

The Fed's Interest Rate Policy and Changes in Tesla's Share Price: Evidence from ARIMA Model

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Abstract. On 26th July, 2023 the US Federal Reserve declared a new round of interest rate hikes, thus continuing its cycle of increase. To test its effect on the stock market, the paper predicts the stock price of Tesla since the starting of the interest rate hike cycle by means of the ARIMA model and compare it with the actual stock price. The paper finds that the stock price of Tesla experiences a rise in the extremely short run, a plump in the short term, and a rebound in the long term. The paper also provides possible explanations behind the results. Suggestions are also given to the governments and investors to focus on the type of the stocks in terms of policymaking and investment respectively. For the investors, it should be aware that, even firms in growth will be greatly affected by the overall monetary policies, the interest rate hike in this case. Although in extremely short term, the stock may witness a continuous growth momentum, the trend will not always be the case. Investors should focus on those actual growth stocks to maintain their earnings in the stock market when there are some changes in the overall monetary policies.

Keywords: ARIMA, Tesla, Fed interest rate, monetary policy, stock market.

1. Introduction

On the 26th of July, 2023, the US Federal Reserve Board declared that the federal funds rate's target range would be augmented by 25 basis points, from 5.25% to 5.5%, thus elevating it to its highest point in 22 years. This is the 11th time the Federal Reserve has raised interest rates since it entered the current rate hike cycle in March 2022, bringing the cumulative increase to 525 basis points. Looking back at the past four decades, it is not the first time that the Federal Reserve started a rate hike cycles. It has already had six interest rate hike cycles. The historical Federal funds rate is shown in Figure 1 [1].

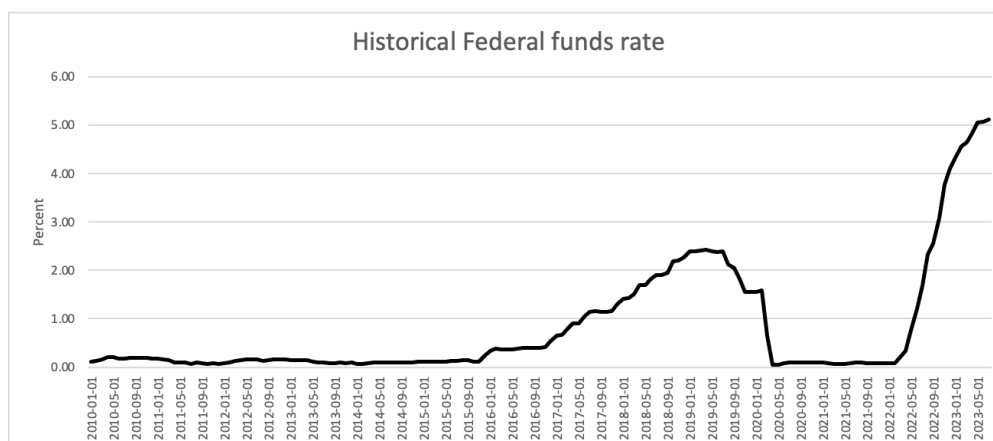


Figure 1. Historical Federal funds rate, Data source: [1], Photo credit: Original

How will the interest rate hike affect the stock market? Theoretically, rising interest rate will make borrowing more expensive for individuals and businesses, leading to higher saving rate and lower willingness on borrowing and investment. In this case, less people will choose to invest on the stock market, which will negatively affect the stock prices. Moreover, higher interest rate will also lead to higher return rate in the bond market, leading to more inflows of money into the bond market. This will further affect the stock market as less money is invested in it.

On the other hand, the hiking interest rate will attract money from all over the world to the US, leading to greater demands on the US dollar, boosting the US dollar exchange rate. Under this circumstance, a large part of the US dollar will flow into the US stock market. Therefore, in theory, the US stock market will experience a first-down-and-then-up moving cycle. In the near future, a sharp dip in the stock market will occur, yet in the long run, it will remain on a steady upward trajectory as the anticipation of sustained rate hikes intensifies.

Empirical techniques are employed in this paper to find out the stock market's reaction to the Federal Reserve's interest rate policy. The paper concentrates particularly on the policy effects on the Tesla stock price. The paper will use the ARIMA time series model to predict the assumed price of the Tesla after the starting of this cycle of interest rate hike, compare the predicted price with the actual price that is observed from the market information, analyze the results of how the interest rate policy will affect the stock price, and try to give an explanation on those results.

In Section 2 and Section 3 of the paper, an exhaustive literature review of the related topics will be presented, as well as the methodology and data source utilized. Organizing the paper's rest is a task that should be undertaken following these instructions. Section 4 shall be devoted to an empirical analysis, with Section 5 delving into the outcomes. The paper's conclusion is found in Section 6

2. Literature Review

The macroeconomic variables of a nation's economy, such as interest rate, have a major impact on the supply and demand of money in the market, influencing inflation, currency exchange, and more. The proper adjustment of the interest rate level is critical to the management of the financial market and the overall economy by the government.

Many researchers have focused on the influence of monetary policy on the equity market. Thorbecke argues that, through event study of Fed policy changes, expansionary policy will increase ex-post stock returns [2]. Bernanke and Kuttner scrutinize the stock market's response to the Federal Reserve's policy, utilizing a monetary policy gauge based on futures data to single out the unforeseen element of policy decisions. A 25-basis-point reduction in the Federal funds rate target, unforeseen, is linked to a 1% rise in the broad stock indexes, as discovered in that paper. The authors' methodology, as proposed by Campbell and Ammer, revealed that the change of expected returns caused by unanticipated monetary policy actions has been the most influential factor in anticipating future stock prices [3]. A VAR coefficient varying with time, employed by Galí and Gambetti, reveals that stock prices will persistently rise in reaction to a monetary policy tightening outside of the country [4].

Other researchers are also focusing on the influence of the changes of the Federal interest rate on other economies, especially in some emerging markets. Conover et al. find that in expansive US and local monetary conditions, foreign stock returns tend to be greater than those in restrictive ones [5]. Utilizing event study techniques, Ehrmann and Fratzscher investigate the impact of the unexpected element of monetary policy choices on equity returns on the days of their declaration. The Tobin q value and financial constraints can be linked to the considerable disparity between the reactions of individual stocks to US monetary policy shocks [6]. Investors, due to the Fed's interest hike, have been driven to invest in higher quality investments in emerging markets, as demonstrated by Jeongsim Kim, using the Korean firm data with event study and cross-sectional ordinary least squares regression [7]. The Mexican economy's condition determines the Mexican equity market's response to alterations in the federal funds target rate, as discovered by Health and Kopchak. When confronted with US monetary surprises, cyclical downturns cause more suffering than expansions [8].

Some researchers also researched on the effect of the interest rate changes of one economy on their own stock market. For example, Ahmad et al. apply the multiple regression model to assess the effect of the change in interest rate and exchange on stock returns. Results demonstrate a noteworthy effect of both alteration in interest rate and exchange rate on stock returns throughout the sample period [9]. Others have done researches on the cause of the Fed interest rate change on different kinds of firms. By using different portfolio sorts, Maio demonstrates that the returns of stocks with a more limited

financial situation are more notable in response to monthly alterations in the Federal funds rate than those with a more advantageous financial standing. Utilizing a VAR approach, he demonstrates that the Fed funds rate's deleterious effect is due to its negative impact on anticipated future cash flows [10]. There are also researches on the effect of Federal Reserve interest rate on other variables, such as the exchange rate. Exploring the effect of Federal Reserve interest rate policy on the US-RMB exchange rate, Ji et al. applied the ARIMA model and discovered that the Fed's rate increase has resulted in the depreciation of the RMB, providing Chinese authorities with some advice on the matter [11].

3. Methodology and Data

3.1. Data Source

The historical data of the Tesla stock price is obtained from Investing.com, a financial platform and news website which provides market information on equities, futures, and options. The date of the raise of interest rate for the first time by the Federal Reserve, t_0 , is set to be March 16, 2022, according to the news and public information on the Internet. The paper uses daily, weekly, and monthly stock-price data of Tesla from July, 2010 to July, 2023, to study the impact of the Federal Reserve raising the interest rate on Tesla's stock price.

3.2. Weak Stationarity Test

The unit root test is used to test whether the series of data satisfies the weakly stationary condition. Specifically, an Augmented Dickey-Fuller (ADF) test is performed to test its weak stationarity. Table 1 reveals that, for daily, weekly, and monthly data, the p-value for first and second order difference is sufficiently diminutive to disprove the null hypothesis that the data series is not weakly stationary. The p-value of the raw data, however, does not refute the null hypothesis, thus indicating that it is not weakly stationary and has the unit root. In other words, the data in first and second order difference satisfies the weakly stationary conditions.

Table 1. Weak stationarity test

		t	p
	Daily		
Raw		-1.564	0.8063
1st order difference		-38.630	0.0000
2nd order difference		-67.183	0.0000
	Weekly		
Raw		-1.429	0.8523
1st order difference		-16.476	0.0000
2nd order difference		-31.180	0.0000
	Monthly		
Raw		-1.645	0.7743
1st order difference		-8.239	0.0000
2nd order difference		-13.781	0.0000

3.3. ARIMA Model

The paper is going to use the ARIMA model to predict the Tesla stock price movements without the rate raise by the Federal Reserve, and compare it with the actual stock price movements. A synthesis of the autoregression (AR) and moving average (MA) models, the ARIMA model is employed to illustrate the development of a given item with temporal data.

Specifically, a typical AR(p) model can be described as follows:

$$Return_t = \phi_0 + \phi_1 Return_{t-1} + \phi_2 Return_{t-2} + \cdots + \phi_k Return_{t-p} + a_t \quad (1)$$

The AR model means that the value of x at time t is designed to be predicted by k lags of itself.

On the other hand, a typical MA(q) model can be described as follows:

$$Return_t = c_0 + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \quad (2)$$

The MA model indicates that the past disturbances can be employed to forecast what lies ahead. The MA model uses a linear combination of the white noise to predict the future x value.

To combine these two kinds of model, we have the ARMA (p, q) model,

$$Return_t = \phi_0 + \phi_1 Return_{t-1} + \phi_2 Return_{t-2} + \dots + \phi_k Return_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \dots - \theta_q a_{t-q} \quad (3)$$

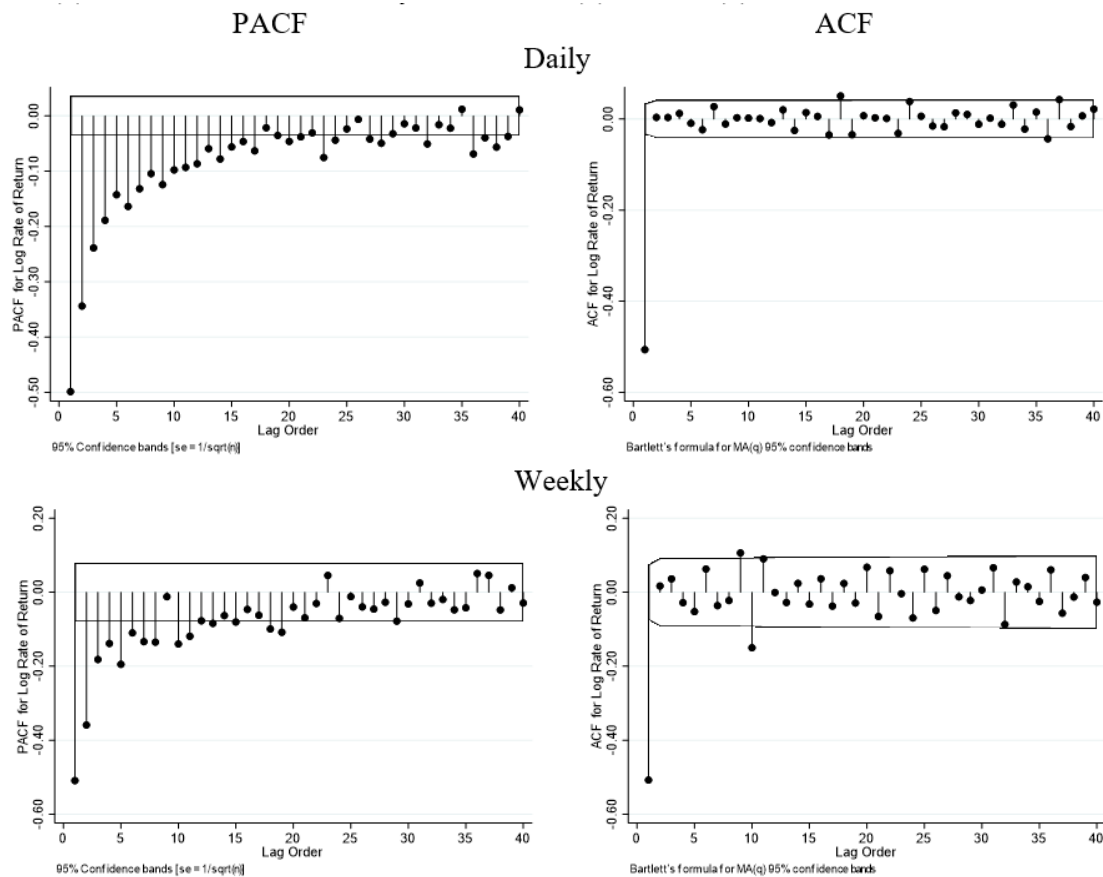
Equation (3) considers both the autoregression factor and the moving average factor in one formula.

From the above analysis, the raw data has the unit root, indicating that it is not weakly stationary. Therefore, the paper uses the differential data to eliminate the unit root problem. The ARIMA (p, d, q) model, which employs a differential model and has d as the order of differential data, is the ARMA model.

4. Empirical Analysis

4.1. Order Identification

By employing PACF and ACF plots, the sequence of the AR and MA model is discerned in this part. The second order differential data for daily, weekly, and monthly is depicted in Figure 2 through the PACF and ACF plots. The AR (10) and MA (1) model is the most advantageous, as demonstrated in Figure 2. The selection of the AR(10) model was due to the potential for overfitting issues arising from a higher order of the AR model. For weekly data, the optimal approach is to employ the AR (9) and MA (1) models, while for monthly data, the AR (5) and MA (1) models are the most suitable.



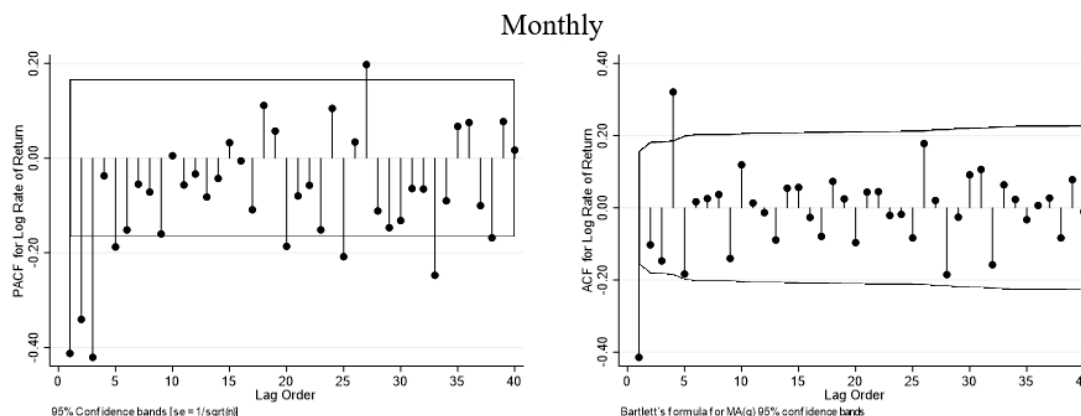


Figure 2. ARMA (p, q) identification, Photo credit: Original

The paper doesn't use the first order differential data to identify the optimal order, because specific order information couldn't be acquired from the PACF and ACF plots of the first order differential data.

As a result, the paper uses the ARIMA (10, 2, 1) model for the daily data, the ARIMA (9, 2, 1) model for the weekly data, and the ARIMA (5, 2, 1) model for the monthly data.

4.2. Analysis of the Results

By using the above mentioned ARIMA model on daily, weekly, and monthly data, the paper predicts the stock price of Tesla after t_0 , which is the first time that the Federal Reserve raised the interest rate.

Prior to examining the regression's outcomes, the paper performs a white noise test. Table 2 reveals that none of the three models refute the null hypothesis that the residual is a white noise sequence, thus leading to the conclusion that the residual of the model is a white noise series.

Table 2. Residual test

Model	Portmanteau (Q) statistic	Prob > chi2
Daily	33.3315	0.7630
Weekly	35.3608	0.6790
Monthly	33.3653	0.7616

First, the fitted value using the daily data along is shown with the actual level in figure 2. From Figure 3, it can be seen that, in the extremely short run, the fitted value of the stock price is relatively stable, while the actual stock price was on the rise. Theory proposes that a rise in interest rates will result in a decrease in the money supply, thus leading to a reduction in investment. Moreover, higher interest rate will lead to higher return rate in the bond market, which in turn leads to lower stock price. Therefore, we expect the stock price to be lower than the fitted value after t_0 . However, by observing the results from the graph, it can be concluded that, in the extremely short run, the stock price of Tesla was not affected by the stimulation in the Federal interest rate. On the contrary, the actual stock price continues to rally. There are two possible explanations. It is possible that the result is caused by the time-lag of the policy, meaning that the market has not reacted to the stimulation in such a short period of time. It is possible that the market was not affected sufficiently by the increase in the interest rate.

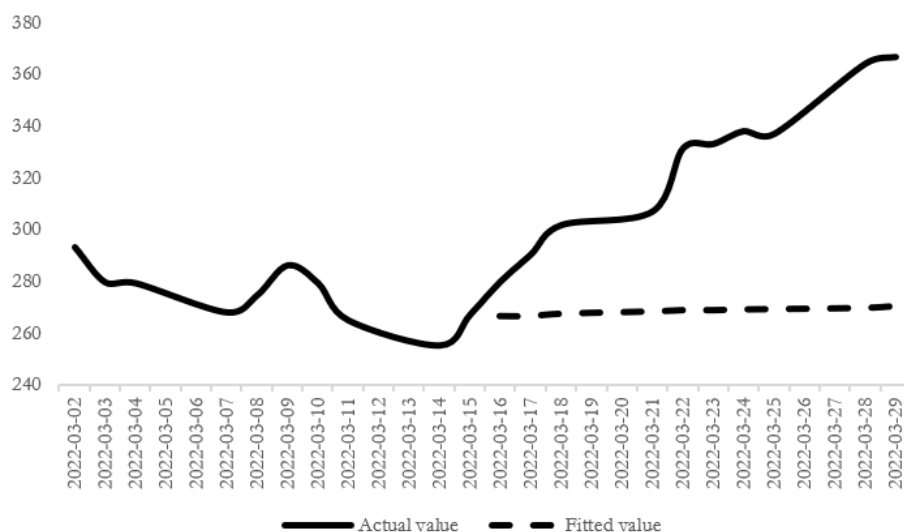


Figure 3. Actual value and fitted value, daily, Photo credit: Original

Similarly, weekly, and monthly data is used to fit the historical stock price, and compare the results with the actual value. From Figure 4, it can be seen that, in the short run, the stock price started to fall, which is aligned with our expectations.

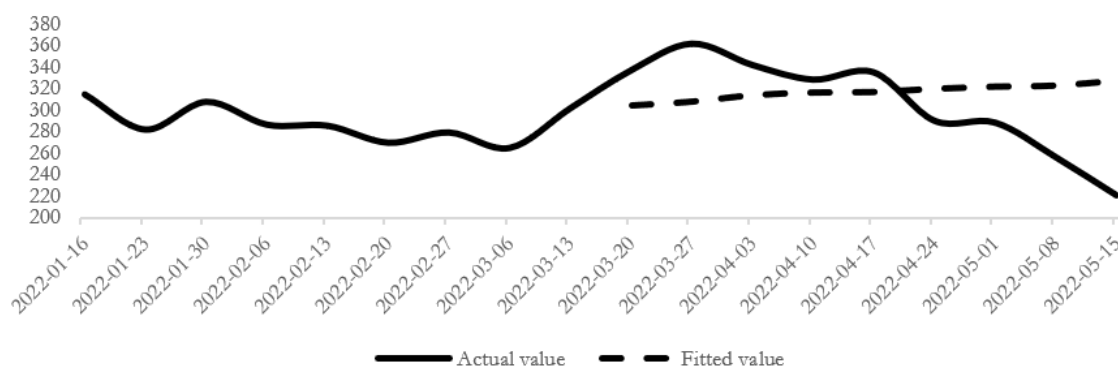


Figure 4. Actual value and fitted value, weekly, Photo credit: Original

While in the long run, by what is observed from Figure 5, it can be indicated that after a steep drop, the stock price started to rise again about 3 months after the first implementation of the interest rate hike. A possible explanation for it is that the fundamentals of Tesla has changed. In this case, the original predictions will not be accurate.

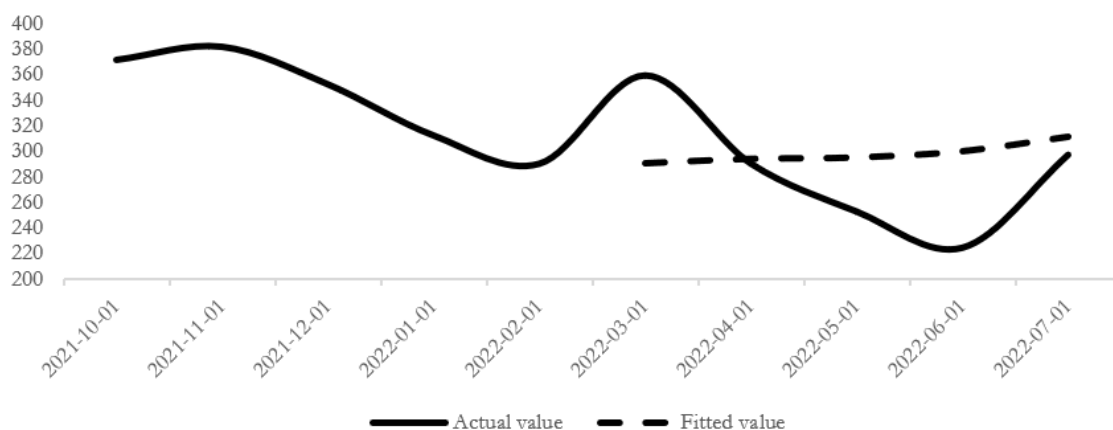


Figure 5. Actual value and fitted value, monthly, Photo credit: Original

The paper also ascertains the mean percentage discrepancies between the fitted value and the actual value of the extremely short, short, and long terms, taking into account both the actual and the fitted values. In the extremely short term, the average difference is about 20.91% of the fitted value,

indicating a significantly surprised hike after the Federal Reserve announced the rate changes. In the short term and the long term, the percentage falls to negative 3.04% and negative 4.62%, indicating that, in comparison to the extremely short term, the difference between the true value and the predicted value is quite insignificant, and the true value is below the assumed value without the interest rate hike.

5. Discussion

Rather than examining the impact of the Federal Reserve's interest rate increase on the entire stock market of a nation or a whole sector, this paper concentrates on its influence on one particular company's stock price. The paper chooses Tesla because the performance of the EV market has been continuously catching people's eyes and Tesla is one of the most famous and well-performed US companies.

Empirical studies have typically been conducted through the utilization of event study methods or VAR models. The paper's pioneering feature is to employ the ARIMA model to forecast Tesla's stock price, then contrast it with the actual worth.

The above results indicate that Tesla's stock price was affected by the interest rate hike stimulation in the short run, but was quickly back on track of its growth three months after the starting of the rate hike cycle. It can be inferred that the long-term effect of the continuous interest rate hike is relatively low and the stock price of a certain country under the monetary policy will alter according to ever-changing fundamentals of the firm. As Investor Place's Luke Lango lays out, contrary to popular belief, rate hikes are not always detrimental to growth stocks. Instead, in the case that companies can showcase growth in both sales and earnings, they can easily counterbalance the valuation contraction brought about by rate increases. Therefore, from what is observed of the actual value and predicted level using ARIMA model, though experiencing a short-term plump of the stock price, Tesla quickly refresh itself and witnessed a rebound in its stock price. The results are also aligned with the previous studies on the effect of the hike in interest rate is greater on more financially constrained stocks than those with more favorable financial conditions.

For governments, they could put less concerns on the effect of rising interest rate on those growth stocks like Tesla. However, they should put more emphasis on those that are more financially constrained, as they may not be able to recover from the changes in the monetary policy quickly, causing continuous damage on their stock returns. Moreover, from the above analysis, the interest rate hike will only take effect once its cumulative increase reaches a certain level, or it has been implemented for a certain period of time. Therefore, the policy-maker should be cautious about the time-lag effect and the cumulative effect of the monetary policy.

For the investors, it should be aware that, even firms in growth will be greatly affected by the overall monetary policies, the interest rate hike in this case. Although in extremely short term, the stock may witness a continuous growth momentum, the trend will not always be the case. Investors should focus on those actual growth stocks to maintain their earnings in the stock market when there are some changes in the overall monetary policies.

6. Conclusion

The continuous hike in the Federal Reserve interest rate has made a stir all over the world. The ARIMA model was utilized in the paper to forecast Tesla's stock price since the commencement of the interest rate hike cycle, and the outcome was then compared to the actual stock price. Data from the paper is collected daily, weekly, and monthly. The unit root test is first conducted to test the weak stationarity of the data. After that, the paper gives the PACF and ACF plots to identify the orders of the AR and MA model.

The research then divided the time period into three kinds, namely the extremely short term, short term, and the long term, and the results are concluded as follows. In extremely short term, the stocks

remained its growing momentum, and did not react to the change in the rate policy, while the predicted data is about flat. The results may be mainly caused by the time-lag factor or the cumulative influence. In the short run, the stock price started to reflect the change in the interest rate, and started to plump. In the long run, the stock price first continued the downward trend, and after about 3 months, the stock price rebounded, mainly caused by the changing fundamentals of the stock. Therefore, although the interest rate hike is still continuing, the stock price will experience different movements due to different reasons.

After giving the results, the paper also gives some comparison between the paper and the previous researches. The paper also gives some suggestions to the investors and governments respectively.

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