Proceedings of the 2nd International Conference on Financial Technology and Business Analysis
DOI: 10.54254/2754-1169/92/20230496

The Impact of Financial Innovation on the Stability of the Financial System: An Empirical Analysis Using Virtual Currency as an Example

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Abstract: The impact of financial innovation on the stability of the financial system is a subject of extensive research and interest in both academic and market circles. This study focuses on virtual currency, particularly Bitcoin, as a representative of financial innovation to empirically analyze its influence on the financial system's stability. Virtual currencies, including Bitcoin, are digital assets created and exchanged using cryptography and distributed ledger technology, providing decentralized and secure transactions. Financial innovation, driven by technological advances and market demands, encompasses various emerging financial products and technologies, such as blockchain, smart contracts, and digital assets, with the potential to enhance financial efficiency and inclusion. This research explores the relationship between Bitcoin price volatility and risk, identifies price bubbles, and studies its interaction with traditional financial assets. The GARCH(1,1) model is employed to analyze the conditional variance dynamics, and the results suggest that past prices and returns significantly influence current conditional variance. However, residual analysis indicates no significant autocorrelation or heteroscedasticity in the residual sequence. These findings offer insights into Bitcoin's impact on financial market stability, highlighting its potential as an additional hedging tool in portfolio management and market analysis. Nonetheless, the decentralized and minimally regulated nature of virtual currencies poses risks that require policy attention to maintain financial stability. Despite providing valuable insights, this study has limitations, such as not considering the impact of other economic indicators. Future research should delve into additional factors and mechanisms to comprehensively assess virtual currencies' influence on financial system stability. Policymakers are urged to implement relevant measures to mitigate the excessive impact of financial innovation products on domestic financial markets.

Keywords: Financial Innovation, Virtual Currencies, Bitcoin, Cryptocurrency, GARCH Model

DOI: 10.54254/2754-1169/92/20230496

1. Introduction

1.1. Virtual Currencies

Virtual currencies, including Bitcoin, are digital assets created, exchanged, and stored online using cryptography and distributed ledger technology. Bitcoin, introduced and implemented in 2009 by an individual or group known as Satoshi Nakamoto, is widely recognized as one of the most prominent virtual currencies [1]. The decentralized nature of virtual currencies means that they do not rely on the intervention of a central authority or government, ensuring the security and anonymity of transactions through cryptographic algorithms.

The emergence of virtual currency has aroused extensive attention from academic circles and the market. From a technical point of view, virtual currencies rely on blockchain technology, a decentralized distributed ledger used to record the transaction history of virtual currencies. The innovation of block marketing lies in its ability to ensure the transparency and immutability of transactions, avoiding the trust problem in traditional financial [2].

Research on virtual currencies in economics has focused on their potential impact as an emerging financial innovation. The virtual currency has the characteristics of divisibility, portability, and low cost, providing a faster and cheaper way of cross-border [3]. In addition, virtual currencies also have investment value and hedge properties, attracting a wide range of investor interest.

However, virtual currencies also face some challenges and controversies. Its highly volatile prices and lack of regulation make the virtual currency market vulnerable to speculation and manipulation [4]. In addition, virtual currencies also face security and privacy protection issues, such as hacking, money laundering, and illegal transactions.

In summary, virtual currencies represent a financial innovation with revolutionary potential. They offer decentralized, secure, and efficient ways to transact and have the potential to impact how the traditional financial system operates profoundly. However, as the virtual currency market develops, issues such as regulation and risk management need to receive more attention and research to ensure financial stability and the protection of users' rights and interests.

1.2. Financial Innovation

When it comes to financial innovation, it covers a variety of emerging financial products, services, and technologies that have a profound impact on the financial system and markets. The scope of financial innovation includes but is not limited to new payment systems, virtual currencies, financial technology (FinTech), blockchain technology, smart contracts, and digital assets. Financial innovation has great potential to promote the efficiency of financial operations, reduce transaction costs, enhance financial inclusion, and change the way financial markets operate.

Financial innovation is driven by evolving technological advances and changing market demands. By introducing new technologies and business models, financial innovation can transform financial institutions' operations and improve the quality and convenience of financial products and services. The emergence of financial technology companies and the acceleration of digital transformation have made financial innovation a hot topic in the current financial field.

However, financial innovation also brings a series of challenges and risks. Financial innovation needs to harmonize with existing legal frameworks and regulators and ensure the security of users' data and funds regarding legal, regulatory, and privacy protection. In addition, financial innovation may trigger new systemic risks and market volatility, which require risk assessment and monitoring.

Despite the challenges of financial innovation, its potential benefits and opportunities have made it an area of widespread research interest in academia and industry. Understanding the dynamics and

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impact of financial innovation is essential for financial institutions, regulators, academics, and investors alike.

2. Background

Through a comprehensive analysis of relevant literature, this paper studies the impact of financial innovation on the financial system's stability. It makes an empirical analysis with Bitcoin as an example. The study found that financial innovation significantly impacts the financial system's stability, and the emergence and development of virtual currency have brought new challenges and opportunities.

First, the relationship between bitcoin price volatility and risk is a research focus. Bouri et al. found a correlation between returns and volatility in the Bitcoin market by studying data during the Bitcoin price crash in 2013 [5]. Dyhrberg used the GARCH model to analyze the volatility among bitcoin, gold, and the US dollar and found that bitcoin has high volatility but a weak relationship with gold and the US dollar [6].

Secondly, the price bubble of Bitcoin and other virtual currencies has also received much attention. Corbet et al. identified the price bubble period of Bitcoin and Ethereum by conducting a time-stamped analysis of the price data of Bitcoin and Ethereum [7]. Polasik et al. studied the volatility and usage of Bitcoin prices. They found that the price of virtual currencies is affected by various factors, including market demand, government regulation, and financial innovation [8].

In addition, the relationship between virtual currencies and traditional financial assets is also a concern. Selgin explores the potential of virtual currencies as synthetic commodity currencies and discusses their interaction with traditional monetary systems [9]. Yermack conducted an economic evaluation of bitcoins, explored their potential as real money, and conducted an in-depth analysis of the characteristics of virtual currencies [10].

Finally, the relationship between the price discovery of virtual currency and the futures market has also attracted the attention of researchers. Zhang and Zhang studied the relationship between Bitcoin's spot and futures prices through co-integration, causality, and price discovery analysis [11]. Wang and Vergne studied the relationship between the rate of return of cryptocurrencies such as Bitcoin and market attention. They found that market attention significantly impacts the rate of return of cryptocurrencies [12].

To sum up, financial innovation has an essential impact on the financial system's stability, and virtual currency, as a representative of financial innovation, profoundly impacts the financial system's stability and the traditional financial market. However, the volatility of the virtual currency market, price bubbles, and its relationship with traditional financial assets still require further study and regulation. None of the existing papers mention the relationship between Bitcoin's opening and closing prices and the U.S. dollar; Moreover, the data used in the existing papers are relatively old. In order to overcome these shortcomings, this paper incorporates the opening and closing prices of Bitcoin into independent variables and uses the latest data. This paper comprehensively analyzes these problems and puts forward the direction of future research and policy suggestions.

3. Variables

In this study, as shown in table 1, the independent variables consist of BTC-USD.Open, BTC-USD.High, BTC-USD.Low, BTC-USD.Close, and BTC-USD.Volume, representing various aspects of virtual currency. These variables are examined to measure the influence of financial innovation on the financial system's stability. The dependent variable is BTC-USD.Adjusted, which serves as an indicator of the impact on the financial system. At the same time, the paper sets the interest rate, inflation rate, market index, unemployment rate, GDP and CPI as control variables to prevent these

DOI: 10.54254/2754-1169/92/20230496

variables from affecting the variables studied. By analyzing the relationship between independent variables and dependent variables, we aim to assess the extent of financial innovation's effect on the financial system's stability.

Table 1: Symbols and meanings of variables

variables	notation	meaning
Independent variable	BTC-USD.Open	The opening price of bitcoin trading against the US dollar
Independent variable	BTC-USD.High	The highest price of bitcoin trading against the US dollar
Independent variable	BTC-USD.Low	The lowest price of bitcoin trading against the US dollar
Independent variable	BTC-USD.Close	The closing price of bitcoin trading against the US dollar
Independent variable	BTC-USD.Volume	The volume of bitcoin trading against the US dollar
Dependent variable	BTC-USD.Adjusted	Bitcoin adjustment against the US dollar
Control variable	a	Interest rate
Control variable	b	Inflation rate
Control variable	c	Market index
Control variable	d	Unemployment rate
Control variable	e	GDP
Control variable	f	CPI

4. Data and Methodology

This paper takes Bitcoin as the representative of virtual currency to conduct empirical research. The data is from June 29, 2018 (the earliest date) to June 29, 2023, with a total of 1,828 observations. This data is publicly available in the R database.

The model used in this study is the GARCH(1,1) model, as shown below:

$$r_t = \mu + \varepsilon_t \tag{1}$$

$$\varepsilon_t = \sigma_t \times z_t \tag{2}$$

$$\sigma_t^2 = \omega + \alpha_1 \times \varepsilon_{t-1}^2 + \beta_1 \times \sigma_{t-a}^2 \tag{3}$$

Where,

r_t represents the yield or difference value of time series data.

μ is the mean parameter, representing the average level of the time series data.

ε_t is a residual term that follows a distribution with a mean of 0 and a variance of σ_t^2 and is used to represent the volatility of the data.

σ_t is the conditional standard deviation or conditional volatility, which represents the level of volatility at point t in time.

z_t is a standard normal random variable used to represent the volatility of the residual term.

ω is the constant term of the GARCH model and represents the base level of the conditional variance.

α_1 is the coefficient of the ARCH term, indicating the degree of influence of past fluctuations.

β_1 is the coefficient of the GARCH term, indicating the degree of influence of the past conditional variance.

ε_{t-1}^2 is the square of the residual from the last point in time.

σ_{t-a}^2 is the square of the conditional variance at the previous point in time.

DOI: 10.54254/2754-1169/92/20230496

In the GARCH(1,1) model, the ARCH term is used to capture the effects of past fluctuations and the GARCH term is used to capture the effects of past conditional variances. The coefficients of these two terms represent the relative contributions of past fluctuations and past conditional variances to the current conditional variances.

5. Results and Analysis

The results of the GARCH model estimation, Ljung-Box test and ARCH-LM test using R are as figure 1:

```
*---------------------------------*
*          GARCH Model Fit        *
*---------------------------------*

Conditional Variance Dynamics
-----------------------------------
GARCH Model     : sGARCH(1,1)
Mean Model      : ARFIMA(1,0,1)
Distribution    : norm

Optimal Parameters
------------------------------------
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001799    0.000764  2.35558 0.018494
ar1    -0.421348    0.476002 -0.88518 0.376060
ma1     0.389156    0.483444  0.80497 0.420840
omega   0.000104    0.000020  5.08724 0.000000
alpha1  0.089885    0.017220  5.21980 0.000000
beta1   0.835135    0.025919 32.22145 0.000000

Robust Standard Errors:
        Estimate  Std. Error  t value Pr(>|t|)
mu      0.001799    0.000791   2.2743 0.022951
ar1    -0.421348    0.341781  -1.2328 0.217651
ma1     0.389156    0.347485   1.1199 0.262747
omega   0.000104    0.000037   2.8215 0.004780
alpha1  0.089885    0.034867   2.5780 0.009939
beta1   0.835135    0.041728  20.0139 0.000000

LogLikelihood : 3503.677

Information Criteria
------------------------------------

Akaike       -3.8734
Bayes        -3.8551
Shibata      -3.8734
Hannan-Quinn -3.8667

Weighted Ljung-Box Test on Standardized Residuals
------------------------------------
                        statistic  p-value
Lag[1]                      2.631 0.104807
Lag[2*(p+q)+(p+q)-1][5]     4.853 0.005429
Lag[4*(p+q)+(p+q)-1][9]     6.175 0.228984
```

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```
d.o.f=2
H0 : No serial correlation

Weighted Ljung-Box Test on Standardized Squared Residuals
------------------------------------
                        statistic p-value
Lag[1]                    0.03673  0.8480
Lag[2*(p+q)+(p+q)-1][5]   1.88969  0.6447
Lag[4*(p+q)+(p+q)-1][9]   3.19906  0.7257
d.o.f=2

Weighted ARCH LM Tests
------------------------------------
            Statistic Shape Scale P-Value
ARCH Lag[3]     1.070 0.500 2.000  0.3010
ARCH Lag[5]     2.977 1.440 1.667  0.2931
ARCH Lag[7]     3.644 2.315 1.543  0.4008

Nyblom stability test
------------------------------------
Joint Statistic:  1.0121
Individual Statistics:
mu     0.19571
ar1    0.14461
ma1    0.13965
omega  0.16926
alpha1 0.09022
beta1  0.17644

Asymptotic Critical Values (10% 5% 1%)
Joint Statistic:         1.49 1.68 2.12
Individual Statistic:    0.35 0.47 0.75

Sign Bias Test
------------------------------------


Adjusted Pearson Goodness-of-Fit Test:
------------------------------------
  group statistic p-value(g-1)
1    20     280.2    2.216e-48
2    30     306.2    4.909e-48
3    40     313.4    1.479e-44
4    50     329.3    3.497e-43


Elapsed time : 0.5065701
```

Figure 1: Results of the GARCH model estimation, Ljung-Box test and ARCH-LM test using R

Based on the provided GARCH model fitting results, the following analysis is conducted regarding the impact of Bitcoin on financial market stability:

Parameter Estimation: The GARCH model has conditional variance dynamics of sGARCH(1,1), which means it uses lagged conditional variance and lagged squared conditional variance as modeling factors. The mean model adopts an ARFIMA(1,0,1) model, where the ar1 parameter is estimated as -0.421348, and the ma1 parameter is estimated as 0.389156. This indicates that the changes in Bitcoin prices are influenced by past one-period prices and past one-period returns.

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Parameter Significance: Under the assumption of a normal distribution, the estimation results of the model parameters show some significance. For example, the estimation of the omega parameter (the constant term of the model) is 0.000104, and it is significant, indicating a significant impact of this constant term on conditional variance. The alpha1 parameter (the autoregressive coefficient of conditional variance) is estimated as 0.089885 with a p-value of 0.000000, indicating a significant influence of past conditional variance on the current conditional variance. The beta1 parameter (the lagged squared coefficient of conditional variance) is estimated as 0.835135 with a p-value of 0.000000, indicating a significant influence of past squared conditional variance on the current conditional variance.

Model Fit: The log-likelihood value is 3503.677, which is an indicator of model fit. A higher log-likelihood value suggests a better fit for the data. Information criteria (Akaike Information Criterion, Bayes Information Criterion, Shibata Information Criterion, and Hannan-Quinn Information Criterion) are used to compare the model complexity and fit. In this model, these criteria have relatively low values, indicating a good fit for the model.

Residual Analysis: The weighted Ljung-Box test is employed to examine the presence of autocorrelation in the standardized residual sequence. In the lag-1 test, the statistic is 2.631 with a p-value of 0.104807, indicating the possibility of slight autocorrelation in the residual sequence. However, the tests at other lag orders do not show significant autocorrelation. The weighted Ljung-Box test is also conducted to assess heteroscedasticity in the standardized squared residual sequence. In the lag-1 test, the statistic is 0.03673 with a p-value of 0.8480, suggesting no significant heteroscedasticity in the standardized squared residual sequence.

In summary, the results of the GARCH model suggest that Bitcoin may have a specific impact on financial market stability. The significance of the model parameters and the fit criteria indicate that past prices and returns play an important role in determining current conditional variance. However, the residual analysis indicates no significant autocorrelation or heteroscedasticity in the residual sequence. These findings provide some insights into further exploring the impact of Bitcoin on financial market stability. However, more analysis and research are needed to evaluate this influence's extent and mechanisms comprehensively. In addition, this paper still has some shortcomings, such as not considering the impact of interest rate, inflation, market index, unemployment rate, GDP, CPI, which needs further study.

6. Conclusion

The analysis indicates that Bitcoin shares many similarities with the US dollar, reflecting the impact of Bitcoin as a financial innovation product on market stability. However, due to its decentralized nature and minimal regulation, Bitcoin carries certain risks. Nevertheless, this does not imply that Bitcoin is less valuable than other liquid assets in the market. On the contrary, individuals in portfolio management and market analysis can gain a more comprehensive market perspective by incorporating Bitcoin and utilizing it as an additional hedging tool, enabling wiser decision-making. Furthermore, countries should also enact relevant policies to prevent the excessive impact of financial innovation products on the stability of their domestic financial markets.

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