Research on the Correlation Between COVID-19 and Bitcoin Price Volatility Based on Time-series Model

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ABSTRACT
From 2020 to 2021, COVID-19 spread across the globe, which has a significant impact on the global economy and people's lives. With the development of the COVID-19 pandemic, people's pessimism about the economy has increased, leading to a significant increase in demand for safe-haven currencies and a sharp rise in the price of safe-haven currencies. Bitcoin, the new safe-haven currency, also saw huge price swings during the pandemic. Select bitcoin price yield index for empirical analysis of time series model. First, this paper use ADF to test the stationarity of the time series and establish the ARMA model. Second, the conditional heteroscedasticity of the residual of the model was found through model testing, and then the GARCH model was modeled. Finally, based on the ARMA-GARCH model, through analyzing the relationship between bitcoin price volatility and the development of COVID-19 in China and the US, the correlation between the two is determined. Through research and calculation, this paper concludes that there is an obvious correlation between the COVID-19 epidemic and the fluctuation of the bitcoin return rate.

Keywords*: COVID-19, Bitcoin, ARMAX, GARCH*

1. INTRODUCTION

In December 2019, viral pneumonia of unknown cause occurred in Wuhan, Hubei Province. The virus was subsequently confirmed as a novel coronavirus, which was named "Novel Coronavirus 2019" by the World Health Organization. This outbreak has spread widely and lasted for a long time. As of May 1, 2021, the cumulative number of confirmed COVID-19 cases has exceeded 200 million and the cumulative death toll has reached nearly 5 million. [1] The epidemic has brought earth-shaking changes to people's lives and has had a serious impact on the world economy. The pandemic has brought an unprecedented impact on global tourism, a severe blow to international trade challenges to global industrial, supply, and value chains, a sharp drop in global capital markets, a severe decline in household wealth, and a continued severe impact on global employment and income. Recent research showed that the pattern of the world economy has also changed. On the one hand, the center of gravity of the global economy is shifting from the west to the east. On the other hand, developed countries are shifting to developing countries.[2] Therefore, the Asian economy has become the locomotive driving the world economy. In response to the huge volatility and uncertainty in the world economy, the demand for and ownership of safe-haven currencies has increased significantly during the COVID-19 pandemic.

Bitcoin, as a new currency, was first proposed by Satoshi Nakamoto after the outbreak of the financial crisis in 2008 and was formally born on January 3, 2009. Bitcoin is a kind of digital currency in the form of P2P. Since its birth, Bitcoin has been issued around the world and can be used as legal currency in some countries. Unlike traditional currencies, Bitcoin does not have a clear currency issuer, and Bitcoin is generated by network computing. Bitcoin does not belong to any country or government, nor is it controlled by central banks or financial institutions. Any individual or enterprise can issue bitcoin. In addition, according to the recent statistics the bitcoin unit price is high, as of October 20, 2021, the price of bitcoin rose to $65,000 per coin.[3] Further research has proved that the above two characteristics of Bitcoin make bitcoin have obvious risk-averse characteristics and become the risk-averse currency chosen by many investors.[4-6] In the view of some Chinese mass bitcoin investors, bitcoin, as a global digital hedge currency, has a strong defense ability against inflation directly and ultimately. When people are pessimistic about the current rate of inflation in the global economy as a whole, it is highly likely to directly lead to the massive circulation of Bitcoin and the rapid growth

of transactions in the digital currency market. This has pushed the price of digital currency up and down in the short term.

Therefore, during the COVID-19 pandemic, as the world economy continues to decline, the price of Bitcoin, as a haven currency, has gradually increased. Therefore, it is of great practical significance to verify the correlation between the price of Bitcoin and the COVID-19 epidemic and study the impact of changes in the COVID-19 epidemic on the price of Bitcoin.

The next parts of this paper are organized as follows: The second part describes the data sources of this paper, ARMAX, and GARCH models, and preprocesses the data according to the study needs. The third part introduces the results of the ADF test and ARMAX and GARCH models calculated with Stata and explains and explains the results. The fourth part analyzes the results of Part 4 by combining the research purpose of this article. The fifth part combines the calculation and analysis of the previous parts to conclude this paper.

2. RESEARCH DESIGN

2.1. Data sources and data preprocessing

To further study the impact of COVID-19 on bitcoin price, this paper selected the bitcoin price from January 11, 2019, to May 1, 20201, the daily number of newly confirmed COVID-19 cases in China, and the daily number of newly confirmed COVID-19 cases in the United States as research objects, and used Stata software for data analysis.

2.1.1 Bitcoin price data

The data selection day's closing price of the currency to the dollar, a total of 477 samples data, data from invest (https://cn.investing.com/crypto/bitcoin/historical-data). In this paper, the daily closing price of Bitcoin is taken logarithmic first and then the difference is made, that is, the logarithmic return rate sequence is calculated. The calculation formula of numerical return series refers to "Equation (1)".

$$d\ln price_t = \ln price_t - \ln price_{t-1} \quad (1)$$

Where price represents the closing price at time T, price-1 represents the closing price at time T-1, and $dlnprice_t$ represents the daily logarithmic return rate.

2.1.2. Data on the number of new COVID-19 cases

This paper records the daily number of newly confirmed COVID-19 cases in China and the United States during this period, with a total of 477 samples. Us data comes from the WHO Coronavirus Dashboard within the World Health Organization. Chinese data are from the National Health Commission, PRC. In this paper, the logarithm of daily newly confirmed COVID-19 cases in the two countries is taken and redefined. The redefined logarithm refers to "Equation (2)" and "Equation (3)".

$$\ln USA_t = \ln(1+USA_t) \quad (2)$$

$$\ln China_t = \ln(1+China_t) \quad (3)$$

Where, USA_t represents the daily number of newly confirmed COVID-19 cases in the United States at time T, and $China_t$ represents the daily number of newly confirmed COVID-19 cases in China at time T.

2.2. Model Specification

2.2.1. ARMA and ARMAX model

ARMA model is a kind of common random time series model and a high precision short-term prediction method of time series. ARMA model is composed of AR model and MA model. AR model has the truncated property of partial autocorrelation function, and the MA model has the truncated property of correlation function. Some causal linear time series have similar behavior to AR and MA, but partial autocorrelation function truncation or correlation function truncation cannot be implemented in low order. ARMA model combines AR and MA model, and in the case of similar goodness of fit to data, a simpler model can often be obtained, and neither partial autocorrelation function nor correlation function is required to truncate.

Its model can be expressed as "Equation (4)".

$$X_t = \phi_0 + \phi_1 X_{t-1} + \ldots + \phi_p X_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \ldots + \theta_q \varepsilon_{t-q} \quad (4)$$

P and q are non-negative integers. P represents the coefficient of autoregressive term and q represents the number of moving average terms. Real parameters $\varphi_1, \varphi_2, \ldots, \varphi_p$ are called the autoregressive coefficient.

The ARMAX model can be obtained by introducing other explanatory variables into the ARMA model, among which the introduced variables are weakly stationary. The purpose of the ARMAX model is to investigate the contribution of other variables to the dependent variable while predicting the future with past realization values and past disturbances. The equation of the ARMAX model is as "Equation (5)".

$$X_t = \phi_0 + \sum_{i=1}^{p} \phi_i x_{t-i} + a_t - \sum_{i=1}^{p} \theta_i a_{t-i} + \sum_{i=1}^{q_1} \gamma_{1q_1} x_{1,t-q_1} + \sum_{i=1}^{q_K} \gamma_{Ki} x_{K,t-i} \quad (5)$$

2.2.2. (G)ARCH cluster model (autoregressive conditional heteroscedasticity model)

According to past research， the Autoregressive conditional heteroscedasticity model is mainly used to study the rules of volatility, such as aggregation, risk premium, leverage effect (asymmetric effect), spillover effect, or adding other explanatory variables.[7,8] It is generally believed that cross-sectional data are prone to heteroscedasticity and time series data are usually autocorrelated. However, according to the past research, time-series data would also have special heteroscedasticity, namely "autoregressive conditional heteroscedasticity"[9,10]. ARCH model considers variance volatility, which can better predict variance and has important application value in the financial field.

ARCH (M) model is shown in the following "Equation(6)" and "Equation(7)".

$$a_t = \sigma_t \varepsilon_t \tag{6}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 a_{t-1}^2 + \ldots + \alpha_m a_{t-m}^2 \tag{7}$$

ε_t is the independent identically distributed white noise of zero mean unit variance， $\alpha_0 > 0$ ， $\alpha_j \geqslant 0$, j=1,2,...,m.

In the ARCH (M) model, the larger m is, the more parameters need to be estimated and the more samples are lost. According to the theory presented by Bollerslev, the GARCH model reduced the parameters to be estimated, so the prediction of future conditional variance was more accurate. [11] GARCH model is an autoregressive part added to the ARCH model.

The model of GARCH (P,q) is set as "Equation(8)".

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \gamma_i \sigma^2{}_{t-i} \tag{8}$$

When there is conditional heteroscedasticity in time series, GARCH or ARCH models can be used. The model setting of the GARCH cluster is very flexible, so it can be flexible according to the purpose to be achieved.

3. THE EMPIRICAL RESULTS

3.1. Report results and analysis of ADF-test

Before establishing the ARMAX model, we first need to carry out the stationarity test. In this paper, the unit root test (ADF) method was used to test the pre-processed bitcoin price, the daily new COVID-19 cases in China, and the daily new COVID-19 cases in the United States. First, make sure null and alternative assumptions.

H0：There is a unit root in the time series.

H1：There is no unit root in time series.

Then Stata software is used to check whether there is unit root in the three time-series. Unit root test results are shown in Table 1.

Table 1. ADF test results of Bitcoin price log yield, the daily No. of newly confirmed cases in China and the USA

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	p-value	N
dlnprice	-24.753	-3.981	-3.421	-3.130	0.0000	475
ln_USA	-3.248	-3.442	-2.871	-2.570	0.0174	476
ln_China	-4.827	-3.981	-3.421	-3.130	0.0004	476

ADF test shows that there is no unit root in the daily logarithmic return series of Bitcoin price and the daily number of new CORONAVIRUS cases in China at the significance level of 1%. There was no unit root in the logarithmic sequence of the daily number of new CORONAVIRUS cases in the United States at the significance level of 5%. ADF test shows that the above three sequences are stable, so the model can be further established.

3.2. Report results and analysis of ARMAX

Before establishing the ARMA model of the logarithmic return rate sequence of bitcoin price, this paper first draws autocorrelation images and partial autocorrelation images to judge the order of AR and MA models, then selects the model with the lowest AIC value according to the comparison of AIC values. The order of AR model and MA model selected in this paper are both

first-order. The autocorrelation image (Figure 1) and partial autocorrelation image (Figure 2) are shown below:

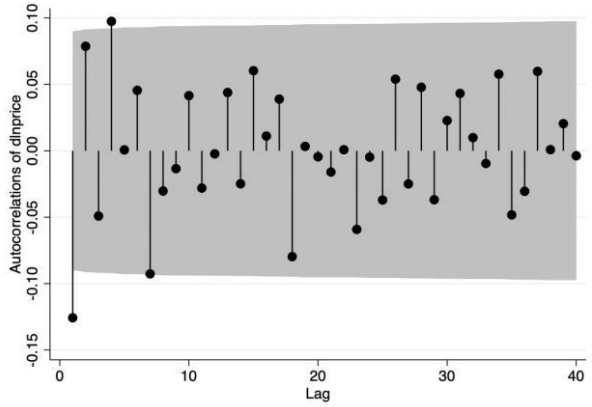

Figure 1 Introduce the results of the AC

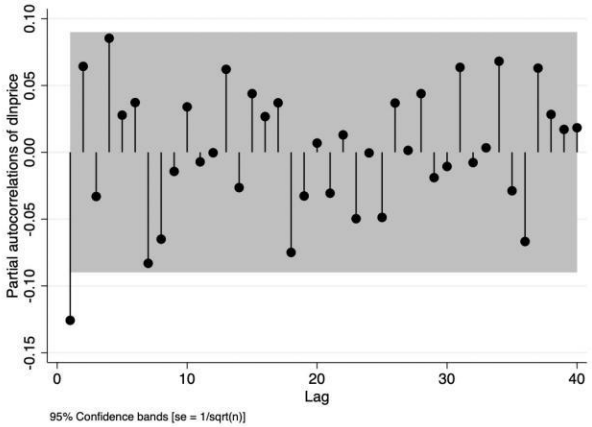

Figure 2 Introduce the results of the PAC

Table 2. Introduce the daily No. of newly confirmed cases in China

Variables	Rate of return, Bitcoin		
	(1)	(2)	(3)
T=0	-0.0004	0.0029	0.0034
	(0.0016)	(0.0041)	(0.0042)
T=-1		-0.0036	-0.0021
		(0.0042)	(0.0050)
T=-2			-0.0020
			(0.0039)
AR (-1)	-	-0.7740***	-0.7708***
	(0.1186)	(0.1174)	(0.1212)
MA (-1)	0.6728*	0.6699***	0.6672***
	(0.1339)	(0.1331)	(0.1369)
Constan	0.0056*	0.0062***	0.0063***
	(0.0056)	(0.0058)	(0.0057)
N	476	476	475

After building the ARMA model, this paper introduced COVID-19 as an external variable into the ARMA model to obtain the ARMAX model. In this paper, the number of newly confirmed COVID-19 cases per day in China and the number of newly confirmed COVID-19 cases per day in the United States and their lag values were used as external variables. After introducing external variables, the ARMAX model was constructed and a significance test was conducted. The results are shown in Table2 and Table3.

Table 3. Introduce the daily No. of newly confirmed cases in the United State

Variables	Rate of return, Bitcoin		
	(4)	(5)	(6)
T=0	0.0009	0.0005	0.0001
	(0.0008)	(0.0084)	(0.0069)
T=-1		0.0003	-0.0044
		(0.0081)	(0.0106)
T=-2			0.0051
			(0.0081)
AR (-1)	-0.7688***	-0.7691***	-0.7591***
	(0.1189)	(0.1196)	(0.1259)
MA (-1)	0.6654***	0.6655***	0.6561***
	(0.1333)	(0.1339)	(0.1397)
Constant	-0.0049***	-0.0049***	-0.0049***
	(0.0085)	(0.0088)	(0.0087)
N	476	476	475

T=0 represents the number of newly confirmed COVID-19 cases introduced daily, T=1 represents the number of newly confirmed COVID-19 cases introduced daily lagged by one stage, and T=2 represents the number of newly confirmed COVID-19 cases introduced daily lagged by two stages. *** means significant at 1% level; ** means significant at 5% level; * means significant at the 10% level.

The results show that the coefficients of the ARMA (1,1) model are significant at 1% level when the newly confirmed COVID-19 cases in China and their lag values are introduced, but the coefficients before the introduction of variables are not significant. The coefficients of the ARMA (1,1) model are significant at the 1% level, but the coefficients before the variables are not significant when the newly confirmed COVID-19 cases in the United States and their lag values are introduced. In the long term, the COVID-19 outbreak in China and the United States does not affect the bitcoin yield.

3.3. Report results and analysis of GARCH

From the sequence diagram of the daily price

logarithmic return sequence of Bitcoin (Picture 3), it is found that the sequence may have heteroscedasticity. Therefore, this paper considers the establishment of a volatility model. First, the ARCH effect was tested.

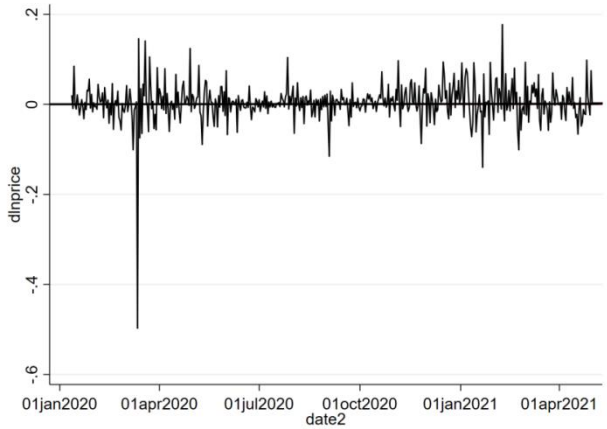

Figure 3 Introduce the sequence diagram of the daily price logarithmic return sequence of Bitcoin

The results of the most basic GARCH (1,1) model are shown in Table 4. It can be seen from the table that both ARCH and GARCH items are significant, indicating that the volatility of logarithmic return rate of bitcoin price has an obvious ARCH effect, so GARCH modeling can be carried out.

After adding the daily increase of COVID-19 in China and the United States and their lag values respectively, the GARCH model results are shown in Table 5:

Table 4. Introduce the result of GARCH (1,1)

Variable	Mean Equation	Variance Equation		
	Constant	ARCH	GARCH	Constant
Coefficient	0.0061***	0.1744***	0.8355***	0.0000***
Std. err	(0.0020)	(0.0241)	(0.0238)	(0.0000)

Table 5. Introduce the daily No. of newly confirmed cases in the United State and China

Variables	Rate of return, Bitcoin					
	(1)	(2)	(3)	(4)	(5)	(6)
Mean Equation						
AR (-1)	-0.4999	-0.7894***	-1.0159***	-0.4729	-0.7884***	-0.6966***
	(0.5594)	(0.1850)	(0.0148)	(0.5214)	(0.1365)	(0.2557)
MA (-1)	0.4360	0.7428***	1.0160***	0.3941	0.7048***	0.6328**
	(0.5742)	(0.2222)	(0.0147)	(0.5373)	(0.1576)	(0.2776)
Constant	0.0047***	-6.0464***	0.0047***	0.0044***	0.0054***	0.0042***
	(0.0016)	(0.1784)	(0.0018)	(0.0017)	(0.0019)	(0.0019)
Variance Equation						
Newly Confirmed Cases, China						
T=0	0.5186***	-0.9774***	-0.5192			
	(0.0321)	(0.1088)	(2.4701)			
T=-1		0.8302***	0.0851			
		(0.1250)	(4.6460)			
T=-2			0.9225			
			(2.3119)			

Newly Confirmed Cases, USA						
T=0				-0.2122***	-0.1589***	0.1026
				(0.0165)	(0.0533)	(0.0697)
T=-1					0.0570	0.0535
					(0.0495)	(0.0600)
T=-2						-0.2481***
						(0.0765)
Constant	-11.7220***	-6.0464***	-11.5587***	-8.0542***	-4.7566***	-4.8817***
	(0.2481)	(0.1784)	(0.3843)	(0.3059)	(0.0912)	(0.1413)
N	476	476	475	476	476	475

After adding the current number of newly confirmed COVID-19 cases in China, the GARCH model indicates that the number of newly confirmed COVID-19 cases in China is significant at the 1% level. After adding the current value of newly confirmed COVID-19 cases in China and the first-phase lag value, the GARCH model indicates that the current value of newly confirmed COVID-19 cases in China and the first-phase lag value are both significant at the 1% level. After adding the current value of newly confirmed COVID-19 cases in China and its first phase lag value and second phase lag value, the GARCH model indicates that the current value of newly confirmed COVID-19 cases in China and its first phase lag value and second phase lag value are not significant.

After adding the current value of newly confirmed COVID-19 cases in the United States, the GARCH model shows that the coefficient in the variance equation of return of bitcoin price logarithm is significant at the 1% level. After adding the current value of newly confirmed COVID-19 cases in the United States and its first-phase lag value, the GARCH model indicates that the current value of newly confirmed COVID-19 cases in the United States is significant at the 1% level, while the first-phase lag value of newly confirmed COVID-19 cases in the United States is not significant. After adding the current value of newly confirmed COVID-19 cases in the United States and the lag value of the first and second phases, the GARCH model indicates that only the second phase lag value of newly confirmed COVID-19 cases in the United States is significant at the 1% level.

4. DISCUSSION

As can be seen from the estimation results of ARMAX, in the long run, neither the newly confirmed cases in China nor the Newly confirmed cases in the United States nor their lag values have a significant impact on bitcoin returns. This shows that in the long run, bitcoin's returns are not significantly affected by the epidemic, and the price is still dominated by production and supply, and demand.

As can be seen from GARCH's estimation results, there is a significant correlation between bitcoin volatility and COVID-19 in the long run.

There is a positive correlation between bitcoin volatility and the COVID-19 outbreak in China. When the variance equation only included the number of newly confirmed cases in China during the period, there was a significant positive relationship between newly confirmed cases and bitcoin price fluctuations. Therefore, an increase in the number of new cases on the day can cause the price of Bitcoin to fluctuate upward. When including the newly confirmed cases in China in the current period and the lag period, there is a significant positive relationship between the newly confirmed cases in the lag period and the price volatility of Bitcoin. Therefore, an increase in the number of new cases on the previous day can cause bitcoin prices to fluctuate upward. The positive relationship between newly confirmed cases and bitcoin price volatility is not significant when including the current period, one period behind, and two periods behind China's newly confirmed cases. Therefore, it cannot explain the influence relationship between the fluctuation of COVID-19 cases and the fluctuation of bitcoin price.

There is a negative correlation between bitcoin volatility and the COVID-19 outbreak in the US. When including the newly confirmed cases in the United States in the current period, there is a significant negative relationship between the newly confirmed cases in the lag period and the price volatility of Bitcoin. Therefore, the increase in new confirmed cases during the period will cause the price of Bitcoin to fluctuate downward. When including the new confirmed cases in the United States in the current period and the lag period, there is a significant negative relationship between the lag period and bitcoin price volatility. Therefore, an increase in the number of new cases on the previous day can cause the price of Bitcoin to fluctuate downward. When the newly confirmed cases in the United States are included in the current period, the first period and the second period, the new confirmed cases in the second period are negatively correlated with the price fluctuation of Bitcoin. As a

result, the increase in new cases over the past two days could cause bitcoin prices to move downward.

5. CONCLUSION

In this paper, using the modeling idea of time series analysis, through the empirical analysis of bitcoin price index return rate from January 19, 2020, to May 1, 2021, through a series of step-by-step modeling, the ARMAX-GARCH model is finally obtained. Under the ARMAX model, there is no significant correlation between the price of Bitcoin and the COVID-19 epidemic, that is, the price of Bitcoin is mainly determined by the supply and demand of money and is less affected by the epidemic. The GARCH model is established in this paper after considering that the volatility of bitcoin price has certain volatility aggregation, that is, the volatility has an obvious ARCH effect. The model eliminates heteroscedasticity well and explains its volatility. In the GARCH model, there is a significant correlation between bitcoin volatility and the COVID-19 epidemic, in the long run, especially the number of newly confirmed COVID-19 cases in the current period has a great impact on bitcoin price fluctuations.

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