Time Series Analysis

DAILY BITCOIN CLOSING PRICES

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MOTIVATION

- **Cryptocurrency Volatility:** Bitcoin, being the most popular cryptocurrency, is highly volatile and depends on a lot of external factors.

- **Growing Popularity:** Over the past few years, Bitcoin has grown from a niche digital asset to a mainstream financial instrument, growing exponentially in terms of popularity.

- **Need for Analysis:** Being highly volatile, it becomes increasingly necessary to analyse the trends in the prices and assess the risk to make more informed financial decisions.

- In this project, we aim to analyse the highly volatile closing price of Bitcoin by detrending it and performing various exploratory and time series analysis methods to gain meaningful insights from the data.

DATASET USED

Date	Open	High	Low	Close	Adj Close	Volume
Apr 15, 2025	84,561.34	85,861.79	84,366.17	85,861.79	85,861.79	28,860,309,504
Apr 14, 2025	83,694.52	85,785.00	83,690.64	84,542.39	84,542.39	34,090,769,777
Apr 13, 2025	85,279.47	86,015.19	83,027.01	83,684.98	83,684.98	28,796,984,817
Apr 12, 2025	83,404.52	85,856.19	82,769.38	85,287.11	85,287.11	24,258,059,104
Apr 11, 2025	79,625.05	84,247.48	78,936.32	83,404.84	83,404.84	41,656,778,779
Apr 10, 2025	82,565.98	82,700.93	78,456.13	79,626.14	79,626.14	44,718,000,633
Apr 9, 2025	76,273.56	83,541.00	74,589.67	82,573.95	82,573.95	84,213,627,038
Apr 8, 2025	79,218.48	80,823.89	76,198.02	76,271.95	76,271.95	48,314,590,749
Apr 7, 2025	78,221.34	81,119.06	74,436.68	79,235.34	79,235.34	91,262,424,987
Apr 6, 2025	83,504.51	83,704.72	77,097.74	78,214.48	78,214.48	36,294,853,736
Apr 5, 2025	83,844.70	84,207.02	82,377.73	83,504.80	83,504.80	14,380,803,631
Apr 4, 2025	83,100.25	84,696.15	81,670.75	83,843.80	83,843.80	45,157,640,207
Apr 3, 2025	82,487.48	83,909.30	81,282.10	83,102.83	83,102.83	36,852,112,080
Apr 2, 2025	85,180.61	88,466.95	82,343.54	82,485.71	82,485.71	47,584,398,470

https://finance.yahoo.com/quote/BTC-USD/history/?guccounter=1

PLOTTING THE RAW DATA

A clear upward trend can be visually observed, but the data is too volatile to get any good estimate about either trend or seasonality.

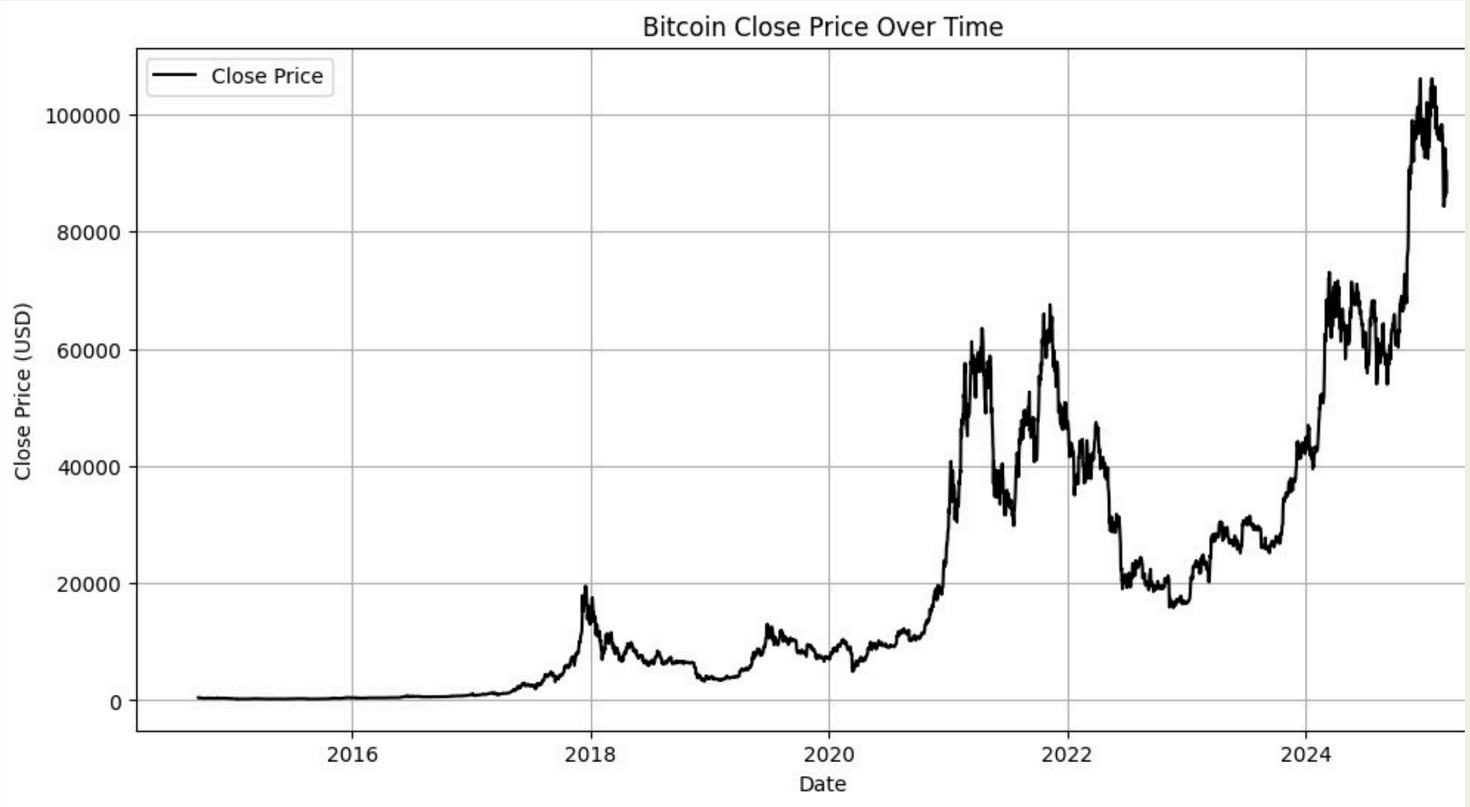

Figure 1: Daily Bitcoin Closing Prices

LOGARITHMIC TRANSFORMATION

The logarithmic transformation compresses the fluctutions at higher prices allowing to better visually observe the linear trend in the log-transformed closing prices.

$$Y_t = \log(X_t)$$

Figure 2: Log-Transformed Daily Closing Prices

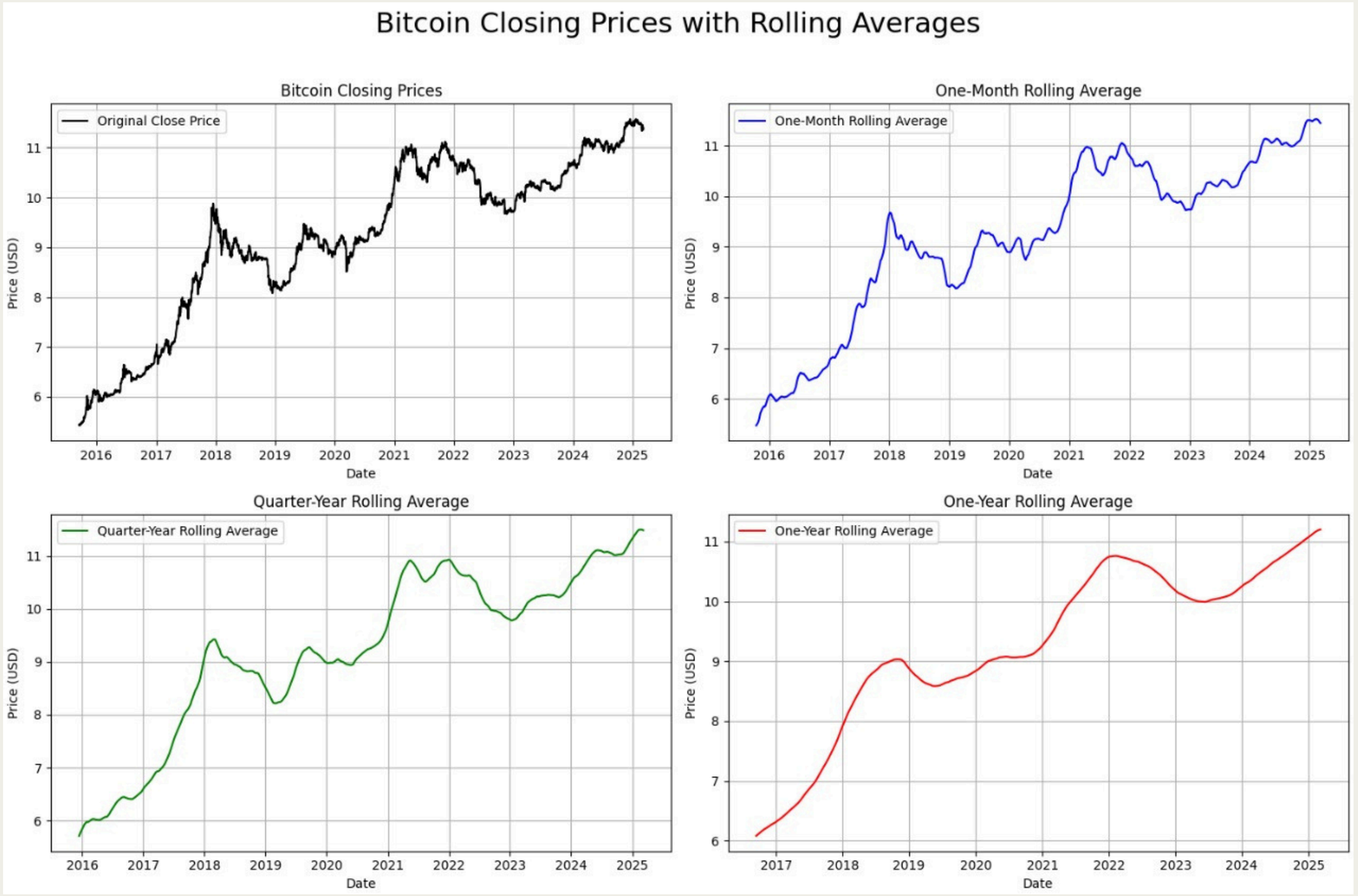

Figure 3: Rolling Averge of Log-Transformed Daily Closing Prices

LINEAR DIFFERENCING

After observing a linear trend in the Log-Transformed closing prices, we perform Linear Differencing to eliminate the trend.

$$Y'_t = Y_t - Y_{t-1}$$

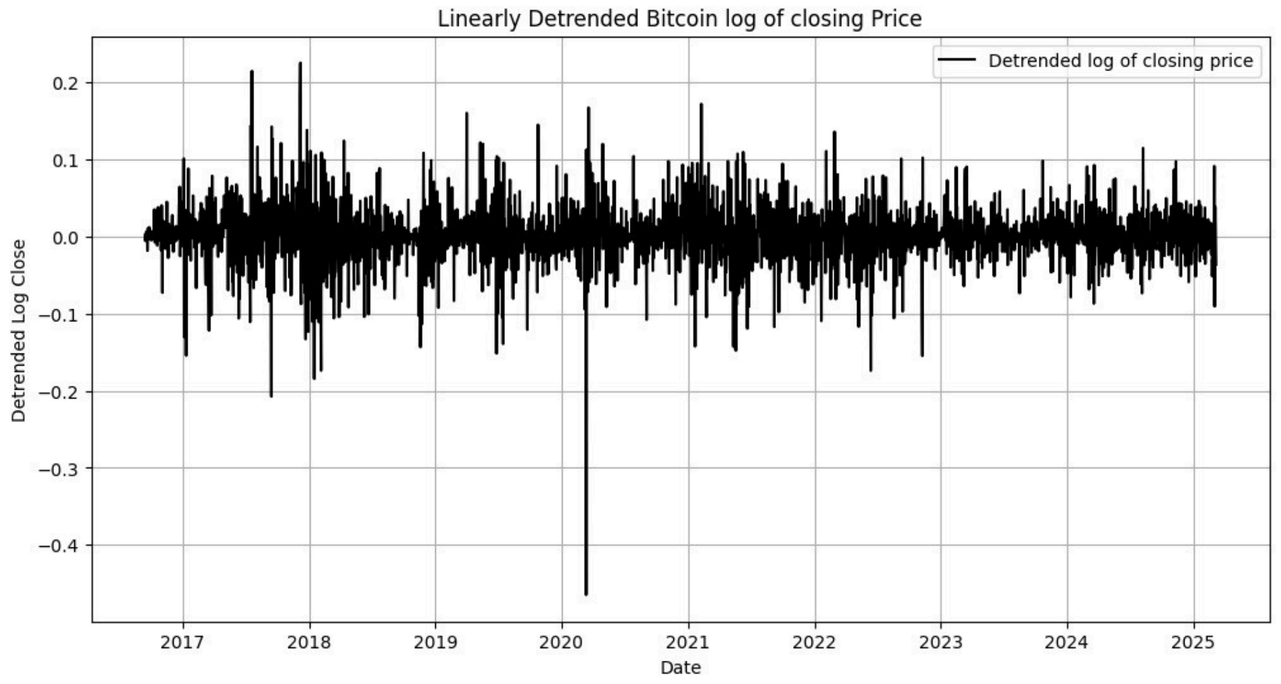

Figure 4: Linearly Differenced Log-Transformed Closing Prices

EVALUATING LOG RETURNS

It is trivial to prove that the log returns of our series are equivalent to the linearly detrended transformed series.

$$\log(1 + R_t) = \log(P_t) - \log(P_{t-1})$$

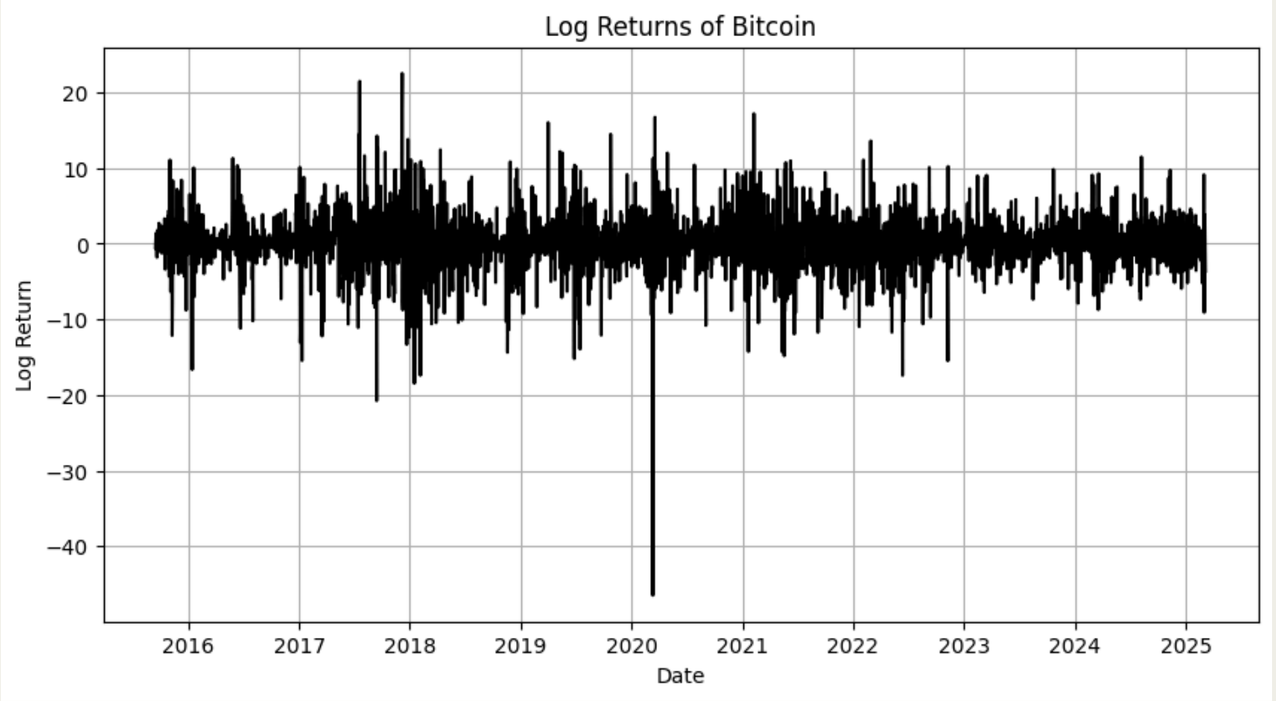

Figure 5: Linearly Differenced Log-Transformed Closing Prices

ROLLING MEAN

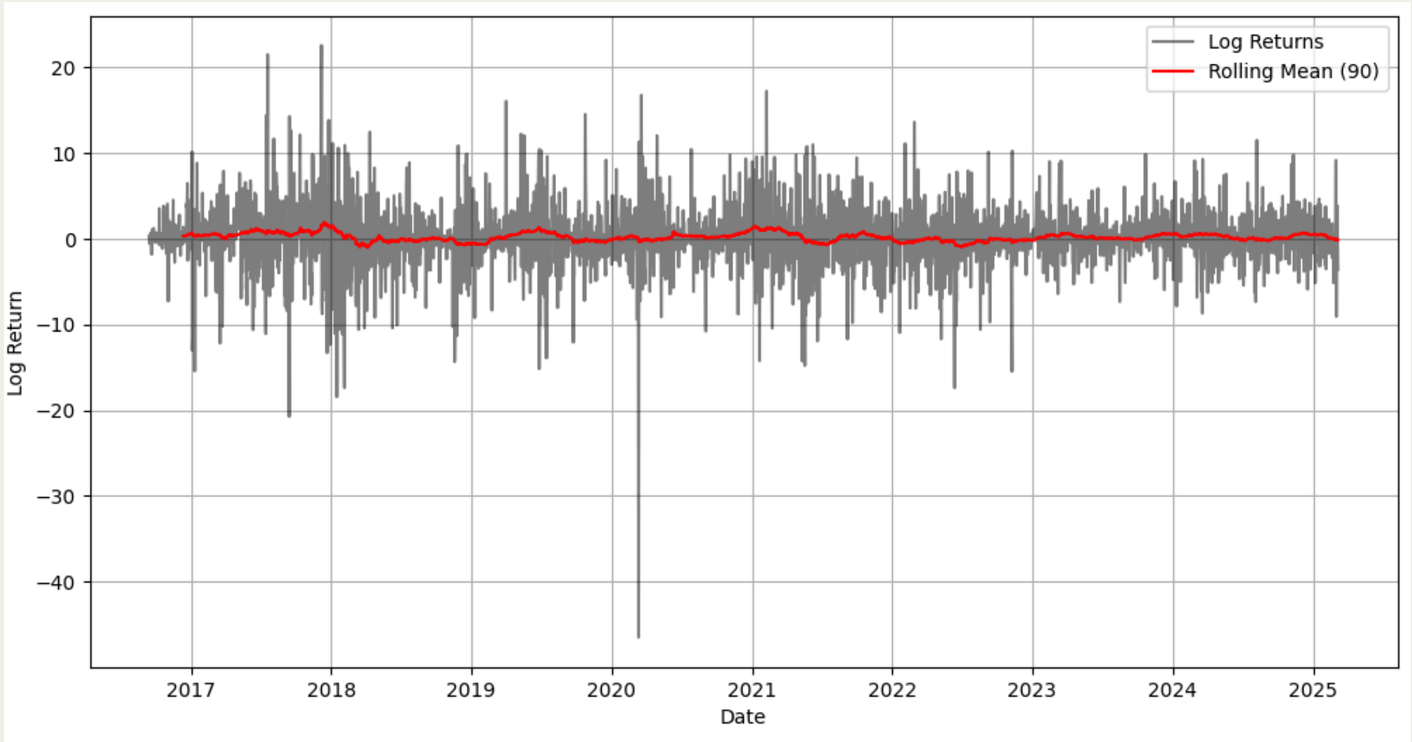

Figure 6: Rolling Mean over 90 Days

OUTLIER ANALYSIS

- While most differences remain within the outlier region, there can be frequent outliers which are often clustered around periods of financial turmoil.

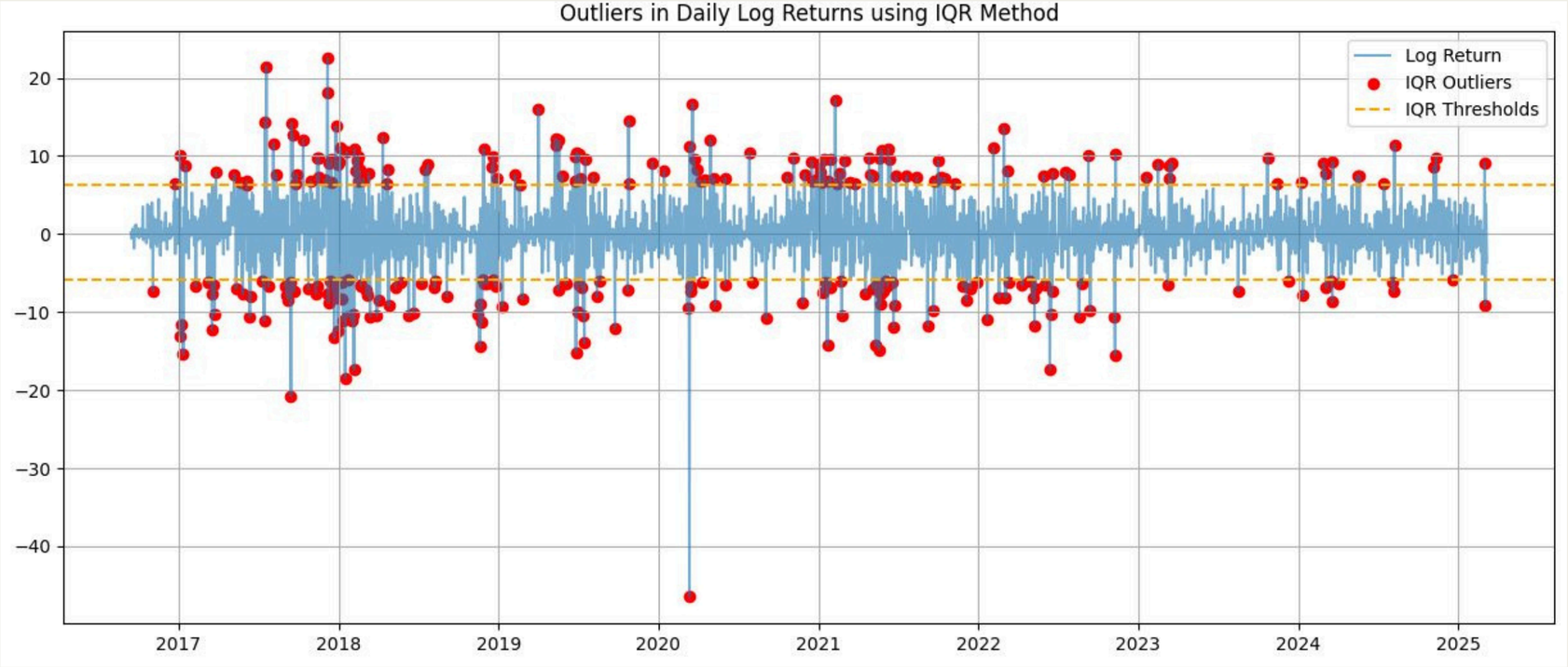

Figure 7: Outliers using IQR Method

ACF OF DETRENDED DATA

- The Autocorrelation Function remains within the 95% confidence region suggesting negligible correlation between any two distinct points in the time series.

- This also suggests that the residual has no significant seasonality.

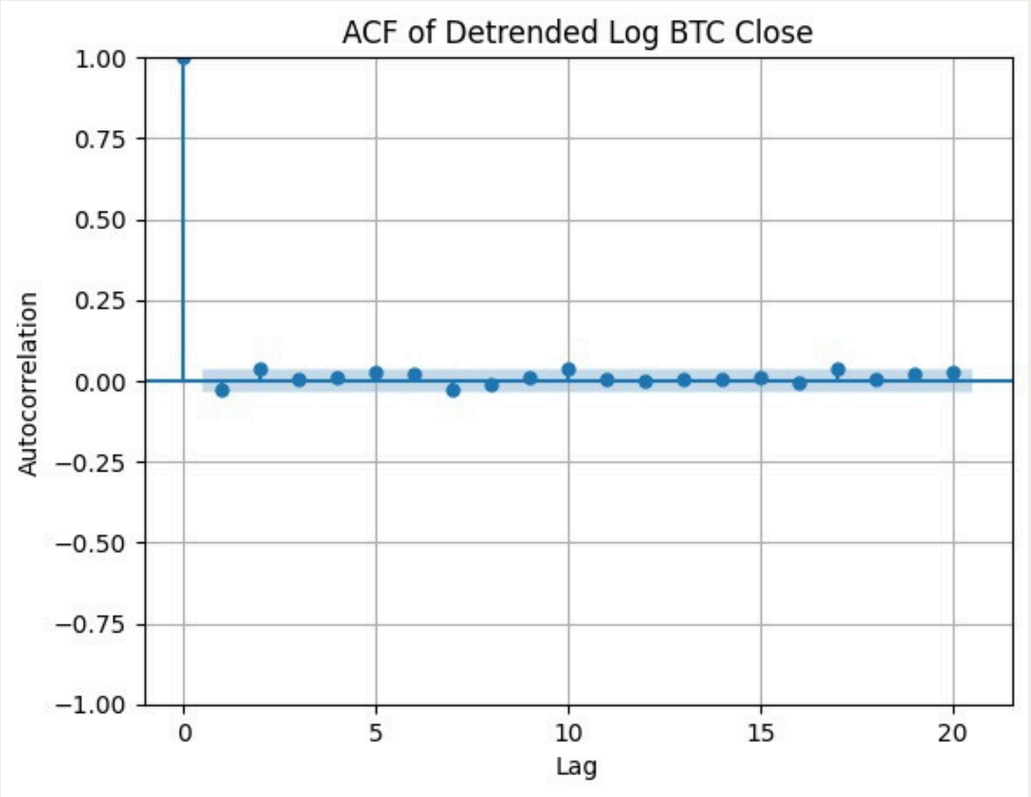

Figure 8: Autocorrelation Function of the Residual

PACF OF DETRENDED DATA

- The Partial Autocorrelation at lag 1 is significantly different from zero, while all higher-order lags fall well within the 95% confidence interval.

- This indicates that only the first lag has a statistically significant effect on the current value, and subsequent lags do not contribute meaningful information.

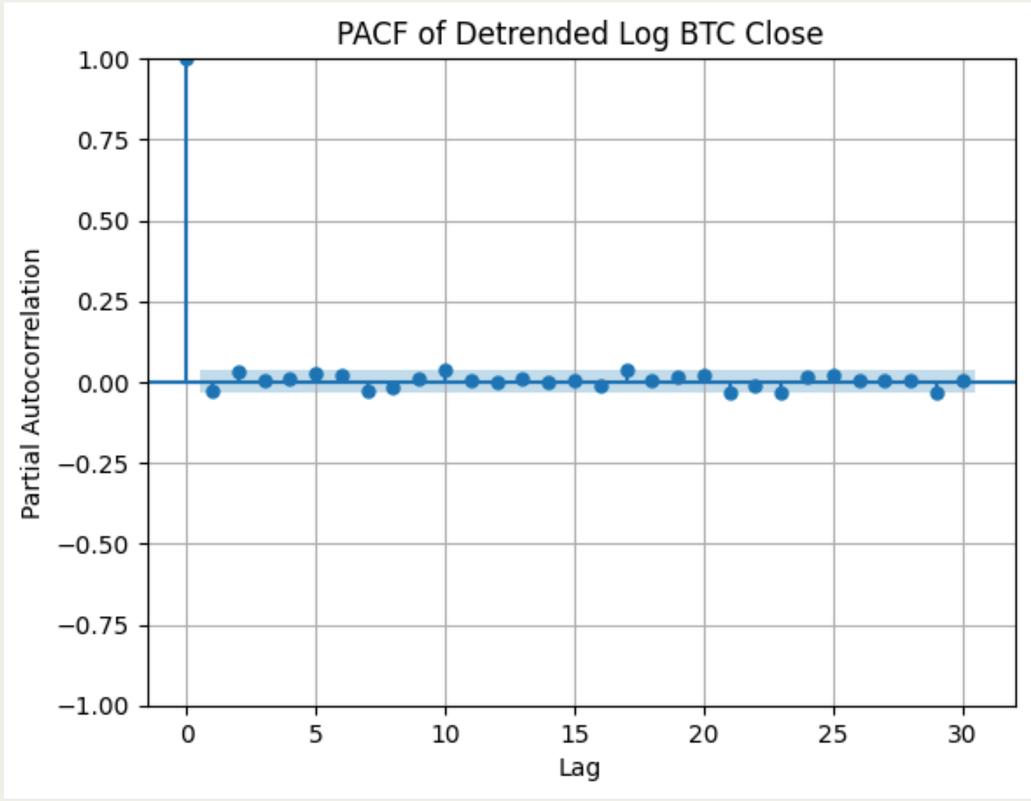

Figure 9: Partial autocorrelation Function of the Residual

DAILY DENSITY FUNCTION

- The daily density function helps us to visually analyse the different aspects about the stochastic process such as the Mean, Variance, Skewness and Kurtosis of the distribution.

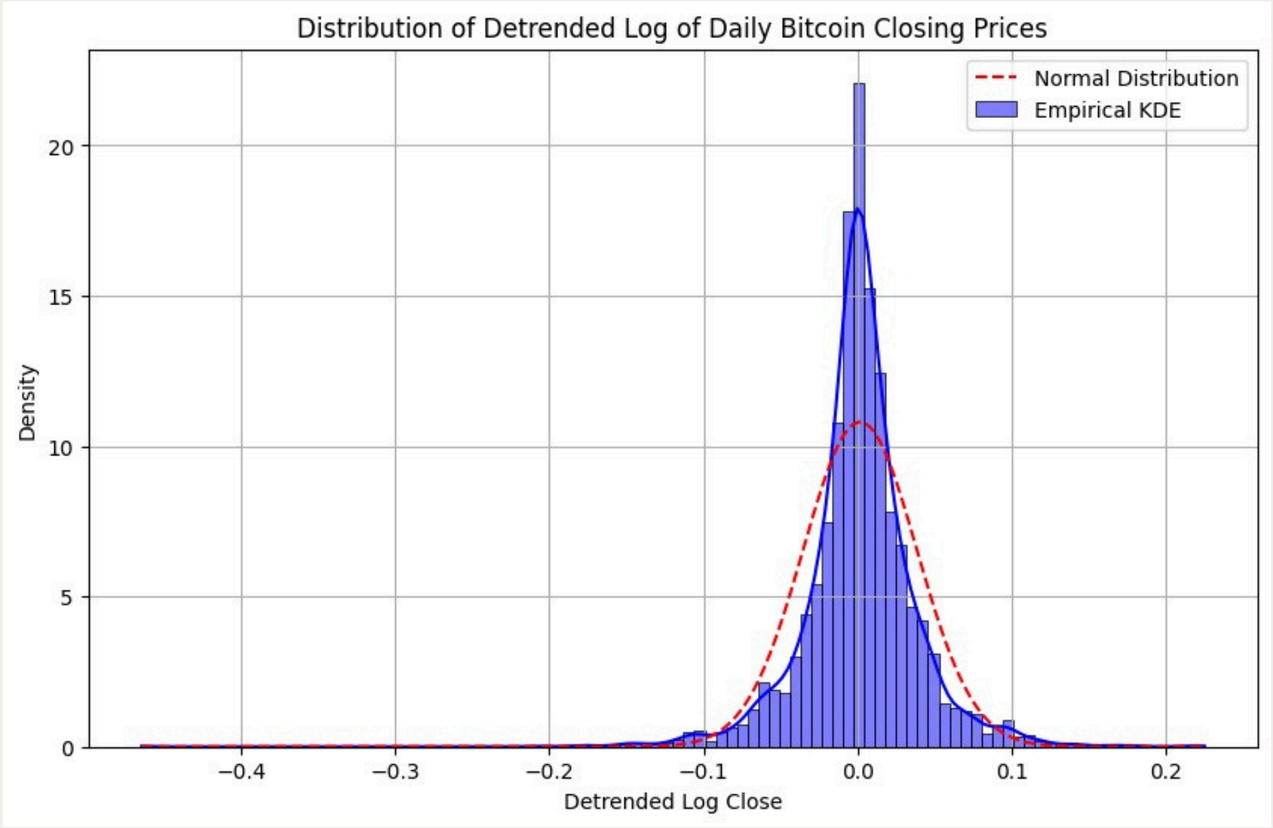

Figure 10: Daily Density Function

QUARTILE-QUARTILE(Q-Q) PLOT WITH NORMAL DISTRIBUTION

- The deviations from the red line (which represents the expected values under a normal distribution) indicate that the data is not perfectly normally distributed.

- The tails (both lower and upper) deviate significantly from the line, suggesting heavy tails or kurtosis.

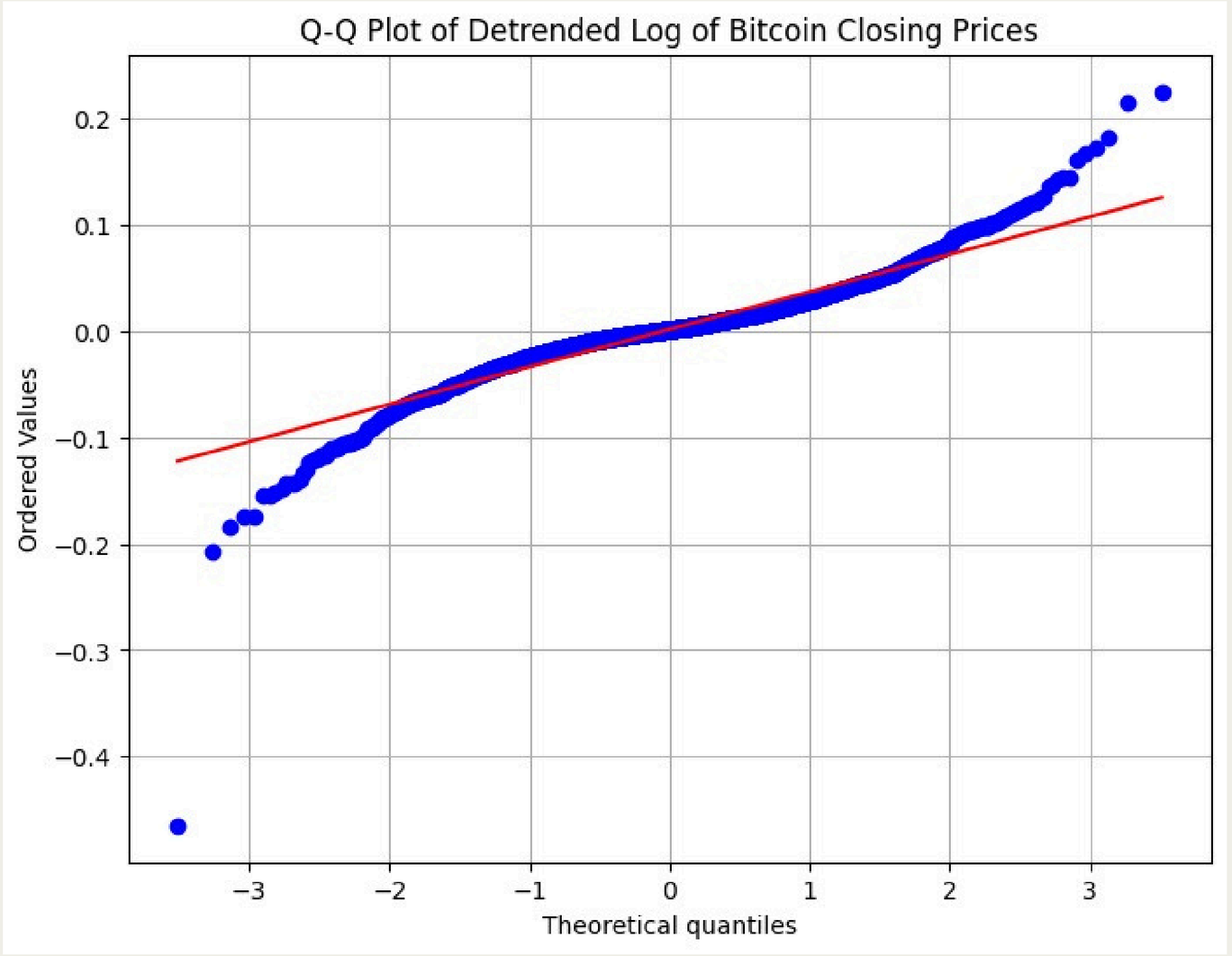

Figure 11: Q-Q Plot

MONTHLY DENSITY FUNCTION

- Aggregation leads to smoothening out of the high peak observed in the daily trend leading to lower kurtosis and thinner tails.

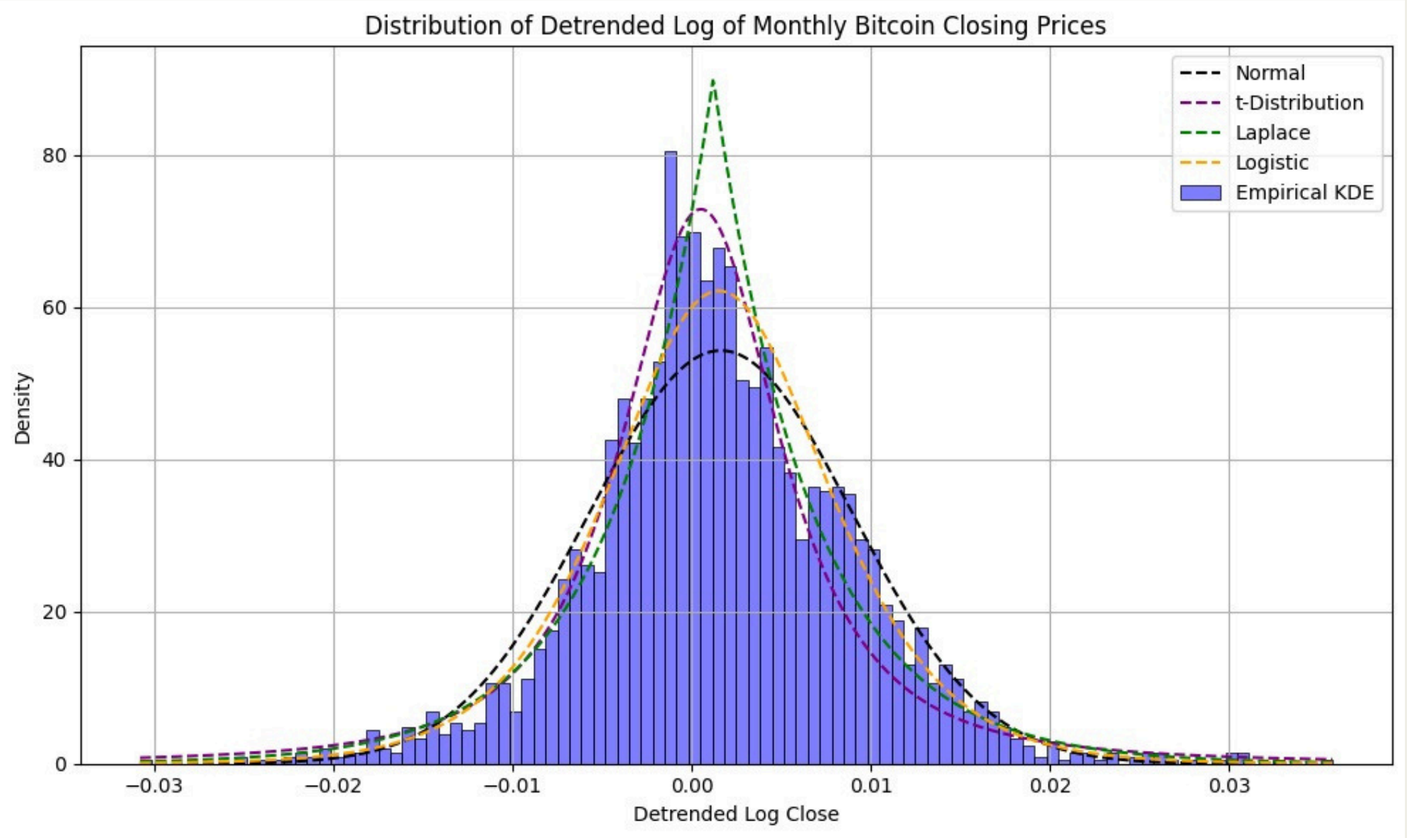

Figure 12: Monthly Distribution Function

CORRELATION BETWEEN CLOSING PRICES AND VOLUME

- The correlation between daily closing prices and trade volume comes up to be 0.6, which suggest moderate correlation.

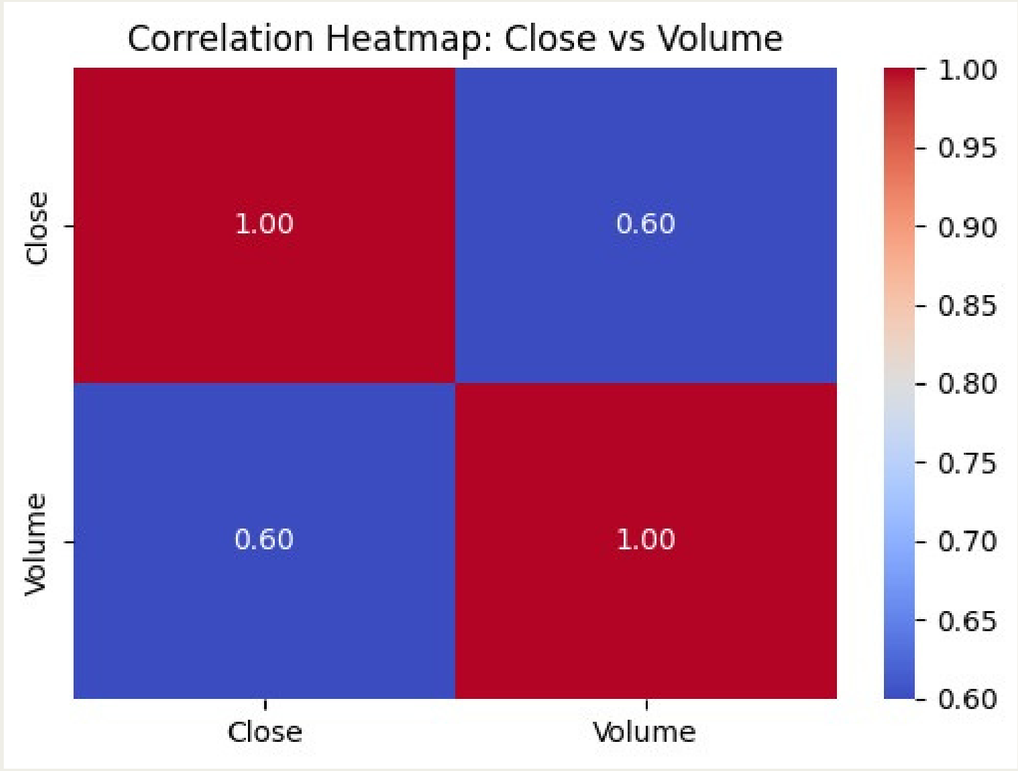

Figure 13: Correlation between Closing Prices and Volume

FUTURE WORK

Forecasting Models

Using robust prediction models such as LSTM Regression to predict the closing price of Bitcoin using the previous data available

Volatility Modelling

Volatility models such as ARCH or GARCH maybe used to better understand the nature and persistence of volitility and the fat-tailed nature of the residual

Multivariate Analysis

Price of Bitcoin depends on a lot of external factors such as market situation or public sentiments which can be taken into account to build a much more robus multivariate model to better study the data.

Thank you!