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Forecasting Tesla's Stock Price Using the ARIMA Model

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Abstract: The stock market is an important economic information center. The economic benefits generated by stock price prediction have attracted much attention. Although the stock market cannot be predicted accurately, the stock market's prediction of the trend of stock prices helps in grasping the operation law of the stock market and the influence mechanism on the economy. The autoregressive integrated moving average (ARIMA) model is one of the most widely accepted and used time series forecasting models. Therefore, this paper first compares the return on investment (ROI) of Apple and Tesla, revealing that the ROI of Tesla is much greater than that of Apple, and subsequently focuses on ARIMA model's prediction on the available time series data, thus concluding that the ARIMA model is better than the Naïve method in predicting the change in Tesla's stock price trend.

Keywords: Stock price forecast; ARIMA model; Naïve method; Tesla

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1. Introduction

Financial markets generally refer to markets where securities are traded, which include the stock market, bond market, foreign exchange market, and derivatives market. Financial markets can allocate resources to enterprises and entrepreneurs, create liquidity, guide the rational allocation of capital, and promote the smooth operation of the capitalist economy. Among the financial markets, the stock market is the most common financial market and an important economic information center. Stocks generate transactions that provide investors with capital gains and dividend income, measure the overall health of the economy, and play a vital role in improving social and economic performances.

Although the stock market cannot be predicted accurately, the stock market's prediction of the trend of stock prices helps in understanding the operation law of the stock market as well as the influence mechanism on the economy. Therefore, a model is needed to predict the overall trend of stock prices. The autoregressive integrated moving average (ARIMA) method is a statistical method used to analyze and build predictive models that best represent time series by modeling correlations in data. Using the ARIMA model to predict time series data is better than the Naïve method because it can predict the changing trend of stock prices more accurately. Therefore, this paper primarily studies the use of ARIMA model to predict the changing trend of Tesla's stock price and compares it with the Naïve method in this respect.

In this paper, we focus on using the Naïve method and ARIMA model to predict the existing time series data, so as to understand the changing trend and investment value of Tesla's stock price in hope that the predicted results will be conducive to investors in making optimal decisions in the future. This paper is

structured as follows: in section 2, we discuss the various applications of the ARIMA model in the stock market and the novelty of this paper in comparison; we discuss the experimental method in section 3, followed by the experimental results based on a detailed analysis of the experimental process in section 4; in Section 5, we draw our conclusion.

2. Literature review

Stock price forecast is an essential topic in finance and economics. It stimulates the interest of stock market researchers to develop better prediction models, effectively reduce the risk of stock market investment, and promote the further development of the economy and society. The ARIMA model has been applied in many studies to detect time series for predicting the changing trend of stock prices. Based on the stock data obtained from the New York Stock Exchange and the Nigerian Stock Exchange, as well as the established stock price prediction model, the results of the joint use of the two models showed that the ARIMA model has a strong short-term stock price prediction potential [1]. In addition, by applying the auto ARIMA model and two custom ARIMA models to Netflix's stock historical data from 2015 to 2020, the calculation results of ARIMA (1,1,33) were found to be more accurate, thus once again reflecting the potential of the ARIMA model for accurate prediction of time series data, which would help investors make decisions [2].

The ARIMA model can also be used with other models. For example, a support vector machine (SVM) was combined with the ARIMA model in a study to form a hybrid model that has linear and nonlinear modeling abilities to predict stock prices; the hybrid model significantly reduced the overall forecast error and better predicted the stock price of SBC Communications Inc. [3]. The effectiveness of several ARIMA-GARCH models in modeling and forecasting the conditional mean and weekly volatility of crude oil spot prices in 11 international markets from February 1, 1997, to March 10, 2009, has been studied [4]. ARIMA-intervention analysis method was used in another study to model the Chinese stock market price index, so as to evaluate the economic movement of the Chinese stock market price at different times [5]. This illustrates the predictable nature of the stock market and the effectiveness of the ARIMA time series model as an analysis and forecasting tool. By referring to published stock data, a study compared the performance of the artificial neural network (ANN) forecasting model with that of the traditional Box-Jenkins ARIMA model, which has been widely used for time series forecasting [6]. The results revealed that both the models are able to make good predictions when applied to practical problems. The DWT-ARIMA-GSXGB hybrid model was proposed in 2020 [7]. Through experimental comparison of 10 stock data sets, the results showed that the DWT-ARIMA-GSXGB stock price prediction model has a better approximation ability, suggesting that the fit to the opening price of the stock index is better [7]. This model greatly improves the performance of the single ARIMA model in stock price prediction.

It can be seen that the ARIMA model is often used to solve practical problems in the stock market. By contrast, the innovation of our study lies in that when predicting time series data. By comparing the ARIMA model with the Naïve method, we conclude that the ARIMA model can predict the overall trend of stock prices and consider the impact of seasonal factors on the forecast results.

3. Methodology: ARIMA model

The ARIMA model is one of the most popular forecasting methods, which is commonly used to analyze time series data for better understanding and forecasting [8,9]. In the ARIMA model, it is assumed that the future of a variable is simply a linear combination of past tenses and past errors, which is expressed as follows:

$$y = \theta_0 + \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \emptyset_p y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \cdots - \theta_q \varepsilon_{t-q}$$

where y_t is the actual value, ε_t is the random error at time t, $\emptyset_i$ and θ_j are coefficients, p and q are integers, which are called autoregressive polynomials and moving average polynomials, respectively. The method consists of three stages: model identification, parameter estimation, and diagnostic test. The ARIMA (0,1,1) model discussed in this paper can be expressed as follows:

$$y_t = \emptyset_0 + \varepsilon_t + \theta_1 \varepsilon_{t-1}$$

The existing time series data can be used by the ARIMA model to predict the stock price. Although there are some errors in the prediction results of the ARIMA model with the actual ones, it is feasible to determine the overall trend of stock price change.

4. Analysis of experimental procedure

Quantmod package was used to obtain the stock prices in R. This package uses Yahoo Finance as its source for stock prices. Using these data, we plotted a candlestick chart (**Figure 1**) from January 2, 2018, to December 30, 2021. Creating a static or interactive chart enables the visualization of stock price data. From the figure, we can intuitively see Tesla's stock price in different periods and also draw attention to the overall trend and periodicity shown by the trading volume.

Figure 1. Tesla's stock price and stock's trading volume

From the figure, we can see that there is an upward trend and seasonal pattern. In order to determine the components of the data, the data was broken down. For convenience, we used the closing price, which can be obtained by the Cl() function, for further analysis in this paper (in the quantmod package, the daily OHLC data, including the opening price, high price, low price, and closing price, can be obtained, among which the closing price is considered to be a useful marker for assessing changes in stock prices over time). We changed the period to monthly data, and the data was broken down into seasonal, trend, and random parts after decompose, using the decompose function. Through the output of the four graphs (**Figure 2**) showing the closing price data, we can see that during the study period, Tesla's stock price showed an overall upward trend (an obvious upward trend began around 2022), with repeated seasonal fluctuations (the closing price of Tesla tended to reach the highest in January, with the lowest in July); there were also irregular or random fluctuations that were not captured by trends and seasonality.

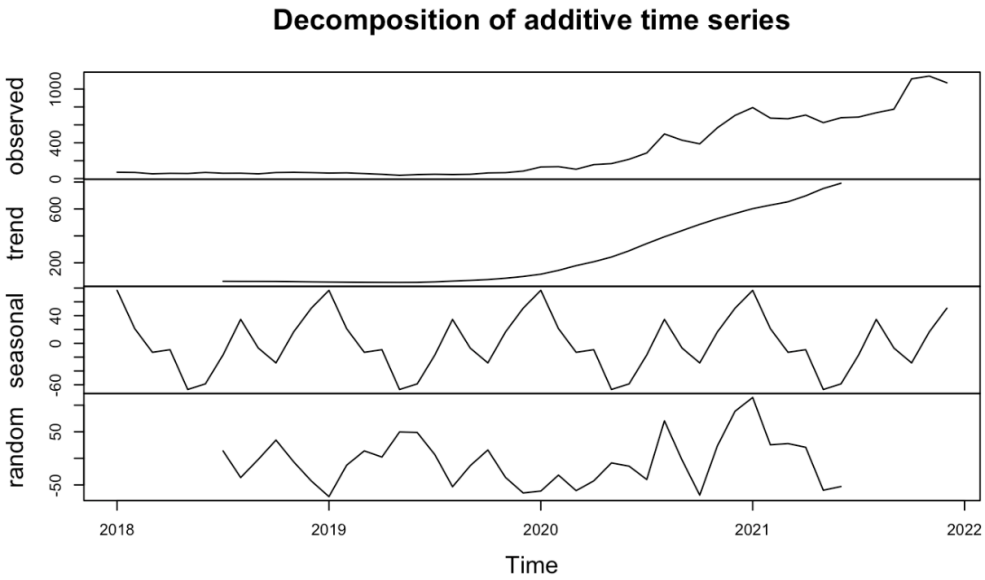

Figure 2. Raw time series data, data trends, seasonal factors, and stochastic components

In order to have a closer look at the investability of Tesla's stock, the closing price of Tesla was compared with that of Apple. As can be seen from the chart, Apple's stock price grew steadily from the beginning of 2018 to the end of 2021.

From the beginning of 2018 to that of 2020, Tesla's stock price changed in the same way as Apple's. Since then, Tesla's stock price has increased significantly, reaching almost six times that of Apple by the end of 2020.

In order to visualize the return on investment of Tesla's and Apple's stocks during this period (**Figure 3**), we used PerformanceAnalytics in R to obtain an overview of the cumulative return (top), daily return (middle), and drawdown (bottom).

From the beginning of 2018 to the end of 2021, it can be seen that both, Tesla and Apple had positive cumulative earnings. Since the beginning of 2020, Tesla's cumulative earnings increased rapidly, whereas Apple's stock price stabilized after a slight increase. The widened gap between Tesla and Apple indicates that Tesla's returns since then are far greater than Apple's. By the end of 2021, Tesla's cumulative stock return was almost four times that of Apple.

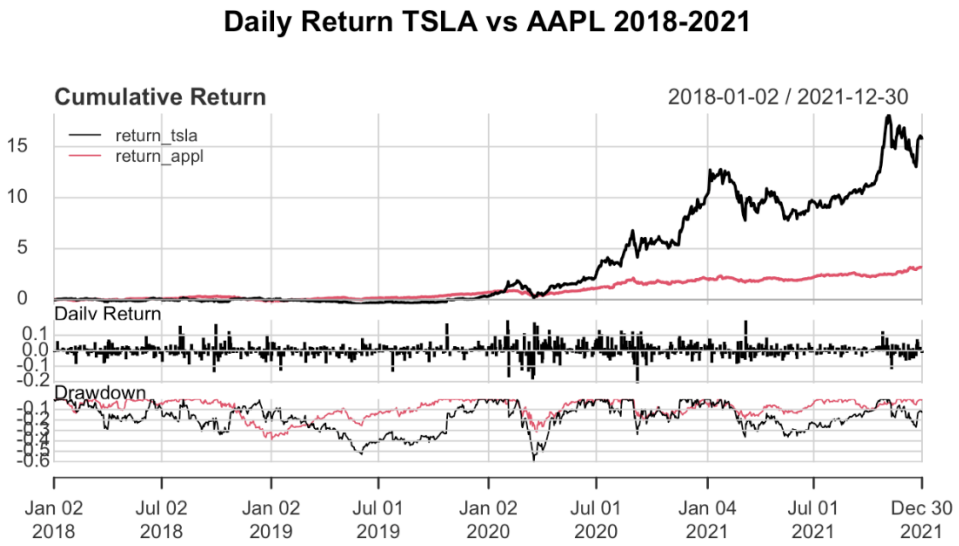

Figure 3. Cumulative return, daily return, and drawdown of Apple's and Tesla's stocks

In order to determine the investment value of Tesla's stock, we predicted the direction of the stock price based on the existing stock price data. In the following experiments, the Naïve method (**Figure 4**) and the ARIMA model were used to predict the time series data. We split the data into training data and test data in order to assess how well the model predicts the data not used in the training model. Two models were used to fit the training data and obtain the prediction results of the test data. The forecast results were plotted. Through Akaike Information Criterion (AIC), AICc (AIC with sample size correction), or Bayesian Information Criterion (BIC) with modified sample size, an ARIMA model with optimal progression can be selected. Using the R auto-arima() function, we obtained two kinds of ARIMA, namely non-seasonal ARIMA and seasonal ARIMA, which correspond to the prediction results of the model shown in **Figure 5** and **Figure 6**, respectively. The blue line represents the average of our predictions, while the darker and lighter areas represent 80% and 95% confidence intervals, respectively. Comparing the results with actual test data, there are differences between the two. The predicted image obtained with the Naïve method is a horizontal line, and it does not predict the upward trend of the test data. Although the ARIMA model's predication showed an upward trend, there is still a difference with the actual value of the experimental data. At the same time, the consideration of seasonal factors has insignificant impact on the prediction results.

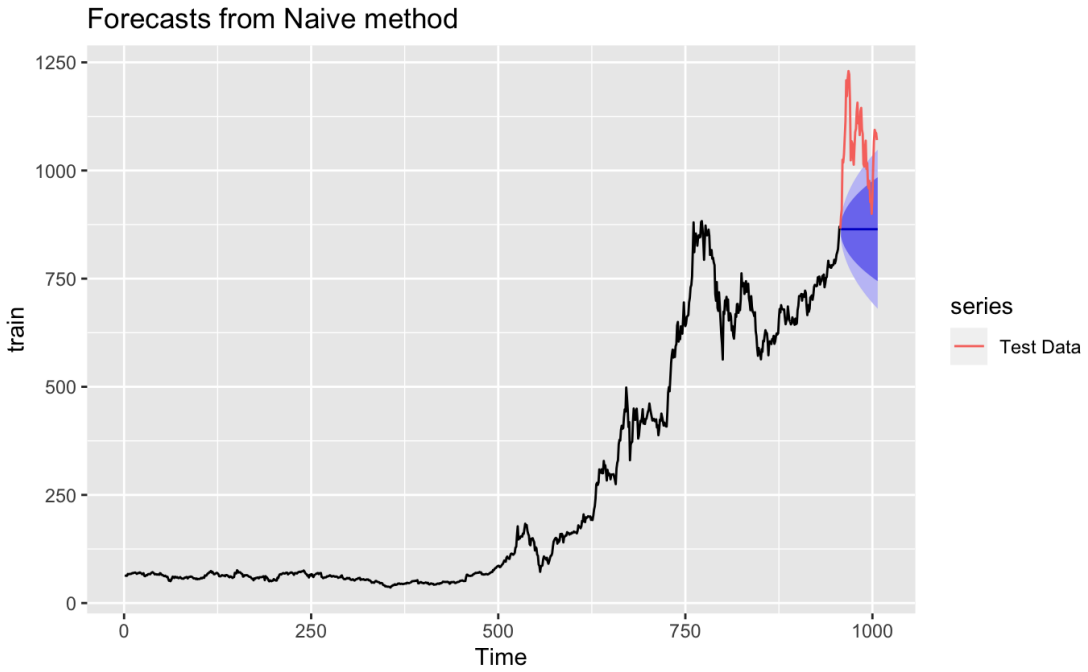

Figure 4. Naïve method

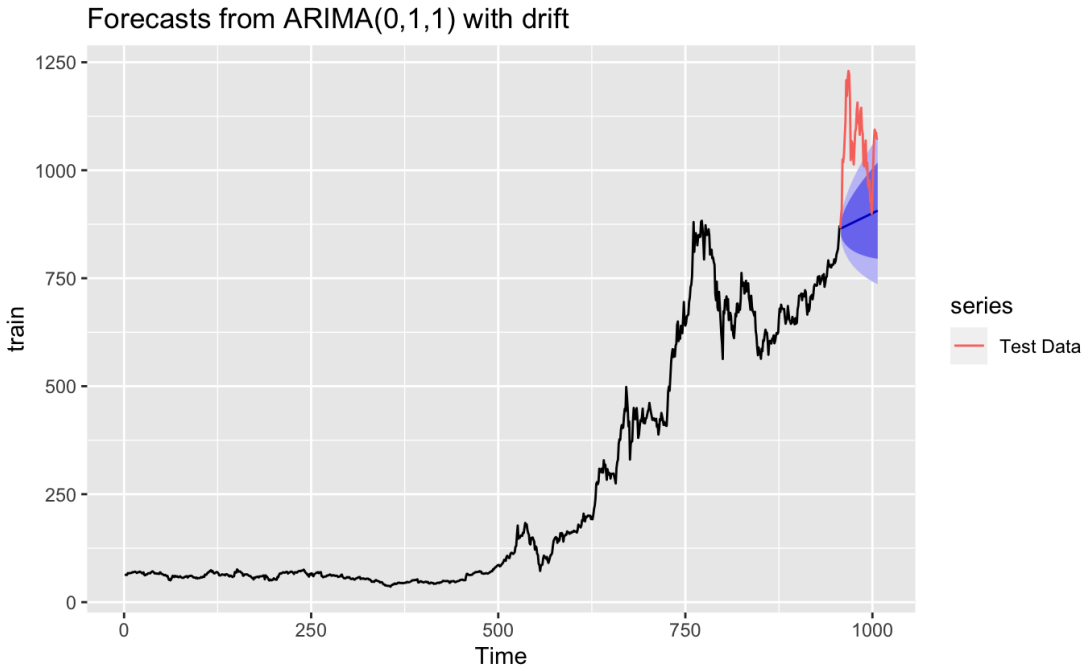

Figure 5. ARIMA (0,1,1) without seasonal trend

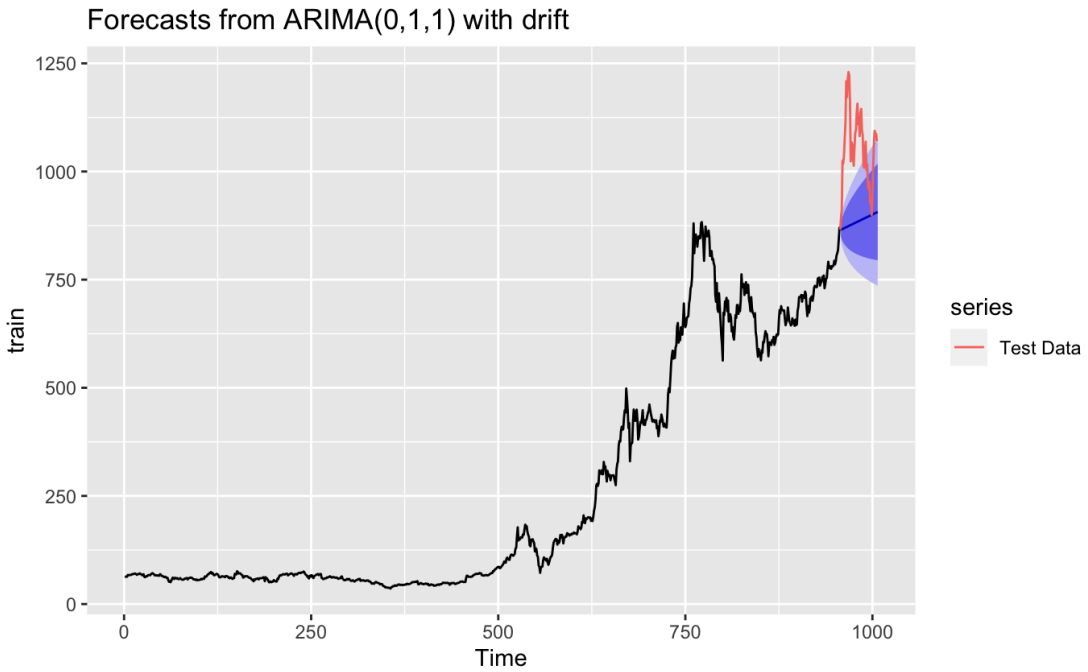

Figure 6. ARIMA (0,1,1) with seasonal trend

From **Table 1**, it can be seen that the mean error (ME) and root mean squared error (RMSE) of the ARIMA model are both, small and naive. The ME of the ARIMA model, which is 0.000282, is much smaller than that of the Naïve method. In other words, the same conclusion can be obtained: the ARIMA model is better at predicting Tesla's closing price than the Naïve method.

Table 1. Accuracy of the two approaches

	ME	RMSE
Naïve method	0.836992	13.25738
ARIMA (0,1,1)	0.000282	13.19243

5. Conclusion

This paper studies Tesla's stock price from 2018 to 2021. Through the decomposition function, we can see the upward trend, seasonal fluctuations, and irregular random fluctuations. By comparison with Apple's stock price, which has investment potential, Tesla's stock returns grew rapidly after 2020, reaching a return of four times that of Apple by the end of 2021. In order to predict the changing trend of Tesla's stock price more accurately, the Naïve method and ARIMA model were used to predict the time series data. It can be seen from the forecast results that the trend of Tesla's stock price cannot be predicted by the Naïve method, and although the ARIMA model has certain errors, it still can predict an upward trend in Tesla's stock price (whether seasonal factors are considered has little impact on the forecast results). The same conclusion can be obtained through RMSE: the ARIMA model is better at predicting Tesla's closing price than the Naïve method.

Through the above experiments, we find that by comparing with Apple's stock price and forecasting model, Tesla's stock price shows an upward trend and has certain investment value. At the same time, the prediction model can only determine the overall trend, but it cannot accurately predict the actual trend of stock prices. In recent years, deep learning has been extensively researched on. Through deep learning, time series prediction based on financial data can also be done. The structure of recurrent neural network (RNN) and long short-term memory (LSTM) models in deep learning is suitable for processing time series data [10,11]. In the future, we will use deep learning methods to fit the data of Tesla's stock price to obtain more accurate results.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

Z.T. conceived the idea of this research and investigated the relevant data. R.L. analyzed the data and process of the experiment as well as summarized the experimental results. Q.W. wrote the paper and arranged it.

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