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**Cryptocurrency Forecasting using ARIMA and ARMA-GARCH Models**

**Introduction:**

I used the “quantmod” package in R that is designed for traders so they can easily import up to date financial data. I’m using the yahoo finance as the source for the cryptocurrency data. The columns in each cryptocurrency data frame are open\_price (price of cryptocurrency at the start of the day), highest\_price (highest price in the given day), lowest\_price (lowest\_price in the given day), closing\_price (price of cryptocurrency at the end of the day), volume (USD amount traded in the given day), adjusted (adjusted closing price). For my analysis, I am going to use adjusted closing price to forecast Bitcoin and Ethereum within the dates November 29, 2020, and November 29, 2021.

Chart, line chart

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Above are the time series plots of Bitcoin (left) and Ethereum (right). Since November 29, 2020, Ethereum has roughly increased 636.4%, while Bitcoin has increased roughly 218%. These are very high percent changes within a year, and I wanted to test whether I can predict the volatility and forecast the closing price for Bitcoin and Ethereum while also comparing the two to see if Bitcoin is easier to predict or vice versa.

**Statistical Analysis**

From the ACF and PACF plots for Bitcoin and Ethereum we can see that there is no seasonal trend and that these time series plots are random walks.

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**Bitcoin:**

Before we move onto to further analysis, I need to make sure that the autocorrelation and data is stationary. To do this I will first take the log of the data. This will help stabilize the variance of the series.

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The time series and ACF plot still are not stationary. So, I need to take the first difference of the log of bitcoin data. This is the same as the log daily returns. This will in turn take help stabilize the mean of the time series.

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**Ethereum:**

Instead, of taking the log difference for Ethereum we are going to only take the difference. Because when we take the log difference, we see a significant lag at lag 10 for both ACF and PACF plot. As you can see though, there is a high cluster of volatility right between May and June.

Chart

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To forecast the data, I am going to using an ARIMA model first. ARIMA models have a linear structure, so it is widely used in model forecasting. They also have three parameters/orders p, d, and q. ARIMA(p,d,q) can be written as:

Xt = α + φ1Xt-1 +…+ φpXt-p+Wt + θ1Wt-1+…+ θqWt-q

Where p and q are the orders of the model and Wt is a white noise time series following a Normal distribution (N,sigma^2).

To reiterate, ARIMA models is a method for linear data and does not work well for forecasting when there is new information. This is the best model for linearity; however it does not have a role when the data is nonlinear. Financial returns data is not linear and very volatile so a model that will help us forecast nonlinear data will be GARCH model. We know this model will work better because of the residual plot has clusters of volatility.

Chart

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GARCH models are used frequently for financial time series to estimate the volatility of returns. A series of returns (rr) follows a GARCH(1,1) model if it can be written as

Rt = μt + σt εt

μt = φ0 + φ1rt-1 ,

σ2t = α0 + α1 r2t-1 + β1 σ2t-1

assumed that, α1+ β1 <1

**ARIMA Model (Bitcoin):**

Given that the ACF and PACF plot do not have any significant lags (shown on page 2), we choose the orders p = 0 and q = 0 and d = 1 because we differenced the data to transform to become stationary. So our ARIMA model is ARIMA(0,1,0).

Graphical user interface

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This graph above is residual diagnostics to ensure the normality and making sure that the data is stationary before I forecast the data. The Ljung-Box statistic p values are essential for determining whether a series is white noise and given that all of the p values are above 0.05 confirms that the data is stationary because we fail to reject the null hypothesis that the data is not stationary.

**ARIMA(0,1,0) Model Forecast (Bitcoin):**

Chart, line chart

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This graph shows 20 days of predicted values on the logarithm bitcoin price. The grey around these points is the confidence interval, as you can see the more days we forecast the higher variance and wider the confidence interval is because we have less information.

**ARMA(0,0) – GARCH(1,1) Fitting (Bitcoin):**

Using the garchFit() function in R we use orders p=0 and q = 0 for ARMA and GARCH(1,1). Also, this function runs the Ljung-Box Test and we obtain p-values greater than 0.05 which is great.

**Output:**

**Statistic P-value**

Ljung-Box Test R Q(10) 8.54869 0.5754012

Ljung-Box Test R Q(15) 14.6528 0.4767037

Ljung-Box Test R Q(20) 21.30279 0.379507

Ljung-Box Test R^2 Q(10) 9.80234 0.4580026

Ljung-Box Test R^2 Q(15) 12.3709 0.6507652

Ljung-Box Test R^2 Q(20) 17.54214 0.6175416

**ARMA(0,0) – GARCH(1,1) Forecasting (Bitcoin):**

meanForecast meanError standardDeviation

1 0.003515319 0.03805905 0.03805905

2 0.003515319 0.03823608 0.03823608

3 0.003515319 0.03840571 0.03840571

4 0.003515319 0.03856827 0.03856827

5 0.003515319 0.03872411 0.03872411

6 0.003515319 0.03887351 0.03887351

7 0.003515319 0.03901678 0.03901678

8 0.003515319 0.03915419 0.03915419

9 0.003515319 0.03928600 0.03928600

10 0.003515319 0.03941245 0.03941245

This table shows the prediction interval for each step ahead and shows that the volatility increases as steps ahead increase.

**ARIMA Model Fitting (Ethereum):**

At lag 10 we see a significant lag for both the pacf and acf plot for Ethereum, however we will disregard this and use the auto.arima() function to get the orders because of this. The function suggests an MA(1) so p =0, q = 1 and d = 1: ARIMA(0,1,1). The residual diagnostics look good, and the data is stationary and normal.

A picture containing graphical user interface

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**ARIMA(0,1,1) Model Forecast (Ethereum):**

Chart, scatter chart

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Similarly, to bitcoin graph, this graph shows 20 days of predicted values on the Ethereum price. The grey around these points is the confidence interval, as you can see the more days we forecast the higher variance and wider the confidence interval is because we have less information.

**ARMA(0,1) – GARCH(1,1) Fitting (Ethereum):**

Using the garchFit() function in R we use orders p=1 and q = 0 for ARMA and GARCH(1,1). Also, this function runs the Ljung-Box Test and we obtain p-values greater than 0.05 which confirms that it is stationary.

**Output:**

**Statistic P-value**

Ljung-Box Test R Q(10) 9.298249 0.504052

Ljung-Box Test R Q(15) 12.75983 0.6208426

Ljung-Box Test R Q(20) 17.90298 0.5937992

Ljung-Box Test R^2 Q(10) 3.941264 0.9499578

Ljung-Box Test R^2 Q(15) 5.434304 0.9877668

Ljung-Box Test R^2 Q(20) 13.48682 0.8555339

**ARMA(0,1) – GARCH(1,1) Forecasting (Ethereum):**

meanForecast meanError standardDeviation

1 1.997266 204.9439 204.9439

2 12.134042 213.0228 212.5788

3 12.134042 220.9291 220.4685

4 12.134042 229.1005 228.6227

5 12.134042 237.5467 237.0512

6 12.134042 246.2781 245.7642

7 12.134042 255.3051 254.7723

8 12.134042 264.6387 264.0863

9 12.134042 274.2902 273.7175

10 12.134042 284.2711 283.6775

This table shows the prediction interval for Ethereum price each step ahead and shows that the volatility increases as steps ahead increase.

**So which model is best and which coin is easier to predict?**

The GARCH Model is better than the ARIMA given that cryptocurrency data is not linear and there are clusters of volatility. The GARCH model uses new information and analyzes the series with up-to-date information. It then uses this information to forecast future values. The ARIMA model only predicts future value linearly and does not incorporate volatility in the data.

Overall, I believe that these models are not the best to predict price action of cryptocurrency longer than couple days. However, I believe it can be useful for next day forecasting when the volatility is low. The cryptocurrency market, compared to other financial markets, is extremely volatile and I believe the reasoning for a lot of these clusters of volatility are in these so called “bull markets” that happen every so often when cryptocurrency is heavily talked about in the news and more innovative decentralized ideas come out for example, decentralized finance, decentralized gaming and NFTs. We can see from the forecasting of the GARCH model that Ethereum has higher volatility, and this makes sense because of the percentage change in the past year compared to bitcoin. Ethereum has increased, respectively, 3 times more than bitcoin has this year. Some reasonings for this could be because of the applications you can build on Ethereum network while bitcoin is only used for a store of value.