Bitcoin (BTC) Time Series Extended Analysis

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***Abstract*—This report presents a comprehensive time series analysis of daily Bitcoin (BTC) closing prices from September 2014 to March 2025.This is the continuation of the porject that I initiiated during my SC435 Time Series Analysis course. The core of this analysis lies in the diagnostic study of the residuals. This study demonstrates that while BTC prices are complex, their risk characteristics can be statistically quantified, providing a necessary foundation for robust volatility modelling.**

I. Introduction

Bitcoin (BTC), the pioneering decentralised digital currency, is notoriously volatile. This volatility poses a significant challenge, as standard financial models often assume a normal distribution of returns—an assumption that fails to capture Bitcoin's frequent, extreme price shocks and "fat-tail" behaviour. The core of this analysis lies in a deep diagnostic study of the stationary residuals. By quantifying their "fat-tailed" and leptokurtic nature, we demonstrate that while BTC prices are complex, their risk characteristics can be statistically quantified. This provides the necessary foundation for robust volatility modelling, such as GARCH, that can properly account for Bitcoin's true risk profile.

II. Data Description

The dataset was collected from Yahoo Finance using the `yfinance` Python package. The dataset spans from September 17, 2014, with 3847 daily records. It contains the historical prices of Bitcoin (ticker: BTC-USD), including the following columns:

TABLE I
Description of columns in the dataset(All prices are in USD)

Column	Description
`Date`	Contains the date of the prices for that day in the format: YYYY-MM-DD 00:00:00+00:00.
`Open`	Opening price for that date.
`High`	Highest price during the trading day.
`Low`	Lowest price during the trading day.
`Close`	Final price at the end of the trading day.
`Volume`	Total number of shares or contracts traded.
`Dividends`	Dividends issued on that day, if any (always zero for BTC).
`Stock Splits`	Records of any stock splits (not applicable to BTC).

III. Analysis of Stationary Residuals

To analyse the stationary residual, we plot the daily and monthly density distributions. This allows us to examine the nature of fluctuations, the frequency of outliers, and the skewness of the fluctuations. In financial time series, studying these fluctuations becomes especially important to perform a better risk analysis.

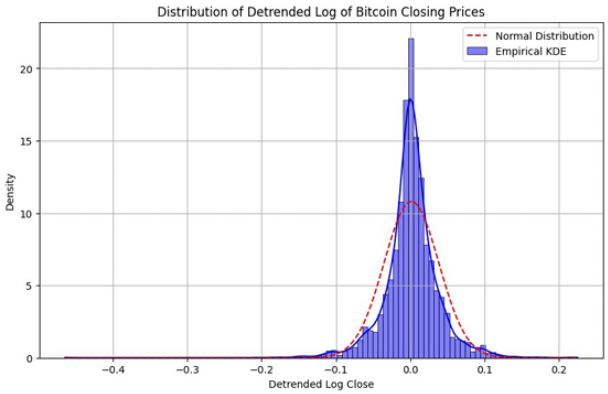

Fig. 7. Daily Density Distrubution

Fig. 1. Daily Density Distribution

The daily density distribution plot has a significantly higher peak than a theoretical normal distribution, implying that it is leptokurtic. It also has a relatively fat tail, suggesting a higher probability of extreme values, which is an expected characteristic given the highly volatile nature of Bitcoin prices.

These observations are in line with the four statistical moments of the distribution calculated numerically:

- Mean: 0.001601
- Variance: 0.001366
- Skewness: -0.671608
- Kurtosis: 11.666637

We also corroborated these observations with the help of a Q–Q plot, which shows that normality may be followed for the central values such as the mean and median, but deviations occur in the tails, indicating heavier tails than a theoretical normal distribution. Overall, this suggests slight deviation from normality, particularly in the extremes — a common trait in financial time series data. We then examined the distribution of the residuals using a monthly moving average. The monthly distribution appeared more central than the daily residuals because aggregation smooths out volatility and extremes. Daily residuals, on the other hand, retain more raw volatility and noise, resulting in a heavier-tailed, less central shape.

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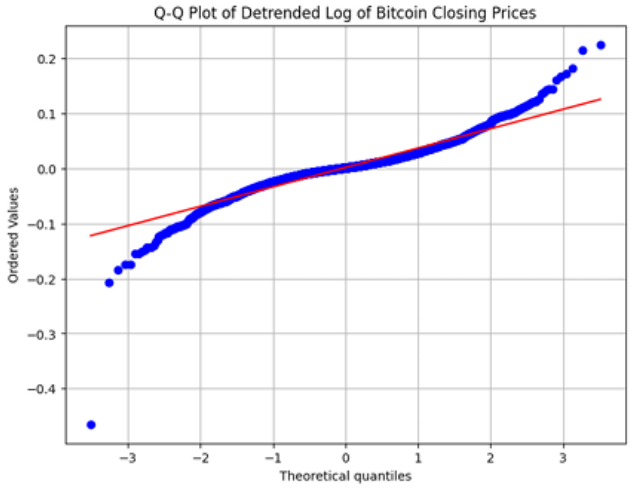

Fig. 8. Q-Q Plot to visualize distribution of the residuals

Fig. 2. Q-Q plot to visualise the distribution of residuals

Fig. 9. Fitted Distributions of Monthly Residuals

Fig. 3. Fitted Distributions of Monthly Residuals

Finally, multiple probability distributions were fitted to the residuals, and we observed that the *t*-distribution provides the best fit for the monthly residual distribution.

IV. Conclusion

While this study has explored the highly volatile nature of Bitcoin's daily closing prices, there remain several areas for future work. These maybe outlined as follows:

- **Volatility Modelling :** Volatility models such as ARCH or GARCH can be used to better understand clustering and persistence of volatility, given the leptokurtic and fat-tailed nature of the residual density distribution.
- **Multivariate Analysis:** Including other aspects such as volume of trade or prices of other cryptocurrencies, which would allow us to do a more in-depth analysis of trends in closing prices.