

The Time-varying Impact of Covid-19 Pandemic on Cryptocurrency: Evidence from VAR and AEMA-GARCH models

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Abstract. To represent the relationship between cryptocurrency market and the Covid-19 pandemic, this paper chose the closing price of BTC and ETH and daily new confirmed cases in China, America, and the global to build VAR and ARMA-GARCH models. After missing data dropped, this paper collected data from Jan 24th, 2021 to Feb 24th, 2022, and there are totally 757 samples in these 2 models. ADF test was used to test the time-series variables' stability. This paper used HQIC, PACF and ACF to identify VAR, AR and MA order, respectively. Empirical results found that the pandemic had a negative effect on the yield of BTC and ETH. This paper found that the effect of the pandemic in China and America was similar but different from that of global in the long term.

Keywords: Bitcoin; Ethereum; Cryptocurrency; Covid-19.

1. Introduction

With the development of technology and the economy, the currency had a new form exist in the market. The first paper money was produced in 1023, and the first form of cryptocurrency, Bitcoin, was invented in 2011. This kind of currency was admitted its value. Recently, the pandemic that was caused by Coronavirus-19 has led to a bad influence on society, people's health, and the economy. The economic effect was inevitable and obvious. Cryptocurrencies as a new media to invest and store wealth, this paper wanted to prove the connection between them and pandemic. The question for this paper was to find whether electronic cryptocurrencies received the impact of the epidemic and the extent to which they were affected.

The calculation tool for this paper was Stata. There were 2 models, VAR model, and ARMA-GARCH model, required for this paper. Before building models, this paper used ADF test to obtain stable time series, yield for cryptocurrencies, and change rate of new cases was stable variables. Based on these variables, this paper then built VAR model and used HQIC method to receive the information that the VAR model was 9-degree. This paper then proved the stability of the VAR model. For ARMA model, this paper used PACF and ACF methods and knew the order for ARMA was (1,1). After that, this paper used the impulse response function to build connections between five variables in the long term. Yields for BTC and ETH were shown to decrease due to the change rate of new cases in the world. Otherwise, yields of these two cryptocurrencies were increased due to the change rate of new cases in China and America, which showed a different trend toward the effect of global new cases. The estimation of ARMA-GARCH modeled the volatility, and it examined the volatility of yield. The slopes between the yield of BTC and the new case change rate of China, America, and global were negative. For ETH yield, the coefficients between it and global and America were negative, and that between it and China was positive.

After the model building and estimation, this paper compared this paper to other experiments. Besides the difference in models, 9 cryptocurrencies were included in the models, which can represent the market more comprehensively. The suggestion was to encourage investment diversification in portfolios.

Salvatore pointed out that the economic recovery after 2009 was slow, and he wondered to know the recovery speed after the 2020 recession [1]. Salvatore demonstrated that despite the effect of depression in 2020 is deeper than that in 2008, more macro policies were adopted in the economy [2]. He listed possible policies of governments to accelerate the economic recovery and growth in the

world, which included increasing the infrastructure investment to speed up Total Factor Productivity (TFP), decreasing the income inequality, repairing the regulation international trading system, and adopting measures to avoid credit and debt crisis.

McCann Philip and Vorley Tim investigated the potential effects of pandemic on productivity. They examined the pandemic impact on the economy, society, and governance in the medium term and long term [3]. They showed that pre-existing challenges to productivity had been eliminated by the pandemic and informed appropriate policy for the economic crisis.

Yeung Bernard, He Zhiguo, and Agarwal Sumit pointed out that the pandemic of Covid-19 was spread at the end of 2019. Many countries applied policies including lockdown and a decrease in face-to-face contact [4]. These policies were useful to prevent the spread of pandemic and to protect human health, but they also brought damage to the development of the economy. The result of the pandemic, the worldwide economic crisis, was huger than the Great Financial Crisis of 2008-2009. Asian Bureau of Finance and Economic Research (ABFER) wondered to provide a complete view of the pandemic to inform the public.

French Joseph J analyzed the effect of the Twitter-based Market Uncertainty index (TMU) and BTC before and during the pandemic [5]. His finding was that TMU was a factor for the BTC profit during the pandemic, and the volatility of TMU on BTC was greater as the pandemic spread than that before the pandemic.

Some scholars demonstrated that the pandemic had caused the financial market unstable. Investors might seek a method to invest from the economic depression [6]. Bitcoin proved its value, but gold was considered a stable property during the crisis. Shehzad and other scholars showed that in the long-term gold would be more profitable than BTC. For this paper, this factor might not be included in the model.

The structure of this paper was divided into five parts. The first part introduced the question and object of this paper, and it concluded main viewpoints from other selected papers. The second part introduced the source of data and model building process, including ADF test, VAR model specification, and ARMA-GARCH model identification. The third part analyzed the result from the second part, determined the orders of models applied, and used the impulse response function. The fourth part discussed the research result and compared the similarities and differences between this paper and other papers. The last part concluded the points of this paper.

2. Research design

2.1 Source of data

In this paper, this paper collected daily new cases of Covid-19, and the scope of statistics covered global, Chinese, and American new cases reported. The data source was recorded on China Stock Market & Accounting Research Database (CSMAR). To obtain a general changing trend of cryptocurrency, this paper chose Bitcoin (BTC) and Ethereum (ETC) as mainly observed objects and collected closing prices per day from Investing. The time range of statistics is from Jan 24th, 2020 to Feb 24th, 2022, which included 757 records [7 8]. To obtain a precise result, incomplete statistics were removed from models and calculations. Model building and data analysis in this paper were based on Stata.

2.2 ADF test

To start ADF test, the null hypothesis (H_0) was settled. H_0 of ADF test assumed that series was not stable. When H_0 is smaller than This result meant that the series tested were non-stationary, and the relationship of sequence would be hard to discover. For the data of BTC and ETH, this paper calculated the change rate of closing prices, and the results of p-value were shown in Table 1: 0.9678 and 0.9473 and both higher than 0.1, so the change rate of BTC and ETH was non-stationary. After that test, change rates of profit of BTC and ETH were calculated. They were both shown as 0.0000, so the change rate of profit of BTC and ETH fulfilled the unit root test. The results were less than

0.01 so it was in the 1% confidence interval. For the series of new cases from Covid-19, this paper calculated the change rate of the new case from China, America, and the global. The result showed that p-value of the change rate of the new case from Chinese and American were 0.0183 and 0.0207, which satisfied unit test roots, and the results were between 0.01 and 0.05, so they were in the 5% confidence interval. For the change rate global, the p-value of the result was 0.0026, so it was also stationary. The p-value was less than 0.01, so it was in 1% confidence interval.

Table 1. ADF test

Variables	t-statistic	p-value
Price		
Bitcoin	-0.774	0.9678
Ethereum	-0.976	0.9473
Yield		
Bitcoin	-19.761	0.0000***
Ethereum	-19.313	0.0000***
Newly confirmed cases		
CN	-3.767	0.0183**
US	-3.726	0.0207**
Global	-4.358	0.0026***

2.3 VAR model specification

To forecast the change of variables, one way is to combine these variables as a system. This method was called Vector Autoregression (VAR).

For the preparation of VAR model, 5 variables were chosen: BTC yield (y_{1t}), the profit change rate of ETH (y_{2t}), daily new confirmed cases in global (y_{3t}), the change rate of new cases in China (y_{4t}), and change rate of new cases in America (y_{5t}). This paper built a VAR model with 5 degrees. VAR model was used to observe relationships between time series variables. 5 variables listed were considered as explained variables, and p-degree lagged values were the explanatory variables of 5 explained variables. This paper then listed a system with five functions.

$$\begin{cases} y_{1t} = \beta_{10} + \beta_{11}y_{1,t-1} + \beta_{1p}y_{1,t-p} + \dots + \gamma_{11}y_{5,t-1} + \dots + \gamma_{1p}y_{5,t-p} + \varepsilon_{1t} \\ y_{2t} = \beta_{20} + \beta_{21}y_{1,t-1} + \beta_{2p}y_{1,t-p} + \dots + \gamma_{21}y_{5,t-1} + \dots + \gamma_{2p}y_{5,t-p} + \varepsilon_{2t} \\ y_{3t} = \beta_{30} + \beta_{31}y_{1,t-1} + \beta_{3p}y_{1,t-p} + \dots + \gamma_{31}y_{5,t-1} + \dots + \gamma_{3p}y_{5,t-p} + \varepsilon_{3t} \\ y_{4t} = \beta_{40} + \beta_{41}y_{1,t-1} + \beta_{4p}y_{1,t-p} + \dots + \gamma_{41}y_{5,t-1} + \dots + \gamma_{4p}y_{5,t-p} + \varepsilon_{4t} \\ y_{5t} = \beta_{50} + \beta_{51}y_{1,t-1} + \beta_{5p}y_{1,t-p} + \dots + \gamma_{51}y_{5,t-1} + \dots + \gamma_{5p}y_{5,t-p} + \varepsilon_{5t} \end{cases} \quad (1)$$

2.4 ARMA-GARCH model identification

The autoregressive moving average model (ARMA) and generalized autoregressive conditional heteroskedasticity (GARCH) were applied in this paper. The objective of ARMA model was to forecast future values by using past real values and disturbance terms simultaneously. The expression of this model was listed: the first part was the polynomial of AR model, and the second part was that of MA model. The degrees of AR and MA model was shown as “p” and “q” in the expression, and they were non-negative integers.

$$x_t = \phi_0 + \sum_{i=1}^p \phi_i x_{t-i} + a_t - \sum_{i=1}^q \theta_i a_{t-i} \quad (2)$$

GARCH model was based on ARCH model, and GARCH model would decrease the number of parameters. The reason for that is GARCH model had an autoregressive component σ^2 in its expression. The expression was shown below:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{1-q}^2 + \gamma_1 \sigma_{t-1}^2 + \cdots + \gamma_p \sigma_{t-p}^2 \quad (3)$$

ARMA-GARCH model combined characters of ARMA and GARCH models. This model could be used to forecast yields and volatilities of BTC and ETH. This paper sets the process of ARMA model as the mean equation of GARCH model.

3. Result and analysis

3.1 Identify the order of VAR model

This paper inputs y_{1t} , y_{2t} , y_{3t} , y_{4t} , and y_{5t} into Stata with the maximum of 12 lags to determine the order of VAR model. The method to determine the order is to find the minimum in Table 2 and its corresponding lag is the appropriate order. To make a simpler model, a VAR model with less degree would be chosen. Also, the degree of VAR model should be greater than 3. As shown in Table 2, 9 degrees were chosen, and the modeling method was HQIC. For the modeling methods of LR and FPE, the appropriate degrees were both 12, which were higher than 9-degree, so these methods were excluded.

Table 2. VAR model identification

Lag	LL	LR	df	p	FPE	HQIC
0	-658.464				4.1e-06	1.79545
1	2421.44	6159.8	25	0.000	1.1e-09	-6.35691
2	2543.41	243.94	25	0.000	8.6e-10	-6.55784
3	2640.68	194.54	25	0.000	7.0e-10	-6.69239
4	2685.35	89.338	25	0.000	6.7e-10	-6.68552
5	2698.26	25.815	25	0.418	6.9e-10	-6.59328
6	2748.17	99.831	25	0.000	6.5e-10	-6.60052
7	2781.98	67.611	25	0.000	6.3e-10	-6.56445
8	2934.67	305.38	25	0.000	4.5e-10	-6.84797
9	2988.57	107.81	25	0.000	4.1e-10	-6.86593*
10	3029.87	82.594	25	0.000	4.0e-10	-6.85
11	3051.48	43.222	25	0.013	4.0e-10	-6.78115
12	3084.55	66.139*	25	0.000	3.9e-10*	-6.7431

After determining the order, another important step for VAR model building is to check its stability. As shown in Figure 1, all the roots filled the circle, which proved the stability of the model. Variable series fulfilled normal distribution.

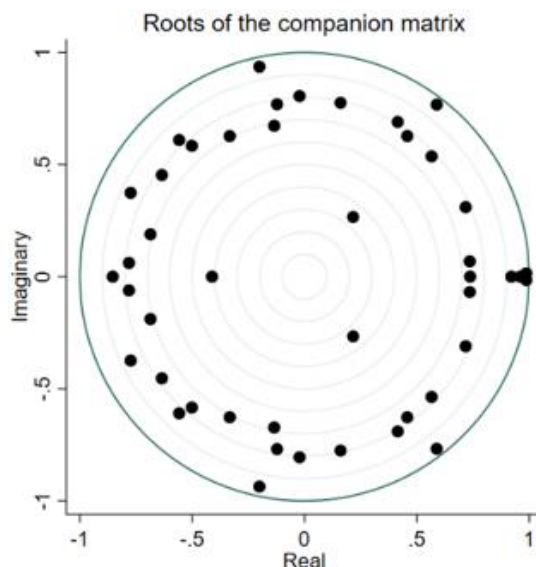


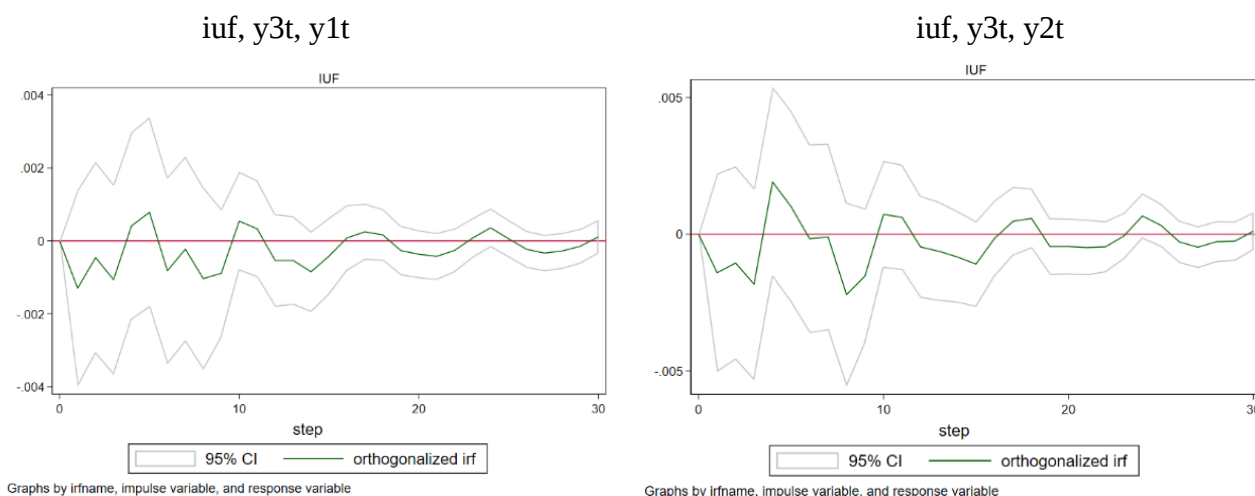
Figure 1. VAR stability

3.2 Impulse response function

The outcome for impulse response is to observe a change in a variable that would cause how much the other variables change in a long term. The expression of this function was listed.

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t'} = \psi_s \quad (4)$$

From the graph of the impulse response, the relationship between y_{1t} , y_{2t} , y_{3t} , y_{4t} , and y_{5t} in long run would be shown. The grey curves in the graphs showed the 95% confidence interval of the series. In Figure 2, the effects of yield from BTC and ETH from global, China, and the United States were shown. In the long run, the change rate of global new cases caused the yields of BTC and ETH to fluctuate, and the whole trend for yield was negative. For the change rate of new cases in China (y_{4t}), it encouraged the yields for BTC and ETH (y_{1t} and y_{2t}) to be positive in the long run. For change rate of new cases in America (y_{5t}), caused y_{1t} and y_{2t} to be negative in the short term, and then to be positive in the long term.



Graphs by irfname, impulse variable, and response variable

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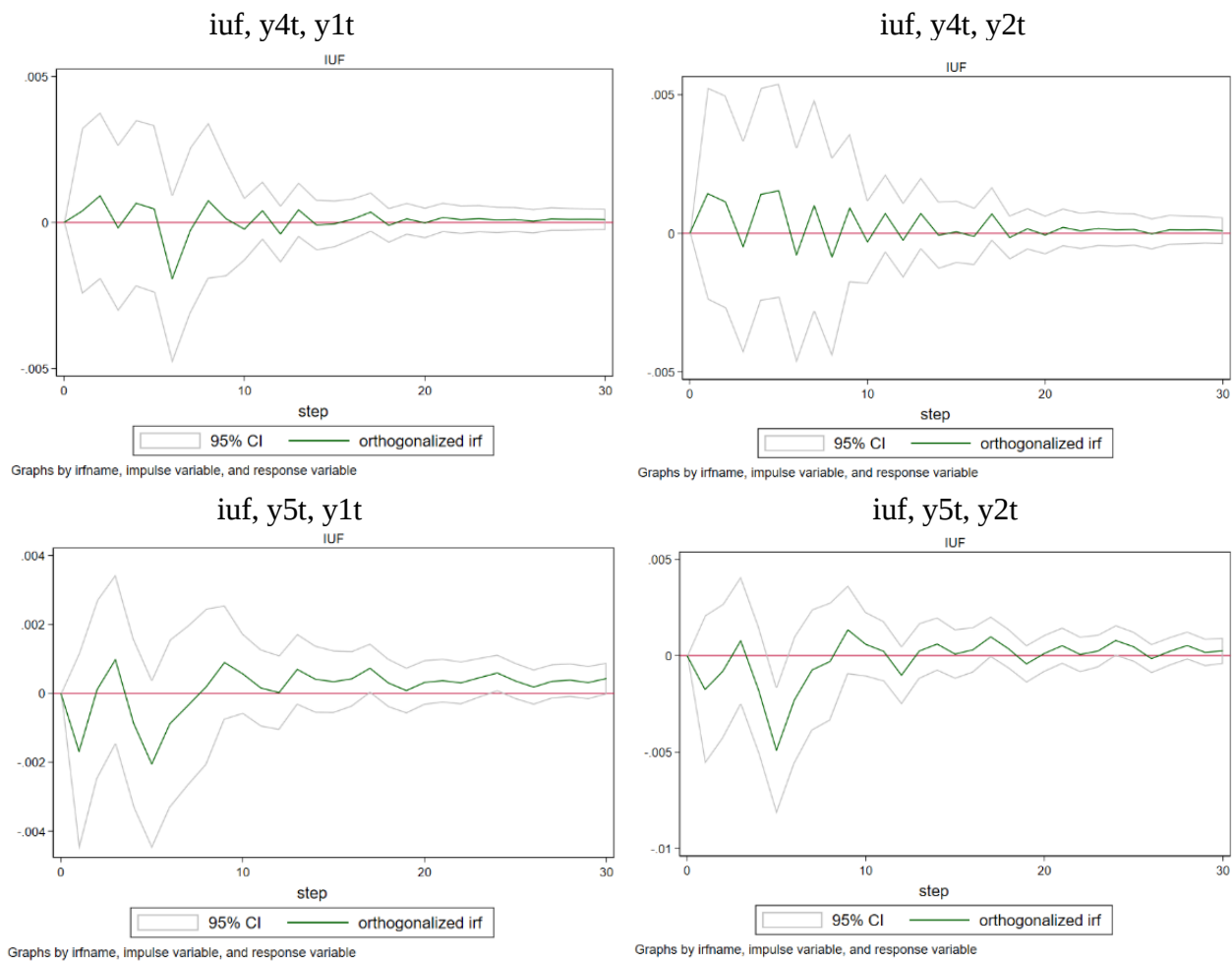


Figure 2. Impulse response

3.3 Determining order for ARMA model

To determine the degree of $AR(p)$, PACF method was used in Stata. To find the appropriate lag order, points that were out of the rectangle of the graphs would be chosen, and the point with the least lags would be the most appropriate one. From Figure 3, the lag order for AR of BTC model was 1. ACF method was used to find the order of MA model. The order for MA model was 1, which was found with a similar method. ARMA (1,1) was identified for BTC.

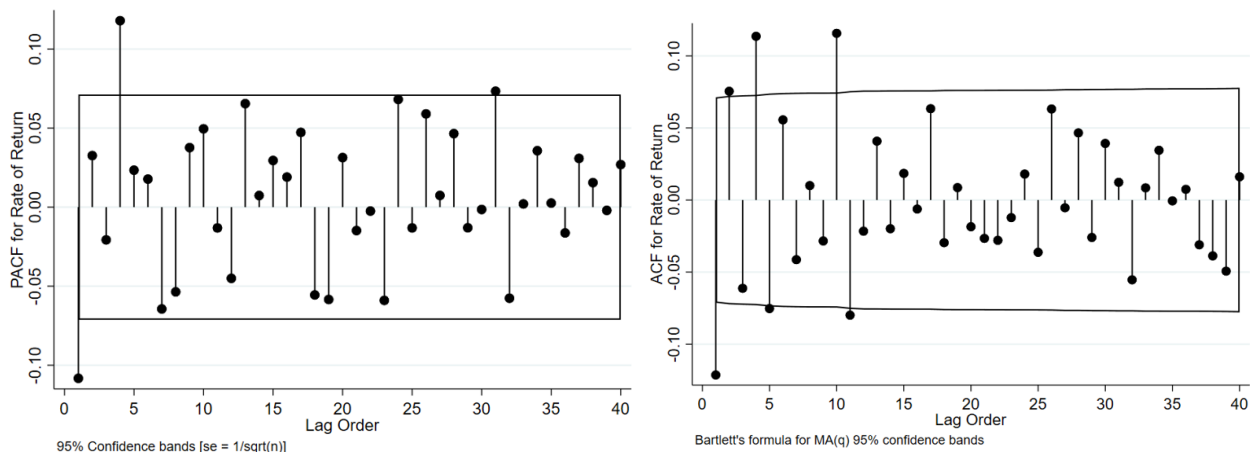


Figure 3. ARMA identification, Bitcoin

Similarly, the order for ETH of ARMA was (1,1), which was shown in Figure 4.

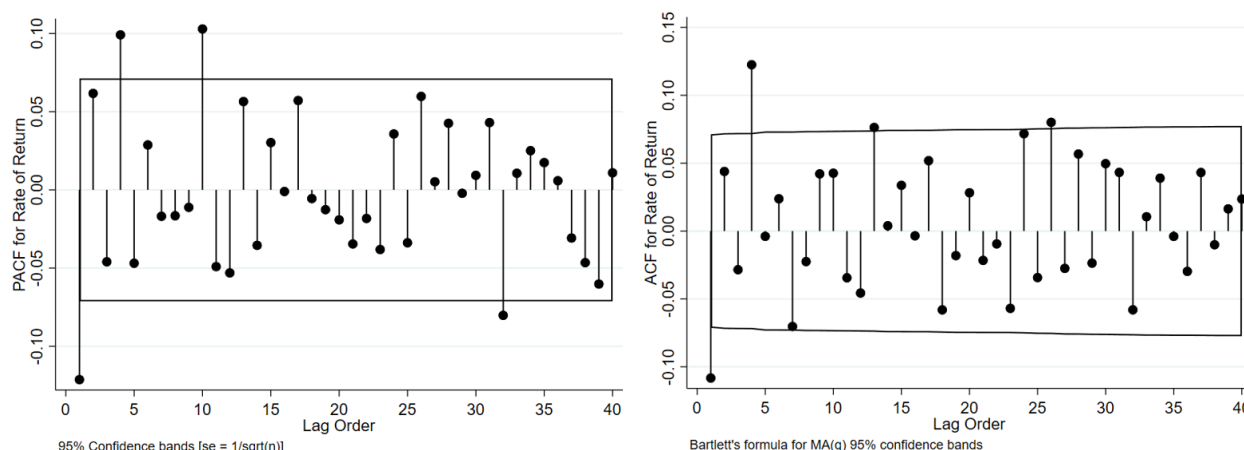


Figure 4. ARMA identification, Ethereum

3.4 ARMA-GARCH estimation results

From Table 3, each group of data has the coefficient and standard errors of two variables from the ARMA-GARCH model. Coefficients were classified based on their p-values. Coefficients were classified according to whether they were significant or not. Coefficients in 10%, 5%, and 1% confidence levels were marked with “*,” “***,” and “****.” In Table 3, y3t, y4t, and y5t all had negative coefficients. For column (1), GARCH had a negative coefficient, and ARCH and constant had positive coefficients. For columns (2) and (3), ARCH and GARCH had positive coefficients, and constant had negative coefficients.

For analysis on ETH, y4t ETH had a negative coefficient, and y3t and y5t had negative coefficients with ETH. ARCH and GARCH had positive coefficients on columns (4), (5), and (6). On the other hand, the constant had all negative coefficients, with the values of -10.1865, -7.2882, and -5.3311.

Table 3. ARMA-GARCH estimation results, variance equation

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Bitcoin			Ethereum		
Newly confirmed cases						
CN	-0.2381***			0.2531*		
	0.0259			0.0876		
US		-0.1907***			-0.1726***	
		0.0136			0.0160	
Global			-0.3406***			-0.3059***
			0.0305			0.0338
GARCH						
ARCH (-1)	0.0061	0.0258***	0.0375***	0.1033***	0.0671***	0.0844***
	0.0141	0.0064	0.0089	0.0136	0.0128	0.0149
GARCH (-1)	-0.4099	0.9441***	0.9350***	0.8784***	0.8956***	0.8846***
	0.2201	0.0132	0.0156	0.0162	0.0187	0.0195
Constant	-5.2673***	-8.0124***	-5.7589***	-10.1865***	-7.2882***	-5.3311***
	0.1688	0.2560	0.2145	0.4973	0.2446	0.2573

4. Discussion

This paper, this paper chose BTC and ETH to represent the cryptocurrency market and built a model to prove the effect on the electronic money market from the pandemic in the world. The model applied was VAR and ARMA-GARCH. Ahmet Faruk Aysan, Asad Ul Islam Khan, and Humeyra Topuz investigated the effect of 9 cryptocurrencies during the pandemic [9]. They used different models to obtain the conclusion. They pointed out that customers would be beneficial from cryptocurrencies if they diversified their portfolios in the long term. The viewpoint of this paper was that yields for BTC and ETH would be negative in the long term due to the pandemic in the world, but they would be encouraged by the change of pandemic in China and America.

The Great Lockdown was led by the pandemic, which caused huge damage to the economy of the world [10]. Due to this reason, cryptocurrencies could be an effective investing way to avoid the depression from the pandemic. This paper has informed the possible relationship between electronic money and pandemic, but the scope is limited. This paper covered the pandemic change in China, America, and the global, and recorded the yields of BTC and ETH in about one year.

It is hard for governments or policymakers to control cryptocurrencies directly, and they would not earn taxes during cryptocurrency transactions. However, Federal Reserve Board had increased the interest rate of deposits continuously, which might cause the depression in the cryptocurrency market. This factor was not included in the model, so it might be a disturbance team shown in the model. The relationship between the policy and the effect on cryptocurrencies needed to be proved by further experiments, which was not covered in this paper.

5. Conclusion

In conclusion, the question of this paper was to find possible relationship between the effect of pandemic and the development of the cryptocurrency market. This paper focused on the pandemic trend global, China, and America, and calculated the yields of BTC and ETH. The purpose of this paper was to observe the general trend from statistics. Firstly, this paper used the ADF test to make the time series stable, and the result was that yield for cryptocurrencies and the change rate of new cases during the pandemic were stable. Secondly, this paper used VAR model and ARMA-GARCH model to confirm the relationships between five variables. Determining the order of VAR model depended on HQIC method, and the order of AR and MA models was calculated from PACF and ACF models. The order for VAR model was 9, and the order for the 2 ARMA models was (2,2). This paper then tried to analyze the relationship through the impulse response curve. The result of global was different from that of China and America. Coefficients and standard errors were founded through ARMA-GARCH model, and the p-values were also shown. In addition to the models of the research, there might be other factors besides the effect of pandemic, which required further experiments to prove their existence.

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