For a black swan event that is suspected to affect reputation, leading investors to anticipate a stock price decline, they should sell the stock in a timely manner before any adjustments are made to the stock price.

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