

Impact of US Dollar Appreciation on Cryptocurrency Market: Evidence from Time Series Model

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Abstract. Since March 16, 2022, when the first federal funds rate hike was announced, federal funds rate has been raised from 0.25% to a level between 0.25% and 0.5%. Until July 27, 2022, the Fed has raised federal funds rate four times, bringing the benchmark of federal funds rate from 0.25% to a range of 2.25% to 2.5%. Against the backdrop of a downward spiral in the US economy and increased inflationary pressure, monetary policy in the US is gradually tightening. This paper selects two typical cryptocurrencies, Bitcoin and Ethereum, and uses time-series model to analyze the impact of US dollar appreciation on cryptocurrency market under the background of Fed rate hike, to fill the research gap and make suggestions for investors and policymakers. This paper concludes that US dollar appreciation would not affect Bitcoin market significantly but would negatively affect Ethereum market. Investors are supposed to be more alert to the risks of cryptocurrency market and reduce the holdings of Ethereum when US dollar index increases. For policymakers, they are suggested to increase regulation of cryptocurrency markets and prevent some malicious speculators' attacks on the unmaturing market from happening.

Keywords: US dollar appreciation, Cryptocurrency market, Time-series model.

1. Introduction

As international and domestic economic situation is becoming increasingly complex, plenty of new cryptocurrencies are popping up. More and more investors turn to cryptocurrency market in order to gain more profit. Cryptocurrencies are virtual assets generated by distributed network computers through preset programs. Typical cryptocurrencies include Bitcoin, Ethereum, Binance Coin (BNB), etc. One of the most typical characteristics of cryptocurrency market is its high volatility. In 2021, the cryptocurrency market heated up dramatically, with bitcoin rising from \$26,875 per coin at the beginning of the year to \$46,219 per coin at the end of the year, up 172%, and reaching a high of \$68,990 per coin, up 257% [1]. Ethereum is up nearly 400%, and Binance Coin (BNB) is up nearly 1300% [1]. However, potential risks lurk behind the frenzied and superficially prosperous market. If investors ignore those potential risks behind cryptocurrency market, they may make poor judgments and investment choices.

To against the backdrop of a downward spiral in the US economy and continuous inflationary pressure, monetary policy in the U.S. is gradually tightening. Since March 16, 2022, when the first federal funds rate hike was announced, federal funds rate has been raised from 0.25% to a level between 0.25% and 0.5% [2]. Until July 27, 2022, the Fed has raised federal funds rate four times, bringing the benchmark from 0.25% to a range of 2.25% to 2.5% [2]. According to a report from Xinlang News, the Fed's rate hike helps to reverse the domestic economic situation of America, curb inflationary tendency and promote economic recovery [3]. With the steady recovery of U.S. economy and slowdown of economic growth of new-emerging market countries, US dollar appreciation is inevitable.

Since US dollar is one of the few currencies that can be directly traded with cryptocurrencies in fiat currency (i.e., US dollar can be directly exchanged for cryptocurrencies), the fluctuation of US dollar is likely to affect cryptocurrency market profoundly. The US dollar index is a composite indicator of the exchange rate of US dollar in the international foreign exchange market, which measures the change degree in the exchange rate of the US dollar against a basket of currencies. Especially, it is calculated as the geometric mean weighted value of six currencies' exchange rate

against US dollar in March 1973. And 100.00 is the benchmark of US dollar index to measure its value. In 2021, US dollar index accumulated a 6.7% gain, recovering almost all its losses in 2020[4]. Under the background of USA monetary policy tightening, the dollar index may fluctuate more in the future. Financial Market Department of China Construction Bank forecasts that US dollar index may show a high trend followed by a low trend in 2022, because of both tightened monetary policy and continued high inflation [4].

How does US dollar appreciation affect the cryptocurrency market? This is the problem that this paper concerns. Thus, this paper will focus on the reaction of cryptocurrency market to the exogenous shocks of US dollar index's change. Exploring the latent correlation between US dollar index and cryptocurrency market is important for maintaining financial stability, preventing risks in cryptocurrency market, and directing investment choices.

The rest of this paper is organized as follows: Part 2 of this paper is literature review, which includes studies related to U.S. dollar exchange rate and studies related to cryptocurrency market. Part 3 exhibits the empirical research design which includes data source introduction, ADF test, VAR model, and AMRA-GRACH model. Part 4 reports the results and empirical analysis of models. In part 5, this paper discusses the empirical results and compares them with previous literature. The last part concludes the impact of U.S. dollar appreciation on cryptocurrency market and make some suggestions.

2. Literature review

2.1. Studies related to US dollar exchange rate

There is no doubt that the US dollar has been acting as an international safe-haven asset and the most widely used currency in the international financial market relying on USA's huge economic stock base and enormous trade volume. In this case, the fluctuation of US Dollar exchange rate is closely related to many types of financial markets and international economies in many ways.

Until now, several theories related to exchange rate determination have come into being. Swedish economist Gustav Cassel proposed the theory of purchasing power parity (PPP) after World War I, whose core element is that the value of a currency is based on the purchasing power of that currency and that the price level between countries directly affects the relative exchange rates of various currencies in the international arena [5-6]. Keynes proposed Interest Rate Parity Theory (IRP) in 1923, which analyzed the impact of interest rates on exchange rates from the perspective of capital flows in the foreign exchange market [7]. After World War II, Balance of Payments Theory (BP) come into being on the basis of Keynesian economics, which establishes the relationship between a country's balance of payments position and its exchange rate [8]. Other theories such as Capital Market Theory, Rational Expectations model, Speculative Bubble theory, Fundamental Equilibrium Exchange Rate model, and so on, all contribute to the analysis of exchange rate determination. However, up to now, there is still no comprehensive theory or empirical finding that is able to fully explain the determination of the dollar exchange rate.

Based on the theories above, various factors lead to US dollar appreciation, such as U.S. government incentives, the decline of commodity prices, and so on. Song Wenyun finds that oil prices, money supply volume, consumer price index, foreign investors' purchases, the Federal Reserve benchmark interest rate, and the trade balance all will influence US dollar exchange rate [9]. Song Xiangyan and Jin Ying point out that U.S. economic growth, Federal Reserve's monetary policies, and political factors are important in determining U.S dollar exchange rate [10]. In general, studies focusing on the reasons for U.S dollar exchange rate fluctuation have been abundant and fruitful, which is of great significance for analyzing and explaining the reason for U.S. dollar appreciation.

As mentioned before, US dollar appreciation will have a great impact on financial markets. Many studies on the impact of US dollar appreciation have been done analyzing the latent impact of U.S. dollar appreciation on financial markets. Pablo Druck argues that US dollar appreciation has a negative effect on new-emerging market economies, for capital outflows, higher international

financing costs, and lower prices of export goods [11]. Huang Xiaolong points out that the dominant position of the US dollar and the unbalanced international currency system has led to an overvaluation of the US dollar exchange rate and global economic imbalance [12].

2.2. Studies related to cryptocurrency market

Domestic and international researches on cryptocurrencies focus on the connotation and characteristics of cryptocurrencies, the exploration of monetary properties, regulation, the market risks of cryptocurrencies and the impact on the financial system. And both qualitative and quantitative methods are mainly used to research cryptocurrency market. Especially, current research on Bitcoin focuses on the characteristics of the bitcoin market, market price volatility and risks [13]. And research on Ethereum focuses on the prospect of Ethereum's technical application in the future [13]. Yonghui Zhai and Fei Zhao selected Bitcoin market data denominated in US dollars from 2012 to 2016 for an empirical study and found that the return series has characteristics such as spikes, thick tails, and volatility clustering and fitting the return tail distribution [14]. They contend that GEV model can measure bitcoin market risk more accurately than the GARCH model [14]. Huang Luo constructed GRACH-VaR model to measure the risks of cryptocurrency market, concluding that the risks in Bitcoin and Ethereum market are relatively high and the GARCH-GEV model is more suitable for the risk measure of cryptocurrencies [13]. In conclusion, although cryptocurrency market has been around for a short time, people's understanding of it has been relatively mature and complete.

Overall, although studies on US dollar appreciation and cryptocurrency market has been relatively well researched, there is still relatively little research on the relationship between US dollar appreciation and fluctuation of cryptocurrency market. Consequently, to fill the research gaps, this paper constructs a time series model to research the impact of US dollar appreciation on cryptocurrency market.

3. Research design

3.1. Data source

Research data comes from a search engine called Choice financial terminal [15]. Data include closing prices of US dollar appreciation and two typical cryptocurrencies, Bitcoin and Ethereum, from March 10, 2016 (since Ethereum's closing prices were recorded) to December 31, 2019 (before the covid-19 outbreak), as a data basis for following empirical analysis to study the impact of US dollar appreciation on cryptocurrency market.

3.2. ADF test

Before analyzing the data, this part must assure that the data is smooth. First, it's necessary to perform a unit root test (smoothness test), and the original hypothesis of unit root test is that the data is not smooth. The result of ADF test is listed in Table 1. From Table 1, we can see that the p-value of the log returns of US index, Bitcoin, and Ethereum are very close to 0. It is apparent that ADF test is significant, so we can reject the original hypothesis that the data isn't smooth, which indicates that our model is feasible.

Table 1. ADF test.

Variables	t-statistic	p-value
Price series		
Bitcoin	-0.975	0.9474
Ethereum	-1.908	0.6506
USD index	-0.591	0.9794
Yield series		
Bitcoin	-21.842	0.0000***
Ethereum	-21.987	0.0000***
USD index	-21.780	0.0000***

3.3. VAR model

The vector autoregressive (VAR) model is a type of time series model, which is often used to estimate the dynamic relationship between jointly endogenous variables. It is achieved by autoregression of all current period variables on several period lags of all variables. The first thing to consider in a VAR model is the differential stability of the equation. In this paper, VAR model is used to analyze the dynamic endogenous relationship within the closing prices of both Bitcoin and Ethereum. VAR model should clarify variables that this research focuses on and the maximum order of lag.

The VAR (p) model is set as follows:

$$X_t = \sum_{i=1}^p \Pi_i X_{t-i} + U_t \quad (1)$$

Among them, X is a time series column vector; U_t is a white noise vector; U_t follows IND (0, Ω).

3.4. ARMA-GARCH model

3.4.1 Model specification: ARMA

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

From equation (2) above, $\phi_0 + \sum_{i=1}^p \phi_i x_{t-i}$ represents the AR (p) model, and $\alpha_t - \sum_{i=1}^q \phi_i \alpha_{t-i}$ represents MA (q) model. Elaborately, $\sum_{i=1}^p \phi_i x_{t-i}$ uses the historical returns of closing prices to forecast the future; and the part $\alpha_t - \sum_{i=1}^q \phi_i \alpha_{t-i}$ uses past volatility to estimate the future closing prices.

3.4.2 Model specification: GARCH

GARCH model (Generalized Autoregressive Conditional Heteroskedasticity) is set up based on ARCH model, with the addition of autoregression of σ_t^2 . GARCH model is used to simulate changes in the volatility of time series variables. Compared with ARCH (q) model, GARCH model reduces the number of parameters. In other words, ARCH (p) model can be simplified as GARCH (1, 1) by iteration. The premise of constructing a GARCH model is the existence of conditional heteroskedasticity in the residual series variance properties.

The model GARCH (p, q) is set as follows:

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

In equation (3) above, the term $\alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_q \varepsilon_{t-q}^2$ is ARCH part. The subscript t represents that variance changes over time. σ_t^2 Depends on the square of the disturbance term in the previous p periods. The last part βUSD_t indicates the logarithmic return of US dollar as an external variable added into the model. The ARMA-GARCH model in this paper utilizes the past closing prices of US dollar index, Bitcoin and Ethereum to predict future volatility.

4. Results and analysis

4.1. VAR model identification

Before performing the impulse response function, it is necessary to test the stability of VAR model. That all unit roots fall within the unit circle means that this model is smooth. The impulse response analysis can be done only if all points fall in the unit circle. The stability test results of VAR model are shown in Table 2 and Figure 1.

Table 2 exhibits the result of VAR model identification. A key factor to build a VAR model is the determination of the number of lags. If the number of lags is too large, it will affect the free degree of the model, but if the number of lags is too small, it may lead to serious autocorrelation between the error terms. This paper adapts likelihood ratio test (LR), FPE, AIC, HQIC, and SBIC criteria to determine the lag order of the model. As can be seen from Table 2, * indicates the determined lag order. This paper chooses 12 as lag order of the VAR model of US dollar index and cryptocurrency market.

Table 2. VAR model identification.

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	7081.42				9.2e-11	-14.5947	-14.5889*	-14.5796*
1	7090.87	18.889	9	0.026	9.2e-11*	-14.5956*	-14.5726	-14.5353
2	7098.62	15.517	9	0.078	9.2e-11	-14.593	-14.5528	-14.4875
3	7103.08	8.9127	9	0.445	9.3e-11	-14.5837	-14.5263	-14.4328
4	7110.66	15.165	9	0.086	9.3e-11	-14.5808	-14.5061	-14.3847
5	7115.04	8.7435	9	0.461	9.4e-11	-14.5712	-14.4793	-14.3299
6	7124.93	19.79	9	0.019	9.4e-11	-14.5731	-14.464	-14.2864
7	7131.33	12.797	9	0.172	9.5e-11	-14.5677	-14.4414	-14.2358
8	7136.48	10.299	9	0.327	9.5e-11	-14.5597	-14.4162	-14.1826
9	7140.3	7.6472	9	0.570	9.6e-11	-14.5491	-14.3883	-14.1267
10	7147.55	14.491	9	0.106	9.7e-11	-14.5455	-14.3675	-14.0778
11	7151.99	8.891	9	0.447	9.8e-11	-14.5361	-14.3409	-14.0232
12	7162.56	21.132*	9	0.012	9.7e-11	-14.5393	-14.3269	-13.9812

Figure 1 is the AR root figure, which shows that all eigenvalues of the coefficient matrix fall within the unit circle. So, the model is smooth and can be used to perform impulse response function.

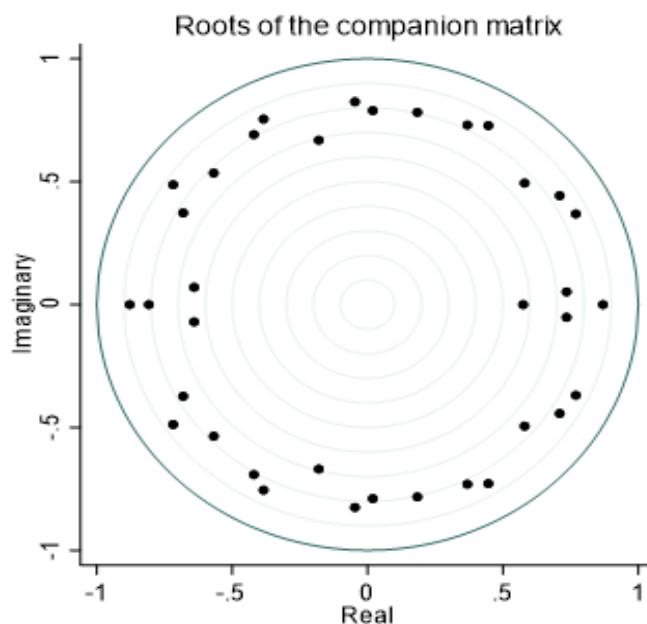


Figure 1. VAR stability.

4.2. Impulse function

The role of impulse response function is to obtain the results of one variable's effect on another variable in multiple periods and predictions. The impulse response function measures the magnitude of the response of the endogenous variables to the shocks from equations, i.e., shocks caused by changes in the stochastic perturbation term to the values of the endogenous variables in each period.

The impulse response function of VAR model helps explain the result of VAR model. The result of impulse and response is shown in Figure 2.

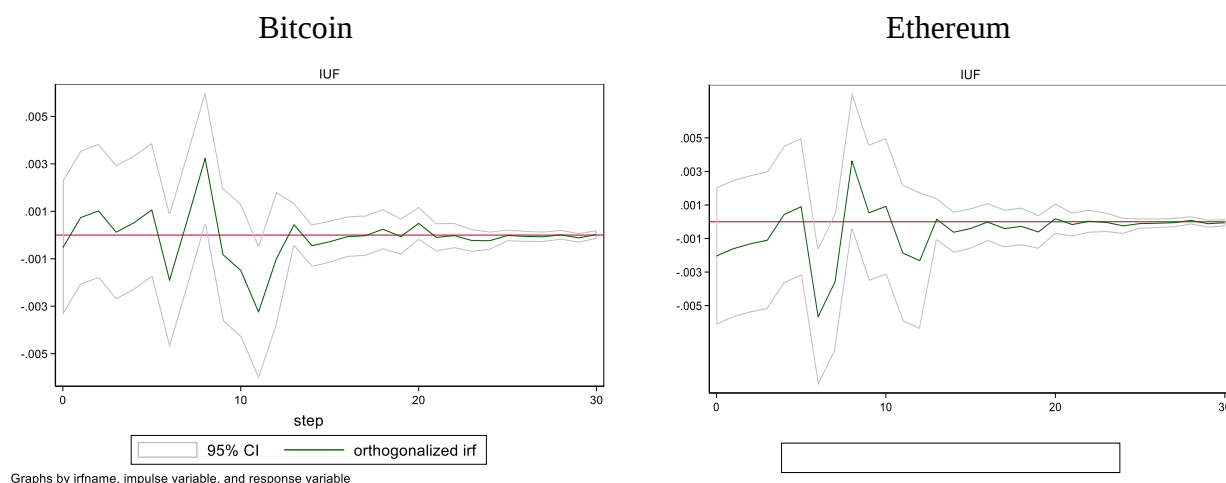


Figure 2. Impulse and response.

From a theoretical analysis, a Fed interest rate hike would lead to higher demand for USD from international lenders and international financial markets, further pushing up USD prices and exchange rates, but there are two economic outcomes to the impact of this phenomenon on the cryptocurrency market. On the one hand, US dollar appreciation may lead to higher demand for cryptocurrencies and prices of cryptocurrencies. US dollar is one of the few currencies that can be directly traded in fiat currency with cryptocurrencies (i.e., the U.S. dollar can be directly exchanged for cryptocurrencies). The international financial markets have increased their holdings of USD, and the extra money may flow to the US domestic stock market, bond market, or other financial markets, and certainly to the cryptocurrency market, leading to higher demand and prices. These are indirect effects of US dollar appreciation. On the other hand, direct effect of US dollar appreciation on international financial market is that as international lenders' holdings of US dollars increase, the potential outflow from other countries or other markets (i.e., a net outflow of capital) may also increase, which in turn leads to lower demand for cryptocurrencies and prices of cryptocurrencies. Based on the analysis above, it is not possible to directly determine the net effect of US dollar appreciation on the cryptocurrency market.

From the model results, this paper finds that the US dollar appreciation triggered by the Fed rate hike has little effect on Bitcoin returns, but leads to lower Ethereum returns. Specifically, in period $t=0$, the logarithmic return on the exchange rate increased 1%. The largest positive effect on Bitcoin returns occurs in period $t=8$, about 0.3%; the largest negative effect on Bitcoin returns occurs in period $t=6$, about -0.3%; and the positive and negative effects in other periods can also be largely offset. However, for Ethereum returns, the positive effect appears only for a small number of periods, and the degree of the negative effect is significantly larger than the positive effect. In other words, the appreciation of the US dollar triggers a decline in Ethereum's return, and the net outflow effect dominates the role of US dollar appreciation.

4.3. Estimation results of ARMA-GARCH model

It is necessary to order the first log-return series using PACF and ACF pairs to conduct ARMA model identification. The results of PACF and ACF identification are reported in Figure 3.

First, this part needs to order the log-returns of the closing prices of Bitcoin and present the results in the figure below. From the fixed order result of the two images in the first row in Figure 3, the first part beyond the x-axis is 10, so AR (P) is of order 10. Likely, MA (q) is also of order 10. It means that the value of p and q are both 10. Then, this paper needs to order the log returns of the closing prices of Ethereum and present the results in the figure below. From the fixed order result of the two images in the second row in Figure 3, the first part beyond the x-axis is 12, so AR (p) is of order 12 and MA (P) is also of order 12. Thus, the value of p and q are all equal to 4.

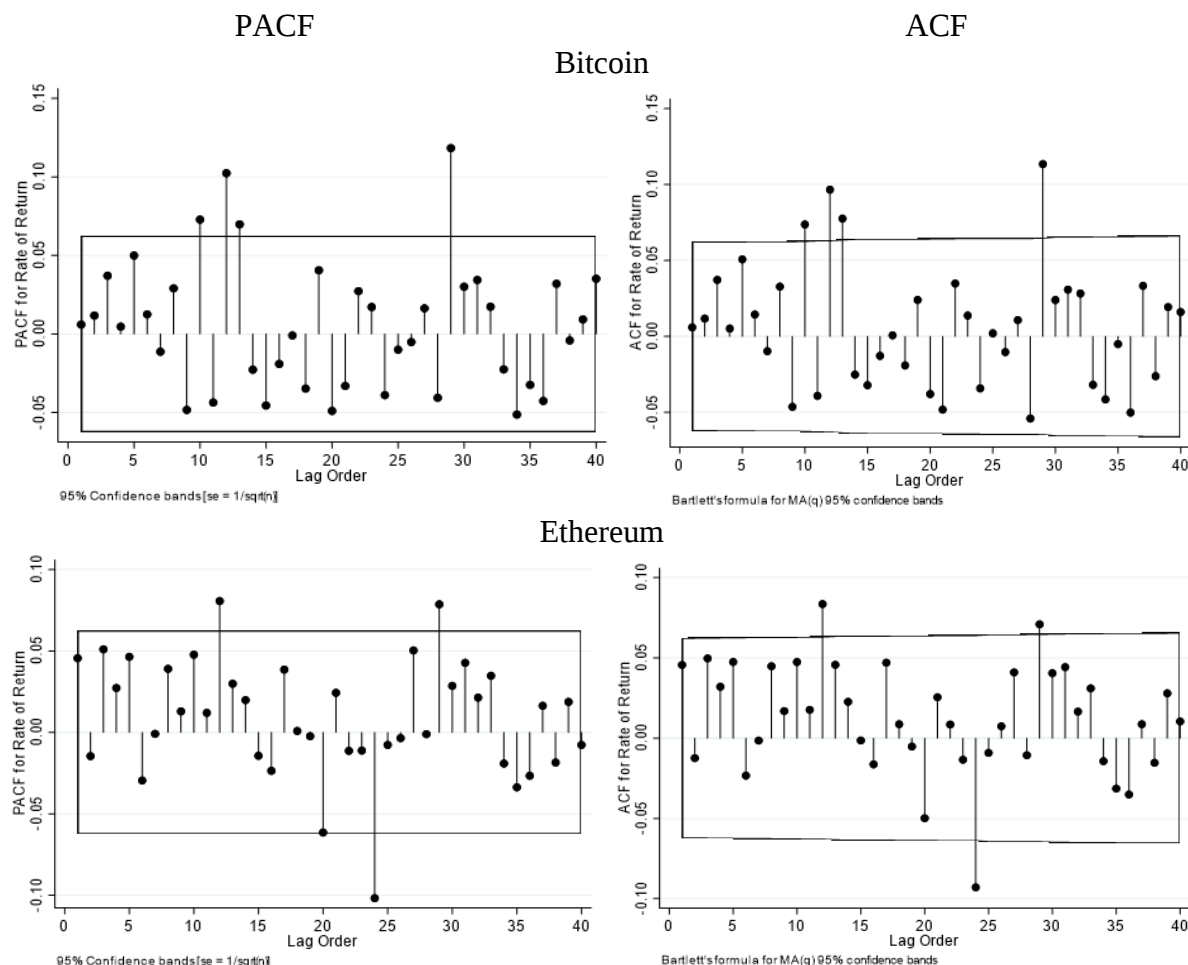


Figure 3. PACF and ACF.

Note: The Y-axis is the dependent variable, PACF, and ACF of the log return on the closing prices of Bitcoin and Ethereum, and the X-axis is the time lag order. The area bounded by $y=\pm 2$ standard error refers to the 95% confidence interval for AR (p) and MA (q).

To better forecast the variance of future closing prices of Bitcoin and Ethereum, the ARCH model is next used to look at the characteristics of Bitcoin return volatility. And the consequences are shown in Figure 4. Figure 4 shows that a clear conditional heteroskedasticity exists in the two log returns, which is expressed in returns fluctuating sharply at one time and less at another. In financial econometric language, this means that when the volatility (variance) is greater in the current period or a few past periods, the volatility (variance) is likely to be greater in future periods, and vice versa. However, whether there is autoregressive conditional heteroskedasticity and how significant the conditional heteroskedasticity is still needed to be judged by the model estimation results.

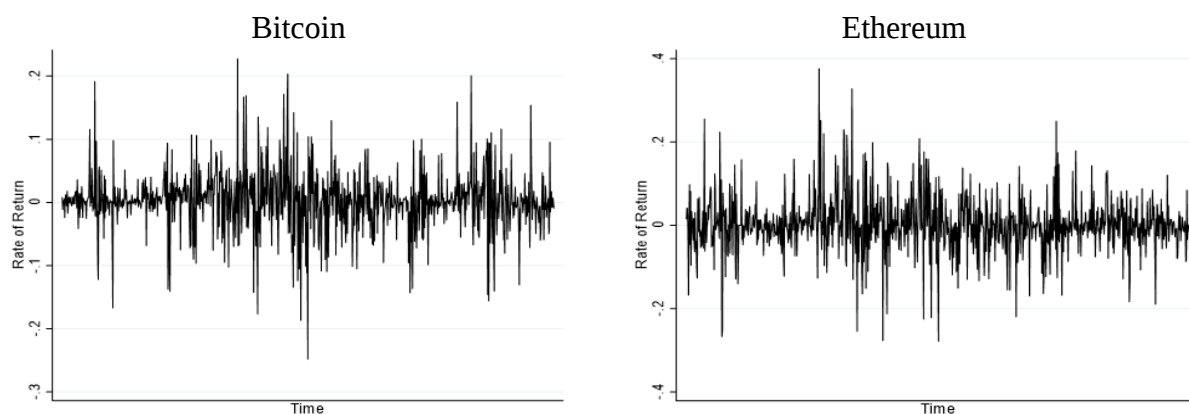


Figure 4. Yield.

From the estimation results of the ARMA-GARCH model, it can be seen that both ARCH and GARCH terms in column (1) are significant, and the GARCH term in column (2) is also significant, indicating that both Bitcoin and Ethereum have significant conditional heteroskedasticity and can be used to construct GARCH model. The estimation results of ARMA-GARCH model are shown in Table 3. From the coefficients of the log returns of exchange rates and their p-value, it is clear that US dollar exchange rate changes do not increase the daily volatility of Bitcoin and Ethereum.

Table 3. ARMA-GARCH estimation results.

	(1)			(2)		
	Coefficient	Std. err	p> Z	Coefficient	Std. err	p> Z
Mean equation						
AR, L10	-0.5217	0.3036	0.086			
MA, L10	0.5812	0.2912	0.046			
AR, L12				-0.3181	0.2708	0.240
MA, L12				0.4152	0.2598	0.110
Constant	0.0026	0.0013	0.044	-0.005	0.0020	0.0786
Variance equation						
USD index	-215.5513	16.6809	0.000	-242.2724	26.2905	0.000
ARCH, L1	0.1079	0.01480	0.000	0.0736	0.0100	0.000
GARCH, L1	0.8295	0.01946	0.000	0.8672	0.0151	0.000
Constant	-9.2015	0.1555	0.000	-8.6578	0.2171	0.000

5. Discussion

Gu Cong finds that the loose monetary policy of the Fed brings extra profit to the cryptocurrency market, and the two highest market value and most influential cryptocurrencies, Bitcoin and Ethereum, have the most significant excess returns [1]. Their results manifest the positive effect of loose monetary policy of USA; while our results show that tight monetary policy has a negative effect on the cryptocurrency market, both of which from two directions separately prove that the fluctuation of US dollar would have impact on the cryptocurrency market. Ma Junjun and his workmates use empirical evidence from different countries to research monetary policies' impact on cryptocurrency market [16]. They find that the impact of monetary policy on different types of cryptocurrencies is different, with the prices of fiat and app-based cryptocurrencies changing significantly in response to monetary policy, while platform-based cryptocurrencies do not respond significantly to monetary policy [16]. Different from them, this paper only focuses on fiat and app-based cryptocurrencies' response.

From empirical results above, it can be seen that US dollar appreciation triggered by the Fed rate hike has little effect on Bitcoin returns, but leads to lower Ethereum returns. Compared with the former research, the results of this paper don't indicate the relationship between Bitcoin market and U.S. dollar appreciation obviously, but this doesn't mean that Bitcoin market is irrelevant to U.S. dollar. The empirical results also show that US dollar appreciation would negatively impact Ethereum market. Although US dollar exchange rate changes do not significantly increase the daily volatility of Bitcoin and Ethereum prices in the model, they may still have impact on Bitcoin and Ethereum prices for a longer period. Thus, investors are supposed to be more careful when considering investing in the Ethereum market and reduce the holdings of Ethereum under the background of US dollar appreciation pressure. For policymakers, it is wise to increase regulation of cryptocurrency markets to avoid some malicious speculators' attacks and maintain the stability of cryptocurrency market.

6. Conclusion

The object of this paper is to study how the US dollar appreciation impact on cryptocurrency market under the background of Fed rate hike, and to forecast the future fluctuation of cryptocurrency market, aiming to help avoid risks and direct investment choices in the cryptocurrency market. This

paper uses the VAR model and ARMA-GARCH model to analyze and represent the impact of US dollar appreciation on the cryptocurrency market. The empirical result is that US dollar appreciation triggered by the Fed rate hike has little effect on Bitcoin returns, but leads to lower Ethereum returns. And the dollar exchange rate's changes do not increase the daily volatility of Bitcoin and Ethereum. The conclusion is that US dollar appreciation would not affect Bitcoin market significantly but would negatively affect Ethereum market.

US economy's weakness and high inflation pressure trigger the federal funds rate hike. Then, federal funds hike boosts the development of USA economy and push US dollar index to increase. As US dollar becomes stronger, it is likely to negatively influence the cryptocurrency market. Because of the volatile and speculative nature of cryptocurrency market, the reaction of it to the fluctuation of US dollar might have an amplification effect.

For this reason, investors are supposed to be more alert to the risks of cryptocurrency market. This paper suggests that investors reduce the holdings of Ethereum when US dollar index increases. For policy makers, it's wise to increase regulation of cryptocurrency markets to avoid some malicious speculators' attack on the unmaturing market.

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