Research on the characteristics of bitcoin price fluctuations based on ARCH effect

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Abstract. Since the appearance of the bitcoin, more and more people have been paying attention to it. Investors have shown great concern about the price of bitcoin through ARCH (Autoregressive conditional heteroskedasticity model) effect test and asymmetric test, we drew the following conclusion: the fluctuations of bitcoin price have the time-varying characteristics and the characteristics of wave agglomeration, but there is no leverage effect.

1. Introduction

At the beginning of bitcoin's emergence, its price is very low, only a few cents. Bitcoin has been booming since 2013, and the number of people paying attention to bitcoin is growing. At the same time, some countries, such as Canada, have accepted bitcoin. And some businesses have begun to accept it to buy goods and services. Bitcoin has its own advantages, such as decentralization. This benefit saves costs and improves economic efficiency, and it also plays an important role in protecting privacy. More and more people are willing to hold and invest in bitcoin. The price of bitcoin has skyrocketed, rising rapidly to a few thousand dollars, and even to nearly $20,000.

While the price of bitcoin is rising overall, it is not rising at every point in time. That is to say, there are price fluctuations in the process, and this price fluctuation is relatively large. And it shows that in some time periods, the price of bitcoin fluctuates less, while in other time periods, the price of bitcoin fluctuates greatly. As following picture shows: This graph is about the price change of bitcoin from March 2017 to March 2018. We can see clearly in the figure: In April, may and other months of 2017, the price of bitcoin fluctuated a little. In November and December of 2017 and January and February of 2018, the price of bitcoin changed a lot. During this period, the difference between the highest and lowest price of bitcoin was nearly $10,000. We see that the fluctuations in bitcoin prices seem to have some kind of signature.
As for the research on the price of bitcoin, some scholars have done the research on the price of bitcoin. For example, Ji Hong Li [1] analyzed the impact of the demand for bitcoin on the price through establishing a model, and concluded that the expansion of the demand for bitcoin transaction has a driving effect on the rise of the price of bitcoin in the long term trend. Gang Liu and Juan Liu [8] used the event research method to draw a conclusion: the price fluctuations of bitcoin are greatly influenced by the policy; Whether the policy information is positive or negative for bitcoin, the bitcoin market will experience violent fluctuations. Yue Yu Niu [7] analyzed the long-term and short-term formation mechanism of bitcoin price volatility using granger causality test. Some scholars have analyzed the properties of bitcoins from a theoretical perspective, as Tao Young [2] has been describing the non-monetary properties of bitcoin in terms of a lack of credit foundation, failure to reflect a particular social production relationship. Xiao Chen Yang [5] analyzed the prospect of bitcoin from the perspective of its operation principle and typical features. At present, most of the existing literatures are about the nature of bitcoin itself, while there are few literatures about the characteristics of bitcoin price fluctuation and its influencing factors.

2. Empirical analysis

In order to test whether the fluctuation of bitcoin price has autoregressive conditional heteroscedasticity, we selected daily data of the bitcoin price as the sample sequence for testing. The data is selected from coinmarket.cap and is selected from March 27, 2017 to March 26, 2018.

2.1. ARCH effect test

In order to eliminate the impact of data fluctuations and make the data smoother, the price of bitcoin \( \{ p_t \} \) is taken as the natural log. A logarithmic sequence \( \{ \ln p_t \} \) was obtained. The log price sequence at time \( t \) was taken as the explained variable. In view of that fact that the sequence of study has one-dimensional random walk features, therefore, the model was set as:

\[
\ln(p_t) = \beta_0 + \beta_1 \ln(p_{t-1}) + \mu_t.
\]  

(1)

| object | variable | Estimated coefficient | Standard error | T statistic | P | Test statistic |
|--------|----------|----------------------|----------------|------------|---|---------------|

Table 1. Estimation results of one-dimensional random walk model of bitcoin price

Figure 1. Bitcoin price change chart from 2017-03 to 2018-03 (unit: usd)
The estimation results of the mean value equation of bitcoin price in table 1 show that the value of goodness of fit is 0.9955, indicating that the overall model is well fitted. The value of F statistic is 80617.06, and the corresponding P value is 0.0000, indicating that the linear influence of the equation overall is significant. The P value of the estimated coefficient of the previous moment’s bitcoin price is 0.0000, which is significantly less than 0.05, indicating that the estimated coefficient of the previous bitcoin price is remarkably different from 0 at the significance level of 5%. The estimator of the random error term, the residual term, is obtained after estimating the model. Whether conditional heteroscedasticity exists in the random error term can be investigated by the following three decisions:

Decision one: residual series were generated in the estimation window of eviews8.0 equation, as shown in the figure below. In figure 2, the horizontal axis refers to the observation date and the vertical axis refers to the residual term. It can be noticed that the fluctuation of residual term is relatively small at some time, such as March, April and May of 2017, while other times are quite large, such as July, September and December 2017. This shows that volatility has the characteristics of "clustering", which indicates that the error term may have conditional heteroscedasticity.

Decision two: residual square correlation graph test: AC, PAC and Q statistics of lagged residual square were tested in the equation estimation interface, and the selected lag order was 36. AC analysis results: autocorrelation coefficient and partial autocorrelation coefficient PAC coefficient of the two are not significantly to 0, P and Q statistics value is very small. Under 10% significance level, the Q statistic is significant. Therefore, we can refuse the original assumption that there is no ARCH effect, it can be concluded that there is an ARCH effect in the residual series of first-order random walk model of bitcoin price.

Decision three: establish the auxiliary regression equation, select the lag order of 7 order, and investigate whether there is a significant relationship between the residual squared term of the current period and the residual squared term of the previous 7 periods. The independent variable is the residual squared term of the previous 7 periods, and the dependent variable is the residual squared term of the current period. Finally, the test statistic of the joint significance of the residual squared
term of the previous 7 periods of the equation, F and ARCH-LM, is obtained. The results are shown in table 2:

| Table 2 | results of Lagrange multiplier test of bitcoin prices |
|---------|------------------------------------------------------|
| F statistic | 2.8243 | P: | 0.0071 |
| $T \times R^2$ statistic | 19.1395 | P: | 0.0078 |

It can be seen that the P value of both statistics is small, and the original hypothesis can be rejected at the significance level of 1%, Which shows that the ARCH effect exists in the bitcoin price model.

2.2. GARCH(1,1) estimation
In accordance with the above, it was found that the price of the bitcoin does have an ARCH effect, which indicates that the price of the bitcoin has the time-varying characteristic and the fluctuating agglomeration. The estimated coefficient in the variance equation is set to be greater than 0, and the conditional variance is guaranteed to be positive. It is estimate with GARCH (1,1) that that variance of the current period is assumed to be affect by the preceding 1 phase and 1 period before the square of error. After a first order difference was made on the logarithm of the price of bitcoin, the meaning of the bitcoin rate of return was obtained.

$$d\ln p = \ln p - \ln p(-1).$$

(2)

Mean value equation of first-order difference sequence:

$$d\ln p = \alpha_0 + \alpha_1 d\ln p(-1) + \mu_t.$$

(3)

Equation of conditional variance:

$$\sigma_t^2 = \omega + \alpha\mu_{t-1}^2 + \beta\sigma_{t-1}^2.$$

(4)

As can be seen from table 3, in the variance equation, the two variable estimates of the coefficient of the P value is less than 0.01. That is, at the significance level of 1%, the coefficients of the variables are all significantly non-zero. For explain the variance of the previous and squared error of the previous period has a significant linear effect on the current condition of variance. The ARCH effect exists, which is consistent with the previous conclusion. The estimated coefficients of GARCH and ARCH in the variance equation of bitcoin price correspond to P values is 0.0000. At the 1% significance level, they are all significantly non-zero. GARCH coefficient is 0.1091, the ARCH coefficient is 0.8807, 0.9898 is less than 1, the sum of both is given to illustrate that the conditional variance is convergent.

| Table 3 | GARCH(1,1) estimation results |
|---------|-------------------------------|
| index | equation | variable | Estimated coefficient | Standard error | Z statistic | P values |
|        |        |        |                        |               |            |         |

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In figure 3, we can see that the residual sequence, real value and fitting value of bitcoin price were obtained after the estimation using the GARCH model. The residual term was found to fluctuate in a small range. The real value has less fluctuation than the fitting value, and the trend is relatively consistent. Therefore, it is reasonable to believe that the fitting situation is better.

2.3. Asymmetric test of bitcoin price - TARCH model

See if there is asymmetry in the price of bitcoin through the TARCH mode, and this kind of asymmetry in the capital markets often shown as: the volatility is more sensitive to negative news than positive news in the market. The setting model is as follows:

$$\sigma^2_t = \omega + \alpha \times \mu_{t-1}^2 + \gamma \times \mu_{t-1}^2 d_t - 1 + \beta \times \sigma_{t-1}^2.$$  \hspace{1cm} (5)

In this formula, $d_{t-1}$ is a virtual variable, when $\mu_{t-1} < 0, d_{t-1} = 1$ otherwise, $d_{t-1} = 0$. As long as $\gamma \neq 0$, there is an asymmetric effect. $\mu_{t-1} < 0$ means bad news, $\mu_{t-1} > 0$ means good news, and the term in the model $\gamma \mu_{t-1}^2 d_{t-1}$ is asymmetric effect term.

| Model  | Estimated coefficient | coefficient | Standard error | P value |
|--------|-----------------------|-------------|----------------|--------|

Figure 3. Estimates the fitting value, actual value and residual error of the model
The estimated value of the asymmetrical coefficient of TARCH model is 0.0828. And the corresponding P value is 0.2464, which indicates that the coefficient is also significantly 0 at the level of 10%. In other words, there is no linear relationship. It shows that there is no asymmetric effect on the price fluctuation of bitcoin, so there is no leverage effect. That is, good news and bad news have the same impact on bitcoin prices.

3. Conclusion
Based on the above analysis, we find that although there is no leverage effect in the price fluctuation of bitcoin. There is an ARCH effect in the price index of bitcoin, with time-varying characteristics and agglomeration of volatility. It shows the currency price fluctuations are more severe, the public investment currency risk is bigger, but the same amount of good news or bad news for the impact of the currency prices are the same.

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