

An Empirical Study on Yield Volatility of Cryptocurrencies

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Abstract. With the rapid development of cryptocurrencies, the volatility characteristics of their yields have received more and more attention. At the same time, many empirical studies show that the GARCH family model is more effective in describing the volatility of financial time series. Firstly, this paper briefly introduces the research background of cryptocurrency and the research method using GARCH model. Next, the daily rate of return is calculated and descriptive statistical analysis is carried out on the collected closing price data of cryptocurrency, and on this basis, the GARCH model is constructed for empirical test to explore the volatility characteristics of its rate of return. Then the corresponding research conclusions and relevant policy recommendations are given.

Keywords: Cryptocurrency, GARCH model, Bitcoin, Yield volatility.

1. Introduction

Cryptocurrency is a medium of exchange that uses cryptography principles to ensure the security of transactions and control the creation of transaction units, and is a rapidly developing and controversial blockchain application in recent years. Central banks in some countries, including China, have begun to research and develop "fiat" or "sovereign" cryptocurrencies. In actual transactions, the technology of cryptocurrency is not yet fully mature, and the current research on mainstream cryptocurrency based on blockchain technology is still insufficient. Therefore, as a kind of financial asset, a further understanding of the operation law of the cryptocurrency market, its risk points and the volatility characteristics of the rate of return will help us put forward relevant suggestions on risks to standardize the supervision of cryptocurrency and deepen our understanding of the central bank's digital currency.

The key problem in modeling the yield volatility of cryptocurrencies is the accuracy of the model. ARCH and GARCH family models can better fit the clustering effect contained in the price time series. At the same time, in the previous literature on cryptocurrencies, most of them studied the volatility characteristics of a single digital currency, and few conducted phased comparative analysis of more than two cryptocurrencies.

Therefore, this paper mainly takes Bitcoin, Litecoin and Ether as analysis objects, which rank the top three in the market value of cryptocurrencies, and selects historical data of each indicator as sample data. The descriptive statistical methods and the empirical analysis method of GARCH model are used to study these three cryptocurrencies in order to explore their volatility characteristics. It is conducive to deepen the understanding of the volatility characteristics of cryptocurrency yield and better grasp the relevant content of econometrics.

2. Test and analysis of cryptocurrency yield

2.1. Data preparation

2.1.1 Sample data acquisition

The price data of Bitcoin, Litecoin and Ether are derived from "investing.com". The earliest quotation time of Ether is March 9, 2016. In order to ensure the consistency of the time stage and the availability of data, the range of closing price data of Bitcoin, Litecoin and Ether selected in this paper is from September 1, 2016 to April 1, 2022. Since the trading of the cryptocurrency exchange market is not affected by holidays, there are 2,039 sets of daily price data.

2.1.2 Processing of sample data

The object of this paper is to study the yield volatility of Bitcoin, Litecoin and Ether. The calculation methods of rate of return mainly include simple rate of return and logarithmic rate of return. Among these two measurement methods, simple rate of return is more widely used. However, most studies on the rule of stock price change choose logarithmic rate of return. Considering the similarities between cryptocurrencies and stock trading, in this paper, the logarithmic return rate of Bitcoin, Litecoin and Ether is selected as the research object, and its expression is as follows:

$$r_t = \ln\left(\frac{p_t}{p_{t-1}}\right) = \ln p_t - \ln p_{t-1} \quad (1)$$

Where p_t is the closing price of a cryptocurrency on day t , p_{t-1} is the closing price of a cryptocurrency on day $t-1$, and r_t is the logarithmic yield of the cryptocurrency on day t .

2.2. Test on the yield of cryptocurrency

2.2.1 Descriptive statistical analysis

By using the calculation method of logarithmic return mentioned above to obtain the daily return series of Bitcoin, Litecoin and Ether. Eviews is used to conduct descriptive statistics, the mean value, median value, minimum value, maximum value, standard deviation, skewness, kurtosis and J-B statistics of return are mainly selected.

Table 1. Descriptive statistical analysis table

Statistic	Bitcoin	Litecoin	Ether
Mean Value	0.002156	0.002770	0.001732
Median Value	0.002253	0.001803	-1.65E-05
Maximum Value	0.227602	0.258599	0.606981
Minimum Value	-0.497278	-0.589639	-0.486778
Standard Deviation	0.041382	0.055490	0.060815
Skewness	-0.865111	-0.578101	0.682959
Kurtosis	15.75593	12.13824	16.21187
J-B Statistics	14071.33	7204.682	14980.93

It can be seen from Table 1 that: (1) The average value of Bitcoin, Litecoin and Ether is positive, indicating that the rate of return of the three shows an increasing trend, and the average daily rate of return of Litecoin is the largest; (2) Among the three cryptocurrencies, Ether has the largest standard deviation, indicating that Ether has greater volatility and higher market risk; The skewness of both Bitcoin and Litecoin is negative, indicating that there are more trading days with less than average returns in these two markets; (4) The kurtosis of the three cryptocurrencies is significantly greater than 3, which means that the return series of the three markets have the characteristics of peak and thick tail, among which Ether is the most obvious; Using J-B statistics to describe the normality of samples, it is found that the J-B statistics of Litecoin is significantly smaller than that of Bitcoin and Ether, indicating that the non-normality of its return series is weak.

2.2.2 Stationarity test

Before using the GARCH model to empirically test and analyze the volatility of the daily rate of return of cryptocurrency, it is necessary to test the stationarity of its rate of return series. According to the characteristics of the research samples, this paper uses ADF unit root test to test the stationarity of the daily return series of Bitcoin, Litecoin and Ether. The test results are shown in Table 2 below.

Table 2. Daily yield unit root test

Variable	ADF Statistic	1% Value	5% Value	10% Value	P-value
Bitcoin daily yield	-47.37500	-3.962553	-3.412015	-3.127916	0.0000
Litecoin daily yield	-47.27906	-3.962553	-3.412015	-3.127916	0.0000
Ether daily yield	-47.18435	-3.962553	-3.412015	-3.127916	0.0000

According to the ADF test results, it can be seen that the T-values of Bitcoin, Litecoin and Ether are all less than the critical value of ADF test at the significance level of 1%, and their corresponding P-values are close to 0, indicating that the daily return series of these three cryptocurrencies are stationary series, and the GARCH model can be applied to empirically test and analyze the volatility of their return rates.

2.2.3 ARCH effect test

Eviews10.0 is used to draw the daily rate of return series of Bitcoin, Litecoin and Ether, as shown in Figure 1, Figure 2 and Figure 3.

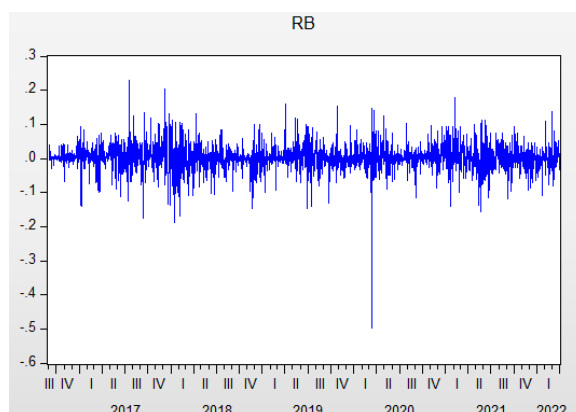


Figure 1. Bitcoin daily yield chart

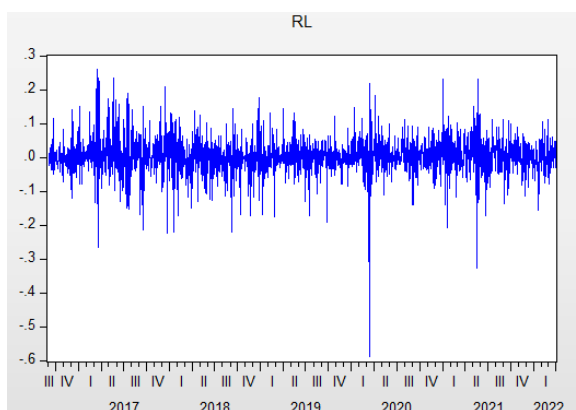


Figure 2. Litecoin daily yield chart

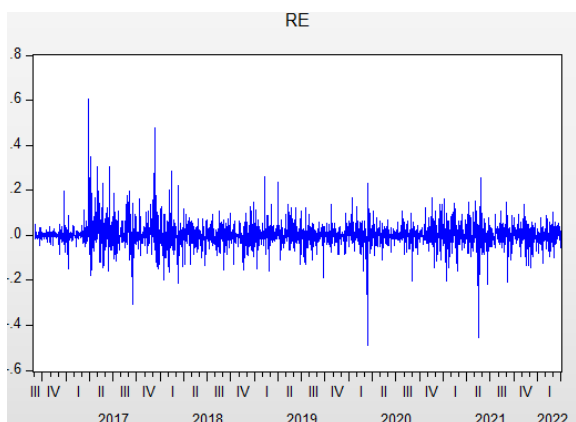


Figure 3. Ether daily yield chart

According to the figure above, there is a significant clustering phenomenon in the daily yield fluctuations of Bitcoin, Litecoin and Ether in the whole sample interval, which is called "volatilityclustering". It indicates that the daily yield series of cryptocurrency is likely to have conditional anisovariance (ARCH effect). In this paper, ARCH-LM, the most commonly used method

in the empirical model, is used to test the yield series of Bitcoin, Litecoin and Ether. By applying Eviews10.0 software, the lag order is selected as 1 order, 2 order and 3 order, and the test results are shown in Table 3 below.

Table 3. Daily return series LM test

Lag Order	Bitcoin Daily Yield			Litecoin Daily Yield			Ether Daily Yield		
	Chi-square statistics	Degree of freedom	P-value	Chi-square statistics	Degree of freedom	P-value	Chi-square statistics	Degree of freedom	P-value
1	10.00245	1	0.0016	26.83110	1	0.0000	39.11997	1	0.0000
2	11.01929	2	0.004	32.65173	2	0.0000	40.07704	2	0.0000
3	11.65592	3	0.008	37.10346	3	0.0000	46.93673	3	0.0000

Regardless of the lags, the P-value corresponding to the residual series of daily returns of Bitcoin, Litecoin and Ether is less than 0.01, indicating that the residual series of daily returns of Bitcoin, Litecoin and Ether has a significant ARCH effect. Therefore, this paper uses GARCH (1, 1) model instead of high-order ARCH model to model the daily return series of Bitcoin, Litecoin and Ether within the full sample interval, and further analyzes the volatility characteristics of the three return series.

2.3. Comparative analysis of yield volatility of cryptocurrencies

Based on the research purpose of this paper and the conditional heteroscedasticity test results of the return series of three cryptocurrencies, this paper chooses GARCH (1, 1) model to compare and analyze the volatility of daily return. The results are shown in Table 4.

Table 4. GARCH model estimation results

Model	Variable	Coefficient	Standard Deviation	Z-statistic	P-value
Bitcoin GARCH model	C1	0.002911	0.000813	3.579574	0.0003
	C2	8.10E-05	8.57E-06	9.455083	0.0000
	RESID(-1)^2	0.113281	0.009285	12.20102	0.0000
	GARCH(-1)	0.850699	0.012420	68.49616	0.0000
Litecoin GARCH model	C1	0.002049	0.001123	0.755	0.4503
	C2	0.000188	2.37E-05	7.914756	0.0681
	RESID(-1)^2	0.115635	0.008601	13.44421	0.0000
	GARCH(-1)	0.829268	0.013826	59.97801	0.0000
Ether GARCH model	C1	0.000947	0.001338	0.707962	0.4790
	C2	0.000137	1.27E-05	10.75092	0.0000
	RESID(-1)^2	0.062896	0.004929	12.75913	0.0000
	GARCH(-1)	0.902570	0.007585	118.9987	0.0000

The equation of the GARCH (1, 1) model for the daily yield estimation of Bitcoin, Litecoin and Ether are as follows.

The variance equation of Bitcoin's daily yield:

$$\widehat{\sigma_t^2} = 8.10 \times 10^{-5} + 0.113281\mu_{t-1}^2 + 0.850699\sigma_{t-1}^2 \quad (2)$$

Z: (8.57E-06) (0.009285) (0.012420)

$R^2 = 0.987$ AIC = -3.6651 SC = -3.6372

The variance equation of Litecoin 's daily yield:

$$\widehat{\sigma_t^2} = 0.000188 + 0.115635\mu_{t-1}^2 + 0.829268\sigma_{t-1}^2 \quad (3)$$

Z: (2.37E-05) (0.008601) (0.013826)

$R^2 = 0.979$ AIC = -3.0770 SC = -3.0632

The variance equation of Ether 's daily yield:

$$\begin{aligned}\widehat{\sigma}_t^2 &= 0.000137 + 0.062896\mu_{t-1}^2 + 0.902570\sigma_{t-1}^2 \\ Z: (1.27E-05) \quad (0.004929) \quad (0.007585) \\ R^2 &= 0.938 \quad AIC = 2.8985 \quad SC = -2.8848\end{aligned}\quad (4)$$

The conclusion of the analysis of volatility agglomeration effect of return rate is that the daily return time series data of Bitcoin, Litecoin and Ether have relatively significant volatility agglomeration. At the same time, in the sample stage selected in this paper, Bitcoin is the most vulnerable to external market shocks, and Litecoin market is more vulnerable than Ether market. The above analysis also reflects from the side that although Bitcoin has become the most valuable cryptocurrency, its market development is not mature, and it is still full of a large number of speculative transactions, and the market is more vulnerable.

From the above empirical results and analysis, it can be seen that GARCH model can better fit and explain the volatility of Bitcoin, Litecoin and Ether to a certain extent, but limited by the assumptions of the model, GARCH model can only explain the symmetry phenomenon in the cryptocurrency market, but cannot explain the asymmetry phenomenon. Therefore, TGARCH model and EGARCH model can be used for further analysis of asymmetries.

3. Literature References on price volatility of cryptocurrencies

3.1. Research on volatility of financial assets

Volatility can be understood as "the conditional difference in the return rate of the underlying asset" [1]. Its possible applications can include risk management, value at risk and asset pricing, and many scholars use finance. The time series data of assets are used to estimate and model volatility. Use more waves in the price of financial assets. The empirical models of dynamic rate are EWMA, ARCH and GARCH family models, among which, ARCH and The GARCH family model is used to study the volatility effect in the price time series of financial assets. The application is more extensive. Existing scholars mainly focus on the time series of asset prices in the capital market. It contains wave aggregation, asymmetry, negative skewness, peak degree and peak sequence, etc., at the same time in a specific situation. In this case, the volatility of asset prices may also have leverage effects.

The research on volatility in foreign countries has gradually shifted from the basic ARCH model to the extended ARCH model. Earlier research literature used Topix index as sample space to analyze the fitting effect of GARCH, EGARCH and other models on the volatility of Topix index return [2]. Some scholars also used TGARCH model to fit the volatility of Chinese stock market return, and found that the model obtained a higher estimated conditional variance [3] during the period of high volatility of return. If the problem of asymmetric information exists in the market is considered, taking the Standard & Poor's 500 Index as an example, when there is no information asymmetry, the volatility characteristics of the S&P 500 index fitted by GARCH (1, 1) model is more accurate, while when there is information asymmetry, the asymmetric ARCH model should be selected for research [4]. If we combine GARCH model and Markov switching model, we can capture all the financial asset prices Significant structural changes improve the fit degree of stock price volatility and thus improve the accuracy of price prediction [5].

Most domestic scholars use the GARCH family model to study the volatility characteristics of China's stock market, and choose the volatility of the return rate of Shenzhen and Shanghai stock indexes to fit and forecast [6, 7, 8, 9]. When the weekly closing price replaces the daily rate of return as the research object, the volatility of stock return shown in China's stock market has both clustering and nonlinear relationship between stock return rates in different time periods [10]. Meanwhile, the GARCH family model is not only applicable to analysis of the volatility of the stock market yield in our country, but the GARCH model of the asymmetric effect is also applicable to empirically and analyze the volatility of the national debt index yield in our country [11].

3.2. Research on the volatility of Bitcoin price

Existing literature studies on the fluctuation of Bitcoin price point out that the Bitcoin market cannot reach the weak efficient market, and its returns are predictable to a certain extent [12, 13, 14, 15, 16]. In the actual Bitcoin trading process, the trading instruments provided by different exchanges are different, resulting in different exchanges. The number of participants and the depth of the market are different, so there are price differences in the price of Bitcoin, which can be arbitrated by high-frequency traders. Such arbitrage not only maintains the price consistency of Bitcoin, but also exacerbates the real-time price fluctuations of Bitcoin being traded to a certain extent [17].

The key problem of modeling the rate of return and volatility of Bitcoin is the accuracy of the model. ARCH and GARCH family models can better fit the clustering effect contained in the price time series of Bitcoin. At present, there are few articles applying financial asset volatility model to study the volatility characteristics of cryptocurrencies. Existing research literature uses GARCH class model and takes 3-5 years as the sample interval to prove some characteristics of the volatility of Bitcoin's return rate. For example, the fluctuation of Bitcoin price shows an obvious peak and thick tail [18], the market of Bitcoin price jumps frequently and has a agglomeration effect [19], the price sequence has structural mutation points, and the response to external information is asymmetric. Its market risk has the characteristics of "self-enhancement" [20] the positive feedback effect leads to the super-exponential growth of asset prices [21].

4. Sumamry

In this paper, the closing price data of Bitcoin, Litecoin and Ether from September 1, 2016 to April 1, 2022 are selected to calculate the daily logarithmic return rate of the three cryptocurrencies respectively, and then the descriptive statistical method is used to analyze them, and the GARCH model is used to study their volatility characteristics. It can be concluded that: (1) The daily rate of return time series data of Bitcoin, Litecoin and Ether, the three cryptocurrencies, all have significant volatility agglomeration. (2) Bitcoin is the most vulnerable to shocks, and Litecoin is more vulnerable than Ether.

Through the volatility research of Bitcoin, Litecoin and Ether, it is found that the three types of cryptocurrency markets are immature, and the market structure and operation mechanism of the market are still to be developed. A large number of studies on cryptocurrency will help the central bank to implement DCEP to a certain extent, and the gradual filling of regulatory gaps will also optimize the development environment of the new financial asset market. Therefore, this article collates the following policy recommendations: (1) Improving government oversight. (2) Enhance information disclosure. (3) Improve the quality of investors. (4) Accelerate the development of legal digital currency.

Acknowledgements

Grateful acknowledgement is made to my tutor who gave me considerable help by means of suggestion, comments and criticism. His encouragement and unwavering support has sustained me through frustration and depression.

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