Research on Risk Measurement and Investment Selection of Cryptocurrencies

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Abstract. Encrypted digital currency is a new form of currency after physical currency, which can be traded 24 hours a day through online circulation without being affected by time zones and regions. Firstly, the concept and characteristics of encrypted digital currency are introduced, and the significant differences between encrypted digital currency and traditional financial assets are pointed out, especially the uncertainty in regulation and technology. This paper discusses the theoretical basis of market risk measurement, including VaR and GARCH models, and analyzes the applicability of these models in the encrypted digital currency market. Through the analysis of the high-frequency data of Bitcoin for six years, the stationarity of the return series is verified, and the EGARCH-EVT model is used to estimate the VaR value, so as to more accurately assess the market risk. The article further discusses the mean-variance portfolio model and risk-adjusted return model, such as Sharpe ratio and Sotino ratio, which provide investors with a set of scientific investment decision-making tools.

Keywords: Cryptocurrency, Digital Currency, Risk Measurement, Investment Selection

1 Introduction

In today's financial market, encrypted digital currency, as a new asset class, is gradually attracting wide attention from investors and scholars. As the market value of digital currencies such as Bitcoin and Ethereum continues to rise, their impact on the traditional financial system is becoming increasingly significant. However, the high volatility, regulatory uncertainty and technical risks of the encrypted digital currency market also make investors face unprecedented challenges. Unlike traditional currencies, encrypted digital currencies are decentralized assets based on blockchain technology, which are not controlled by any central authority, but ensure the security and transparency of transactions through encryption algorithms [1]. This characteristic makes encrypted digital currency tamper-proof and anonymous in theory, but it also brings regulatory difficulties and technical risks. The risk measurement of encrypted digital currency is the key to investment decision-making.

P. Dou and K. Zhang (eds.), *Proceedings of the 2024 2nd International Conference on Economic Management, Financial Innovation and Public Service (EMFIPS 2024)*, Advances in Economics, Business and Management Research 327,
https://doi.org/10.2991/978-94-6463-706-9_26

Traditional risk measurement methods, such as VaR (Value at Risk) and CVaR (Conditional Value at Risk), have been widely used in mature markets such as the stock market, but they are facing the problem of applicability in the encrypted digital currency market. Due to the particularity of the encrypted digital currency market, such as high volatility and immaturity of market participants, the traditional risk measurement model may not accurately reflect the real risk of the market. Therefore, this paper will explore how to combine the characteristics of encrypted digital currency to develop a more appropriate risk measurement model.

On the basis of risk measurement, how investors make investment choices is also an important issue. Investment in the encrypted digital currency market is not without rules. Through in-depth analysis of market data, we can find some key factors affecting the price of encrypted digital currency, such as market sentiment, technological development, macroeconomic environment and so on. Investors can make use of these factors and combine their own risk preferences to formulate more reasonable investment strategies.

Starting from the risk measurement method of encrypted digital currency, this paper will discuss how to assess and manage the risk of this emerging asset class. At the same time, this paper will also study how investors make more wise investment choices under the premise of controllable risk.

2 Relevant Theoretical Basis

2.1 Concept of Encrypted Digital Currency

Digital currency is a form of chain currency based on blockchain technology, which is composed of data blocks in chronological order and guaranteed not to be stolen by cryptography [2]. According to the different issuers of digital currency, this paper divides it into central bank digital currency and encrypted digital currency. Among them, the central bank's digital currency is a centralized digital currency formulated by the central banks of various countries on the basis of fully drawing lessons from the technical principles of encrypted digital currency, which has the same legal effect as the legal currency, such as China's digital RMB, which is different from the central bank's digital currency, and the encrypted digital currency is issued by the main body outside the country. The European Banking Authority believes that encrypted digital currencies are not issued and managed by central banks, but have been recognized by the public and can be used as online payment and transaction tools through the Internet, such as Bitcoin, Litecoin and Ethereum.

2.2 Theoretical Basis of Market Risk Measurement

VaR method is the mainstream tool for estimating the market risk of financial investment at present, which effectively solves the problem that the sensitivity analysis and volatility analysis cannot describe the fat tail characteristics of financial data [3]. As a commonly used risk quantification index, the biggest advantage of VaR method is that it can be used in dynamic analysis to quantify risk, and it is clearly recommended by the Bank for International Settlements and the Basel Committee to be used to calculate market risk. Because the traditional calculation method of VaR has some limitations. The traditional VaR calculation method cannot measure the tail loss of financial series samples, and it is not suitable for the sample data which does not follow the normal distribution. Based on this background, more and more scholars use GARCH models to describe the market risk of financial time series.

Assuming a p-th order autoregression, the ARCH (p) model is:

$$y_t = \lambda x_t + \varepsilon_t \tag{1}$$

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \cdots + \alpha_p \varepsilon_{t-p}^2 \tag{2}$$

Among the formulas, y_t is the mean equation,σ_t^2Is by the constantα_0 and ARCH. The ARCH model can well depict the characteristics of financial time series, and it is believed that the positive and negative effects have the same effect on the volatility rate of the series, but in fact, the effect of the positive and negative effects on the volatility rate is asymmetric, and the model parameter estimation needs to be limited by the assumption of normal distribution, so the estimated conclusion has a certain deviation [4].

The GARCH model was proposed by Bollerslev in 1986, which extends the ARCH model to the GARCH model (generalized conditional heteroscedasticity), assumes the normal distribution, t distribution and generalized error distribution for the distribution of disturbance items, and fits the time financial series accordingly. The GARCH (p, q) model is obtained by adding the prediction variance of the previous Q period to the ARCH model:

$$y_t = \lambda x_t + \varepsilon_t \tag{3}$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j \, \sigma_{t-j}^2 \tag{4}$$

Among the formulas, y_t is the mean equation, σ_t^2 is variance equation composed of ARCH and GARCH terms, p is autoregressive order of σ_t^2; The lag order of, to guarantee the conditional variance σ_t^2 greater than zero, required $\alpha_0, \beta_j \geq 0$, and $\sum_{i=1}^{p} \alpha_i + \sum_{j=1}^{q} \beta_j < 1$.

3 Risk Measurement of Encrypted Digital Currency

3.1 Sample Selection

Bitcoin is selected as the research object, and the time span is from August 20, 2018 to August 20, 2024, with a total of 6 years of high-frequency data. The sample is the market unit price in USD with the time difference of UTC-5 per hour. The sample data comes from two authoritative encrypted digital currency market databases, CoinMarketCap and CryptoCompare, which ensure the comprehensiveness and accuracy of the data. The selected time period covers several important stages in the history of Bitcoin, including the bear market period from 2018 to 2019, the halving event in 2020 and the bull market period in 2021, in order to comprehensively analyze the risk characteristics of the Bitcoin market. In this paper, the effective observation value of Bitcoin in the sample interval is 46680, and the price trend chart with US dollar as the unit price in the sample interval is shown in Figure 1.

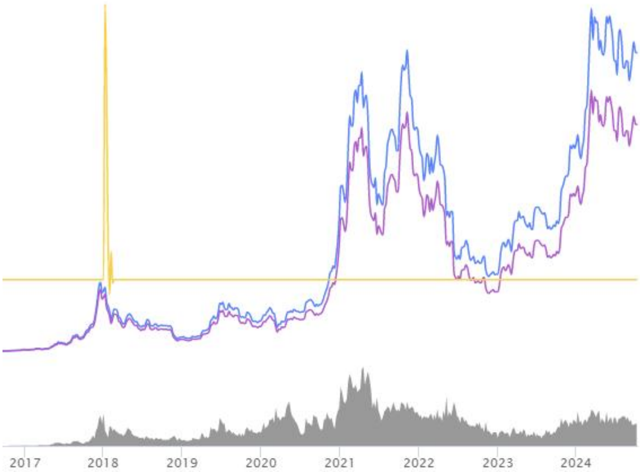

Fig. 1. Purple Curve: Bitcoin Price Chart (figure credit: https://www.baidu.com/link?url=ggOuyw1uBWktd4Yzi-gc_y9DaXJ71iXtwuq67B8NjyJO-aQrszN7pmlqydE2J9VaYeY5CLWa-Y4zArs82u4ZBhxkZvwMZNLogy3az-abPuW&wd=&eqid=83badde1006f673900000005670aa20b)

3.2 Data Analysis

By collating the daily closing price data of Bitcoin, the yield sequence of Bitcoin in the past six years is obtained. Table 1 shows the descriptive statistics of the Bitcoin return series, including statistical indicators such as mean, median, maximum, minimum, standard deviation, skewness and kurtosis. The results show that the return series of Bitcoin has significant skewness and kurtosis, indicating that its distribution shows obvious peak and fat tail characteristics, that is, the market volatility is large, and the frequency of extreme values is high.

Table 1. Descriptive statistical analysis.

Statistics	Mean value	Median	Maximum value	Minimum value	Standard deviation	Skewness	Kurtosis
Numerical value	-0.0025	0.0012	0.0876	-0.1003	0.0157	0.8545	12.5678

In order to verify the stationarity of the return series, ADF (Augmented Dickey-Fuller) test and PP (Phillips-Perron) test are used in this study. Table 2 shows the results of the two tests, showing that the return series of Bitcoin statistically rejects the original hypothesis of the existence of a unit root, that is, the return series is stationary. This finding provides a basis for subsequent volatility modeling.

Table 2. Stationarity test.

Type of inspection	ADF statistic	Threshold (1%)	Threshold (5%)	Threshold (10%)	Conclusion
ADF	-3.456	-3.432	-2.862	-2.567	The null hypothesis is rejected and the sequence is stationary
PP	-3.567	-3.432	-2.862	-2.567	The null hypothesis is rejected and the sequence is stationary

The null hypothesis of the ADF test and the PP test is that the series contains a unit root, that is, the series is non-stationary. If the test statistic is less than (more negative) critical value, we reject the null hypothesis and consider the series to be stationary [5]. In Table 2, the statistics of ADF and PP tests are -3.456 and -3.567, respectively, which are less than critical values of 1%, 5% and 10% (-3.432, -2.862, -2.567). Therefore, we can reject the null hypothesis and consider that the return series of Bitcoin is stable in these 6 years. This consistency of results suggests that the Bitcoin return series is statistically stationary and suitable for further time series analysis, such as volatility modeling and forecasting.

The test results of autocorrelation coefficient (ACF) and partial autocorrelation coefficient (PACF) are shown in Table 3. The results show that the series of Bitcoin returns has significant autocorrelation, especially in the short term. This finding suggests that we need to consider the autoregressive effect in modeling to improve the fitting degree and prediction accuracy of the model.

Table 3. Autocorrelation test.

Number of lag orders	ACF value	PACF value
1	0.2345	0.1987
2	0.1456	0.1123
3	0.0987	0.0789
4	0.0654	0.0567

The results of heteroscedasticity test show that the return series of Bitcoin has heteroscedasticity, that is, the volatility of the return changes with time. Table 4 shows the results using the LM (Lagrange Multiplier) test, which rejects the null hypothesis that there is no ARCH effect. This finding indicates that conditional heteroscedasticity models, such as GARCH models, need to be considered in modeling to more accurately capture and predict market volatility.

Table 4. ARCH-LM test for heteroscedasticity.

Type of inspection	LM statistic	Degrees of freedom	P-value
LM	0.0456	1	<0.001

3.3 Establishment of GARCH Model

This paper uses the EGARCH-EVT model to calculate the VaR value of the spot market risk of encrypted digital currency. This model combines the EGARCH model's ability to capture volatility and the EVT model's ability to estimate tail risk, and aims to improve the accuracy and applicability of VaR value in the risk assessment of encrypted digital currency market [6].

After confirming the stationarity of the data series, the EGARCH model is established to capture the volatility characteristics of the return series [7]. In this paper, the parameters of EGARCH model, including the parameters of mean equation and wave equation, are estimated by maximum likelihood estimation method. On this basis, this paper further introduces the generalized extreme value distribution (GPD) to model the tail risk of the return series. Using the GPD model, we estimate the tail risk of the return series. By calculating the VaR value under different confidence levels, this paper obtains the VaR value of Bitcoin under different confidence levels. The results show that the VaR value gradually increases as the confidence level increases, indicating that the market risk of Bitcoin is assessed higher at higher confidence levels. In order to verify the effectiveness of EGARCH-EVT model, Kupiec backtesting is carried out. By comparing the actual loss exceeding the VaR estimate with the model prediction, this paper finds that the EGARCH-EVT model can fit the market risk of Bitcoin well under different confidence levels, and verifies the applicability and accuracy of the model. In this paper, the VaR value of spot market risk of encrypted digital currency is calculated by EGARCH-EVT model, and the VaR value of Bitcoin under different confidence levels is obtained. The results show that the model can effectively capture the volatility of the encrypted digital currency market and provide an effective market risk measurement tool for investors.

4 Investment Options for Encrypted Digital Currencies4.1 Mean-Variance Portfolio Model

Mean-variance portfolio model (Mean-Variance Variance Portfolio Model) was proposed by Harry Markowitz in 1952, which aims to optimize the portfolio by balancing the expected return and risk. The model assumes that investors are risk averse and seek to maximize expected return at a given risk level or minimize risk at a given expected return. The basic assumption of the mean-variance model is that investors are rational and that they are risk-averse. This means that at a given level of risk, investors will seek to maximize the expected return; or at a given expected return, reduce the risk as much as possible [8]. The model constructs the Efficient Frontier by calculating the expected return and variance of the portfolio (a measure of risk), which is a path representing the best combination of risk and return among all possible portfolios. A portfolio is assumed to consist of multiple cryptocurrencies, with each asset having its expected return and risk (variance). The total expected return of a portfolio is the weighted average of the expected returns of all the individual assets, while the total risk (variance) of a portfolio depends on the covariance between the assets. Mathematically, the expected return and variance of a portfolio can be expressed as:

$$E(R_p) = \omega^T \mu \tag{5}$$

$$\sigma_p^2 = \omega^T \quad \omega \tag{6}$$

In the encrypted digital currency market, investors can choose a portfolio of assets through the mean-variance model. For example, considering two assets, Bitcoin and Ethereum, investors first need to estimate the historical returns and covariance of these two assets. Then, according to this information, investors can calculate the expected return and variance of the portfolio under different weights, so as to find the optimal portfolio [9]. In this way, the mean-variance model provides cryptocurrency investors with a scientific way to evaluate and manage the risk and return of their portfolios, helping them make more informed investment decisions in a complex and changing market.

4.1 Risk-Adjusted Return Model

In investment decision-making, risk-adjusted return model is an important tool to evaluate investment performance, which considers the trade-off between risk and return of investment. The risk-adjusted return model is particularly important in the cryptocurrency market due to its high volatility and potentially high returns. This section explores two common risk-adjusted return models: the Sharpe Ratio and the Sortino Ratio.

The Sharpe ratio was developed by William Sharpe to measure the ratio of the excess return on an investment relative to a risk-free asset to the risk taken. The formula for the Sharpe ratio is:

$$Sharpe\ Ratio = \frac{E(R_p) - R_f}{\sigma_p} \tag{7}$$

$E(R_p)$ is the expected return of the portfolio; R_f is a risk-free interest rate. σ_p is the standard deviation of the portfolio. The higher the Sharpe ratio, the higher the excess return per unit of risk.

The Sotino ratio is a variant of the Sharpe ratio, which considers only the downside risk of a portfolio, that is, the portion of the portfolio's return that is below the risk-free rate. The formula for the Sotino ratio is:

$$Sortino\ Ratio = \frac{E(R_p) - R_f}{\sigma_{down}} \tag{8}$$

σ_{down} is the standard deviation of the downside risk of the portfolio, that is, the standard deviation when the return of the portfolio is lower than risk-free rate. The Sotino ratio is particularly useful for investors who are sensitive to downside risk. In the cryptocurrency market, investors can use these risk-adjusted return models to evaluate the performance of different cryptocurrencies or portfolios. For example, if an investor holds a portfolio that includes Bitcoin and Ethereum, they can calculate the Sharpe Ratio and Sotino Ratio for that portfolio and compare it to other investment options or benchmarks. Through these models, investors can better understand the risk and return characteristics of the portfolio, and thus make more informed investment decisions.

4.2 Investment Decision Analysis

In the cryptocurrency market, investment decision analysis is a complex process involving in-depth understanding of market dynamics and accurate assessment of individual risk tolerance. This section will analyze market sentiment, technical analysis and macroeconomic factors to help investors make more wise investment choices.

First of all, market sentiment is an important factor affecting the price fluctuation of encrypted digital currency. Investor sentiment is usually measured through social media analysis, news reports and market sentiment indicators. For example, positive media coverage and positive discussions on social media may drive up the price of a digital currency, while negative news may cause the price to fall. Therefore, investors need to pay close attention to changes in market sentiment and consider how these changes affect their investment decisions. Secondly, technical analysis is another important tool in the investment decision of encrypted digital currency. By analyzing historical price data and trading volumes, investors can identify market trends and patterns to predict future price movements. Commonly used technical analysis tools include moving averages, the relative strength index (RSI), and Bollinger bands. These tools can help investors determine the timing of market entry and exit, as well as set stop-loss and stop-profit points. Finally, macroeconomic factors also have an important impact on the encrypted digital currency market. Factors such as global economic conditions, monetary policy, inflation rate and political stability may affect the price of encrypted digital currencies [10]. Therefore, investors need to pay close attention to macroeconomic indicators and analyze how they affect the cryptocurrency market.

Combining the mean-variance portfolio model and the risk-adjusted return model, investors can construct a portfolio considering both expected return and risk. For example, through the mean-variance model, investors can balance the expected return and risk of different cryptocurrencies such as Bitcoin and Ethereum to achieve the optimal portfolio allocation. At the same time, through risk-adjusted return models such as the Sharpe ratio and the Sotino ratio, investors can evaluate the performance of their portfolios and ensure that the level of risk remains within an acceptable range while pursuing returns.

5 Conclusions

Although the encrypted digital currency market has high volatility and uncertainty, investors can effectively manage risks and seek returns through scientific risk measurement methods and reasonable investment decision-making models. The EGARCH-EVT model provides an effective method for risk assessment of cryptocurrencies, while the mean-variance portfolio model and risk-adjusted return model provide investors with tools to optimize their portfolios and evaluate their investment performance. The paper also highlights the importance of market sentiment, technical analysis and macroeconomic factors in cryptocurrency investment. This study provides a systematic risk management and investment decision-making framework for cryptocurrency investors, and helps them make more rational and effective investment choices in the complex and changeable market.

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