The Comparison of Pricing Models for Cryptocurrency

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Abstract—Since cryptocurrency went viral, it has been a profound question about how to evaluate the price value for this special currency. On account of the attributes of cryptocurrency, the factors that would be considered are different from traditional stock in asset pricing. This paper introduces four models used for asset pricing of cryptocurrency: CAPM, three-factor model, four-factor model, and n-factor model. Based on the overview of these models and research results, we draw some conclusions related to the actual applications and practicality of the models. In consideration of the cryptographic features of blockchain, we compare these results of models to figure out a better method to recognize the price changing of cryptocurrency and propose some flaws in these approaches. With the asset pricing model being modified and more factors being taken into the discussion, the accuracy of the prediction has been improved significantly step by step. At last, the complication of cryptocurrency makes it difficult to have the exact number of prices. Hence, we are looking forward to establishing perfect models to give a more accurate explanation for the price changing in the CC market with a more fully interpretation of it. These results shed light on offering a thorough look at the current model to evaluate cryptocurrency.

Keywords- cryptocurrency; bitcoin; CAPM; factors model; asset pricing; Fama-French factors models

1. INTRODUCTION

Since the advent of Bitcoin in 2009, approximately 1,500 other cryptocurrencies have been introduced to the market. All cryptocurrencies share the underlying blockchain technology and reward mechanism. Many of them were created based on Bitcoin, and others were created based on blockchain technology [1]. The cryptocurrency market crossed the $100 billion market cap threshold in June 2017 and is expected to reach $1.7 billion in 2027 [2].

The Fama-French three factor model and the CAPM model both provide a reference direction to explain the average return and risk premium factors of financial products in the financial

ICEMME 2022, November 18-20, Nanjing, People's Republic of China

DOI 10.4108/eai.18-11-2022.2327109

markets [3]. These approaches have been influential in the field of analyzing the stock in the financial market. There has been less previous evidence for researchers to use a mathematical model to analyze the situation of cryptocurrencies. The use of such models as a tool for analyzing the cryptocurrency market is a topic that has not yet received much attention from researchers.

This paper analyses the impact of CAPM, three-factor, four-factor, and N-factor models on cryptocurrency market risk. According to our analysis, multi-factor models with a wider range of risk factors allows us to price cryptocurrency risk more precisely. The key contribution of this work is the solution. It provides different angles of thinking about the cryptocurrencies market.

The rest of the paper is organized as follows. Sec. 2 will introduce the basic overview of today's digital currency market, the mode of operation of cryptocurrencies during trading and their own characteristics, and analyse the impact of cryptocurrencies on financial markets. Sec. 3 will illustrate the classic CAPM and show a test result of CAPM applied in the cryptocurrency market, then by analyzing the results, and draw some conclusions from the model and put forward some flaws of it. In addition, we have the test results of the 3-factor model, compare them with the CAPM, and appraise its practicality. Sec. 4 and Sec.5 discuss the origin of the four-factor N-model and its application in the cryptocurrency market with a final test. Eventually, Sec. 6 gives a brief summary.

With thousands of different types of cryptocurrencies worldwide and their total market capitalization exceeding trillions of dollars, the cryptocurrency market analysis has been a topic of great interest.

2. BACKGROUND INFORMATION OF CRYPTOCURRENCIES

With the development of the Internet, Internet of Things and mobile Internet, a wide variety of electronic and virtual currencies have emerged in the global marketplace and are being integrated into economic and social development. Money can be described as something generally accepted as a medium of exchange, a measure of value, or a means of payment [4]. Although these electronic and virtual currencies are not digital currencies in the true sense, they perform some of the same functions as digital currencies in the financial market, e.g., serving as a medium of exchange, a measure of value, a means of payment, etc. Cryptocurrency can be conceived of as a digital asset built to function as a medium of exchange, based on cryptographic technology to safeguard transactional flow and manage the generation of extra currency units [5]. The current mainstream of digital currencies is the "decentralized" digital currency represented by Bitcoin, publicly available source code. In contrast, other "decentralized" digital currencies are mostly modified, with the main system like Bitcoin.

Based on the data, electricity usage to mine Bitcoin, the process of generating Bitcoins, is close to the electricity consumption by a medium-sized country [6]. One is in the payment settlement model, which does not rely on third-party intermediaries. In the case of Bitcoin, for example, first, some engineers designed the rules of Bitcoin, not regulators [7]. Second, Bitcoin emphasizes decentralization. Instead of storing transactions on any one server or set of servers, it uses a distributed transaction log, also known as a blockchain [8]. In this blockchain, all information, including the date and time of the transaction, is recorded, and each node in the network has a complete copy of the blockchain, so it cannot be forged or double paid.

The latter one is the issuance of production. According to the framework of Bitcoin's design, the total amount of Bitcoin is fixed, which means that the computing power of mining machines will become more and more demanding, "mining" will become more and more difficult. The growth rate of the supply will continue to decrease. In fact, the natural flaw of these digital currencies is that they are not guaranteed by national credit and are difficult to be recognized by participants, and can only be used as a trading asset, making it difficult to stabilize the value of the currency.

Contemporarily, many cryptocurrencies have been created, e.g., bitcoin, Ethereum, and Tether, and as of August 2021, the market is growing with over 5,000 different cryptocurrencies [9].

The vast majority of digital currencies are small in size, and the current digital currency market is still dominated by bitcoin. Still, Ethereum, Tether, and Binance Coin also occupy a certain market share. The top four digital currencies account for more than 70% of the total market capitalization, as shown in Table. I.

TABLE I. INFORMATION OF FOUR CRYPTOCURRENCIES

Currency	Market Cap (Million USD)	Price	Volume(24h) (Million USD)	The ratio of market value in circulation
Bitcoin	$758,764	$40291.19	$36,147	45.69%
Ethereum	$325,142	$2772.7	$31,054	18.73%
Tether USDT	$62,013	$1.0	$68,294	4.01%
Binance Coin	$56,312	$333.82	$1,536	3.49%

Data resource: https://coinmarketcap.com/ , August 6, 2021 Single Day Data

The emergence of digital currencies may positively and negatively impact the traditional monetary and financial system. In terms of positive impacts, specifically, one is that its novel concept and model may improve transaction convenience and reduce transaction costs. The decentralized system allows users to conduct peer-to-peer transactions directly without going through financial institutions, improving transaction efficiency and saving transaction costs. At the same time, its distribution is a terminus model, making it impossible for anyone to counterfeit digital currencies can reduce transaction risks. In addition, the low transaction costs of digital currencies may bring competition to traditional payment systems and prompt banks and other financial institutions to improve their services and reduce transaction fees.

Admittedly, there are many negative effects of digital currencies, e.g., digital currencies may endanger financial stability. In the case of Bitcoin, for example, although its decentralized network is not closely linked to the mainstream financial sector, Bitcoin can be exchanged for real money through its trading platform. The lack of constraints on bitcoin prices makes it extremely risky for speculators to operate, and ordinary investors could suffer huge losses by following the trend. Second, digital currencies can also be used for terrorist financing and money laundering because of their anonymity and lack of geographical restrictions. The "decentralized" digital currency represented by Bitcoin provides information like a "pseudonym" in the transaction process, which cannot be matched with the real identity [10]. Therefore, this mode of transaction could be used for illegal financial transactions.

Overall, the typical cryptocurrency (e.g., bitcoin, ETH) has certain values in terms of a type of asset. From the financial point of view, we believe that any item can be treated as monetary if it has the existence of a popular consensus, characteristics that cannot be easily counterfeited (easy to carry, circulate, store), and can be easily divided. The core support of any monetary system is “consensus”, i.e., a reliable backing of trust. As long as a consensus can be formed in a community or mass group, and everyone recognizes its existence, its transaction function, circulation function, and storage function. Then, it can be circulated in the community. Bitcoin, ethereum and other digital currencies have their own consensus communities, regardless of their community size. When all community members reach a consensual agreement that allows digital currencies, e.g., bitcoin to be traded and circulated within the community. Consequently, these digital currencies naturally have the same value as ordinary currencies. On this basis, the implementation of CAPM and corresponding improvement multifactorial model are applicable for cryptocurrency at least to some extents.

3. CAPM AND 3-FACTOR MODEL

3.1 Descriptions for CAPM

CAPM, which is the capital asset pricing model based on the hypothesis of Markowitz, proposed by Sharp (1964), Lintner (1965), Black (1972) [11], interprets the relationship between the expected return and the risk of an asset. It is a fundamental model in the stock market. They recognize a beta as an assessment of the volatility of one specific stock to the whole market. In this way, they reckon that the unsystematic risk will be totally diversified because of diversification, and the only thing related to the return is the market risk. To distinguish CAPM from stock market to cryptocurrency market, the latter one could also be called C-CAPM.

3.2 3-factor model

While the calculation of Beta is quite complicated in previous times and the model's premise is too idealized because the actual conditions are too far from these assumptions and more complex. According to some empirical tests afterwards, the CAPM fails does not perform well in these tests. Based on CAPM and Fama-French (1993) 3-factor model [12], Shen et al. (2020) [13] found some factors could interpret the difference between the expected return of stock other than beta.

3.3 Modelling of CAPM

The formula of CAPM is:

$$E(R_i) = R_f + \beta \cdot (R_m - R_f) \tag{1}$$

where R_i represents the expected return; Rf represents the free risk rate; Rm represents the market rate. Table II shows the beta of the selected 21 cryptocurrencies calculated by data ranging from January 2018 to November 2020. Then, one can use the saving rate of 3 months and take it average to turn into a weekly rate as a free-risk rate. Using the beta and plugging them in Eq. (1), one could calculate the mean expected turn of each cryptocurrency. After conducting regression on the mean and beta, the results are obtained as listed in Table. III.

TABLE II. THE INDEX BETA OF DIFFERENT CRYPTOCURRENCIES [14]

NO.	Name	Results	NO.	Name	Results
1	*Binance*	0.891 2	12	*Monero*	1.015 1
2	*Bitcoin*	0.794 6	13	*NEM*	0.964 3
3	*BCH*	1.458 6	14	*Neo*	1.265 8
4	*Cardanco*	1.310 5	15	*Stellar*	1.182 1
5	*Chainlink*	1.256 6	16	*Tether*	0.008 9
6	*Dai*	0.657 1	17	*Tezos*	0.978 0
7	*Dash*	1.125 9	18	*THETA*	1.144 6
8	*EOS*	1.292 2	19	*TRON*	1.851 9
9	*Ethereum*	1.150 5	20	*VeChain*	1.279 6
10	*Litercoin*	1.151 1	21	*XRP*	1.042 6
11	*Maker*	0.717 8			

TABLE III. REGRESSION ANALYSIS [14]

N	R^2	T	F
149	0.071	0.865	1.302 5

Table III illustrates that among all the collected samples, the linear equation of CAPM could only explain 7.1% of the variable beta, could not explain 92.9% of it. And the value of T and F shows that the model is not significant.

3.4 Results of CAPM

It could say that the CAPM could not explain the cryptocurrency market well because CAPM could not take other factors into account, such as the size factor, which is important to the cryptocurrency. Additionally, it could be figured out that the model is not suitable for cryptocurrency partly because the cryptocurrency market is basically different from the stock market. Firstly, the unsystematic risk could not be fully diversified. Because the policy hasn't been modified yet, the market still has some potential risks that could not be diversified by diversification. Secondly, in calculating the market portfolio, the BTC has taken a large part of it because it occupies a huge portion of the market. This is attributed to the special characteristics of cryptocurrency that it could have a quicker and bigger change in value in a short time than the stock market. In this way, the market portfolio estimate can be wrong because the currency's market value other than BTC can change sharply, so the market portfolio may change all the time.

3.5 3-factors modelling

The formula of the 3-Factor model is:

$$E(R_i) = R_f + \beta \cdot (R_m - R_f) + \beta_{SMB} \cdot SMB + \beta_{HML} \cdot HML \quad (2)$$

where SMB represents small minus big, which is the market portfolio of size; HML represents high minus low which is the book-to-value factor. Since the book to market value is hard to acquire based on cryptocurrency, Shen et al. (2020) [13] proposed another yardstick DMU to instead HML.

Table IV lists a comparison between C-CAPM and the three-factor model. It's clear to see that C-CAPM only have 0.52% of the ability to interpret the expected returns of cryptocurrency. As two additional factors, which are size and reversal factors, taken into account, the expected returns can be explained by 6.95%. It indicates that two factors make great effort to help explain the model and offer improvement to the previous one.

TABLE IV. C-CAPM AND THREE-FACTOR REGRESSIONS TO EXPLAIN WEEKLY EXCESS RETURNS IN PORTFOLIOS [13]

Panel A: Intercepts from C-CAPM and three-factor regressions

	a					t(a)				
	Up	2	3	4	Down	Up	2	3	4	Down
C-CAPM										
Big	-0.043	-0.014	-0.008	-0.017	-0.003	-3.607	-1.077	-0.830	-1.438	-0.265
2	-0.065	-0.010	-0.009	-0.012	-0.009	-4.857	-0.879	-0.771	-1.075	-0.688
3	-0.102	-0.015	-0.013	-0.004	0.021	-7.065	-0.939	-0.814	-0.267	1.651
4	-0.101	-0.016	0.014	0.007	0.029	-5.889	-1.133	0.907	0.473	1.991
Small	-0.122	0.020	0.013	0.044	0.178	-6.925	0.723	0.733	2.180	7.999
Three-factor										
Big	-0.031	-0.009	-0.003	-0.039	-0.012	-2.007	-0.664	-0.409	-2.737	-0.848
2	-0.048	-0.015	-0.009	-0.027	-0.038	-2.517	-0.992	-0.795	-1.933	-2.419
3	-0.076	-0.040	-0.020	-0.007	-0.014	-3.880	-2.348	-1.298	-0.827	-0.933
4	-0.097	-0.012	0.000	-0.025	-0.012	-4.178	-0.813	-0.809	-1.687	-0.721
Small	-0.082	-0.010	-0.024	-0.009	-0.007	-4.436	-0.525	-1.363	-0.597	-0.575

Panel B: Summary statistics for regressions.

	|a|	R^2	s(a)		|a|	R^2	s(a)
C-CAPM	0.0356	0.0052	0.0149	**Three-factor**	0.0266	0.0695	0.0146

3.6 Results of 3-factor model

We can see that we have a much more specific result when improving the CAPM into a 3-factor model. Nevertheless, it is still not enough to satisfy our requests to have a future estimation. That means there must be other potential factors other than these three that could affect the market, which is crucial to the estimation. It is reasonable that one could not have a relatively precise result of the measurement to some extent because the cryptocurrency market is too volatile to be estimated, e.g., they are affected by the level of people's concern which is subtle to be determined.

3.7 The impact of blockchain features on modeling

Since cryptocurrency is based on blockchain, and the blockchain could be reckoned as a technology backup for cryptocurrencies, it is obvious that some characters of blockchain can affect the asset pricing process. For example, the characters of encryption and decentralization has not been considered in the model. Unlike the traditional financial market, almost all trade the buyers and owners can be finished just with themselves directly. Therefore, some data we collected may not reflected all the risk in the cryptocurrency market. Additionally, we know that the feature of encryption makes it different from the traditional markets for we could not know the information, which can be tracked by methods, making the risk difficult captured accurately.

4. FOUR FACTORS MODEL

4.1 Origination

In 1993, Fama and French [12] pointed out that a three-factor model can be established to explain the stock return. The model believes that the excess return of an investment portfolio (including a single stock) can be explained by its exposure to three factors, which are: market asset portfolio (Rm − Rf), market value factor (SMB), book-to-market value ratio Factor (HML).

When the time came to 1995, Carhart constructed a four-factor model based on Fama-French three-factor model by introducing momentum factors. The four-factor model in the general definition refers to this model. The four-factor model can show portfolio's returns as an equilibrium achieved under the combined effects of market factors (MKT), scale factors (SMB), value factors (HML) and momentum factors (UMD).

4.2 Definition

The Carhart four-factor model was proposed and used as an additional factor in the Fama-French three-factor model. The newly added momentum factor in the model can effectively explain the "momentum effect" in the market. The time interval of the "momentum effect" it represents can be a longer period. The Carhart four-factor model is given by:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,MKT}MKT_t + \beta_{i,SMB}SMB_t + \beta_{i,HML}HML_t + \beta_{i,UMD}UMD_t + \varepsilon_{i,t} \quad (3)$$

Among them, $R_{i,t}$ represents the portfolio rate of return, $R_{f,t}$ represents the risk-free rate of return in the market, which seems to represent the difference between the average rate of return of the market portfolio and the market's risk-free rate of return. SMB represents the small market capitalization stock and the large. The difference in the yield of market capitalization stocks, HML, represents the difference between the yields of high-book-to-market-value (BE/ME) stocks and low-book-to-market capitalization (BE/ME) stocks UMD, represents the return of high-yield stocks and low-yield stocks the difference in rate.

4.3 Function

In contrast to the Fama-French model, the four-factor model can more comprehensively evaluate portfolio performance and more effectively measure the portfolio's ability to obtain excess returns through active investment management.

The first is that the four-factor model can examine the investment performance of open-end portfolios from both macro and micro perspectives and is more comprehensive in portfolio performance evaluation. From a macro perspective, taking the overall portfolio as the research object can reasonably evaluate the operating performance of open-end portfolios, which is a set of reasonable financing methods; from a micro perspective, examining the excess return rate of a single portfolio can obtain a portfolio performance ranking based on a four-factor model, which is convenient Compare the investment performance of individual open-end portfolios. The second is that the four-factor indicators in the four-factor model can subdivide the source of portfolio performance, realize a reasonable analysis of portfolio performance attribution, and improve the reliability of open-end portfolio performance evaluation. The third is to analyze the regression coefficients of each risk factor in the model, which can examine the investment style and strategy of the portfolio as a whole or a single portfolio.

4.4 In cryptocurrencies markets

In the research of Grobys and Sapkota [15], they believe that there is no continuous momentum effect in the cryptocurrency market, which was also corroborated in the subsequent study of Shen et al. [13]. As mentioned earlier, the decentralization of cryptocurrency makes the cryptocurrency market full of fanatical speculators. Important evidence of the herding effect and contagion of Bitcoin and other cryptocurrencies was discovered by Ferreira and Pereira in 2019 [16]. Meanwhile, da Gama Silva [17] and others pointed out the contagious effect of the cryptocurrency market. Tiwari also pointed out the extreme dependence and risk of contagion among the three major cryptocurrencies. Based on the contagion effect produced by the special nature of cryptocurrency, Shahzad et al. [18] propose a four-factor model based on the risk of contagion. With the addition of the 'bad contagion', Shahzad et al. [18] expanded the three-factor model into a four-factor model. Here, the BW, BM, BL, SW, SM, and SL are defined as following: B and S represent big and small; W, M, and L represent high-prior returns, medium-prior returns, medium-prior returns, and low-prior returns, respectively. The variables in the remaining function are based on the Fama-French model. Therefore, the four-factor model's expression is:

$$r_{i,t} - R_{f,t} = \alpha + \beta_{i,1} MRP_t + \beta_{i,2} LMW_t + \beta_{i,3} SMB_t + \beta_{i,4} C_t + \varepsilon_{i,t} \quad (4)$$

where C_t is the bad contagion index of the cryptocurrency market as estimated. The $R_{i,t}$represents the risk-free rate of return of time t. $r_{i,t}$ represents the rate of return of asset I at time t; $\beta_{i,1}, \beta_{i,2}, \beta_{i,3}, \beta_{i,4}$ are the coefficients of the four factors respectively.$\varepsilon_{i,t}$ is the radom error term. Shahzad et al. [18] also examined this model. Table. V summarizes the results, which tells us that the estimated model load is not affected by multicollinearity.

TABLE V. DESCRIPTIVE STATISTICS OF THREE FACTORS T [18]

Variables	Mean	Std. Dev.	Skew.	Kurt.	MKT	WML	SMB
MKT	-0.0027	0.0425	-0.7383	7.2960	1.000		
WML	-0.1121	0.0568	-0.4230	4.3594	0.021	1.000	
SMB	-0.0076	0.0565	0.3103	7.5543	-0.011	0.044	1.000

As shown in Fig. 1, the model fits well with the findings of Bouri et al. [19]: the contagion in cryptocurrencies is still very high. Besides, the articles [18] also show that the 4-factor model is more accurate than the three-factor model.

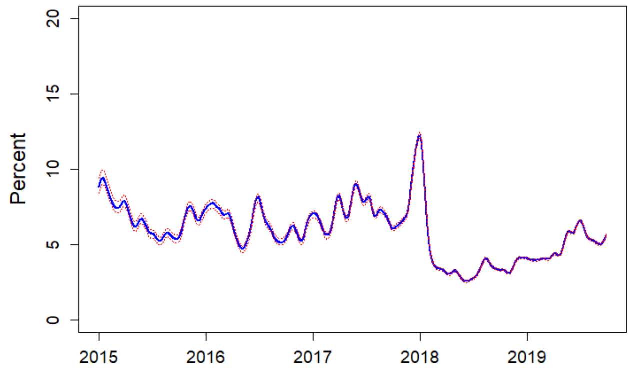

Figure 1. Bad contagion in cryptocurrencies [18]

These results greatly expand the accuracy of the three-factor model in the cryptocurrency market and provide digital visual modeling for bad contagion factors. Generally, it has greater accuracy and reference value than the CAPM model and the three-factor model.

5. N FACTORS MODEL

In 2020 and even 2021, the world is full of rumors about the collapse of cryptocurrencies. After several declines in cryptocurrencies, people feel scared and confused: What are the risks of cryptocurrencies? In the other parts of the previous article, we demonstrate how the four-factor model adds the contagiousness of the cryptocurrency market to the traditional three-factor model. In another article written in Dobrynskaya [20], another factor is mentioned-downside market risk. (Many factors in the market affect the pricing of cryptocurrencies, and here is one of them.) in reference to Ang et al. [21], lettau et al., [22], Atanasov and Nitschka. After the research results of lettau et al. [22], Dobrynskaya [20] got the following expression:

$$r_i - r_f = \beta_i \lambda + (\beta_i^- - \beta_i) \underbrace{\left(\frac{x^- - \gamma^\lambda}{1-\gamma}\right)}_{\lambda^-} + \mu + \varepsilon_i \tag{5}$$

The relative downside beta $\beta_i^- - \beta_i$ measures the degree of asymmetry in the upside and downside risks. If the asymmetry is insignificant, $\beta_i^- \approx \beta_i \approx \beta_i$ and$\beta_i^- - \beta_i \approx 0$. The greater the difference in the upside and downside betas, the greater the absolute level of the relative downside beta. The relative downside beta premium λ^- shows how this extra downside risk is priced. The positive premium essentially means that the downside beta premium is higher than the upside beta premium. It means that downside risks are more important to investors.

Dobrynskaya [20] used descriptive statistics of sorted portfolios for examination. This is a very conventional method. In the article, Dobrynskaya [20] reports average returns (in absolute values) and various risk characteristics of cryptocurrency portfolios, sorted by trailing downside betas, regular betas and upside betas.

This multi-factor model takes into account the symmetry of the upward and downward markets, and at the same time, explains the return of cryptocurrency better than the CAPM model. The return comes from various risk factors, and risk factors are widely present in the cryptocurrency market. Compared with the four-factor model, the multi-factor model has a wider range of considerations. Different factors can be considered to solve different problems, and their accuracy also changes due to specific problems.

6. CONCLUSION

In summary, we discussed some developments for cryptocurrency assets evaluation approaches proposed so far. The special nature of cryptocurrency makes its value difficult to estimate for ordinary investors. Some scholars choose to apply some professional models to price cryptocurrencies. According to our analysis, the Fama-French model will have more accuracy than the traditional CAPM model. Moreover, considering different factors, the derivative four-factor model of the Fama-French model and even the multi-factor model can categorically consider the pricing of cryptocurrencies under different risks. The four-factor model and the multi-factor model are not strictly substitutable, and each model has its own practical scenario.

Besides, it is also found that the cryptocurrency market still has huge uncertainties. There are still some factors that are not mentioned in the article (e.g., policy factors). In 2021, cryptocurrency investment caused a large number of investors to suffer a great loss. This article aims to re-introduce the main ideas of cryptocurrency pricing and some common pricing models by reviewing other people's research on cryptocurrency pricing models. In the future, owing to the impact of the COVID-19 virus epidemic and the policies of different countries, more and more investors may hope to make profits by investing in cryptocurrencies, and many researchers will also participate in it. Conduct research on cryptocurrency market investment. From our perspective, identifying the risks will be a long-term issue of cryptocurrency pricing analysis. These results offer a guideline for pricing the cryptocurrency choose to apply some professional models to price cryptocurrencies.

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