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The Asymmetric Effects of the Interest Rate on the Bitcoin Price

Nezir KÖSE - Department of Economics, Beykent University

Emre ÜNAL - Urban Institute, Kyushu University & Department of Economics, Firat University (eunal@firat.edu.tr) *corresponding author*

Abstract

The news about the US interest rate is expected to cause significant changes in cryptocurrency markets in the 2020s. The asymmetric effects of the interest rate on the Bitcoin price were analyzed by using a SVAR model for the monthly period between January 2012 and October 2022. The selected variables are the VIX, interest rate spread, positive and negative real interest rates, DXY, the gold price, and the oil price. According to the variance decomposition, negative real interest rate shocks created a stronger influence than positive real interest rate shocks on the Bitcoin price. The negative real interest rate shocks became the most explanatory indicator over the period. Impulse response functions indicated that the response of the Bitcoin price to the positive interest rate was insignificant. However, its response to the negative real interest rate became negative and significant only during the mid-term. As a consequence, the negative real interest rate significantly influences the Bitcoin price. The results provide important implications for policymakers, portfolio managers, and investors.

1. Introduction

The perception of payment and investment systems has evolved as a result of globalization and technological advancements. Cryptocurrency markets started with the invention of Bitcoin (Nakamoto, 2008). As electronic systems are widely accepted, the number of cryptocurrencies has increased and gained popularity around the world. It is assumed that Bitcoin indicates a form of gold in the virtual world. It has not been accepted as a reserve in central banks. However, it has become an asset for lending based on the interest rate in markets (Shuai et al., 2021). Moreover, Bitcoin is gradually recognized as a way of payment by individuals, firms, and organizations in economies. Cryptocurrency markets are disorganized and non-regulated. It is easy to access these markets twenty-four hours a week. The transaction is easier, and the price is determined by free market conditions. In stock exchanges, when there are large price movements in assets, their volatilities are limited and controlled by financial identities. When compared to assets traded on

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stock exchanges, there is no limit to volatility in cryptocurrency markets. In exchange rates, when there is high fluctuation, central banks can determine a new margin for currency markets to reduce risks. In cryptocurrency markets, there are no such limits or controls. These markets are open to speculation. The US dollar gained value against other world currencies as a result of news concerning the US interest rate policy. Although it is known that central banks cannot create control over cryptocurrencies, in fact, they may be influenced by economic policies in the US. Bitcoin has been a leading and the first cryptocurrency. It also has the largest share in the cryptocurrency markets. Hence, the question of whether the US interest rate policy has an impact on the price of Bitcoin is raised. Moreover, this work studies whether negative or positive real interest rate shocks affect the Bitcoin price more. This research seeks to answer these questions. If this is possible, cryptocurrencies behave like conventional assets or official currencies. Thus, they can be impacted by conventional economic policies.

In this study, a SVAR model was used to explore the asymmetric impacts of the interest rate on the Bitcoin price over the monthly period between January 2012 and October 2022. The CBOE's Market Volatility Index (VIX), interest rate spread, negative and positive real interest rates, DXY, the gold price, and the oil price are among the indicators examined. These variables are assumed to be significant indicators of the Bitcoin price. Thus, they are selected to conduct a comparative analysis to assess how much the interest rate explains changes in the Bitcoin price. The impacts of interest rates on cryptocurrencies have been an important question because current works based on this issue remain quite limited. It has been discussed that Bitcoin does not indicate the patterns of conventional assets. However, if there is a connection between the interest rate and the Bitcoin price, then it can be said that Bitcoin is dependent on macroeconomic policies. In the near future, this can open a new gate for government institutions and central banks to follow policies by considering cryptocurrency markets.

The US has global financial variables such as oil, bonds, stocks, and exchange rates (Bhuiyan et al. 2021; Symitsi and Chalvatzis, 2019). With its large and dominant economy around the globe, the US has the potential to influence global determinants. Moreover, it is a country that holds a large part of cryptocurrencies. Trading of cryptocurrencies is generally based on the US dollar, similar to that of conventional currencies. In the modern world, it is evident from the news that US interest rate policy can affect a variety of global economic dynamics. Investors who expect a large increase in the interest rate in the US could choose an alternative option to the US dollars to avoid risks. Globally, the rising interest rate in the US causes depreciations in exchange rates. For instance, the yen experienced significant depreciation against the US dollar. Moreover, after the news from the FED signaling increases in the interest rate, cryptocurrencies dramatically lose value. Therefore, the interest rate was taken into account to perceptibly explain its role in cryptocurrency markets. The interest rate is a policy tool to create control over exchange rates and inflation. In countries, if the exchange rate depreciates, an interest rate policy can be implemented to reduce large volatility in currencies. Additionally, it is known that interest rates can have relationships with exchange rates, gold, other commodities, and stocks (Salisu and Vo, 2021; Liu and Lee, 2020). Akbar et al. (2019) mentioned that depreciations in exchange rates were responded to by rising interest rates. Moreover, it was stated that a one-unit positive shock in the interest rate caused declines in gold and stock prices. Yung (2021) indicated that interest rate factors help explain fluctuations in exchange rates. Li et al. (2021a) pointed out that foreign exchange rates had a strong cross-correlation with interest rates in a number of developed economies. The interest rate can cause asymmetric effects on the exchange rate, commodities, or stocks. Long et al. (2022) found that the asymmetric relationship between Sino-US interest rate differentials and the RMB exchange rate was significant. Kang et al. (2020) investigated the relationships among Bitcoin, T-bonds, stock markets, US dollars, and gold. It was explored that asymmetric causality existed between Bitcoin and other variables. Salisu et al. (2020) stated that interest rate differentials created both asymmetric and time-varying impacts on the exchange rate. As inflation increases in the US during the 2020s, the interest rate can also be used to reduce it. The modern world is more digitalized. It is not possible to assume that the effects of the interest rate would be limited to only conventional investment options. Many studies have attempted to assess Bitcoin as a currency or as digital gold (Mokni and Ajmi, 2021; White et al., 2020; Baur et al., 2018). Kwon (2020) stated that Bitcoin could be traded as an alternative for a medium of exchange and a means of investment. However, it cannot be expected that positive or negative interest rate shocks would create symmetrical effects. The effects can be quite diverse in financial markets. Hence, it is desirable to focus on whether the interest rate has a significant asymmetrical effect on the Bitcoin price.

This work contributes to existing works by considering the role of positive and negative interest rate shocks on the Bitcoin price by a SVAR model. Research on this issue remains quite limited. Panagiotidis et al. (2019) estimated a weak interaction between Bitcoin and macroeconomic variables. Thus, it was mentioned as a research gap that further research is required to assess the role of economic policies on cryptocurrencies. Vidal-Tomás and Ibañez (2018) mentioned that Bitcoin was not affected by monetary policy news. This result shows the absence of any kind of control over Bitcoin. Moreover, their findings indicate that Bitcoin is a financial asset without any connection to the policies of central banks. Different from the studies above, our work proves that the Bitcoin price can be influenced by the conventional economic policies of the government and central bank. It was found that the Bitcoin price was significantly influenced by the interest rate. A negative real interest rate indicated a leading role for explaining changes in the Bitcoin price more than a positive real interest rate. In other words, when there is high inflation in the market, this can create a negative real interest rate, which positively impacts the Bitcoin price.

This work is organized as follows: In Section 2, previous research and the current work are discussed. In Section 3, assumptions and data collection are introduced. In Section 4, the SVAR model is presented. In Section 5, policy implications are laid out. The paper is concluded in Section 6.

2. Literature Review

There is a considerable amount of research explaining the determinants of the Bitcoin price. Works those took real interest rate remained quite limited. However, there are some related works based on economic policies and macroeconomic factors. These are introduced in this section.

Marmora (2022) investigated how monetary policy announcements influence local Bitcoin demand by implementing event study designed on a panel for 26 emerging countries for the period between 1 January 2015 and 31 December 2019. It was mentioned that monetary policy announcements increase both local Bitcoin attention and trade volume on days when people were cautious to inflation. Choi and Shin (2022) analyzed whether Bitcoin could hedge inflation or could behave like a safe haven commodity gold. A VAR model was used for weekly period between 21 July 2010 and 31 December 2020. It was mentioned that Bitcoin appreciated against inflation shocks. However, the Bitcoin price declined when there was financial uncertainty. It was also pointed out that Bitcoin did not decrease after policy uncertainty shocks. This suggests that Bitcoin is independent from government authorities. Moreover, the Bitcoin price does not indicate statistical response to nominal interest rate shocks. Aboura (2022) applied regression models and a VAR-based spillover model to analyze the effect of FED funds rate on the Bitcoin price for the daily period spans from 1 January 2015 to 28 February 2021. It was stated that FED fund rates created nonlinear effects and temporarily strong spillover effects on Bitcoin. Nguyen et al. (2022) investigated the effects of federal funds rate and the Chinese interbank rate on stablecoins and traditional cryptocurrencies by using GARCH, EGARCH and Fixed Effects models for the daily data from December 2018 to December 2019. It was mentioned that a higher federal funds rate and the Chinese interbank rate compressed the prices and price volatility of stable coins. However, higher rates increased the prices and the price volatility of traditional cryptocurrencies. It was found that the federal funds rate created more significant impact on both types of coins compared with the Chinese interbank rate.

Hernandez et al. (2021) examined the short and long-term effects of economic policy uncertainty on the Bitcoin price. An autoregressive distributed lag (ARDL) model was applied for the monthly period between December 2011 and June 2020. Results indicated that the magnitude of economic policy uncertainty on Bitcoin returns weakens in the long-term. Li et al. (2021b) implemented a wavelet analysis to investigate the correlation of volatility between Bitcoin, stock and gold by using weekly data starting from 12 July 2010. It was found that selected variables were positively correlated with each other when there were high economic policy uncertainties.

Jareno et al. (2020) applied quantile regression approach for the period between 2010 and 2018. The sensitivity of Bitcoin was analyzed by including several determinants such as the gold price, the VIX, US stock market returns, interest rate, crude oil price and the Saint Louis financial stress index. It was stated that change in interest rates created negative and significant impact on Bitcoin returns in the highest quantile and the full period. Corbet et al. (2020) implemented GARCH methods to explain the reaction of cryptocurrencies to the US monetary policy based on interest rate and quantitative easing by using periods between 26 April 2013 and 30 June 2017. The evidence indicated that there was volatility spillover transfer from US monetary policy announcements to Currency-based cryptocurrencies. Moreover, it was estimated that mineable cryptocurrencies were more susceptible to monetary policy volatility spillovers transfer compared with non-mineable cryptocurrencies.

Panagiotidis et al. (2019) employed VAR and FAVAR models to examine the effects of stock market returns, exchange rates, gold, oil returns, FED's and ECB's rates, and internet trends on Bitcoin returns by using daily data between 18 July 2010 and 31 August 2018. It was estimated that there was a significant relationship between Bitcoin and traditional stock markets but weaker relationship with FX markets and the macroeconomy. Nguyen et al. (2019) investigated asymmetric impacts of monetary policies on cryptocurrency returns by selecting four cryptocurrencies; Bitcoin, Ethereum, Litecoin and Ripple. The Generalised Method of Moments (GMM) was used in the analysis for the period between 1 October 2015 and 15 August 2018. It was mentioned that there were significant responses of four major currencies to tightening monetary policies in China. However, the study indicated that monetary policies in the US did not create significant effect on cryptocurrency returns. Vidal-Tomás and Ibañez (2018) implemented a methodology of the event study with the AR-CGARCH-M model for the periods 13 September 2011 to 17 December 2017, and from 13 September 2011 to 25 February 2014, respectively, to examine whether Bitcoin was influenced by monetary policy events. It was pointed out that Bitcoin market is clearly inefficient when monetary policy events are considered. It was also mentioned that Bitcoin was mostly influenced by Bitcoin news and was not affected by news from central banks.

There are also recent works those assess movements in the Bitcoin price. Huynh et al. (2020) studied the prediction power of the ratio of gold to platinum on the Bitcoin price by using wavelet multiple correlation and several other models. Daily period between 1 May 2013 and 28 October 2019 was considered. It was found that the ratio could predict future Bitcoin return. Foglia and Dai (2022) studied spillovers across economic policy uncertainty and cryptocurrency uncertainty indices by using TVP-VAR model for the monthly period spans from December 2013 to February 2021. The result indicated that there was cross-country spillovers of economic policy uncertainty. It was suggested that investors should follow regular news about growth, policy changes and crises when they invest in cryptocurrency markets.

When the discussion above is evaluated, this work carries a number of originalities. To the best of our knowledge, a prominent approach, a SVAR model, is used for estimating the impacts of the interest rate on the Bitcoin price for the first time. Second, works about the effects of interest rate shocks on cryptocurrencies have remained limited. For instance, a recent work by Aboura (2022) stated that there were nonlinear and temporary spillover effects of FED fund rates on Bitcoin. This paper explores whether the Bitcoin price responds asymmetrically to interest rate policies. The influence of the interest rate on the Bitcoin price was assessed as negative and positive shocks. This work is the first to include various interest rate variables. In contrast to earlier studies that discovered a weak correlation between interest rates and the Bitcoin price or that found a rising interest rate has a positive impact on the Bitcoin price, in our work, it was concretely indicated a high connection between the interest rate and the Bitcoin price. First, the interest rate was divided into negative and positive real interest rates. Moreover, an interest rate spread between the treasury security rate and the federal funds rate was considered for the analysis. This shows that a negative real interest rate creates a more significant influence than a positive real interest rate. Additionally, when the gap between the treasury security rate and the federal funds rate becomes larger, the Bitcoin price is significantly influenced. Both results indicate that a low interest rate policy or a negative real interest rate has a positive impact on the Bitcoin price. As a consequence, the Bitcoin price could be analyzed by selecting new variables to indicate different results. It is expected that this paper will provide new work for policymakers, portfolio managers, and investors to assess movements in the Bitcoin price by considering the interest rate in the US. Our work sheds light on the relationship between interest rate policy and cryptocurrency markets. It also contributes to other studies that looked at how interest rates affect the financial market.

3. Assumptions and Data Collection

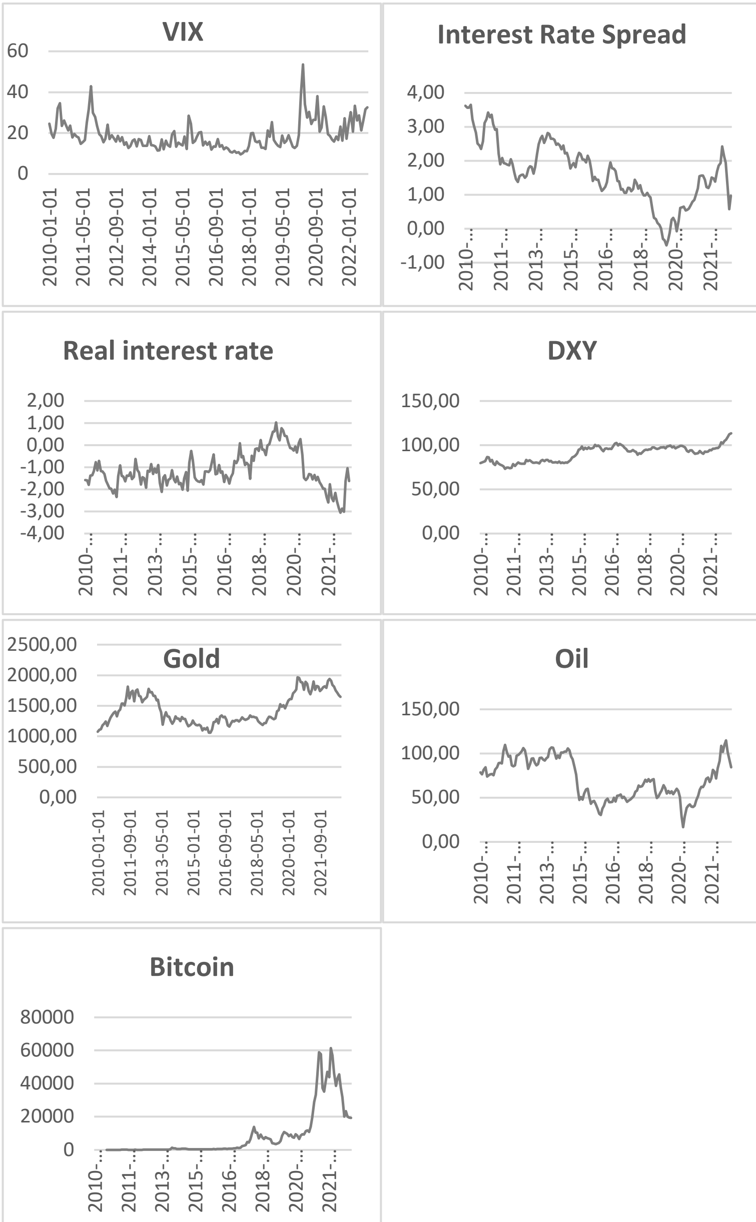
The selection of the variables for the study is supported by a number of assumptions. Uncertainty can indicate a higher risk in the market. Thus, similar to conventional assets, it is assumed that cryptocurrencies can be impacted by rising fear and uncertainty. The VIX can be an indicator of uncertainty and implied volatility in the market. The connection between the Bitcoin price and the VIX can show that cryptocurrencies are speculative assets and vulnerable to panic in the financial market. It was found that Bitcoin could be influenced by global economic policy uncertainty. Thus, Bitcoin cannot always be considered to hedge policy uncertainty (Qin et al., 2021). Hasan et al. (2022) pointed out that cryptocurrency policy uncertainty can determine the movements of the Bitcoin price. Wang et al. (2022a) also indicated that economic policy uncertainty negatively impacts the Bitcoin price. Thus, it cannot be said that Bitcoin acts as a hedge or safe-haven asset. The VIX has a determining power in the financial world to assess how an asset can be influenced by rising fear. Therefore, the VIX was included in the analysis.

Exchange rates can influence the Bitcoin price. Bitcoin can have some features of fiat currencies and can have hedging behavior (Majdoub et al., 2021). Hui et al. (2020) mention that Bitcoin behaves between fiat currency and a crypto-commodity used for trading and investments. It is a global variable. Its value cannot be limited to interest rate policy in the US. Bitcoin investors are not only residents of the US. Some measures of interest rate spread between the U.S. and the rest of the world could be considered. This is a limitation of the work. As an alternative, the developments in the rest of the globe might be captured using the exchange rate of the US dollar against a basket of major currencies. As a result, DXY was chosen as a currency basket indicator. DXY increases indicate appreciation, while drops indicate depreciation in exchange rate.

The other aspect of Bitcoin can be defined by its comparison with gold. Analyzing the relationship between the gold price and the Bitcoin price can help understand whether the cryptocurrency can be a safe haven (Wen et al., 2022). It was stated that an increase in the Bitcoin price undermined the hedging ability of the gold price, and a decrease in the Bitcoin price caused the gold price to rise (Su et al. 2020). It has also been examined that the gold price keeps its position as a traditional safe haven, whereas the Bitcoin price is positively influenced when there is less uncertainty in the market (Long et al., 2021). Gold was also found to be a better diversifier than Bitcoin (Pho et al., 2021). Political and economic stress can negatively impact the safe haven property of Bitcoin (Aharon et al., 2021). This suggests that both assets act oppositely in the market. If there is a connection between the two variables, then it can be said that the gold price plays an explanatory role in the Bitcoin price. Janson and Karoubi (2021) analyzed whether Bitcoin shows the features of a store of value. It was found that there was a cointegration relationship between Bitcoin, Gold, and the Swiss Franc. Baur and Dimpfl (2021) pointed out that Bitcoin could not function as a medium of exchange because of its high volatility, but it displayed a store of value characteristics in the long term. Hence, it can be said that Bitcoin can have a relationship with the gold price. Thus, the gold price was considered for the analysis.

Cryptocurrencies do not have physical identities. They exist in digital platforms. To reach these markets, electricity, and internet connections are necessary. Additionally, it is assumed that cryptocurrencies consume a huge amount of energy for the mining process. Hence, the oil price can be a strong indicator of the Bitcoin market. Some studies have found a connection between oil prices and Bitcoin prices (Li et al., 2022; Lin and An, 2021; Moussa et al., 2021; Dutta et al., 2020; Okorie and Lin, 2020; Jin et al., 2019). The oil price is a large indicator of cost in the energy sector. The markets require substantial energy because of mining processes and transactions (Huynh et al., 2022). Rising energy prices can also be an indicator of increasing prices of Bitcoin. Furthermore, higher energy prices can be a risk for mining because of rising costs. As a consequence, the oil price must be included in the analysis.

Figure 1 Representation of the Variables



Economic policies can change investor sentiments in markets. Cryptocurrencies are highly globalized, and it is very easy to reach these assets through the internet and smartphones. Interest rate policy can influence investment decisions around the world. Hence, it is assumed that the interest rate can be a significant tool that can change the perception of investors for cryptocurrencies. In particular, the real interest rate should be taken into account. Rising the real interest rate can reduce the demand for coins. Additionally, decreasing the real interest rate can lessen yield and can make cryptocurrencies more attractive. Blau et al. (2021) pointed out that there was a connection between Bitcoin and inflation. Bitcoin could be used as a hedge against inflation. It is known that the main determinant of interest rate policy is inflation. In this work, it is assumed that a low real interest rate can create a positive change in the Bitcoin price. As a result, a high inflation rate will increase risk, which will also push the security rate up. To control inflation, the central bank can intervene in the market by rising interest rates. This means high inflation will cause a low real interest rate that will change the direction of investments toward cryptocurrency markets. The interest rate spread is derived from the difference between the security rate and the federal funds rate. When the gap widens between the two variables, it can mean that there is a possibility that a large difference will emerge between interest rate and inflation. This can cause rising demand for cryptocurrencies until the interest rate starts increasing and catching up with inflation.

All variables were collected as monthly data between January 2012 and October 2022. Figure 1 illustrates the movements in the variables over the period. This time period was taken into account because the beginning of the 2010s was when Bitcoin started becoming popular in financial markets. The VIX, DXY, the gold price, and the Bitcoin price were derived from investing.com. All other indicators were collected from the Federal Reserve Bank of St. Louis. The oil price is based on West Texas Intermediate (WTI) US dollars per Barrel. The security rate is derived from Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity. The federal funds rate is used to obtain the interest rate spread. This suggests that when the federal funds rate decreases, it can stimulate inflation. Thus, the security rate can increase as a response. In other words, the gap between the two variables will be widened. When the real interest rate based on securities decreases or becomes negative in the market, it can positively impact cryptocurrencies. The inflation expectation is used to estimate the real interest rate. For the details of the data sources, see Table 1A in the Appendix. According to the assumptions, the variables are described as follows:

Vix : The CBOE's Market Volatility Index
Irs : Interest rate spread ($Security\ rate - Federal\ funds\ rate$)
Rir : Real interest rate ($Security\ rate - Inflation\ expectation\ rate$)
DXY : US dollar index
$Gold$: Gold price XAU/USD
Oil : Oil price
Btc: Bitcoin price BTC/USD

In econometric analyses, $Gold$, Oil, and Btc were taken in logarithmic form.

4. Empirical Analysis

4.1 Unit Root Tests

The commonly used methods to test for the presence of unit roots in the series are the Augmented Dickey–Fuller (ADF, 1981) or Phillips-Perron (PP, 1988) tests. However, Perron (1989) argues that the ADF test is biased toward the nonrejection of the unit root null hypothesis in the presence of a broken trend. Zivot and Andrews (1992), Perron (1997), and Vogelsang and Perron (1998) recommend unit root tests that allow for structural breaks to be determined endogenously from the data. To check the stationarity of the variables in a robust manner, three alternative unit root tests, augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Vogelsang-Perron (WP), were used.

The unit root test results are reported in Table 1. According to the table, a different result was obtained for only the negative and positive real interest rates at the 5% significance level when the ADF and PP tests were considered. The integrated order for the negative and positive real interest rates are obtained as one for both the breakpoint unit root test and the ADF unit root test, whereas they are determined as zero by the PP unit root test. All series except the VIX are obtained as non-stationary at the 1% significance level in all unit root test results. The integrated order for the VIX is obtained as zero in all unit root test results. The results indicate that the integrated order of each variable except the VIX is one. These results show that all series except the VIX are stationary in the first difference, while the VIX is stationary in level.

Table 1 Unit Root Test Results

	Augmented Dickey-Fuller (ADF)		***Phillips-Perron (PP)***		***Breakpoint Unit Root Test (Vogelsang and Perron, WP)***	
Variable	**t-Statistic**	**p-value**	**Adj. t-Stat**	**p-value**	**t-Statistic**	**p-value**
Vix	−5.06	0.0000	−5.06	0.0000	−6.44	0.0000
Btc	−1.40	0.5799	−3.01	0.0361	−3.20	0.5658
ΔBtc	−9.24	0.0000	−9.24	0.0000	−11.20	0.0000
$Gold$	−1.97	0.2990	−1.93	0.3168	−3.22	0.5544
$\Delta Gold$	−13.27	0.0000	−13.33	0.0000	−14.09	0.0000
Oil	−2.04	0.2682	−2.06	0.2628	−3.17	0.5864
ΔOil	−9.51	0.0000	−9.03	0.0000	−10.93	0.0000
DXY	−0.84	0.8045	−0.40	0.9058	−3.43	0.4262
ΔDXY	−7.82	0.0000	−12.84	0.0000	−13.28	0.0000
Irs	−2.49	0.1191	−2.34	0.1616	−3.49	0.3909
ΔIrs	−9.15	0.0000	−8.75	0.0000	−9.55	0.0000
$Prir$	−2.18	0.2164	−4.61	0.0002	−4.05	0.1408
$\Delta Prir$	−6.33	0.0000	−14.69	0.0000	−7.17	0.0000
$Nrir$	−1.63	0.4668	−3.18	0.0233	−4.33	0.0700
$\Delta Nrir$	−6.62	0.0000	−20.31	0.0000	−15.96	0.0000

Notes: Exogenous variable is only constant. Appropriate lag length for ADF and WP tests has been selected using Akaike information criterion (AIC) for a maximum lag of 12 periods. Appropriate Newey-West bandwidth for PP unit root tests is selected using Bartlett kernel. Break date is selected by using Dickey-Fuller min-t.

4.2 Testing Symmetry: Slope-Based Test

There are three approaches for asymmetric specification in the literature. These are asymmetric specification (Mork, 1989), scaled specification (Lee et al., 1995), and net specification (Hamilton, 1996). The aim of this study is to investigate the claim that the effect of a positive shock in the interest rate while the real interest rate is negative ($Nrir_t$) and the positive shock in the interest rate while the real interest rate is positive ($Prir_t$) is asymmetrical. Therefore, it would be more appropriate to use the Mork (1989) approach for asymmetric specification in the study.

The asymmetric specification by using the Mork (1989) approach is defined as follows:

$$Prir_t = \begin{cases} Rir_t & if\ Rir_t > 0 \\ 0 & otherwise \end{cases} \text{ and } Nrir_t = \begin{cases} Rir_t & if\ Rir_t \leq 0 \\ 0 & otherwise \end{cases} \quad (1)$$

Policymakers, portfolio managers, and investors consider the real interest rate in the market. Considering the nominal interest rate and inflation separately cannot create a convincing result for the analysis. Basher and Sadorsky (2022) mentioned that inflation is not a strong predictor of the Bitcoin price. This suggests that Bitcoin is not a good hedging asset for inflation. Many researchers will wonder about the real interest rate which determines many economic dynamics, and decision-making processes. However, descriptive data indicates in which period the interest rate is low and inflation is high. Therefore, in this research, the real interest rate was separated as negative when the inflation was higher than the interest rate and as positive when the interest rate was higher than inflation. Hence, there is no need for a special separation to indicate whether inflation or nominal interest rate is effective. This research shows that a positive shock toward the negative real interest rate will mean a fight started against inflation. As it happened in the US, when the nominal interest rate was low and inflation was rising due to COVID-19, it was clear that the Bitcoin price was high because the interest rate was lower compared with inflation. To take measures against inflation, the FED started increasing interest rate.

The null hypothesis, which claims that the effect of the negative and positive real interest rates on the Bitcoin price is symmetrical, can be tested by the following equations using the symmetry approach of Kilian and Vigfusson (2011):

$$Rir_t = b_{10} + \sum_{i=1}^{p} b_{11,i} Rir_{t-i} + \sum_{i=1}^{p} b_{12,i} Btc_{t-i} + \varepsilon_{1t} \quad (2)$$

$$Btc_t = b_{20} + \sum_{i=0}^{p} b_{21,i} Rir_{t-i} + \sum_{i=1}^{p} b_{22,i} Btc_{t-i} + \sum_{i=0}^{p} g_{21,i} Rir_{t-i}^{-} + \varepsilon_{2t} \quad (3)$$

The first equation of the resulting encompassing model is identical to the first equation of a standard linear VAR in Rir_t and Btc_t, but the second equation now includes both Rir_t and Rir_{t-i}^{-} and, as such, both positive real interest rate and negative interest rate affect Btc_t. Given estimates of these coefficients, one can calculate the dynamic responses to unanticipated positive and negative real interest rates. The OLS residuals of the above model are uncorrelated. This means that the model can be estimated by standard regression methods (Kilian and Vigfusson, 2011).

The test of all symmetry restrictions on the slopes involves the null hypothesis

$$H_0: g_{21,0} = g_{21,1} = \cdots = g_{21,p} = 0 \tag{4}$$

The second equation of the above model can be estimated by least squares and uses a Wald test to determine whether including $(Rir_{t-i}^{-})_{i=0}^{p}$ improves the fit of the model. This modified slope-based test has an asymptotic χ_{p+1}^{2} distribution. It can be shown that this test has a similarly accurate size but may have higher power than Mork's test (1989), making it useful to consider both types of slope-based tests (Kilian and Vigfusson, 2009).

The p value corresponding to the chi-square test statistic with the modified test of symmetric slope coefficients by using a 12-lag VAR model was found to be 0.0262. The null hypothesis, which indicates that slope-based symmetry is valid, can be rejected at the 5% significance level. This result indicates that the effect of the positive shocks in the real interest rate on the Bitcoin price differs when the real interest rate is negative or positive, and therefore, the relationship between the Bitcoin price and the real interest rate is asymmetrical.

4.3 SVAR Model

A vector autoregressive (VAR) model can be defined as a reduced form of a structural VAR model. SVAR models are based on additional identifying assumptions for building contemporary relations among endogenous variables. These assumptions require institutional knowledge, economic theory, or other extraneous constraints. These are designed according to the model's responses. The orthogonalization of the reduced-form residuals (the innovation terms of a VAR model) is performed by applying either recursive Cholesky decomposition or non-recursive structural factorization. The orthogonalization by Cholesky decomposition means that a particular causal chain is implemented rather than learning about causal relationships from the data. This mechanical solution does not make economic sense without a plausible economic interpretation for the recursive ordering (Kilian, 2013). A SVAR model by using structural factorization applies economic theory to sort out the contemporaneous links among variables (Bernanke, 1986; Blanchard and Watson, 1986; Sims, 1986). SVAR models require identifying assumptions that allow correlations causally to be interpreted. These identifying assumptions can include the entire VAR. Thus, all of the causal links can be spelled out, or just a single equation, so that only a specific causal link is identified in the model (Stock and Watson, 2001).

VIX shocks are not affected contemporaneously by other variable shocks, but its shocks have an effect contemporaneously on the shocks of other variables except interest rate spread. Thus, the VIX is an exogenous factor (Lucey et al., 2022; Wang et al., 2022b). Interest rate spread shocks have an effect contemporaneously on the shocks of other variables except for the VIX. Moreover, interest rate spread shocks are affected by only negative and positive real interest rate shocks. There is no contemporaneous relationship between negative and positive interest rate shocks. Their shocks are affected by the VIX and interest rate spread shocks, and they have a contemporaneous effect on the shocks of other variables except for the VIX. The exchange rate (DXY) is contemporaneously affected by the VIX, interest rate spread, negative real interest rate, and positive real interest rate, while it affects the prices of gold, oil, and Bitcoin contemporaneously.

Gold price shocks are affected contemporaneously by the VIX, interest rate spread, negative and positive real interest rate shocks, its shocks have an effect contemporaneously only on Bitcoin price shocks. Otherwise, there is not a contemporaneous relationship between gold and oil price shocks. As gold price and oil price shocks also have an effect contemporaneously only on the Bitcoin price, its shocks are affected contemporaneously by the VIX, interest rate spread, negative and positive real interest rate shocks. Moreover, Bitcoin price shocks are affected contemporaneously by all of the other variable's shocks (Basher and Sadorsky, 2022; Raheem, 2021). In other words, the Bitcoin price is an endogenous variable that is affected by other all variables in the VAR model.

Under these assumptions, the SVAR model identified with non-recursive short-term restrictions can be used. To examine the asymmetric impacts of the real interest rate on the Bitcoin price, their structural shocks can be used to generate variance decomposition and impulse response functions for the Bitcoin price.

The results of the unit root test imply that all series except the VIX are stationary in the first difference at a 1% level of significance, the VIX is stationary in the level at 1% significant level. The short-term analysis is conducted by using the SVAR model in the stationary form. Under these restrictions, a structural VAR model with A and B matrices can be specified as below:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & a_{23} & a_{24} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 & 0 & 0 \\ a_{41} & a_{42} & 0 & 1 & 0 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & 0 & 0 & 0 \\ a_{81} & a_{82} & a_{83} & a_{84} & a_{85} & a_{86} & a_{87} & 1 \end{bmatrix} \begin{bmatrix} e_t^{Vix} \\ e_t^{\Delta Irs} \\ e_t^{\Delta Nrir} \\ e_t^{\Delta Prir} \\ e_t^{\Delta DXY} \\ e_t^{\Delta Gold} \\ e_t^{\Delta Oil} \\ e_t^{\Delta Btc} \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & b_{77} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & b_{88} \end{bmatrix} \begin{bmatrix} u_t^{Vix} \\ u_t^{\Delta Irs} \\ u_t^{\Delta Nrir} \\ u_t^{\Delta Prir} \\ u_t^{\Delta DXY} \\ u_t^{\Delta Gold} \\ u_t^{\Delta Oil} \\ u_t^{\Delta Btc} \end{bmatrix}$$

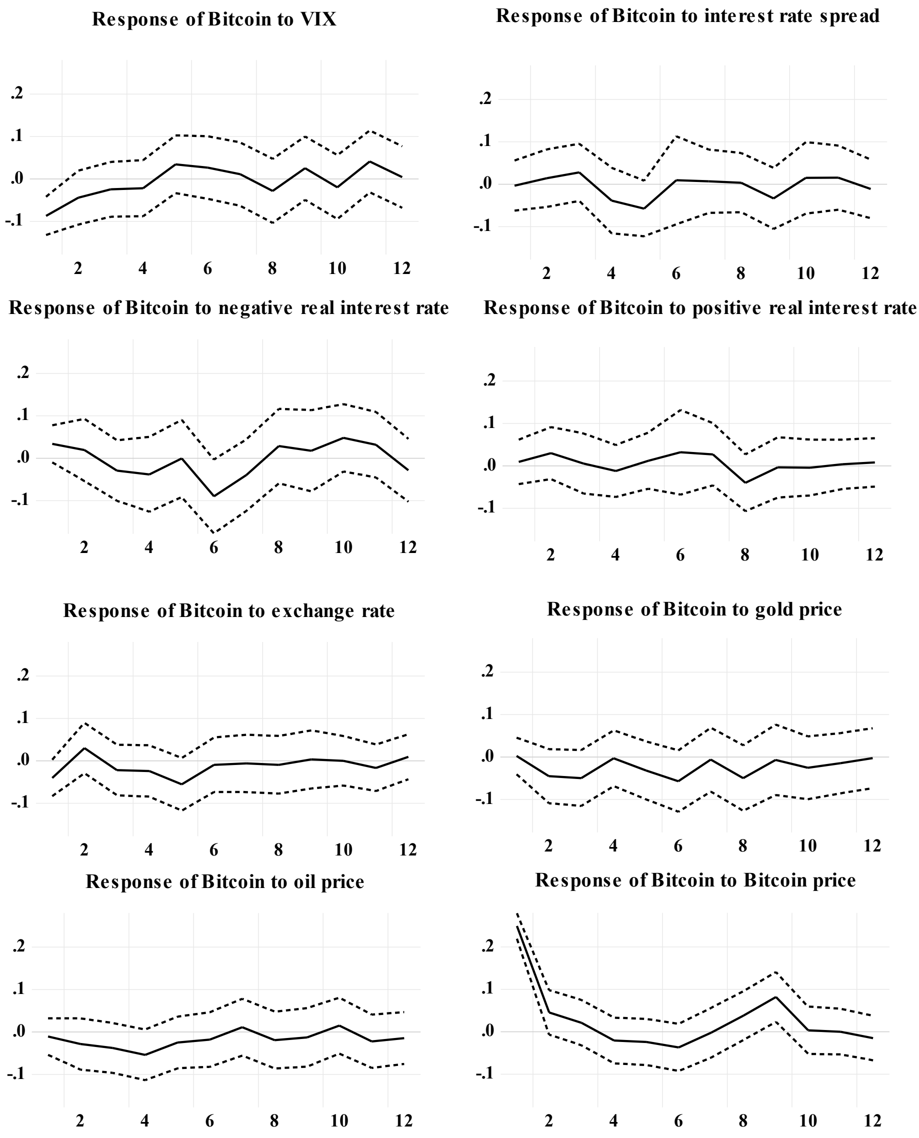
The optimal lag of the VAR model is determined as 8 by using sequential modified LR test statistic at 5% level. Before constructing the SVAR model, identification needs to be checked. There are seven variables in our SVAR model. To satisfy exact identification, $2K^2 - \frac{1}{2}K(K+1) = 92$ restrictions are needed, where K is the number of variables. However, for this study, there are 105 restrictions. This shows that the SVAR model has over identification problem and the availability of over identification for this model must be controlled. Since the SVAR model is over-identified, the likelihood ratio (LR) test for over-identification is also reported. The p-value for the LR statistic was found to be 0.0382, null hypothesis which indicates that over-identification is valid, is not rejected at 1% significant level. However, the null hypothesis that "the autocorrelation is not present in k-lags" is not rejected at 5% level of significance at 1 to 8 lags. According to White heteroskedasticity tests, the null hypothesis is not be rejected at 5% level of significance. These test results showed that there were no autocorrelation and heteroskedasticity for the residuals in the VAR (8) model whose parameters were estimated.

4.4 Impulse Response Functions

Figure 2 indicates the response of the Bitcoin price to the variables. The response of the Bitcoin price to structural one standard deviation positive innovations was estimated. Impulses are the VIX, interest rate spread, negative real interest rate, positive real interest rate, the gold price, and the oil price. According to the figure, the response of the Bitcoin price to the VIX was negative and statistically significant for the first and second months. This means that the VIX creates a negative influence on the Bitcoin price and vice versa. In other words, when the VIX increases, the Bitcoin price declines. Bitcoin cannot be considered safe heaven, as it can be negatively affected by panic in the financial market.

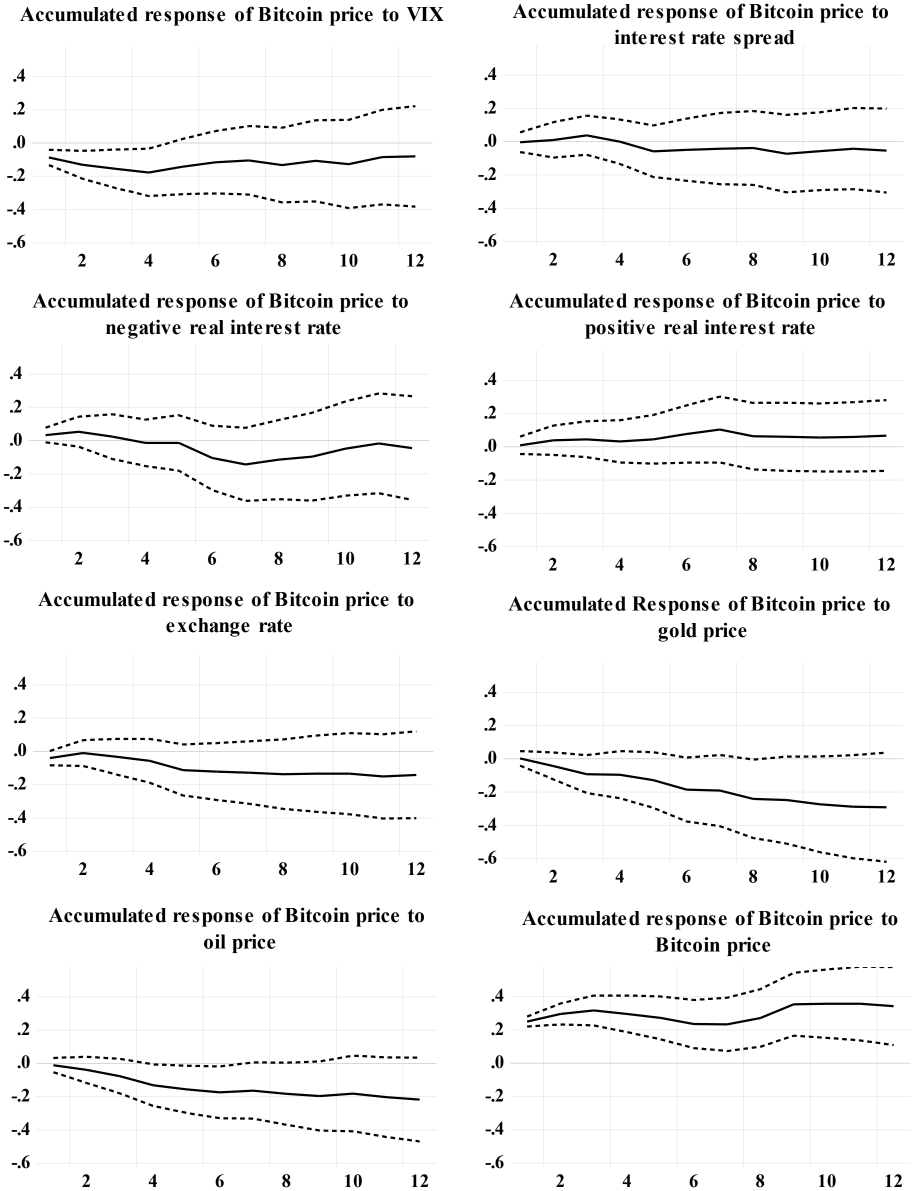
The response of the Bitcoin price to the negative real interest rate was insignificant in the early months. However, its response to the negative real interest rate became negative and significant only during the mid-term. As a consequence, the negative real interest rate significantly influences the Bitcoin price for a short period of time. The impulse response functions predict that, in terms of positive shock innovations, the Bitcoin price would increase if the real interest rate were to turn negative. In other words, when interest rates fall, Bitcoin becomes more popular. Nonetheless, it takes just one month for the Bitcoin price's response to a negative real interest shock to become statistically noteworthy. As a result, the findings only offer weak evidence in favor of any impact of a negative real interest rate on the Bitcoin price. The responses of the Bitcoin price to interest rate spread, positive real interest rate, DXY, the gold price, and the oil price were insignificant for the entire period of time. The response of Bitcoin to itself was initially positive and statistically significant. However, this did not last long. It became insignificant after the third month. This means that the Bitcoin price has an influence on itself in the short term. A high Bitcoin price generates expectations of a high Bitcoin price. The effect of positive shocks in real interest rates on the Bitcoin price was explored using impulse response functions. A positive shock innovation in the negative real interest rate is greater than one in the positive real interest rate. The findings from this research indicate that the effect of positive shock innovations in interest rates on the Bitcoin price is asymmetrical.

Figure 2 Response of the Bitcoin Price to Structural One Standard Deviation Positive Innovations



Notes: Y-axis shows responses and X-axis shows monthly periods.

Figure 3 Accumulated Response of the Bitcoin Price to Structural Positive Innovations ± 2 S.E.



Notes: Y-axis shows responses and X-axis shows monthly periods

Figure 3 shows the cumulative responses of the Bitcoin price to other variables. The figure also illustrates long-term shocks. The cumulative response of the Bitcoin price to the VIX was found to be negative and statistically significant for the first four months. This result shows that the positive shock in the VIX on the Bitcoin price in the first four months continued significantly in a negative direction, and its effect disappeared from the fifth month. The cumulative effect of the positive shock in the oil price on the Bitcoin price was found to be statistically significant in the third, fourth, and fifth months, and the effect was negative. Additionally, it was determined that the cumulative effect of the positive shock in the Bitcoin price on its own price remained statistically significant from the first to the twelfth month. The cumulative effect of the Bitcoin price on its price is positive for all forecast periods. The cumulative responses of the Bitcoin price to positive shocks in other variables were found to be statistically insignificant. The results obtained show that the VIX negatively affects the Bitcoin price in the short term, while the oil price and its own price are effective in the long term.

4.5 Variance Decomposition

Table 2 indicates the results of the forecast error variance decomposition analysis for the Bitcoin price. The results were reported for a 12-month period. In the first month, the VIX caused a high influence on the Bitcoin price. The explanatory share of the VIX was 10.38%. This share increased slightly in the following forecast periods to 10.74% in the 12th month. This result shows that the VIX's influence on the Bitcoin price is quite high in the short term, and this increases slightly in the long term.

The influence of interest rate spread was barely apparent in the first month. It was approximately 0.02%. Over the months, its explanatory share significantly increased. It reached 5.09% in the 12th month. These results show that the interest rate spread has no influence on the Bitcoin price in the short term, but its role rises in the long term. Negative and positive real interest rates did not cause a large influence on the Bitcoin price in the first month. Their shares were 1.59% and 0.12%, respectively. The power of the negative real interest rate significantly rose to 3.95% in the fourth month. It became the largest source of change in the Bitcoin price compared with the other variables over the months. Its role in the Bitcoin price became 12.43% in the 12th month. The effect of the positive real interest rate on the Bitcoin price was 1.21% in the fourth month. Its share increased slightly more in the following periods. Its influence reached only 3.19% in the 12th month. The explanatory share of DXY was approximately 2.23% in the first month. Its share picked at 6.27% in the fifth month. In the 12th month, its influence decreased to 4.85%.

The roles of the gold price and the oil price on the Bitcoin price indicate different patterns. The gold price constituted an important position in changes in the Bitcoin price. Its influence was only approximately 0.01% in the first month. It peaked at approximately 8.60% in the eighth month but decreased to 8.17% in the 12th month. The importance of the oil price in explaining the Bitcoin price became more significant over the months. This is because oil is a commodity that is used for mining and daily energy consumption. It is demanded at a determined price level. It can also be stocked. Therefore, it is assumed that it creates a more significant change in later periods. Its influence on the Bitcoin price was quite low at approximately 0.16% in the first month. The importance of the oil price in explaining the Bitcoin price became more significant over the months. Its explanatory share reached 5.56% in the fifth month. Its influence slightly decreased to 5.23% in the 12th month. The explanation of the Bitcoin price by itself fell from 85.50% in the first month to 50.31% in the 12th month. Its role remained significantly high. This indicates that the Bitcoin price is also influenced by expectation, but its importance decreases over the months. As a consequence, these results show that both the gold price and the oil price can affect the Bitcoin price in the long term. Additionally, the influences of negative and positive real interest rates on the Bitcoin price are asymmetrical. A negative real interest rate has a greater power on the Bitcoin price compared with a positive real interest rate.

Table 2 Results of Variance Decomposition for the Bitcoin Price

Period	*Vix*	*Irs*	*Nrir*	*Prir*	*DXY*	*Gold*	*Oil*	*Btc*
1	10.38	0.02	1.59	0.12	2.23	0.01	0.16	85.50
2	11.55	0.25	1.87	1.20	3.08	2.51	1.14	78.39
3	11.30	1.09	2.67	1.14	3.38	5.09	2.65	72.67
4	10.91	2.55	3.95	1.21	3.72	4.71	5.49	67.47
5	11.02	5.41	3.58	1.23	6.27	5.23	5.56	61.70
6	10.25	4.82	9.75	1.92	5.58	7.26	5.14	55.27
7	10.14	4.76	10.79	2.47	5.49	7.14	5.13	54.08
8	10.15	4.49	10.79	3.55	5.24	8.60	5.12	52.05
9	9.95	5.01	10.32	3.33	4.91	8.08	4.92	53.48
10	9.95	5.03	11.65	3.26	4.78	8.32	4.94	52.08
11	10.84	5.05	12.02	3.18	4.84	8.25	5.14	50.68
12	10.74	5.09	12.43	3.19	4.85	8.17	5.23	50.31

4.6 Sensitivity Analysis

4.6.1 Ordering Variables

In VAR models, various restriction methods based on existing theory and model preferences have been employed. Some empirical studies identify the VAR model through the commonly used Cholesky decomposition of orthogonalized reduced-form disturbances. On the other hand, a generalized method with non-recursive structures (defined as SVAR), which impose restrictions only on contemporaneous structural parameters, has been used by some empirical studies (e.g., Sims, 1986; Bernanke, 1986; Blanchard and Watson, 1986; Kim and Roubini, 2000). Cholesky decomposition is used to identify the economic shocks and impulse response functions of interest. Since there is not enough theory to determine a correct ordering for the variables, the ordering is essentially arbitrary. The ordering of the variables in the VAR matters for the results in a recursively identified model with zero restrictions on the impact effects. In other words, a different ordering of the variables might produce different outcomes with respect to impulse responses. Structural VAR is a restriction VAR based on the relevant theory. The theory used in the model should be sourced from previous research or put forward by the expert. The biggest theoretical difference between the SVAR and the VAR model is that the variable ordering of the former is determined by the subjective judgment of the researcher in processing the contemporaneous problems of random shocks. Different ordering may lead to different results. Hence, the VAR model, which is not based on theory, cannot be used to obtain only a set of impulse response functions. On the contrary, when processing the contemporaneous problems of random shocks, the SVAR model must limit the time-ordering relationship according to economic theory to obtain the only set of impulse response functions. Therefore, a specified structural VAR model is not affected by the ordering of variables.

4.6.2 Lag Selection

For the sensitivity analysis, a different lag was considered for the research. The maximum lag is 12, while the appropriate lag length is estimated as 12 by the AIC. The variance decomposition for the Bitcoin price obtained using lag 12 is given in Table 3 and the results of impulse response functions are shown in Figure 4. According to the variance decomposition analysis, the explanatory share of interest rate spread was 0.29% in the first month and its effect significantly increased to 13.77% in the 12th month. The influence of the negative real interest rate also significantly rose from 1.36% to 6.67% over the months. The role of the negative interest rate becomes more important in the long term. The explanatory share of the positive interest rate did not indicate significant change. It was 4.96% in the first month and it became 5.88% in the 12th month. The impact of the VIX showed lower influence compared with the analysis according to lag selection with the LR test. Its effect was 2.06% in the first month. Then, it increased to 4.13%. Nevertheless, all the determinants of the interest rate still constituted the largest change in the Bitcoin price together.

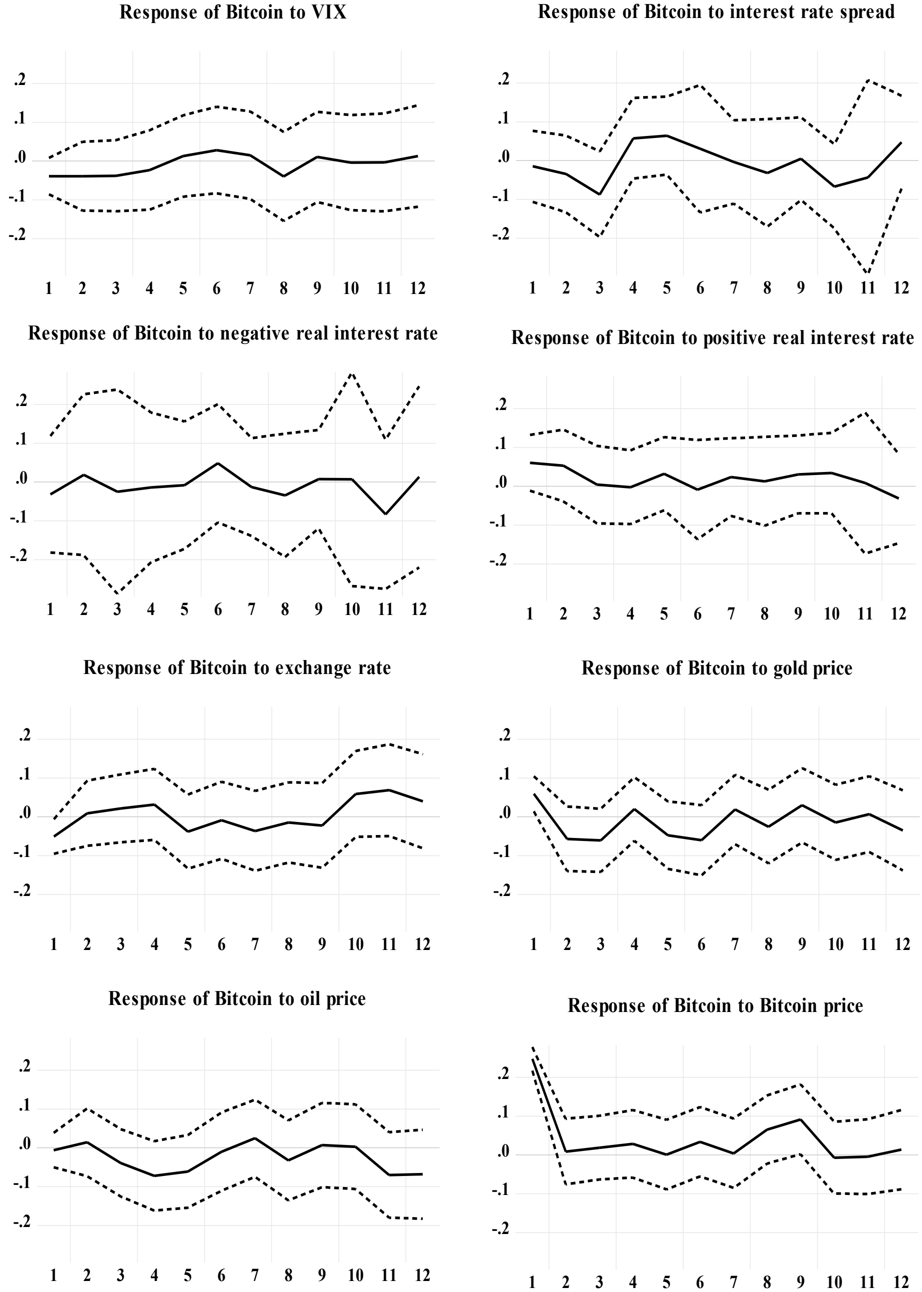
Figure 4 shows that the Bitcoin price only had a statistically significant negative response to the exchange rate for the first month. In other words, the Bitcoin price is negatively impacted by the appreciation in the exchange rate. In the first month, the response to the gold price was positive and statistically significant. In the beginning, Bitcoin's response to itself was positive and statistically significant, but after the second month, it lost its significance. Throughout the whole time span, the responses of the Bitcoin price to other factors were not significant.

Table 3 Results of Variance Decomposition for the Bitcoin Price

Period	*Vix*	*Irs*	*Nrir*	*Prir*	*DXY*	*Gold*	*Oil*	*Btc*
1	2.06	0.29	1.36	4.96	3.47	4.81	0.05	83.01
2	3.64	1.69	1.62	7.80	3.17	8.12	0.28	73.66
3	4.52	9.08	1.98	6.59	3.14	10.54	1.77	62.38
4	4.54	11.12	1.96	5.90	3.74	9.81	6.32	56.61
5	4.20	13.32	1.81	6.13	4.53	10.61	8.67	50.73
6	4.51	13.12	3.44	5.77	4.28	12.63	8.15	48.11
7	4.57	12.81	3.48	6.04	5.14	12.59	8.40	46.97
8	5.34	12.61	4.05	5.73	4.93	12.16	8.54	46.64
9	5.04	11.74	3.80	5.93	4.90	11.88	7.98	48.74
10	4.76	13.75	3.62	6.30	6.71	11.33	7.53	46.01
11	4.29	13.38	6.98	5.70	8.60	10.22	9.42	41.40
12	4.13	13.77	6.67	5.88	8.92	10.26	11.25	39.14

According to the findings, the negative real interest rate continued to have a greater influence than the positive real interest rate in the long term. The sensitivity analysis also found that the interest rate spread became more important over the period. The largest movement in the Bitcoin price was still caused by all of the interest rate factors combined. Nevertheless, the impulse response functions showed that the negative real interest rate's impact on the Bitcoin price had totally disappeared.

Figure 4 Response of the Bitcoin Price to Structural one Standard Deviation Positive Innovations



5. Policy Implications

This work attempted to understand the connection between the Bitcoin price and real interest rate shocks. Therefore, three indicators of the interest rate were considered for the analysis. The interest rate spread was derived as a gap between the US Treasury Securities 10-year maturity rate and the federal funds rate. According to the variance decomposition, it was revealed that the interest rate spread was a source of change in the Bitcoin price. The greater the gap between the two variables is widened, the more Bitcoin is influenced in the long term. When the federal fund rate decreases, it can be a sign of rising inflation in the market. It is a policy for countries to support economic growth through a lower real interest rate. However, a declining interest rate could stimulate inflation as well. This phenomenon emerged in the US in the 2000s. Lower interest rates supported consumption and credits. As a consequence, inflation started rising in the economy, which finally pushed the interest rate up. The nominal interest rate is a significant determinant of the real interest rate. Nevertheless, it is also true that when there is a lower interest rate, it can be accompanied by rising inflation due to rising money supply (e.g., before the 2008 crisis and the COVID-19 period). Hence, inflation is not considered as a proxy but as a natural result of a lower interest rate. A lower interest rate environment gives a sign for markets to forecast inflation in the future. As a consequence, the interest rates of other instruments, such as securities, could start rising. This can widen the gap between the federal rate and the security rate. An increasing gap can emerge due to the high level of inflation.

Explaining the determinants of the Bitcoin price is still a question in financial analysis. This issue is still new and there is still an important research gap to understand this digital asset. Therefore, it cannot be assumed that a single variable will explain a large part of the coin. To strengthen our claim, other global variables are taken into account as well. Compared with these variables, the negative real interest rate shocks constituted the largest explanatory share in the long term according to the variance decomposition analysis. Moreover, its effect significantly increased over the periods and reached 12.4% explanatory share. In addition, even if it is barely significant, the response of the Bitcoin price to the negative real interest rate is negative and statistically significant in the sixth month. This result supports our findings from the variance decomposition analysis that the response of the Bitcoin price to the negative real interest rate becomes significant in the long term. The effect of the real interest rate is taken into account as a shock rather than as a change. Therefore, a positive shock to the negative real interest rate can indicate a policy starting to deal with rising inflation. Under this condition, the Bitcoin price can be affected as a negative real interest rate becomes dominant in the economy. A negative real interest rate creates the largest source of change in the Bitcoin price. This means that the economic policy that stimulates inflation can also cause a negative real interest rate. As a consequence, the Bitcoin price starts rising. The variance decomposition indicates that although the influence of a positive real interest rate becomes more significant in the long term, its effect is not larger than that of a negative real interest rate. All analyses also indicate that there is a weak relationship between the gold price and the Bitcoin price. This means that the Bitcoin price cannot be considered as a strong safe haven. Additionally, the VIX indicates that Bitcoin is vulnerable to panic in the financial market.

This work finds different results than many works in the literature. This indicates that the Bitcoin policy is sensitive to the economic policies of the government or central bank. In particular, when the interest rate and inflation are considered, it can be seen that the Bitcoin price can be significantly influenced by these factors. This paper is intended to provide a guide for policymakers, portfolio managers, and investors. A high inflation environment and low interest rate translate into greater Bitcoin trade. As interest rate policy influences future inflation rates, this can change the direction of investments. Policymaking can create a significant long-term consequences for Bitcoin investments. From a practical perspective, the findings can create significant implications for the financial market. Echoing a high interest rate policy by the Federal Reserve creates a perception that the negative real interest rate will be decreased. This policy can make Bitcoin unattractive and can create important effects on investments in cryptocurrency markets. Demystifying Bitcoin can stop losses of assets and protect investments.

As of July 2020, monthly real interest rates for the US have always remained negative. This period corresponds to the period of the COVID-19 pandemic. During this period, the US central bank lowered interest rates, and as a result, real interest rates remained negative. However, as of March 2022, the US central bank has started to raise interest rates due to high inflation. In other words, while the real interest rate was negative, it started to give positive shocks to the interest rate. Therefore, this study implicitly reflects the impact of the COVID-19 pandemic period.

6. Conclusions

In this paper, the asymmetric effects of the interest rate on the Bitcoin price were analyzed by using monthly data between January 2012 and October 2022. It aimed to explain whether the Bitcoin price is influenced by the interest rate policy in the US. Three forms of interest rates were included in the analysis. These are interest rate spread, which is derived from the gap between the US Treasury Securities rate and the federal funds rate, negative real interest rate, and positive real interest rate, which are calculated through inflation expectation. Moreover, four other variables, the VIX, DXY, the gold price, and the oil price, were also taken into account.

The results of forecast error variance decomposition indicated that the VIX caused a larger change in the Bitcoin price in the early months. However, its effect did not significantly increase over the period. The interest rate spread gained more importance for explaining the change in the Bitcoin price in the long term. The effect of the oil price became more significant in the long term. Although DXY and the gold price also indicated high influence until the mid-term, the importance of DXY started decreasing later on. Impulse response functions showed that there was no statistically significant relationship between interest rate spread, positive real interest rate, DXY, the gold price, the oil price, and the Bitcoin price. The VIX created a negative and significant relationship with the Bitcoin price. However, this continued for a few months. The variance decomposition indicated that the negative real interest rate became the most significant variable that explained the Bitcoin price in the long term. A positive real interest rate also indicated rising significance, but its effect remained lower than that of a negative real interest rate. Moreover, the impulse response functions provide that the negative real interest rate becomes positive and significant in the mid-term period. The cumulative responses of the Bitcoin price to shocks of other variables indicated that the VIX negatively affects the Bitcoin price in the short term, while the oil price and its own price are more effective for explaining Bitcoin in the long term. The cumulative responses of the Bitcoin price to positive shocks in other variables were estimated to be statistically insignificant.

As a result, the Bitcoin price is negatively influenced by the VIX, and it does not indicate a strong relationship with gold and oil. This means that the Bitcoin price cannot be assessed as a safe haven. Bitcoin is a speculative asset that is in demand when risk appetite rises or when the VIX declines. Additionally, the research indicates that the Bitcoin price can be affected by interest rate policy. In particular, a negative real interest rate can be a decisive factor in explaining the Bitcoin price. In other words, when the negative real interest rate is reduced, this can make Bitcoin an unattractive option or vice versa.

This research has some limitations to be addressed. For the analysis, different methods and techniques could be used to assess the influence of COVID-19 periods on interest rate policy. Moreover, a proxy can be used for the rest of the world to understand the impact of their economic policies on the Bitcoin price. The volatility of the Bitcoin price can be determined by Bitcoin-specific news (Lyocsa et al., 2020). In other words, the price can be influenced by speculations. It could be important to conduct further research on this determinant. Different and related variables can be included in the analysis. Additionally, the work can be extended by using other cryptocurrencies.

APPENDIX

Table 1A Data Sources

Data	***Source***
Bitcoin (BTC/USD)	investing.com
VIX (CBOE's Market Volatility Index)	investing.com
DXY (US dollar index)	investing.com
Gold price (US Dollars per Troy Ounce)	investing.com
Federal funds rate	Federal Reserve Bank of St. Louis
Security rate (10-Year Constant Maturity)	Federal Reserve Bank of St. Louis
Inflation expectation (1-Year)	Federal Reserve Bank of St. Louis
Oil price (WTI)	Federal Reserve Bank of St. Louis

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