Financial stock data analysis:
Stock Returns of ZTO Express

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Introduction

The data in this report used is called ZTO, available in the quantmod library, which is a popular package for quantitative financial modeling and analysis in R. ZTO Express (Cayman) Inc. is a Chinese express delivery company that provides courier services for e-commerce businesses said Lai (2002).

Our primary objective is to calculate the returns of the ZTO stock over time and use Generalized Autoregressive Heteroscedasticity (GARCH) models to analyze the volatility of these returns. The focus will be on selecting the best model that fits the data and provides the most accurate predictions.

Methodology

Exploratory Analysis

The ZTO dataset is a time series object that contains daily stock price data for ZTO Express Inc. The data of data begin on 2016-10-27 and end on 2023-02-28. It has a total of 1594 observations and 6 variables which are every day's open price, high price, low price, close price, volume, and adjusted closing price. For the daily Volume variable, the minimum value is 418000, the maximum value is 55321100, the median is 2341600, and the mean is 2869155. For the daily adjusted closing price, the minimum value is 10.62, the maximum value is 37.94, the median value is 21.53, and the mean is 22.26. The latest update time is 2023-04-04 17:26:03. However, in this report, I used the data between 2016-10-27 and 2023-02-28.

Modeling

Before modeling, we needed to know if the data are stationary. Since using non-stationary time series data could result in unreliable forecasts. On the other hand, a stationary process was one that was mean reverting, meaning that it fluctuated around a constant mean with a constant variance. After drawing a plot of the data and having an Augmented Dickey-Fuller Test, I figured that the data was stationary since the p-value was smaller than the significant value 0.05. Then I split the data into a training set and a testing set, to be specific, the data from 2016-10-27 to 2022-12-31 was the training set and the data from 2023-01-01 to 2023-02-28 was the testing set.

Since the GARCH model needed both an ARIMA model for the mean of the series and a GARCH model for the volatility of the series, I found the best ARIMA model first. I used auto.arima() function to let the R programming choose the best model. Then I used Maximum Likelihood, Diagnostics, and Box-Ljung Test to check whether the residual was white noise. It is important since if the residuals were not white noise, then this could indicate that the model was misspecified or that there were other patterns or trends in the data that needed to be accounted for. The result was that it was white noise.

The GARCH model was used to model volatility, and it is an extension of the ARCH model that is appropriate when there is a correlation in the squared residuals. The presence of autocorrelation in the squared residuals can be determined by examining the ACF and PACF plots. In order to use the GARCH model, we first needed to select the best ARIMA model using the auto.arima() function in R. We then checked the residuals using Maximum Likelihood, Diagnostics, and the Box-Ljung Test to ensure that they were white noise. Finally, we used accuracy and AIC to select the best GARCH model.

Analysis

Exploratory Analysis

When I examined the data, I plotted the daily volume and adjusted closing price from 2016-10-27 to 2023-02-28 in **Figure 1**. The green color represented positive returns. Overall, the plot exhibited an increasing trend over time. There were two significant spikes in the plot, one from April to July 2020 and the other from January to March 2021. However, there were also some drops in the plot, including the periods from July 2020 to January 2021, from March 2021 to April 2021, from January 2022 to February 2022, and from October 2022 to December 2022.

Figure 1. Daily Volume and Adjusted Closing Price from 2016-10-27 to 2023-02-28

Main data analysis

In this report, I used the ARIMA model, and it was important to check whether the data were stationary. Based on the plot I created of the daily returns of the data (see **Figure 2**) and the Augmented Dickey-Fuller test, which yielded a p-value of 0.01, the time series was found to be stationary.

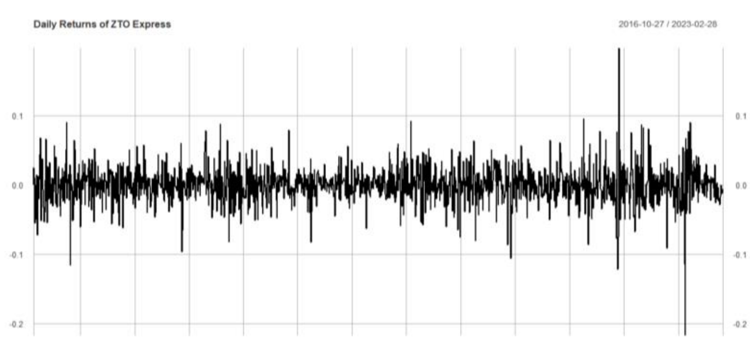

Figure 2. Daily Returns of ZTO Express

Before selecting the best ARIMA model, I split the data into two parts: the training set was from 2016-10-27 to 2022-12-31, and the testing set was from 2023-01-01 to 2023-02-28. After using AIC to determine the best model in the training set, R programming indicated that the ARIMA (3,0,0) model with zero means was the best model, with an AIC value of -6938.24. This model had a third-order autoregressive (AR (3)) component. The residual plot and ACF & PACF diagram (see Figure 3) suggested that the residuals were white noise. The Box-Ljung test, with a p-value of 0.7158, also confirmed this.

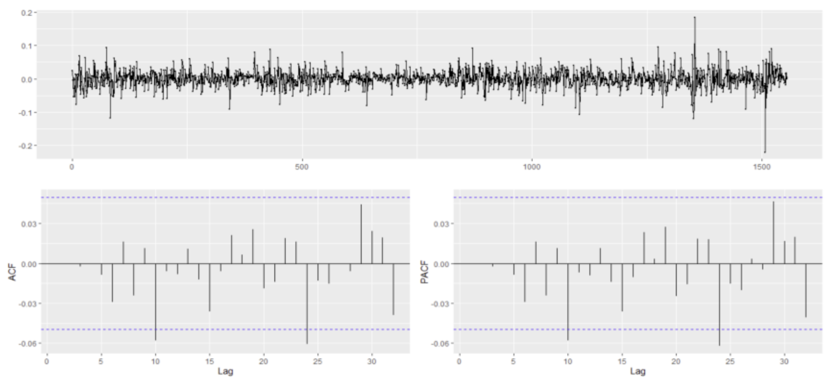

Figure 3. Residual, ACF, and PACF of returns

The GARCH process was a useful model for financial data if the squared residuals exhibit significant autocorrelation. To determine if the squared residuals exhibited significant autocorrelation, we could analyze the autocorrelation function (ACF) and partial autocorrelation function (PACF) plots of the residuals (see **Figure 4**). The figure showed significant autocorrelation and partial autocorrelation at the first few lags, followed by a sharp cut-off or decay. This suggested that the data exhibit a tendency for the volatility of financial returns to persist over time, with periods of high volatility followed by more high volatility periods, and periods of low volatility followed by more low volatility periods. The GARCH model was designed to capture this clustering behavior and provide improved forecasts of future volatility. By incorporating past squared residuals to model the conditional variance of the returns, the GARCH model could adjust for the changing volatility of the data and produced more accurate predictions.

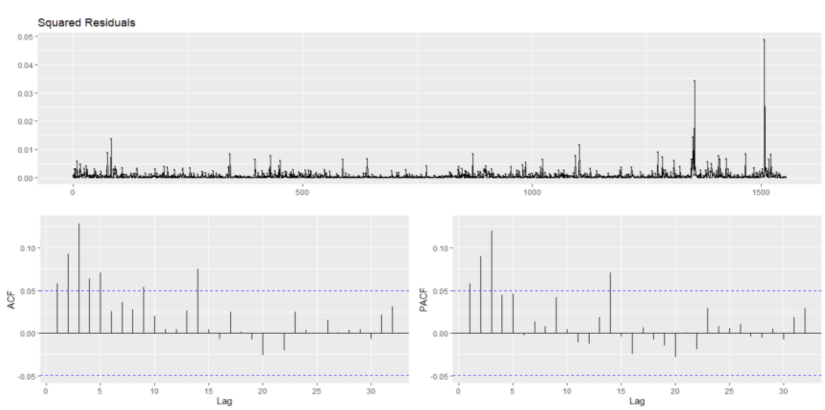

Figure 4. Squared Residual, ACF, and PACF of returns

Discussion

I modeled four GARCH models with ARIMA (3, 0, 0), and found that the one with the best AIC value was ARIMA (3,0,0) + GARCH (1,1). However, when I tried to use accuracy metrics such as ME, RMSE, MAE, MPE, and MAPE to compare the models, I found that their values were too similar to distinguish between them (see **Figure 5**). As a result, I decided to use AIC, BIC, and HQIC to identify the best model. **Figure 6** shows the values of these criteria, and it turns out that the smallest AIC value (-4.5322) was shared by two models: ARIMA (3,0,0) + GARCH (1,1) and ARIMA (3,0,0) + GARCH(2,1). For BIC, the smallest value (-4.5081) corresponded to ARIMA (3,0,0) + GARCH (1,1), while for HQIC, the smallest value (-4.5232) belonged to ARIMA (3,0,0) + GARCH (1,1). Taking all these factors into account, I selected ARIMA (3,0,0) + GARCH (1,1) as the best GARCH model and used it to forecast the next 30 days (see **Figure 7**). The forecast suggests a general decreasing trend, although there are three instances of an increasing trend.

Model	ME	RMSE	MAE	MPE	MAPE
ARIMA(3,0,0) + GARCH(1,1)	-0.00382	0.01493	0.01185	92.25061	101.00760
ARIMA(3,0,0) + GARCH(1,2)	-0.00382	0.01493	0.01185	92.25153	101.00690
ARMIA(3,0,0) + GARCH(2,1)	-0.00381	0.01492	0.01185	92.32297	100.94100
ARIMA(3,0,0) + GARCH(2,2)	-0.00381	0.01492	0.01185	92.32297	100.94110

Figure 5. The Accuracy of the four GARCH models

Model	AIC	BIC	HQIC
ARIMA(3,0,0) + GARCH(1,1)	-4.5322	-4.5081	-4.5232
ARIMA(3,0,0) + GARCH(1,2)	-4.5309	-4.5034	-4.5207
ARMIA(3,0,0) + GARCH(2,1)	-4.5322	-4.5046	-4.5219
ARIMA(3,0,0) + GARCH(2,2)	-4.5309	-4.4999	-4.5194

Figure 6. The AIC, BIC, and HQIC values for the four GARCH models

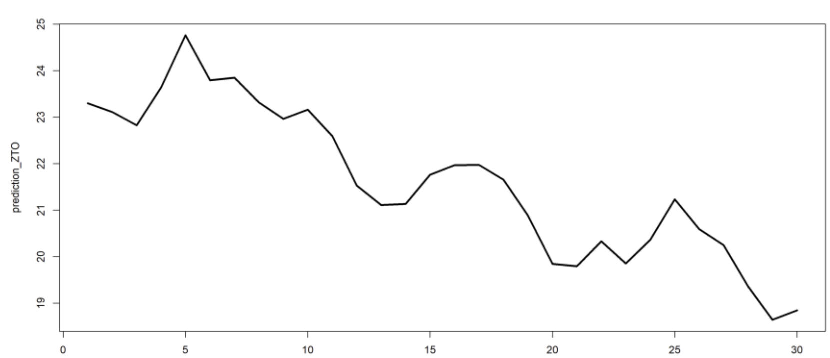

Figure 7. The Forecast price for the next 30 days

Conclusion

In this report, I use the ZTO financial stock data from the quantmod library in R programming to calculate the return and find an appropriate model to analyze the return. After exploring and analyzing the data, I used the ARIMA model to find the best AIC. As a non-stationary time series can have a time-varying mean and variance, making it difficult to model and predict future values accurately, it was important to make sure that the data is stationary Then use the GARCH to find the best model, as the GARCH included the ARIMA, I then used the best ARIMA model that I had identified previously. There were several methods for identifying the best model, such as accuracy and AIC. At first, I wanted to use accuracy to find the appropriate GARCH model, however, their value of them are quite similar with a difference of 0.00001. Therefore, I used minimum AIC, BIC, and HQIC to find the best one. Then I forecasted the model in 30 days, which showed a decreasing trend.

Reference

Lai, M. (2002, May 8). ZTO Profile. *ZTO EXPRESS*. Retrieved from: https://zto.investorroom.com/