Applicability Analysis of Cryptocurrency Market Based on Capital Asset Pricing Model

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Abstract. At present, there are approximately 9300 types of cryptocurrencies in the cryptocurrency market, with Bitcoin, Ethereum, and other representative cryptocurrencies receiving widespread attention. Currently, scholars have conducted a lot of research on stock pricing using the Capital Asset Pricing Model (CAPM), but there is little research on the application of CAPM in the emerging cryptocurrency market. This article uses the CAPM to conduct an applicability analysis of CAPM of the top 10 cryptocurrencies in the cryptocurrency market from August 1 2021 to July 31 2023. The analysis process involves first conducting a mathematical analysis of the returns and coefficient β of cryptocurrencies, and then using the OLS regression model to fit the cryptocurrency data and CAPM formula with analyses of the OLS regression results. The research conclusion of this article is that in most cases, CAPM is not applicable in the cryptocurrency market. This article demonstrates an applicability analysis of CAPM in the cryptocurrency field, providing reference value for scholars conducting research in this field and investors in cryptocurrencies.

Keywords: Cryptocurrency; Capital Asset Pricing Model; Cryptocurrency Return; Risk-free Rate of Interest; OLS Regression.

1. Introduction

Economists Treynor, Sharpe, Lintner, and Mossin proposed the famous Capital Asset Pricing Model (CAPM) based on Markowitz's Modern Portfolio Theory (MPT) [1-4]. William Sharpe won the Nobel Prize in Economics in 1990, which made CAPM one of the main frameworks for analyzing investor behaviour under risk conditions in financial economics [5]. CAPM describes the connection between returns and risks by employing the anticipated asset returns and the coefficient denoted as β [6]. With the development of the financial market, the study of capital asset pricing has become a significant topic in financial investment [7].

Since 2009, blockchain technology has matured, with around 9300 cryptocurrencies now in the market, leading to widespread adoption and a surge in decentralized payment systems. Cryptocurrencies represented by Bitcoin have become a hot research topic in the academic community [8]. At present, there are many studies on the use of CAPM in stock pricing by scholars, but there is little research on the emerging cryptocurrency market [9-11].

This article uses the CAPM to analyze the data of the cryptocurrency market from August 1 2021 to July 31 2023. The analysis method of this article is to first conduct a mathematical analysis on cryptocurrency return, and examine the correlations between the variables in CAPM, and then analyze the β value of the selected cryptocurrency, and finally use OLS regression analysis to analyze the applicability of the CAPM.

The framework of this article is arranged as follows: firstly, this article introduces CAPM and then introduces the Data and Variables required for the model. Finally, based on the research results, this article concludes with a Conclusion.

2. Capital Asset Pricing Model

The CAPM model uses mathematical formulas to demonstrate the relationship among the returns of cryptocurrency, the risk coefficients, and systemic risks. For a given cryptocurrency *i*, the connection between its anticipated return on a cryptocurrency and the anticipated return on the cryptocurrency market is:

$$E(r_i) = r_f + \beta_i[E(r_m) - r_f] \tag{1}$$

$$\beta_i = \frac{Cov(r_i, r_m)}{\sigma^2(r_m)} \tag{2}$$

In equation (1), E (r_i) represents the anticipated return on the *i*-th cryptocurrency, and r_f is the riskless interest rate, representing the minimum return on a default-free investment across a duration of time. β_i is the systematic risk assessment of the *i*-th cryptocurrency, defined as equation (2). Cov(r_i, r_m) is the covariance between the return of *i*-th cryptocurrency and that of the cryptocurrency market, while σ^2 (r_m) is the variance of the returns of the cryptocurrency market. E (r_m) represents the anticipated cryptocurrency market return, whereas E (r_m) - r_f represents the cryptocurrency market's risk premium, the disparity between the anticipated cryptocurrency market's return and the riskless rate of interest.

3. Data and Variables

This article takes the closing prices of cryptocurrencies from August 1 2021 to July 31 2023 (730 days) as the research object, and takes the top 10 cryptocurrencies (see Figure 1) with the highest market value as the research sample according to the cryptocurrency statistics website Coincapmarket.com, a source that has been widely adopted by studies focusing on cryptocurrencies.

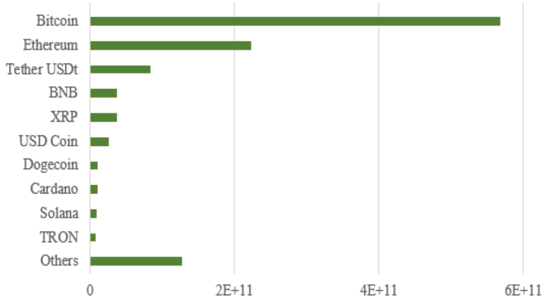

Fig 1. Crypto market cap on 31/07/2023($).

3.1. Riskless Rate of Interest

The riskless interest rate, also known as the rate at which investors can borrow without incurring risk, is substituted in this article with the arithmetic mean of 5.3165% from the August 2023 overnight bank funding rate data sourced from the Federal Reserve Bank of New York,.

3.2. Cryptocurrency Return

Pre-process the return R_{it} for the *i*-th cryptocurrency on day t using the following formula (3), where R_{it} is computed by using the closing price P_{it} of the *i*-th cryptocurrency on day t and the closing price $P_{i(t-1)}$ of the *i*-th cryptocurrency on preceding day (t-1):

$$R_{it} = \frac{P_{it} - P_{i(t-1)}}{P_{i(t-1)}}. \tag{3}$$

R_{Mt} represents the average of the cryptocurrency market's return on day t, calculated using the following formula (4):

$$R_{Mt} = \frac{1}{n} * R_{it} \tag{4}$$

4. Results

4.1. Mathematical Analysis on Cryptocurrency Return

By calculating the Mean, Variance, Skewness, and Kurtosis for each cryptocurrency within 730 days (Table 1), it was found that 10 cryptocurrencies have the following characteristics: Solana has the highest average daily return, Cardano has the lowest average return, and only Tether USDt, Cardano, and Dogecoin have negative average daily returns. The variance of Solana, Dogecoin, XRP, and Cardano is relatively large, indicating high volatility. The variance of while Tether USDt and USD Coin is relatively small, indicating low volatility. The distribution of daily returns of XRP, Dogecoin, Tether USDt and Cardano is right-skewed, while the distribution of USD Coin and BNB is left-skewed, and the skewness of other daily returns is close to 0, and the distribution is roughly symmetrical. The kurtosis of the 10 cryptocurrencies is all greater than 0, indicating that it is steeper than the normal distribution, among which USD Coin, XRP, Tether USDt and Dogecoin have abnormally high kurtosis, with USD Coin the highest kurtosis, and there may be extreme spikes. Additionally, according to Table 2, except for USDT and USDC, the correlation coefficients of the other crypto assets are over 0.7, suggesting that the risk premium of these 8 cryptocurrency returns is positively correlated with that of cryptocurrency market risk premium (CMRP), and the degree of correlation is relatively high, while the correlation coefficients of USDT and USDC are less than 0.1, indicating that there is almost no correlation between the risk premium of these 2 cryptocurrency returns and the CMRP.

Table 1. Mathematical Analysis on Cryptocurrency.

Crypto	Mean	Variance	Skewness	Kurtosis
Bitcoin	4.59E-06	0.0010	-0.1295	3.4964
Ethereum	0.0004	0.0016	-0.0601	2.8612
Tether USDt	-4.98E-07	1.83E-07	0.4931	37.0669
BNB	0.0002	0.0013	-0.3930	3.3545
XRP	0.0011	0.0026	4.3291	59.5715
USD Coin	1.29E-06	1.89E-06	-6.3997	312.2466
Cardano	-0.0010	0.0021	0.4635	2.9777
Dogecoin	-8.94E-05	0.0026	1.3577	12.1000
Solana	0.0012	0.0036	0.1205	5.6147
TRON	0.0009	0.0013	-0.0006	6.0261

Table 2. Calculation Results of Correlations.

	BTC	ETH	USDT	BNB	XRP	USDC
BTC	1.0000					
ETH	0.8701	1.0000				
USDT	0.0198	0.0426	1.0000			
BNB	0.7727	0.8024	0.0507	1.0000		
XRP	0.6057	0.6385	0.0547	0.5982	1.0000	
USDC	0.0402	0.0073	-0.3130	0.0326	0.0005	1.0000
ADA	0.7276	0.7438	0.0465	0.7189	0.7012	0.0492
DOGE	0.6401	0.6750	0.0584	0.6331	0.5378	0.0155
SOL	0.6723	0.7152	0.0814	0.6555	0.5479	0.0305
TRX	0.6382	0.6351	-0.0013	0.6292	0.5446	0.0275
Rf	9.54E-18	-3.76E-17	-1.12E-17	-1.44E-17	-1.59E-17	-1.09E-18
CMRP	0.8738	0.9042	0.0581	0.8593	0.7878	0.0339

Continued Table 2

	ADA	DOGE	SOL	TRX	Rf	CMRP
ADA	1.0000					
DOGE	0.6226	1.0000				
SOL	0.6716	0.5375	1.0000			
TRX	0.6212	0.5328	0.5092	1.0000		
Rf	1.16E-17	1.10E-17	-7.04E-18	-2.39E-17	1.0000	
CMRP	0.8750	0.7849	0.8180	0.7489	6.13E-16	1.0000

4.2. β Coefficient

As shown in Table 3, the calculation results of β are all positive, indicating that the returns of these 10 cryptocurrencies are positively correlated with the returns of the cryptocurrency market and the β values of the four cryptocurrencies are less than 1, indicating that the volatility of these 10 cryptocurrencies is less than that of the cryptocurrency market, and their systemic risk is lower than that of the cryptocurrency market. Among them, the β values of USD Coin and Tether USDt are approximately equal to 0, indicating that these 2 crypto assets are less affected by the market. Secondly, the β values of 6 crypto assets are greater than 1, indicating that the volatility of these 6 cryptocurrencies is greater than that of the cryptocurrency market, and their systemic risks are higher than that of the market. Among them, the risk of Solana is higher than that of other cryptocurrencies, that is, the price volatility caused by overall factors such as macroeconomics is higher [12].

Table 3. Calculation Results of β.

β_i	Cryptocurrency	Results
β_1	Bitcoin	0.9404
β_2	Ethereum	1.2445
β_3	Tether USDt	0.0009
β_4	BNB	1.0524
β_5	XRP	1.3848
β_6	USD Coin	0.0016
β_7	Cardano	1.3798
β_8	Dogecoin	1.3806
β_9	Solana	1.6976
β_{10}	TRON	0.9173

4.3. CAPM Applicability Analysis

By transforming the CAPM formula and adding regression residuals, equation (5) demonstrates that a cryptocurrency's risk premium is proportional to the CMRP. According to this scenario, the CAPM predicts that in the regression between the risk premium of cryptocurrency returns and that of cryptocurrency market returns, the intercept will be 0 [13]. Therefore, if the coefficient of γ_0 is significantly not 0, the CAPM is not applicable.

$$R_i - R_f = \beta_i\left(R_m - R_f\right) + \varepsilon_i \tag{5}$$

When using the OLS Regression to test the CAPM, the following equation (6) is generally used, where $Y_i = R_i - R_f$, $\gamma_1 = R_m - R_f$, and ε_i is the regression estimation residual, which satisfies the normal distribution:

$$Y_i = \gamma_0 + \gamma_1\beta_i + \varepsilon_i \tag{6}$$

The regression results to the equation (6) are shown in Table 4. It can be seen from the table that except BNB, the P values of γ_0 of the other 9 crypto assets are less than 0.05, indicating that the γ_0 of these 9 crypto assets are significantly different from 0 at the 95% confidence level. The fitting results of Tether USDt and USD Coin are poor, while those of the other 8 cryptocurrencies are better. The P value of β of 8 crypto assets is less than 0.05, indicating that β values of these crypto assets are significantly different from 0 at the 95% confidence level, therefore, there is a significant linear relationship between the risk premium of the cryptocurrencies and the CMRP. The P value of the coefficient β of Tether USDt and USD Coin is greater than 0.05, indicating that the β values of these two crypto assets are significantly 0 at the 95% confidence level, and a notable linear correlation between the risk premium of cryptocurrencies and that of the market is absent. Overall, the γ_0 values obtained by the OLS regression of 9 crypto assets (except BNB) are significantly different from 0 at the 95% confidence level. The goodness of fit between 2 crypto assets (Tether USDt and USD Coin) and CAPM is bad, and the β values are significantly 0 at the 95% confidence level, so the CAPM model is not applicable in most cases.

Table 4. OLS Regression Results.

	Crypto assets		Params	Std error	t	P	F	R^2	Adj. R^2
1	Bitcoin	γ_0	-0.0034	0.0012	-2.9222	0.0036	2349.4621	0.7634	0.7631
		β	0.9404	0.0194	48.4713	0.0000			
2	Ethereum	γ_0	0.0130	0.0013	9.9165	0.0000	3260.8497	0.8175	0.8172
		β	1.2445	0.0218	57.1039	0.0000			
3	Tether USDt	γ_0	-0.0531	0.0000	-1611.6972	0.0000	2.4696	0.0034	0.0020
		β	0.0009	0.0005	1.5715	0.1165			
4	BNB	γ_0	0.0027	0.0014	1.9229	0.0549	2054.5588	0.7384	0.7380
		β	1.0524	0.0232	45.3272	0.0000			
5	XRP	γ_0	0.0212	0.0024	8.7446	0.0000	1190.9043	0.6206	0.6201
		β	1.3848	0.0401	34.5095	0.0000			
6	USD Coin	γ_0	-0.0531	0.0001	-500.5112	0.0000	0.8362	0.0011	-0.0002
		β	0.0016	0.0018	0.9144	0.3608			
7	Cardano	γ_0	0.0189	0.0017	11.0482	0.0000	2377.3867	0.7656	0.7653
		β	1.3798	0.0283	48.7612	0.0000			
8	Dogecoin	γ_0	0.0198	0.0024	8.1166	0.0000	1168.3867	0.6161	0.6156
		β	1.3806	0.0404	34.1817	0.0000			
9	Solana	γ_0	0.0379	0.0027	14.1872	0.0000	1472.3647	0.6691	0.6687
		β	1.6976	0.0442	38.3714	0.0000			
10	TRON	γ_0	-0.0037	0.0018	-2.0637	0.0394	929.5999	0.5608	0.5602
		β	0.9173	0.0301	30.4893	0.0000			

5. Conclusion

CAPM is an effective risk asset price prediction model in the capital market. This article uses CAPM to analyze the applicability of the top 10 cryptocurrency markets from August 1 2021 to July 31 2023. The research idea is to first preprocess the cryptocurrency data, conduct mathematical analysis on the return rate and coefficient β of cryptocurrency, and use the OLS regression model to regress and fit the cryptocurrency data and CAPM formula. The regression results indicate that the applicability of CAPM in the cryptocurrency market is not strong, and that is, the risk premium of cryptocurrencies and that of the market are not the linear relationship expected by CAPM. The systemic risk of the cryptocurrency market cannot play a role in the pricing of all cryptocurrencies, possibly because other risk factors play an undeniable role in the pricing of cryptocurrencies. At the same time, this article did not consider the variation of β over time. When β changes over time, standard OLS inference is incorrectly specified and cannot be used to evaluate the fit of CAPM.

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