Prediction of Moderna Adjusted Closing Stock Price Trend Using ARIMA Model

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Abstract. Taking a glance at the pandemic, the adjusted closing stock price trend of Moderna company as an excellent sample is worth studying whether the statistical method of prediction can be used in an unnormal case. This paper examines whether the ARIMA model forecasting tool analyzes Moderna's adjusted closing stock price trend between the seventh of December twenty eighteen to the first of November twenty-two. The historical data of the closed stock price of Moderna Inc was collected from Yahoo Finance. Incorporating evidence from academic papers and the processing of computing the differences, judgement of stationary data and parameter selection, this study illustrates that the ARIMA model is a useful statistical tool to predict the stock trend. It argues for the limitations of using the ARIMA model and offers future outlooks. Ultimately, ARIMA [4, 1, 2] offers an appropriate model for summarizing the forecasting of the adjusted closing stock trend of Moderna Inc under the limited data in this case.

Keywords: ARIMA model; Moderna; Adjusted closing stock price; Forecast.

1. Introduction

As a worldwide crisis, the happening of COVID-19 gives a threat to global finance at different levels. During this period, the economies in various countries have massive disruptions and economic losses: one is the high cost of government funding for the protection of public health, which leads governments to have to increase the tax rate to reach a balance; and the other hand is lots of company stock price falling dramatically such as companies of tourism since the policy of quarantine limits people to travel [1]. However, in this global public health event, we find that listed companies in the biopharmaceutical industry outperformed the overall market. Not only were they not affected by the risk of the financial recession, but they also did not decline in performance due to upstream and downstream constraints in the supply chain, which provides us with significant research exposure. Moderna, a vaccine company, offers an unusual data set of the company's closed stock prices during the pandemic because of the increasing demand for vaccines in the global market [2]. This scenario implies a significant meaning in studying the sample of Moderna's stock trends.

The goal of this study is to find out an appropriate model by using the ARIMA method and compare the actual data and forecasting data to conclude whether the ARIMA method works in the case of Moderna's stock trend. The rest of the paper is divided into four parts: The second part is literature review that shows the ARIMA model has already been used in some analyses of stock trends of public health companies, and the results of those studies are significant that implies the ARIMA model is reliable to use in the study in order to check whether the ARIMA model is suitable for forecasting one company closed stock prices under emergencies; the following part is a data description, which illustrates several crucial details for analysis of historical data by using the ARIMA model, such as time series data induction, differencing of time series data and measuring stationary of data; fourth, the model selection part aims that using the method of parameter selection in ARIMA model, [p, d, q] parameter selection method, to decide the ultimate model for using in the stock trend prediction; eventually, the part of some conclusions and suggestions gives a brief of the analyzing procedure of using ARIMA model and several suggestions of using ARIMA model in cases of stock trend of public health.

2. Literature Review

Moderna is a biotechnological company focused on using messenger ribonucleic acid technology to develop drugs and vaccines [3]. Ariyo and Ayo (2014) claim that the ARIMA model is helpful in predicting stock trends in finance and economics because the ARIMA method has a strong potential for short-term prediction [4]. Also, Benvenuto (2020) reports that the ARIMA model as a simple prediction model can be worked on analysing of datasets of public health, such as the COVID-2019 epidemic dataset [5]. Doroftei (2022) points out that the ARIMA model is appropriate for forecasting infection trends and the course of a vaccination rate [6], which implies that the ARIMA model has already been used in the area of public health for forecasting. Besides, Moderna Inc has a strong competitor named Pfizer Inc in the vaccination area, so the situation of volatile stock trends should be considered using the ARIMA forecasting method. Kollewe (2021) illustrates some detailed data on profit trends with a comparison with Moderna and Pfizer [7], which shows the necessity for consideration of the stock market competition when using the ARIMA method to forecast. In this study, the adjusted closing stock price would be chosen because the adjusted closing stock price is more accurate than the closing stock price since the adjusted closing price includes other factors for a measure such as dividends and stock splits etc. (Norton, 2011) [8].

3. Data Description

The adjusted closed stock price during this period is plotted as a time series pattern which illustrates that the stock price is generally stable between year twenty eighteen and year twenty-nineteen. And then, from the Year twenty-nineteen to Year two thousand and twenty, the stock price trend shows a dramatic increase, reaching a peak in December twenty nineteen. One of the reasons is that the demand in the global market has increased since COVID-19 happens and is expanding fast. After approximately Year two thousand and twenty, Moderna's stock price decreased since the other vaccine company, Pfizer, is very competitive in the global public health market, which leads to shrinking demand for Moderna vaccine worldwide. The following figure will give a visual reaction to Moderna's adjusted closed stock trend:

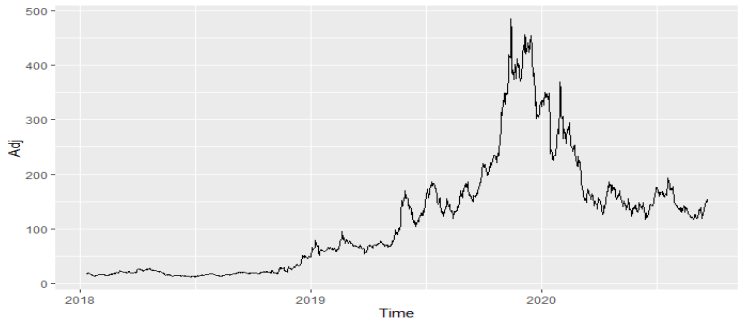

Fig. 1 Moderna’s adjusted closing stock price time series data

From the above figure, the only thing that can be sure to conclude is that the time series pattern of Moderna's adjusted closing stock price is volatile. Thus, it is necessary to discover some strong evidence to help decide whether the ARIMA method can be used for forecasting. First, the ARIMA method must be used while the data is stationary [9]. Through differencing the time series data, the differencing graph would offer a direct view of whether the data is stationary. Second, the ARIMA model performs better in short-term than long-term forecasting. Under this situation, the time series data above is divided into two parts: one data set is for training (eight hundred and seventy-three observations), and the other is for forecasting, which includes one hundred observations.

According to the above information, the autocorrelation function would be used for the first step to review details of whether the time series data is stationary:

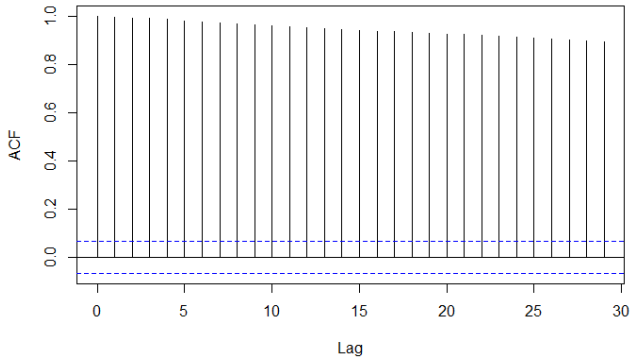

Fig. 2 ACF plot

The autocorrelation Function (ACF) describes whether the current stock price correlates with all prices during a specific period [9]. From figure 2 points out that the training data set is not stationary since the ACF of the data does not decrease dramatically after Lag 1. Therefore, the conclusion of data observation about the training data set of Moderna's stock trend is that the data is not stationary since the pandemic happens. Also, the data trend does not have a regular repeat pattern. Thus, in order to continue using the ARIMA model for forecasting Moderna's stock price, changing data to be stationary is necessary.

Next, for the ARIMA model to be used, the differencing method should be used to construct the data stationary. This way, the number of using the method of differencing should be checked first, showing that the data should differ once to become stationary data. The following figure illustrates the time series data pattern of comparison before differencing and after using the differencing method:

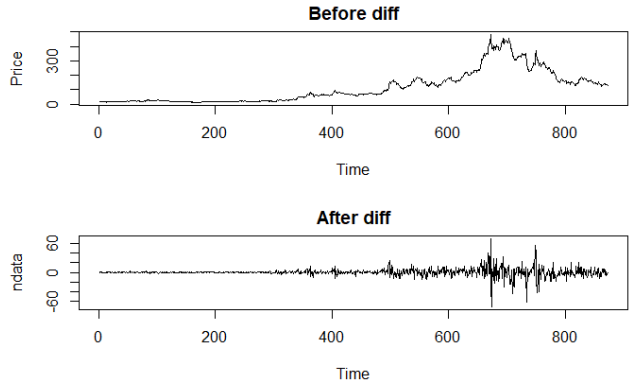

Fig. 3 Data differencing

From the pattern of ACF after using the method of difference, the data is stationary now because the data has dropped dramatically since Lag 1. Also, the average of all random variables is not equal to zero, which indicates that the data is not white noise. Thus, the ARIMA model can be used for forecasting from now. In this way, the choosing of coefficients in ARIMA should be processed.

4. Model Selection

The ARIMA model representation includes three parameters (p, d, q) that give an explanation of a time series model [10]. Specifically, parameter selection procedure can be explained that the parameter p represents how many immediately preceding observations can influence one observation; the parameter d refers to the number of times for differencing; the parameter q shows the moving average in a specific model [10]. Back to Moderna's adjusted closing stock price training data set, the following pattern (Figure 4) of ACF illustrates the data value decreases to zero dramatically since Lag 1, and the PACF pattern shows the data does not die at the end, which indicates that choosing the form of MA(q) model is suitable in this specific situation. Specifically, the reason for choosing it

is that COVID-19 is an emergency event and the form MA(q) model has a better performance in forecasting the trends of some impactful events [10].

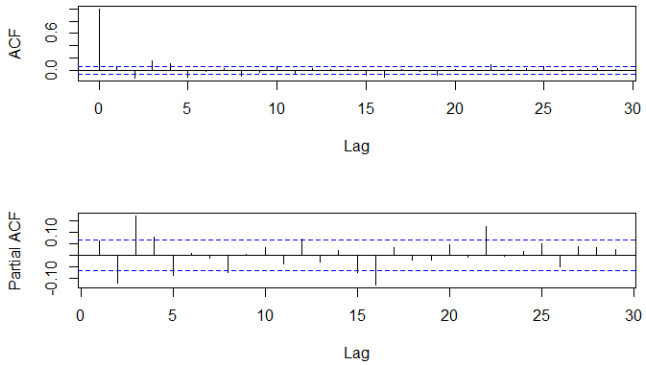

Fig. 4 ACF and PACF

Through the application of parameter selection above, several pairs of parameters can be selected according to the ACF and PACF pattern, that is, the AR process in [1, 2, 3, 4] and the MA process in [1, 2]. Clearly, there are eight matched pairs of parameters that can be considered that are [1, 1, 1], [1, 1, 2], [2, 1, 1], [2, 1, 2], [3, 1, 1], [3, 1, 2], [4, 1, 1] and [4, 1, 2]. The following figures show that the ARIMA model with these parameters can be plotted as follows:

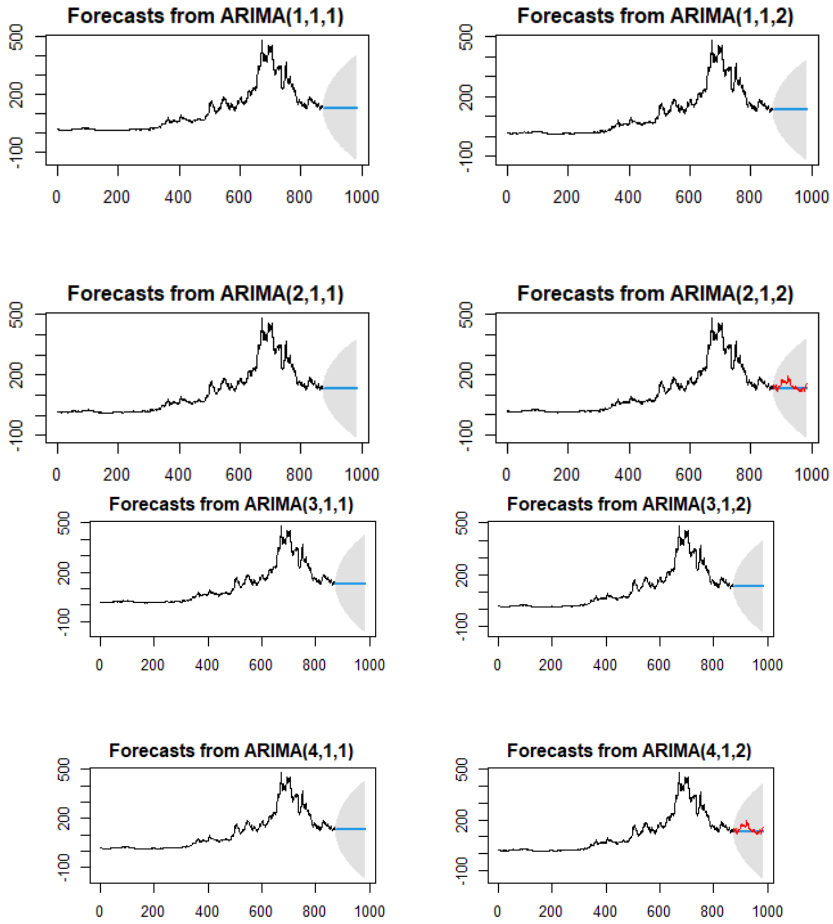

Fig. 5 Model selection

According to the optimal ARIMA model chosen, a parameter which contains the smallest AIC and BIC will be chosen for the suitable model in order to forecast the following [11]. The following data

shows that the ARIMA [4, 1, 2] contains the smallest AIC value, but the ARIMA [2, 1, 2] contains the smallest BIC value:

Table 1. AIC and BIC values

	AIC	BIC
(1, 1, 1)	6233.232	6247.545
(1, 1, 2)	6229.319	6248.402
(2, 1, 1)	6225.848	6244.931
(2, 1, 2)	6205.612	6229.466
(3, 1, 1)	6208.649	6232.503
(3, 1, 2)	6204.057	6232.682
(4, 1, 1)	6203.485	6232.11
(4, 1, 2)	6201.322	6234.718

Since the form of the MA(q) model is chosen above, so the p value does matter very much. Under this situation, taking the example of the parameter pair [4, 1, 2], the method of checking residuals would be performed by Ljung-Box. According to Hyndman& Athanasopoulos (2018), the large value of Q* (calculated by Ljung-Box) implies that the autocorrelations do not come from white noise [9]. The following chart shows that the p-value is greater than 0.05, which means the residuals are not distinguishable from white noise. In other words, the model can pass the LB test.

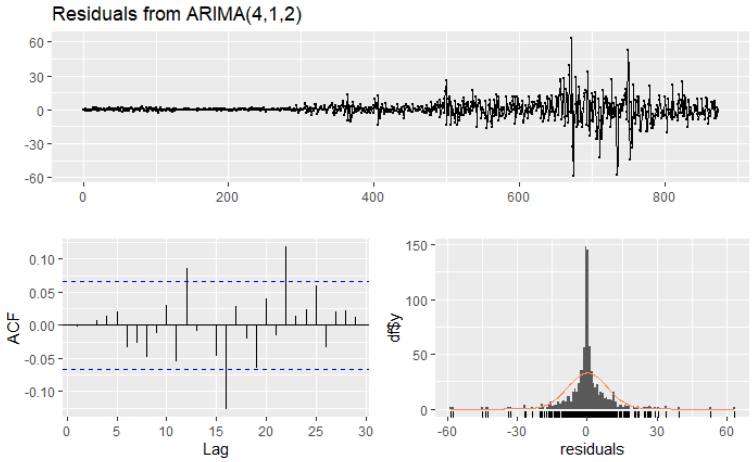

Fig. 6 ARIMA [4, 1, 2] residuals

After passing the Ljung-Box test, the model of ARIMA [4, 1, 2] can be performed to forecasting Moderna's adjusted closing stock price. Here is the pattern containing the comparison of the actual test data set of Moderna's observations (red line) and the prediction data (blue line) from the above method:

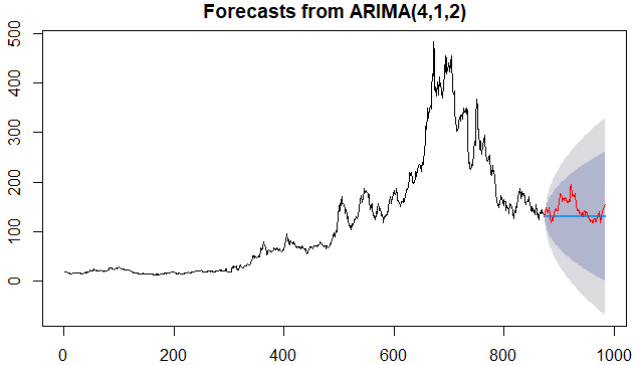

Fig. 7 Forecasting

Following Figure 7 above, the forecasting line illustrates a stable trend of these one hundred observations, which can be explained by the fact that Moderna Inc has a constantly adjusted closing stock trend after COVID-19. Back to the primary data set, the training data set shows a more stable stock trend than the actual data trend during COVID-19.

5. Limitations and Future Outlook

According to the ARIMA model used above, the forecasting trend shows that there is a horizontal line for the last one hundred observations. In fact, the line represents a mean of the actual value data set that leads to a limitation of the forecasting of Moderna's adjusted closing stock trend using the ARIMA model only. Since the ARIMA model requires a large number of data, one of the main reasons is that more than the data is needed in this case. Moreover, the ARIMA model is better for short-term forecast rather than long-term forecasting. Thus, the result of ARIMA [4, 1, 2] can be explained that Moderna's adjusted closed stock price will be stationary at the value of where the prediction line indicates in the short-term. Due to the prediction line displaying the value from the historical stock data, it cannot conclude that the ARIMA [4, 1, 2] model fits Moderna's adjusted stock price in the long term. The reason is that COVID-19 is an unusual event, leading to the data trend during that period being volatile significantly. In order to obtain a more accurate result, other methods, such as SVR and GARCH methods, can be considered to add to this paper further [12].

6. Conclusion

Some literature stimulates the motivation for this study about public health companies' economic situations during the pandemic. It aims to discover the most appropriate ARIMA model to forecast the adjusted closing stock trend of Moderna Inc. During the method operation, the time series data of Moderna Inc is used in order to induce the following steps, such as data differencing, ACF and PACF observation and parameter selection. After obtaining the AIC and BIC values through the range of parameter pairs, the ARIMA model selection result is decided to choose ARIMA [4, 1, 2] for the prediction of Moderna's adjusted closing stock price trend. The ultimate result concludes that the forecasting line as a mean value can reflect the stock trend roughly, even though the volatility of the prediction line is not as exact as the volatility of the historical data. For those limitations already existing in the ARIMA [4, 1, 2] model, two suggestions are claimed in the section on limitations and future outlooks to overcome those limitations in further study. They are expanding the data size and adding more methods to support the ARIMA model when analyzing some uncommon cases under abnormal situations, such as predicting adjusted closing stock price trends in COVID-19.

References

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