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Does Sentiment Impact Cryptocurrency?

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ABSTRACT

This study examines the impact of investor sentiment on cryptocurrency returns. We use a direct survey-based measure that captures the investors' sentiment on Bitcoins. This direct measure of Bitcoin investor sentiment is obtained from the Sentix database. The results of the study found that the Bitcoin prices experience appreciation when investors are optimistic about Bitcoin. Bitcoin sentiment has significant power in predicting the Bitcoin prices after controlling for the relevant factors. There is also evidence that the sentiment of the dominant cryptocurrency, i.e., Bitcoin, influences the price of other cryptocurrencies. Further, we extend our analysis by investigating the impact of equity market sentiment on cryptocurrency returns. We proxy equity market sentiment using two measures viz: Baker-Wurgler sentiment Index and the VIX Index. When the equity market investors' sentiment is bearish, cryptocurrency prices rise, indicating that cryptocurrency can act as an alternative avenue for investment. Our results remain unaffected after controlling for potential factors that could impact cryptocurrency prices.

KEYWORDS

Investor sentiment; Bitcoin sentiment; Sentix; Equity market sentiment; Bitcoin; Cryptocurrency

1. Introduction

The traditional economic theory states that investors are rational. They argue that markets are efficient, and the asset prices reflect all the information. If the asset prices move away from their intrinsic value, the arbitrage process will converge them back to their fundamentals (Fama 1970). However, behavioral economic studies have shown that investors are not entirely rational, so asset prices are affected by their sentiment, emotions, and beliefs. Black (1986) found that noise traders trade on noise rather than information, which drifts the price away from the fundamentals. The actions of arbitrageurs cannot move the prices back toward the fundamentals due to limits to arbitrage (Shleifer and Summers 1990). Thus, investor psychology has a significant role in the asset markets.

The cryptocurrency market has achieved widespread attention since the introduction of Bitcoins in 2008 (Nakamoto 2008). The number of altcoins[1] has surged from a single cryptocurrency in July 2010 to 2419 cryptocurrencies in Feb 2020. The total market capitalization of cryptocurrencies has increased from $1.6 billion in April 2013 to $278 billion in February 2020 (Global Charts 2021, source:www.coinmarketcap.com). The cryptocurrency market is decentralized and unregulated, as opposed to centralized fiat currency. Investors' expectations drive the demand for cryptocurrency, and these are increasingly becoming attractive, with investors choosing them to diversify their portfolios (Subramaniam and Chakraborty 2020). Cryptocurrencies are relatively young, highly volatile, and prone to frequent shocks. It is challenging to value cryptocurrencies as there are no underlying fundamental factors (Cheah and Fry 2015). The characteristics of cryptocurrency are similar to speculative stocks(Baker and Wurgler 2006), so the investors' perceptions and sentiments are likely to drive their prices (Corbet et al. 2019; Celeste, Corbet, and Gurdgiev 2018).

The earlier studies investigated the impact of sentiment on cryptocurrency prices using various proxies such as Google search trends (Panagiotidis, Stengos, and Vravosinos 2018), Wikipedia search results (Kristoufek 2013), news sentiment (Karalevicius, Degrande, and De Weerdt 2018), Twitter sentiment (Kraaijeveld and De Smedt 2020), and cryptocurrency blog sentiment (Ahn and Kim 2020). We use a novel data set that captures the investors' sentiment on Bitcoins. This direct measure of Bitcoin investor sentiment is obtained from the Sentix database (www.Sentix.de) accessed through Bloomberg. It is captured through surveys of global traders, individuals,

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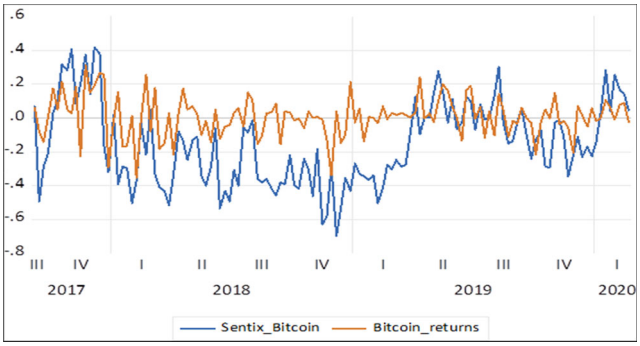

Figure 1. Illustration of movement of Bitcoin returns with weekly survey based Sentix Bitcoin Sentiment Index.

institutional investors, analysts, asset managers, and the likes. More than 5000 investors from over 20+ countries participate in the survey. The Sentix Bitcoin Sentiment Index represents the market expectations of investors over one month. It reflects the sentiment of investors toward Bitcoins, which fluctuates between fear and greed. Figure 1 graphs the Bitcoin returns and Sentix Bitcoin sentiment index. The graph indicates that Bitcoin returns move in tandem with the sentiment.

The study aims to investigate the impact of bitcoin sentiment on bitcoin prices and extends to other cryptocurrency prices. Apart from interlinkages within the cryptocurrency market, the equity market also plays a significant role in influencing the cryptocurrency market. The study of Bouri et al. (2017a) found that bitcoin acts as a diversifying asset against the equity market. Thus, the equity market sentiment would impact the cryptocurrency prices which are documented in studies of Gurdgiev and O'Loughlin (2020) and Jareño et al. (2020). Based on the previous research, we extend the study to investigate the impact of equity market sentiment on the cryptocurrency market. The equity market sentiment is proxied by the Baker-Wurgler sentiment index (BW) and the VIX index (See Figures A1 and A2 in the Appendix).

The result of the study suggests that Sentix Bitcoin sentiment has a positive impact on the Bitcoin returns, indicating that sentiment plays a significant role in determining its prices. Further, for the other cryptocurrencies, we find that the Bitcoin sentiment significantly influences the returns of Ethereum, Ripple, Litecoin, and Bitcoin-Cash (See Figure A3 in the Appendix). With respect to Equity market sentiment, BW Sentiment Index has a negative impact on Bitcoin returns. The VIX index used as a proxy for the fear in the equity market has a positive influence on the Bitcoin, Ethereum, and Litecoin returns. The results indicate that bearish sentiment and fear in the equity market seem to lead investors to diversify and invest in alternative avenues such as the cryptocurrency market.

Our study contributes to the existing literature in the following ways. First, we use a direct measure that captures the Bitcoin investor sentiment. The past studies have used various proxies such as Google trends, Wikipedia search, Twitter sentiment, news sentiment, and cryptocurrency blogs to measure the investor sentiment in the cryptocurrency market. These studies capture the investor's attention toward cryptocurrencies, which is an indirect measure to capture the investor sentiment. Our study uses a Bitcoin-specific survey-based sentiment index that is new to the existing literature. Second, we analyze the information spillover from Bitcoin to other cryptocurrency prices. Since Bitcoin is the most dominant and influential one in the cryptocurrency market, we seek to analyze the influence of Bitcoin sentiment on altcoins. To the best of our knowledge, this is the first study that examines the Bitcoin sentiment impact on the other cryptocurrencies' prices. Third, this study is among the few studies to examine the impact of equity market sentiment on cryptocurrency prices. Previous studies found the diversification and hedging properties of bitcoin against the world equity markets. Gil-Alana, Abakah, and Rojo (2020) found bilateral linkages between the major stock market indices and the cryptocurrency market. Bouri, Hussain Shahzad, and Roubaud (2020) showed that cryptocurrency acts as a hedge against the Equity market. They found that Bitcoin, Ripple, Stellar, Litecoin, and Monero have a negative relationship with the U.S. market-wide equity Index. Hence, our study extends the literature and examines the impact of equity market sentiment on cryptocurrency prices.

The remaining of the paper is structured as follows: Section 2 discusses the existing literature and theoretical background about investor sentiment and factors affecting the cryptocurrency market. Section 3 describes data and methodology, Section 4 discusses empirical results, and Section 5 concludes.

2. Literature review and hypothesis development

2.1. Investor sentiment in asset markets

The efficient market hypothesis (EMH) proposes that the market prices reflect all the available information (Fama 1970; Samuelson 1973). However, studies in behavioral economics have given evidence that financial markets are inefficient, and market prices are affected by investors' cognitive biases. Brown and Cliff

(2004) studied the impact of investor sentiment on the stock market. They found that the aggregate investors' sentiment measure strongly co-moves with the stock market returns. Baker and Wurgler (2006) developed a measure of Equity market sentiment using a top-down approach. Their study revealed that sentiment has a more pronounced effect on speculative stocks such as young, volatile, non-dividend paying, low profitability, and growth stocks. Tetlock (2007) developed a news media sentiment and found that media pessimism leads to downward pressure on the equity market prices. Da, Engelberg, and Gao (2015) used a novel Financial and Economic Attitudes Revealed by Search (FEARS) Index to investigate the influence of sentiment on the stock returns. Their study found that the sentiment impacts the stocks that are difficult to arbitrage. This emphasizes the importance of sentiment and bias in investor decision-making and asset pricing.

Many studies have found the cryptocurrency market to be inefficient (Urquhart 2016; Nadarajah and Chu 2017). Palamalai, Kumar, and Maity (2020) tested the random walk hypothesis in the cryptocurrency market and found it to be weak-form inefficient. They have shown evidence that prices do not follow the random walk model. They found the value of Bitcoin to be positively skewed, indicating that the market reacts more toward the good news than the bad news. Cheah and Fry (2015) found that Bitcoin is priced for its speculative component, and its fundamental value is zero. Gurdgiev and O'Loughlin (2020) show that investor sentiment can predict price movements indicating the impact of herding and anchoring biases. Urquhart (2016) also found evidence of inefficiency in the Bitcoin market. They argue that Bitcoin is relatively a new investment asset, and the cryptocurrency market is akin to an emerging market. Thus, it experiences inefficiency. Kristoufek (2013) measured the Bitcoin sentiments using Google and Wikipedia's search queries and found a significant bidirectional relationship between Bitcoin prices and sentiment. They also document that speculation and trend-chasing are dominant in Bitcoin prices. Oad Rajput, Soomro, and Soomro (2020) used Google search volume Index and built a Bitcoin Sentiment Index (BSI). Their study revealed a significant positive association of BSI on the Bitcoin returns and volume. Karalevicius, Degrande, and De Weerdt (2018) studied the interaction between media sentiment and Bitcoin prices and found that investors overreact to the news. Ahn and Kim (2020) quantified emotion using posts from a cryptocurrency blog and found sufficient evidence that emotions drive Bitcoin prices. Subramaniam and Chakraborty (2020) investigated investor attention's impact on cryptocurrency prices and found evidence of attention-induced price pressure in the cryptocurrency market.

The above literature suggests that optimistic sentiment toward Bitcoin is associated with a higher propensity by an investor to buy it or continue their investment holdings. On the other hand, pessimistic sentiment toward Bitcoin may lead to downward pressure on the prices. However, the literature used various indirect proxies to capture the Bitcoin sentiment. This study uses a direct survey-based measure of investor sentiment toward Bitcoin. We formulate the following hypothesis, which suggests that bullish Bitcoin sentiment leads to higher prices, and bearish Bitcoin sentiment leads to lower prices.

Hypothesis 1. Bitcoin experiences a price increase when the Bitcoin investor sentiment is bullish.

2.2. Information spillover in the cryptocurrency market

Past studies have found evidence of information spillover in the cryptocurrency market. Fry and Cheah (2016) found spillover from Ripple to the Bitcoin market. Corbet, Lucey, and Yarovaya (2018) provide evidence of interlinkages in the price discovery of Bitcoin and Ethereum. Kyriazis (2019) demonstrated strong interlinkages between Bitcoin, Ethereum, Litecoin, and Ripple. Yi, Xu, and Wang (2018) found that cryptocurrencies with high market capitalization are most likely to propagate volatility shocks in the market. In another study by Ji et al. (2019a, 2019b), there was evidence that shocks from Bitcoin and Litecoin affect other cryptocurrencies' returns. Aslanidis, Bariviera, and Perez-Laborda (2021) also found substantial linkages in the returns and volatility of cryptocurrencies. Kyriazis (2019) found that Bitcoin remains the most dominant cryptocurrency and net-transmitter in the cryptocurrency market. Thus, sentiment toward the dominant cryptocurrency, i.e., Bitcoin, may influence the price movement in other cryptocurrencies (See Figure A3 in the Appendix). We assume that optimistic sentiment toward Bitcoins will instill investors' confidence toward other cryptocurrencies, leading to increased prices. We formulate the following hypothesis to analyze the impact of Bitcoin sentiment on the return generating process of other cryptocurrencies.

Hypothesis 2. Altcoins experience a price rise when Bitcoin investor sentiment is optimistic.

2.3. Equity market sentiment and the cryptocurrency market

The past few years have witnessed considerable research regarding the importance of including cryptocurrency in a portfolio of stocks and other assets. Baur, Hong, and Lee (2018) found that Bitcoin is held for investment purposes, and it offers better diversification benefits compared to other asset classes both in normal times and tumultuous times. Kristoufek (2015) study revealed that cryptocurrency acts as a dual asset exhibiting financial and speculative asset features. Bouri et al. (2017a) reported that Bitcoin acts as a strong hedge against Japanese and Asia-pacific stocks' movements. Sarwar (2017) investigated the impact of uncertainty on the stock market. Their results show that investors tend to utilize cross-market hedging during high uncertainty periods. Dyhrberg (2016) provides evidence of Bitcoin's hedging capabilities against the Financial Time Stock Exchange Index (FTSE) and dollar. Thus, the stock market sentiment may influence cryptocurrency prices.

This study uses two proxies to capture the Equity market sentiment. First is the Baker-Wurgler Sentiment index (Baker and Wurgler 2006), a top-down approach to measuring sentiment. We assume that the BW sentiment will have a negative impact on cryptocurrency prices. When the equity market sentiment is low or pessimistic, investors seem to invest in cryptocurrency as an alternative asset to diversify the portfolio. The second proxy is the VIX Index by Chicago Board Options Exchange (CBOE). It is also regarded as the "Fear Index." Many studies have shown a significant impact of the VIX index on cryptocurrency prices. Bouri, Azzi, and Dyhrberg (2016) explored the hedging relationship of Bitcoin with VIX and found evidence that Bitcoin acted as a hedge before the Bitcoin-US Dollar price crash of 2013. Bouri et al. (2017b) show that the relationship is positive between Bitcoin returns and VIX of different countries during short investment horizons. Their result suggests that Bitcoin does act as a hedge against the stock market. We expect that VIX will have a positive relationship with cryptocurrency returns. If the VIX index is high, it implies high fear and anxiety in the equity market, causing investors to seek refuge in the cryptocurrency market. Thus, the extant literature guides the following hypotheses, suggesting the likely link between equity and the cryptocurrency market.

Hypothesis 3a. When Equity market sentiment (BW sentiment) is bearish, the cryptocurrency prices rise.

Hypothesis 3b. When the VIX (Fear Index of Equity market) increases, the cryptocurrency prices rise.

3. Data and methodology

3.1. Data

In this study, we first analyze the impact of Bitcoin sentiment on Bitcoin prices. The Bitcoin investor Sentiment Index data available on a weekly basis is obtained from the Sentix database (www.Sentix.de) accessed through Bloomberg terminal for the period September 2017 to February 2020. The Sentix surveys the investors' expectations on the Bitcoin prices through emails every Friday and publishes the investor sentiment index on Sunday. The participants include institutional and individual investors. The survey asks investors whether they expect the Bitcoin prices to remain bullish, bearish, or neutral over one month. The sentiment index's construction is as follows: Sentiment= (ΣBullish - ΣBearish)/ΣTotal participants. The value of the investor sentiment index ranges from −1 to 1.

The Sentix collects the investor expectations only for the dominant cryptocurrency, Bitcoin, and is not available for other cryptocurrencies. So, next, we investigate whether the Bitcoin sentiment influences the other cryptocurrency returns. For this purpose, we have chosen four altcoins, such as Ethereum, Ripple, Litecoin, and Bitcoin Cash, based on their market capitalization and data availability (Refer to Tables A1 and A2 in the Appendix).

We also study the U.S. equity market sentiment impact on cryptocurrencies. The equity market sentiment is captured using two proxies viz: Baker-Wurgler Sentiment Index (BW) obtained from http://people.stern.nyu.edu/jwurgler/ and Volatility Index (VIX) sourced from Thomson Reuters Eikon Database (TRED). The BW index is a monthly sentiment index, and the VIX is a daily index. The sample period varies across different cryptocurrencies depending upon their launch date and availability of the data. A detailed description of the sample period is appended in Table A1 in the Appendix.

The prices of cryptocurrencies denominated in USD are taken from TRED. The bid-ask spread, gold price, and S&P 500 index closing value is obtained from TRED. EPU is sourced from www.policyuncertainty.com. All variables are log-transformed and differenced (Refer to Table A3 in the Appendix).

The descriptive statistics of the weekly data series of all the variables are presented in Table 1.[2] The average returns of Bitcoin, Ethereum, and Ripple returns are positive, whereas the average Litecoin and Bitcoin cash returns are negative. The average Sentix Bitcoin sentiment is negative. The skewness is within

Table 1. Descriptive statistics of the variables.

	(1) Mean	(2) Median	(3) Max.	(4) Min.	(5) Std. Dev.	(6) Skewness	(7) Kurtosis	(8) Jarque-Bera	(9) p-values	(10) Outliers	(11) BDS
Sentix_Bitcoin	−0.158	−0.169	0.415	−0.7	0.244	0.31	2.452	3.678	0.159	No	0.071***
Bitcoin_Returns	0.006	0.006	0.312	−0.355	0.122	−0.227	3.517	2.54	0.28	Yes	0.008
Bitcoin_bidask	0.101	0	49.97	−49.97	8.49	−0.039	19.82	1520.659	0.000***	Yes	0.030***
Ethereum_Returns	−0.004	−0.006	0.129	−0.213	0.05	−0.573	5.322	36.051	0.000***	Yes	0.007
Ethereum_bidask	−2.642	0	6101.96	−6097.6	767.569	0.017	62.807	19225.59	0.000***	Yes	0.062***
Ripple_Returns	0.002	−0.008	1.142	−0.48	0.192	2.182	13.982	750.64	0.000***	Yes	0.025**
Ripple_bidask	−0.002	0	1.031	−0.9	0.172	0.899	21.348	1826.903	0.000***	Yes	0.096***
Litecoin_Returns	0	0.009	0.812	−0.337	0.159	1.043	7.516	133.029	0.000***	Yes	−0.004
Litecoin_bidask	−0.497	0	180.22	−82.32	22.683	3.455	34.691	5654.869	0.000***	Yes	0.059***
BitcoinCash_Returns	−0.003	−0.001	0.917	−0.643	0.221	0.944	7.133	110.118	0.000***	Yes	0.011
BitcoinCash_bidask	−4.74	0.01	5854.53	−5846.19	1002.003	0.02	29.894	3857.553	0.000***	Yes	0.062***
EPU	0.036	0.012	0.563	−0.579	0.205	0.098	2.935	0.23	0.891	Yes	−0.005
Gold_Returns	0.002	0.001	0.041	−0.031	0.014	0.247	3.213	1.559	0.458	Yes	−0.004
S&P_Returns	0.001	0.002	0.021	−0.032	0.009	−0.998	5.176	46.894	0.000***	Yes	0.042***

This table provides the descriptive statistics of all the variables(weekly series). Jarque-Bera tests the normality of the series. Brock, Dechert, Sheinkman and LeBron (BDS) tests the linearity of series. Rejection of null hypothesis at 1%,5%, and 10% levels are denoted by ***,**, and *.Sentix_Bitcoin is Sentix Bitcoin Sentiment, Bitcoin_Returns is Bitcoin returns, Bitcoin_bidask is change in Bitcoin bid ask spread, Ethereum_Returns is Log differenced Ethereum returns, Ethereum_bidask is change in Ethereum bid ask spread, Ripple_Returns is Log differenced Ripple returns, Ripple_bidask is change in Ripple bid ask spread, Litecoin_Returns is Log differenced Litecoin returns, Litecoin_bidask is change in Litecoin bid ask spread, BicoinCash_Returns is Log differenced Bitcoin Cash returns, BitcoinCash_bidask is change in Bitcoin Cash bid ask spread, EPU is Log differenced U.S. Economic Policy Uncertainty Index, Gold_Returns is Gold returns, and S&P_Returns is S&P 500 Index returns.

acceptable limits. However, there is excess kurtosis exhibited by all variables. The Jarque-Bera test rejects the normality in all variables except Gold Returns, Sentix Bitcoin Sentiment, Bitcoin Returns, and EPU. Except for Sentix, all other variables have the presence of outliers. Brock, Dechert, Sheinkman and LeBron (BDS) tests the linearity of series. We use the Augmented Dickey-Fuller Test to check for stationarity in the data series. The results present in Table A4 in the Appendix show that all the variables across monthly, weekly, and daily frequencies are stationary.

3.2. Methodology

We first study the relationship between the Bitcoin Sentiment and the Bitcoin returns as in *Hypothesis 1*. We regress the Bitcoin returns on the Sentix Bitcoin sentiment and lagged value of Bitcoin returns as shown in the equation below:

$$Bitcoin\_Returns_t = c + \beta_1 Bitcoin\_Returns_{t-1} + \beta_2 Sentix\_Bitcoin_t + e_t \quad (1)$$

We also control for other potential factors that may have a considerable effect on the prices. The macro-economic factors considered are the Economic Policy Uncertainty (EPU) Index of the U.S. to control the uncertainty prevailing in the economy (Jareño et al. 2020), gold returns to control the metal market factor (Bouoiyour and Selmi 2015), and S&P 500 returns to account for the financial market factor (Baur, Hong, and Lee 2018). The market participants play a significant role in determining the cryptocurrency prices. Further, cryptocurrencies are in the introductory life cycle stage. Hence market microstructure factors also influence cryptocurrency prices. Baek and Elbeck (2015) used bid-ask spread as a measure of liquidity, Urquhart (2016) used volume, Dimpfl and Peter (2020) used the number of transactions, and Celeste, Corbet, and Gurdgiev (2018) used volatility and found that these factors help in the price discovery process of cryptocurrency. Based on previous research, we consider bid-ask spread, the number of transactions, and volatility to control for market microstructure factor. However, due to multicollinearity issues, we could include only the bid-ask spread and dropped other variables.

Thus, the control variables are added to Eq. (1). The modified version is represented in Eq. (2) below:

$$\begin{aligned} Bitcoin\_Returns_t = {} & c + \beta_3 Bitcoin\_Returns_{t-1} \\ & + \beta_4 Sentix\_Bitcoin_t \\ & + \beta_5 Bitcoin\_bidask_t + \beta_6 EPU_t \\ & + \beta_7 Gold\_Returns_t \\ & + \beta_8 S\&P\_Returns_t + e_t \end{aligned} \quad (2)$$

Secondly, we study the impact of Bitcoin sentiment on other cryptocurrencies' returns as in *Hypothesis 2*. We regress the cryptocurrency's returns on the Sentix Bitcoin sentiment and lagged value of cryptocurrency returns as shown in the equation[3] below:

$$CryptoReturns_{i,t} = c + \beta_1 CryptoReturns_{i,t-1} + \beta_2 Sentix\_Bitcoin_t + e_t \quad (3)$$

We use similar control variables as in Eq. (2) for the other cryptocurrencies:

$$CryptoReturns_{i,t} = c + \beta_3 CryptoReturns_{i,t-1} + \beta_4 Sentix\_Bitcoin_t + \beta_5 CryptoBidask_{i,t} + \beta_6 EPU_t + \beta_7 Gold\_Returns_t + \beta_8 S\&P\_Returns_t + e_t \quad (4)$$

Lastly, we analyze the influence of equity market sentiment on the cryptocurrency market as in *Hypothesis 3a and 3b*. We use Baker-Wurgler Sentiment Index (BW) and the VIX Index to proxy Equity market sentiment. To capture Equity Market sentiment impact, we run the following equation[4]:

$$CryptoReturns_{i,t} = c + \alpha_1 CryptoReturns_{i,t-1} + \alpha_2 Equity\_market\_sentiment_{j,t} + \alpha_3 CryptoBidask_{i,t} + \alpha_4 EPU_t + \alpha_5 Gold\_Returns_t + \alpha_6 S\&P\_Returns_t + e_t \quad (5)$$

All equations are estimated using the Robust L.S. method[5].

4. Empirical findings and discussion

4.1. Impact of bitcoin sentiment on bitcoin returns

Table 2 presents the impact of Bitcoin sentiment on Bitcoin returns. The results in column (1) show that Sentix Bitcoin sentiment has a significant positive impact on Bitcoin returns. This implies that the Bitcoin prices experience appreciation when investors are optimistic about Bitcoin. This result is consistent with the findings of Baig, Blau, and Sabah (2019) and Gurdgiev and O'Loughlin (2020). They also found the significance of investor sentiment in predicting the direction of cryptocurrency prices.

Column 2 of Table 2 shows the impact of Sentix Bitcoin Sentiment on Bitcoin returns in the presence of control variables specified in Eq. (2). The significance of Sentix Bitcoin sentiment is found to be robust after including the control variables.

With respect to the control variables influencing the Bitcoin returns, only the lagged Bitcoin returns and Bitcoin bid-ask spread is found to be significant. It is interesting to note that the other control variables such as EPU, Gold returns, and S&P 500 index returns are found to be insignificant in impacting the Bitcoin returns. This result is consistent with the study of Baek and Elbeck (2015), who also found that Bitcoin returns are influenced only by the Bitcoin microstructure factors.

Table 2. Regression of Sentix Bitcoin Sentiment Index on Bitcoin Returns.

	(1) $Bitcoin\_Returns_t$	(2) $Bitcoin\_Returns_t$
Constant	0.025(0.005)	0.033(0.005)
$Bitcoin\_Returns_{t-1}$	−0.176**(0.082)	−0.203**(0.081)
$Sentix\_Bitcoin_t$	0.124***(0.018)	0.134***(0.018)
$Bitcoin\_bidask_t$	–	0.003***(0.001)
EPU_t	–	−0.023(0.019)
$Gold\_Returns_t$	–	0.187(0.284)
$S\&P\_Returns_t$	–	0.239(0.471)
R^2	0.237	0.283
Adj. R^2	0.225	0.287

Notes: This table presents the regression results of Eqs. (1) and (2). Columns 1 and 2 reports the results of Eqs. (1) and (2), i.e., the effect of Sentix Bitcoin sentiment on Bitcoin returns. Bitcoin_Returns is log-differenced Bitcoin returns, Sentix_Bitcoin is Sentix Bitcoin Sentiment Index, $Bitcoin\_bidask_t$ is change in Bitcoin bid-ask spread, EPU is Log differenced U.S. Economic Policy Uncertainty Index, Gold_Returns is Log differenced Gold returns, and S&P_Returns is Log differenced S&P 500 Index returns. Standard errors are within parenthesis. ***, **, and * denote the significance level at 1%, 5%, and 10%.

The study also suggested that the Bitcoin exchange participants majorly drive Bitcoin prices. As the competition and acceptability of Bitcoin improve, the linkages with the macroeconomic factors would be more evident.

4.2. Impact of bitcoin sentiment on other cryptocurrencies' returns

The results of Eqs. (3) and (4) are reported in Panel A and Panel B of Table 3. The Sentix Bitcoin sentiment has a positive impact on Ethereum, Litecoin, and Bitcoin Cash returns. The results confirm our *Hypothesis 2*. It establishes that there is information spillover within the cryptocurrency market. The dominant cryptocurrency, i.e., Bitcoin, influences the returns of other cryptocurrencies (Kyriazis 2019; Ji et al. 2019a, 2019b; Aslanidis, Bariviera, and Perez-Laborda 2021). Panel B of Table 3 presents the regression coefficients of variables specified in Eq. (4). The estimates reveal that the impact of Sentix Bitcoin Sentiment on Ethereum, Litecoin, and Bitcoin-Cash persists after controlling other factors. The results become significant for Ripple as well after the inclusion of all the control variables. The bid-ask spread has a significant positive impact on Ripple prices. However, the macro-economic factors are not significant for any of the altcoins similar to the evidence found for Bitcoin.

4.3. Impact of equity market sentiment on cryptocurrency returns

4.3.1. Baker-Wurgler equity market sentiment on cryptocurrency returns

Table 4 presents the impact of Equity market sentiment on the cryptocurrency returns as in Eq. (5).

Table 3. Regression of Sentix Bitcoin Sentiment Index on Cryptocurrency Returns.

	(1) $Ethereum\_Returns_t$	(2) $Ripple\_Returns_t$	(3) $Litecoin\_Returns_t$	(4) $BitcoinCash\_Returns_t$
Panel A				
Constant	0.002(0.005)	0.009(0.012)	0.034(0.013)	0.038(0.017)
$CryptoReturns_{i,t-1}$	0.157*(0.808)	0.033(0.054)	−0.138*(0.074)	−0.123*(0.066)
$Sentix\_Bitcoin_t$	0.031*(0.017)	0.140(0.043)	0.264***(0.048)	0.351***(0.060)
R^2	0.051	0.052	0.141	0.131
Adj. R^2	0.036	0.036	0.127	0.117
Panel B				
Constant	0.004(0.005)	0.014(0.013)	0.034(0.014)	0.039(0.018)
$CryptoReturns_{i,t-1}$	0.139*(0.082)	−0.006(0.073)	−0.178*(0.098)	−0.131*(0.068)
$Sentix\_Bitcoin_t$	0.029*(0.016)	0.142***(0.042)	0.264***(0.049)	0.348***(0.061)
$CryptoBidask_{i,t-1}$	−0.000(0.000)	0.228***(0.080)	0.000(0.001)	−0.000(0.000)
EPU_t	0.002(0.019)	−0.083(0.050)	−0.084(0.056)	−0.124(0.070)
$Gold\_Returns_t$	−0.380(0.285)	0.148(0.767)	0.541(0.839)	0.558(1.105)
$S\&P\_Returns_t$	−0.610(0.462)	−0.538(1.241)	1.466(1.373)	1.830(1.749)
R^2	0.073	0.098	0.16	0.157
Adj. R^2	0.027	0.053	0.119	0.116

Notes: This table presents the regression results of Eqs. (3) and (4). Columns 1, 2, 3, and 4 in Panel A report results of Eq. (3), i.e., the effect of Bitcoin sentiment on Ethereum, Ripple, Litecoin, and Bitcoin Cash, respectively. Columns 1,2,3, and 4 in Panel B report results of Eq. (4), i.e., the effect of Bitcoin sentiment in the presence of control variables on Ethereum, Ripple, Litecoin, and Bitcoin Cash, respectively. $CryptoReturns_{i,t-1}$ is cryptocurrency returns where i denotes each of the cryptocurrency and t denotes a week. $CryptoBidask_{i,t-1}$ is cryptocurrency bid-ask spread where i denotes each of the cryptocurrency and t denotes a week. Sentix_Bitcoin is Sentix Bitcoin Sentiment, $Ethereum\_Returns_t$ is log-differenced Ethereum returns, $Ripple\_Returns_t$ is log-differenced Ripple returns, $Litecoin\_Returns_t$ log-differenced Litecoin returns, and $BitcoinCash\_Returns_t$ is log-differenced Bitcoin Cash returns. The rest of the notations are as in Table 2. Standard errors are within parenthesis. ***, **, and * denote the significance level at 1%, 5%, and 10%.

Panel A of Table 4 shows the impact of Baker-Wurgler Equity market sentiment (BW) on cryptocurrency returns[6]. The BW sentiment has a negative impact on the Bitcoin returns confirming our *Hypothesis 3a*. This implies that when the investors are bearish in the equity markets, Bitcoin experiences an increase in prices, suggesting that bitcoin has the potential to be used as one of the diversifying assets against the stock markets. This result is consistent with the findings of Gurdgiev and O'Loughlin (2020); when investors are uncertain about the stock market, they seek to invest in other avenues like Bitcoin. However, this negative relationship is significant only for Bitcoin. Bitcoin is the most popular and highly recognized cryptocurrency. Hence, investors are swayed more toward Bitcoins as one of the diversifying assets during times of uncertainty than any other cryptocurrency, as evidenced by our results. Our results resonate with Yi, Xu, and Wang (2018), who also established in their study the dominance of Bitcoin in the cryptocurrency market. Qiao, Zhu, and Hau (2020) also showed in their study that the price movement in Bitcoins is much ahead of other cryptocurrencies.

4.3.2. VIX Equity market fear index on cryptocurrency returns

We further use the VIX Index as another equity market sentiment proxy. Panel B of Table 4 represents the impact of the VIX equity index on cryptocurrency returns. The results show that the VIX index has a significant and positive impact on Bitcoin, Ethereum, and Litecoin returns. It implies that when the VIX value increases, i.e., when there is fear in the stock market, investors seem to invest in cryptocurrency as one of the alternative assets. This leads to an appreciation in the cryptocurrency prices. This result is consistent with Dyhrberg (2016), Kristoufek (2015), and Bouri, Azzi, and Dyhrberg (2016), who found that investors can protect themselves from stock market price shocks using Bitcoin as a diversifying and hedging asset. Our results indicate that Bitcoin, Ethereum, and Litecoin are potential diversifying assets against the stock market when there is fear sentiment prevailing in the equity market.

4.4. Impulse response analysis

We employ impulse response functions[7] to examine the reaction of cryptocurrency returns' to the shocks of sentiment proxies' over time. The reaction period is plotted up to twenty periods for Sentix Bitcoin sentiment, which is weekly data; six-period for Baker Wurgler Sentiment, which is monthly data; and ninety periods for VIX, which has daily observations. Figures 2–4 presents the response of cryptocurrency returns to one standard deviation shock in Sentix Bitcoin Sentiment, Baker-Wurgler Sentiment, and the VIX Index, respectively. The middle line depicts the impulse response function, while the dotted lines are the 95% confidence interval bands. The impulse response to shock is statistically different from zero at a 5% significance level, where the confidence interval lines do not hover around the zero line.

Table 4. Regression of Equity Sentiment Index on Cryptocurrency Returns.

Panel A

	(1) $Bitcoin\_Returns_t$	(2) $Ethereum\_Returns_t$	(3) $Ripple\_Returns_t$	(4) $Litecoin\_Returns_t$
Constant	−0.020(0.035)	0.074(0.081)	−0.007(0.041)	−0.028(0.025)
$CryptoReturns_{i,t-1}$	−0.040(0.134)	0.005(0.172)	0.059(0.079)	0.242***(0.058)
BW_t	−0.557**(0.250)	−1.308(1.064)	−0.021(0.503)	−0.237(0.321)
$CryptoBidask_{i,t}$	0.001(0.015)	0.001*(0.001)	1.128***(0.130)	0.007***(0.001)
EPU_t	−0.317(0.354)	−0.286(0.844)	0.077(0.447)	−0.433(0.313)
$Gold\_Returns_t$	0.083(0.804)	4.252*(2.312)	2.438**(1.106)	−0.439(0.653)
$S\&P\_Returns_t$	3.667(2.401)	3.611(6.061)	−0.147(3.018)	−0.239(2.018)
R^2	0.151	0.253	0.305	0.319
Adj. R^2	0.051	0.116	0.199	0.243

Panel B

	(1) $Bitcoin\_Returns_t$	(2) $Ethereum\_Returns_t$	(3) $Ripple\_Returns_t$	(4) $Litecoin\_Returns_t$	(5) $BitcoinCash\_Returns_t$
Constant	0.001(0.000)	0.000(0.001)	0.002(0.000)	−0.000(0.001)	−0.002(0.001)
$CryptoReturns_{i,t-1}$	0.385***(0.010)	−0.069***(0.008)	−0.092***(0.009)	−0.074***(0.009)	−0.034**(0.014)
$VIX\_Returns_t$	0.014**(0.006)	0.031**(0.013)	−0.005(0.013)	0.019**(0.009)	0.009(0.016)
$CryptoBidask_{i,t}$	0.000***(0.000)	0.002***(0.000)	1.168***(0.000)	0.008***(0.000)	0.001***(0.000)
EPU_t	−0.007(0.004)	−0.008(0.015)	0.012(0.014)	0.003(0.011)	−0.020(0.018)
$Gold\_Returns_t$	0.121**(0.050)	0.116(0.101)	0.152(0.098)	0.100(0.069)	0.153(0.126)
$S\&P\_Returns_t$	0.052(0.048)	0.218**(0.112)	0.257**(0.114)	0.265**(0.087)	0.498***(0.118)
R^2	0.185	0.171	0.134	0.159	0.286
Adj. R^2	0.182	0.168	0.132	0.157	0.282

Notes: This table presents the regression results of Eq. (5). Columns 1,2,3, and 4 in Panel A report results of the effect of Baker-Wurgler Equity sentiment on Bitcoin, Ethereum, Ripple, and Litecoin respectively. We could not run a regression of Bitcoin Cash on Baker-Wurgler Equity Sentiment Index due to insufficient monthly data. Columns 1,2,3,4, and 5 in Panel B report results of the effect of VIX Equity sentiment on Bitcoin, Ethereum, Ripple, Litecoin, and Bitcoin Cash, respectively. BW is Baker Wurgler Sentiment Index, VIX_Returns is log differenced VIX Index Returns and Bitcoin_Returns is log-differenced Bitcoin returns. The rest of the notations are as in Table 3. Standard errors are within parenthesis. ***, **, and * denote the significance level at 1%, 5%, and 10%.

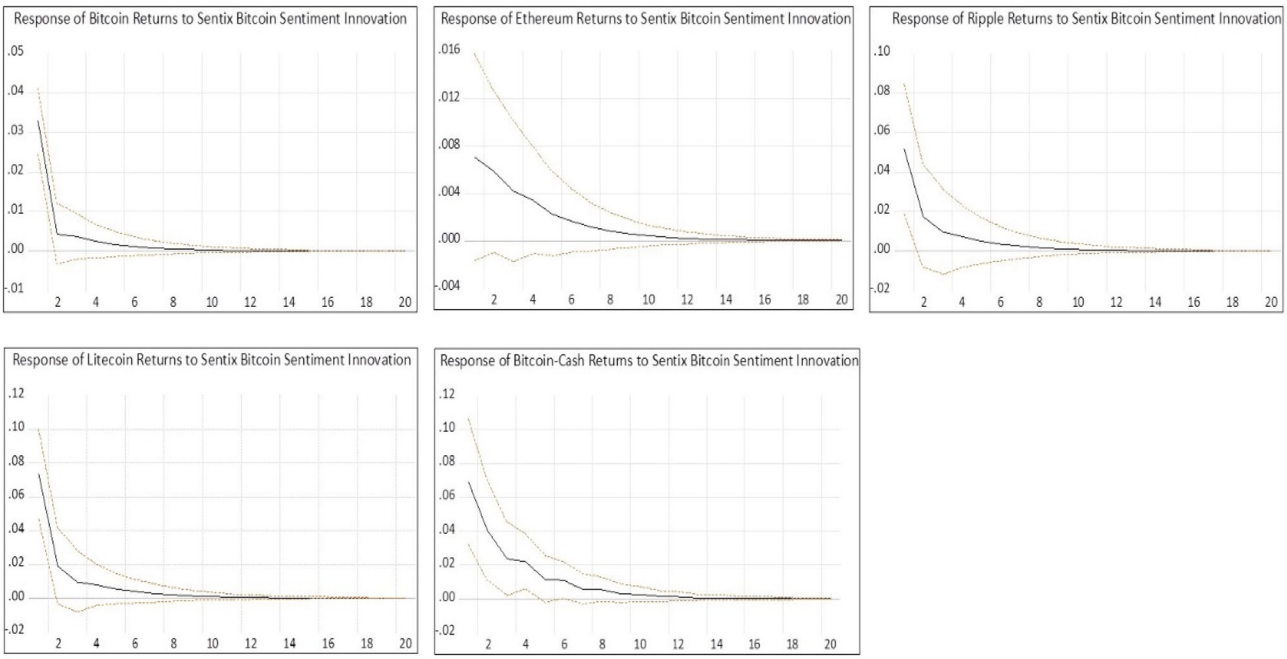

Figure 2. This figure plots the impulse response of cryptocurrency returns to one standard deviation innovations in Sentix Bitcoin sentiment. The middle line shows the Generalized impulse response function, and the dotted lines represent the ±2 standard error, i.e., 95% confidence interval.

Figure 2 depicts that the Sentix Bitcoin sentiment shock generates a positive response for Bitcoin up to eight periods, then converging toward zero beyond the tenth period. In the case of Ethereum, Ripple, Litecoin, and Bitcoin Cash, the Sentix Bitcoin sentiment shock generates a positive response up to twelve periods and converges to zero.

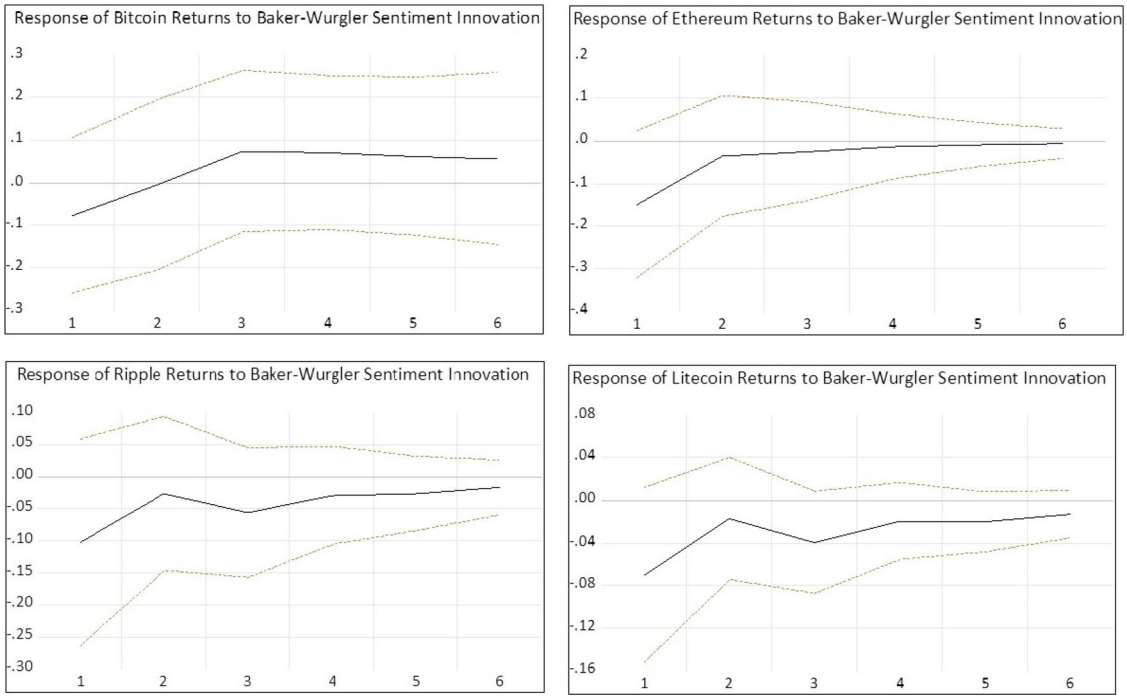

Figure 3. This figure plots the impulse response of cryptocurrency returns to one standard deviation innovations in Baker-Wurgler Sentiment. The middle line shows the Generalized impulse response function, and the dotted lines represent the ±2 standard error, i.e., 95% confidence interval.

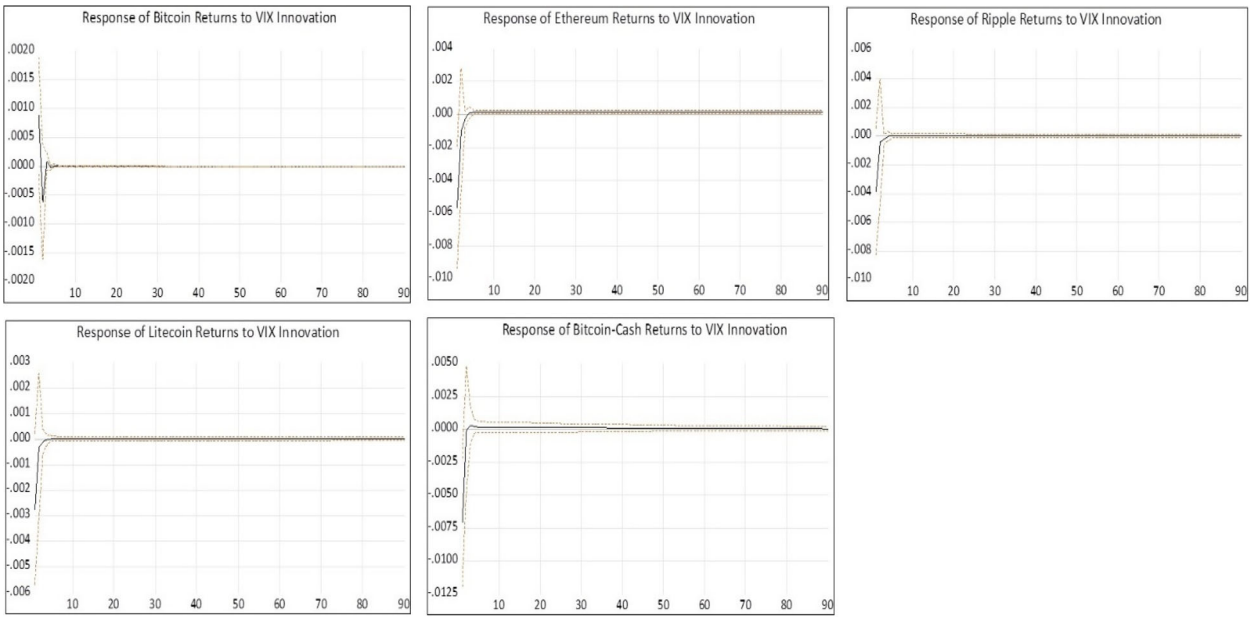

Figure 4. This figure plots the impulse response of cryptocurrency returns to one standard deviation innovations in VIX Index. The middle line shows the Generalized impulse response function, and the dotted lines represent the ±2 standard error, i.e., 95% confidence interval.

Figure 3 shows that the BW sentiment shock generates a negative response for Bitcoin for the first two periods, followed by positive fluctuations up to the sixth period. However, in the case of Ethereum, Ripple, and Litecoin, the BW sentiment shock generates a negative response up to six periods and then converges toward zero.

Figure 4 illustrates that the VIX Index impulse generates a positive response for Bitcoin for the first two periods, followed by a negative response third period onwards and finally converging toward zero near the tenth period. In the case of Ethereum and Ripple, the VIX generates a negative response up to period two, followed by a positive response in the third period,

and then converges to zero. The VIX Index is in daily frequency, so it may take time for the market to adjust. Therefore, we see a positive impact only after the second period. In the case of Litecoin and Bitcoin Cash, the VIX generates a negative response up to period two and then converges to zero. Thus, the results of the impulse response function show that the effect of sentiment reverses in subsequent periods as markets correct themselves after initial overreaction (Daniel, Hirshleifer, and Subrahmanyam 1998; Dellavigna and Pollet 2009; Smales 2014).

5. Conclusion

The inefficiencies in the cryptocurrency market motivated this study to analyze the behavioral aspect of their price discovery process. In our study, we use a direct survey-based Sentix measure capturing investors' sentiment toward Bitcoin to investigate the impact of investor sentiment on cryptocurrency returns. The results of the study found that Sentix Bitcoin sentiment has a positive impact on the Bitcoin returns supporting our hypothesis that behavioral aspects play a significant role in determining its prices. Further, with respect to altcoins, the returns of Ethereum, Ripple, Litecoin, and Bitcoin cash are significantly influenced by the Bitcoin sentiment indicating that there is information spillover from the dominant cryptocurrency to other cryptocurrencies.

Additionally, we investigate the impact of the equity market sentiment on cryptocurrency returns. Investors may diversify their position in alternative investments such as gold and cryptocurrency during times of financial fear and uncertainty. To proxy for the equity market sentiment, we use the Baker-Wurgler Sentiment Index and the VIX Index. The BW Sentiment Index has a negative impact on the Bitcoin returns. The VIX index used a proxy for the fear in the equity market is found to have a positive influence on the Bitcoin, Ethereum, and Litecoin returns. The results support our hypothesis that bearish sentiment and fear in the equity market seem to lead investors to invest in the cryptocurrency market as one of the alternative assets, thereby causing an increase in cryptocurrency prices. We also see the dominance of Bitcoin as a preferred alternative investment asset as compared to other cryptocurrencies. Investors are more attracted to Bitcoin during uncertain times as Bitcoin has the longest track record and the most secure network. The results remain robust after controlling for variables related to market microstructure, macro-economic uncertainty, metal market, and the financial market.

Our results contribute to the existing literature on the role of behavioral factors in determining cryptocurrency prices. The study will be helpful to multiple stakeholders. The findings of our study depict that Sentix Bitcoin Investor Sentiment has a significant influence on cryptocurrency prices. Thus, traders and investors may use Sentix Sentiment data and design trading strategies accordingly. The use of bitcoins as a possible diversifying asset against the stock market has increased (Dyhrberg 2016; Kristoufek 2015; Bouri et al. 2017a). It will be helpful for hedgers and investors to design their portfolios better. The cryptocurrency market is unregulated and highly speculative (Hameed and Farooq 2016). When the investor sentiment is exceptionally pessimistic or optimistic, there is a possibility of extreme movement in the prices. This study will help a country's sovereign authorities understand and assess the sentiment-induced cryptocurrency crisis and take necessary steps.

Notes

1. Altcoin refers to all cryptocurrencies other than Bitcoin.
2. The descriptive statistics of monthly and daily series are available on request.
3. This equation is representative of all cryptocurrencies. For example, to see the impact of Bitcoin sentiment on Ethereum, the equation would be $Ethereum\_Returns_t = c + \alpha_j Ethereum\_Returns_{t-1} + \alpha_k Sentix\_Bitcoin_t + e_t$
4. This equation is representative of both the Equity market sentiment proxies. For example, to see impact of Baker-Wurgler sentiment on Ethereum, the equation would be $Ethereum\_Returns_t = c + \alpha_j Ethereum\_Returns_{t-1} + \alpha_k BW_t + \alpha_m EPU_t + \alpha_n Gold\_Returns_t + \alpha_o S\&P\_Returns_t + e_t$
5. Due to the presence of outliers and heteroscedasticity (Refer Table A5 in the appendix), we use Robust-LS estimation method.
6. Baker- Wurgler sentiment Index are provided monthly. We could not run a regression of Bitcoin Cash on Baker-Wurgler Equity Sentiment Index due to insufficient monthly data.
7. We employ VAR to estimate Impulse Response Function.

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Appendix

Table A1. Market capitalization of Cryptocurrencies.

Name	Market Capitalization	Percentage share
Bitcoin	$175,114,812,896	63.07%
Ethereum	$28,209,394,308	10.16%
Ripple	$11,883,485,004	4.28%
Bitcoin Cash	$6,802,462,210	2.45%
Litecoin	$4,442,424,300	1.60%
Others	$51,198,940,063	18.44%
Total market capitalization of cryptocurrency market: $277,651,518,781		

Note: The table shows the market capitalization of cryptocurrencies and their share in the total cryptocurrency market capitalization as on February 21, 2020. Source: www.coinmarketcap.com.

Table A2. Sample Period.

	Launch Month and Year	Monthly Series	Weekly Series	Daily Series
Bitcoin	January 2009	30-07-2010 to 31-12-2018	08-09-2017 to 21-02-2020	19-08-2011 to 09-10-2020
Ethereum	July 2015	31-07-2015 to 31-12-2018	08-09-2017 to 21-02-2020	07-08-2015 to 09-10-2020
Ripple	June 2012	30-01-2015 to 31-12-2018	08-09-2017 to 21-02-2020	21-01-2015 to 09-10-2020
Litecoin	October 2011	29-11-2013 to 31-12-2018	08-09-2017 to 21-02-2020	24-10-2013 to 09-10-2020
Bitcoin Cash	August 2017	29-09-2017 to 31-12-2018	08-09-2017 to 21-02-2020	01-08-2017 to 09-10-2020

Table A3. Description of the variables.

Variables	Source	Description
BW	http://people.stern.nyu.edu/jwurgler/	Monthly series of Baker-Wurgler Sentiment Index.
Sentix_Bitcoin	www.sentix.de accessed via Bloomberg Terminal	Weekly series of Sentix Bitcoin Sentiment Index.
VIX_Returns	Thomson Reuters Eikon Database	Log difference of VIX index closing value, i.e., log of VIX index value at day t minus the log of index value on day t − 1.
$CryptoReturns_{i,t}$	–	Cryptocurrency returns, where i is each of the five cryptocurrencies, i.e., Bitcoin, Ethereum, Ripple, Litecoin, and Bitcoin Cash. And t is the time period.
$CryptoBidask_{i,t}$	–	Cryptocurrency bid-ask spread, where i is each of the five cryptocurrencies, i.e., Bitcoin, Ethereum, Ripple, Litecoin, and Bitcoin Cash. And t is the time period.
Bitcoin_Returns	Thomson Reuters Eikon Database	Log difference of Bitcoin price closing value, i.e., log of Bitcoin price index at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Bitcoin_bidask	Thomson Reuters Eikon Database	Change in Bitcoin spread, i.e., Bid-ask spread at time t minus the bid-ask spread at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Ethereum_ Returns	Thomson Reuters Eikon Database	Log difference of Ethereum price closing value, i.e., log of Ethereum price index at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Ethereum_bidask	Thomson Reuters Eikon Database	Change in spread of Ethereum, i.e., Bid-ask spread at time t minus the bid-ask spread at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Litecoin_Returns	Thomson Reuters Eikon Database	Log difference of Litecoin price closing value, i.e., log of Litecoin price index at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Litecoin_bidask	Thomson Reuters Eikon Database	Change in spread of Litecoin, i.e., Bid-ask spread at time t minus the bid-ask spread at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Ripple_Returns	Thomson Reuters Eikon Database	Log difference of Ripple price closing value, i.e., log of Ripple price index at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Ripple_bidask	Thomson Reuters Eikon Database	Change in spread of Ripple, i.e., Bid-ask spread at time t minus the bid-ask spread at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
BitcoinCash_Returns	Thomson Reuters Eikon Database	Log difference of Bitcoin Cash price closing value, i.e., log of Bitcoin Cash price index at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
BitcoinCash_bidask	Thomson Reuters Eikon Database	Change in spread of Bitcoin Cash, i.e., Bid-ask spread at time t minus the bid-ask spread at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
EPU	www.policyuncertanty.com	Log difference of EPU index, i.e., log of EPU index at time t minus the log of EPU index at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
Gold_Returns	Thomson Reuters Eikon Database	Log difference of Gold closing price, i.e., log of gold closing price at time t minus the log of price at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.
S&P_Returns	Thomson Reuters Eikon Database	Log difference of S&P 500 index closing value, i.e., log of index closing value at time t minus the log of index closing value at time t − 1, where t is a month, a week, or a day depending upon the Sentiment Proxy being used.

Table A4. Augmented Dickey Fuller test statistics.

	(Monthly)		(Weekly)		(Daily)	
	ADF t-statistic	p-value	ADF t-statistic	p-value	ADF t-statistic	p-value
BW	−4.026	0.001***				
Sentix_Bitcoin			−4.699	0.000***		
VIX_Returns					−52.28	0.000***
Bitcoin_Returns	−7.598	0.000***	−10.982	0.000***	−49.496	0.000***
Bitcoin_bidask	−9.821	0.000***	−10.057	0.000***	−16.493	0.000***
Ethereum_Returns	−5.557	0.000***	−9.037	0.000***	−81.18	0.000***
Ethereum_bidask	−5.914	0.000***	−10.786	0.000***	−13.681	0.000***
Ripple_Returns	−6.258	0.000***	−9.719	0.000***	−58.65	0.000***
Ripple_bidask	−8.943	0.000***	−8.073	0.000***	−15.47	0.000***
Litecoin_Returns	−10.986	0.000***	−10.493	0.000***	−18.742	0.000***
Litecoin_bidask	−4.544	0.001***	−11.443	0.000***	−17.305	0.000***
BitcoinCash_Returns	−3.298	0.033**	−11	0.000***	−31.645	0.000***
BitcoinCash_bidask	−3.545	0.024**	−8.112	0.000***	−8.924	0.000***
EPU	−8.307	0.000***	−11.485	0.000***	−33.93	0.000***
Gold_Returns	−11.271	0.000***	−11.175	0.000***	−49.858	0.000***
S&P_Returns	−11.117	0.000***	−12.686	0.000***	−15.562	0.000***

This table provides the Augmented Dickey Fuller(ADF) statistics of all the variables(monthly, weekly, and daily series). ADF test is used to check the stationarity of the series. Rejection of null hypothesis at 1%,5%, and 10% levels are denoted by ***, **, and *. BW is Baker Wurgler Sentiment, Sentix_Bitcoin is Sentix Bitcoin Sentiment, VIX_Returns is Log differenced VIX Index returns, Bitcoin_Returns is Bitcoin returns, Bitcoin_bidask is change in Bitcoin bid ask spread, Ethereum_Returns is Log differenced Ethereum returns, Ethereum_bidask is change in Ethereum bid ask spread, Ripple_Returns is Log differenced Ripple returns, Ripple_bidask is change in Ripple bid ask spread, Litecoin_Returns is Log differenced Litecoin returns, Litecoin_bidask is change in Litecoin bid ask spread, BitcoinCash_Returns is Log differenced Bitcoin Cash returns, BitcoinCash_bidask is change in Bitcoin Cash bid ask spread, EPU is Log differenced U.S. Economic Policy Uncertainty Index, Gold_Returns is Gold returns, and S&P_Returns is S&P 500 Index returns.

Table A5. The Breusch-Pagan-Godfrey Heteroscedasticity test under OLS estimations.

Model 1								
Obs R-squared	1.826							
p-value	0.401							
Model 2								
Obs R-squared	4.596							
p-value	0.597							
Model 3								
	Ethereum	**Ripple**	**Litecoin**	**Bitcoin Cash**				
Obs R-squared	14.114***	1.198	6.356**	0.071				
p-value	0.001	0.549	0.042	0.965				
Model 4								
	Ethereum	**Ripple**	**Litecoin**	**Bitcoin Cash**				
Obs R-squared	20.591***	12.221**	10.618*	11.677*				
p-value	0.002	0.057	0.1	0.07				
Model 5								
	Baker-Wurgler Sentiment				**VIX**			
	Ethereum	**Ripple**	**Litecoin**	**Bitcoin Cash**	**Ethereum**	**Ripple**	**Litecoin**	**Bitcoin Cash**
Obs R-squared	9.146	2.476	4.219	5.407	366.235***	49.821***	17.419***	70.028***
p-value	0.166	0.871	0.647	0.492	0.000	0.000	0.008	0.000

Notes: This table reports the Breusch-Pagan-Godfrey heteroscedasticity test statistic of Model 1,2,3,4, and 5 under OLS estimation. ***, **, and * denotes the rejection of null hypothesis of homoscedasticity 1%, 5%, and 10% level of significance.

Table A6. Variance Inflation factor.

	(Monthly) VIF	(Weekly) VIF	(Daily) VIF
BW	1.065672		
Sentix_Bitcoin		1.230128	
VIX_Returns			1.005902
Bitcoin_Returns	1.103282	1.231025	1.001767
Bitcoin_bidask	1.033437	1.02339	1.025234
Ethereum_Returns	1.314162	1.152768	1.002122
Ethereum_bidask	1.099031	1.051469	1.000537
Ripple_Returns	1.089789	1.934616	1.000563
Ripple_bidask	1.059706	1.866173	1.003513
Litecoin_Returns	1.169354	1.904339	1.000827
Litecoin_bidask	1.064927	1.760142	1.00143
BitcoinCash_Returns	2.330888	1.11458	1.016087
BitcoinCash_bidask	1.848191	1.042244	1.004056
EPU	1.146025	1.009164	1.00093
Gold_Returns	1.135448	1.019142	1.012026
S&P_Returns	1.239508	1.075809	1.019317

This table provides the Variance Inflation Factor(VIF) of all the variables(monthly, weekly, and daily series). BW is Baker Wurgler Sentiment, Sentix_Bitcoin is Sentix Bitcoin Sentiment, VIX_Returns is Log differenced VIX Index returns, Bitcoin_Returns is Bitcoin returns, Bitcoin_bidask is change in Bitcoin bid ask spread, Ethereum_Returns is Log differenced Ethereum returns, Ethereum_bidask is change in Ethereum bid ask spread, Ripple_Returns is Log differenced Ripple returns, Ripple_bidask is change in Ripple bid ask spread, Litecoin_Returns is Log differenced Litecoin returns, Litecoin_bidask is change in Litecoin bid ask spread, BitcoinCash_Returns is Log differenced Bitcoin Cash returns, BitcoinCash_bidask is change in Bitcoin Cash bid ask spread, EPU is Log differenced U.S. Economic Policy Uncertainty Index, Gold_Returns is Gold returns, and S&P_Returns is S&P 500 Index returns.

Table A7. Correlation Matrix.

Panel A

	Sentix_Bitcoin	Bitcoin_Returns	Bitcoin_bidask	EPU	Gold_Returns	S&P_Returns
Sentix_Bitcoin	1					
Bitcoin_Returns	0.515***	1				
Bitcoin_bidask	−0.066	0.159*	1			
EPU	0.028	−0.016	0.073	1		
Gold_Returns	0.085	0.068	−0.012	−0.027	1	
S&P_Returns	0.165*	0.093	0.079	0.023	−0.098	1

Panel B

	Sentix_Bitcoin	Ethereum_Returns	Ethereum_bidask	EPU	Gold_Returns	S&P_Returns
Sentix_Bitcoin	1					
Ethereum_Returns	0.237***	1				
Ethereum_bidask	0.018	0.091	1			
EPU	0.028	0.009	0.083	1		
Gold_Returns	0.085	−0.083	−0.048	−0.027	1	
S&P_Returns	0.165*	0.101	−0.052	0.023	−0.098	1

Panel C

	Sentix_Bitcoin	Litecoin_Returns	Litecoin_bidask	EPU	Gold_Returns	S&P_Returns
Sentix_Bitcoin	1					
Litecoin_Returns	0.423***	1				
Litecoin_bidask	0.136	0.054	1			
EPU	0.028	−0.004	−0.015	1		
Gold_Returns	0.085	0.076	0.027	−0.027	1	
S&P_Returns	0.165*	0.088	0.093	0.023	−0.098	1

Panel D

	Sentix_Bitcoin	Ripple_Returns	Ripple_bidask	EPU	Gold_Returns	S&P_Returns
Sentix_Bitcoin	1					
Ripple_Returns	0.273***	1				
Ripple_bidask	0.068	0.139	1			
EPU	0.028	0.107	−0.067	1		
Gold_Returns	0.085	0.129	0.137	−0.027	1	
S&P_Returns	0.165*	0.039	0.175**	0.023	−0.098	1

Panel E

	Sentix_Bitcoin	BitcoinCash_Returns	BitcoinCash_bidask	EPU	Gold_Returns	S&P_Returns
Sentix_Bitcoin	1					
BitcoinCash_Returns	0.393***	1				
BitcoinCash_bidask	−0.024	0.026	1			
EPU	0.029	−0.091	−0.063	1		
Gold_Returns	0.069	0.059	0.137	−0.025	1	
S&P_Returns	0.171*	0.018	0.109	0.023	−0.085	1

Notes: This table reports the correlation matrix of the variables (weekly series). ***, **, and * denotes significance level at 1%, 5%, and 10%. Sentix_Bitcoin is Sentix Bitcoin Sentiment, Bitcoin_Returns is Bitcoin returns, Bitcoin_bidask is change in Bitcoin bid ask spread, Ethereum_Returns is Log differenced Ethereum returns, Ethereum_bidask is change in Ethereum bid ask spread, Ripple_Returns is Log differenced Ripple returns, Ripple_bidask is change in Ripple bid ask spread, Litecoin_Returns is Log differenced Litecoin returns, Litecoin_bidask is change in Litecoin bid ask spread, BicoinCash_Returns is Log differenced Bitcoin Cash returns, BitcoinCash_bidask is change in Bitcoin Cash bid ask spread, EPU is Log differenced U.S. Economic Policy Uncertainty Index, Gold_Returns is Gold returns, and S&P_Returns is S&P 500 Index returns.

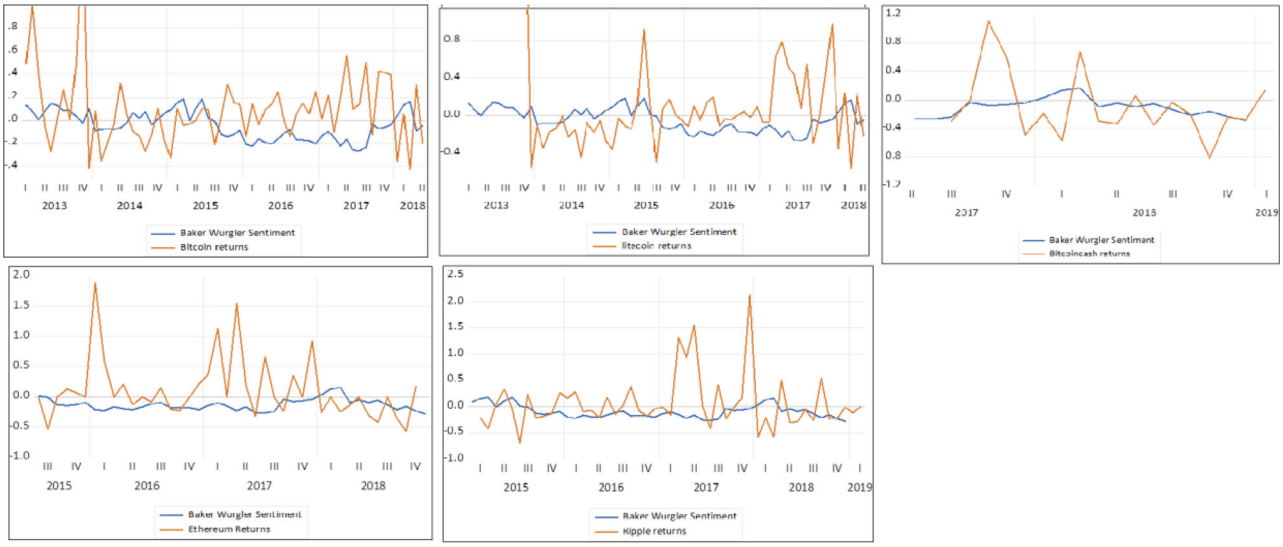

Figure A1. Illustration of movement of cryptocurrency returns with Baker-Wurgler Equity market Sentiment.

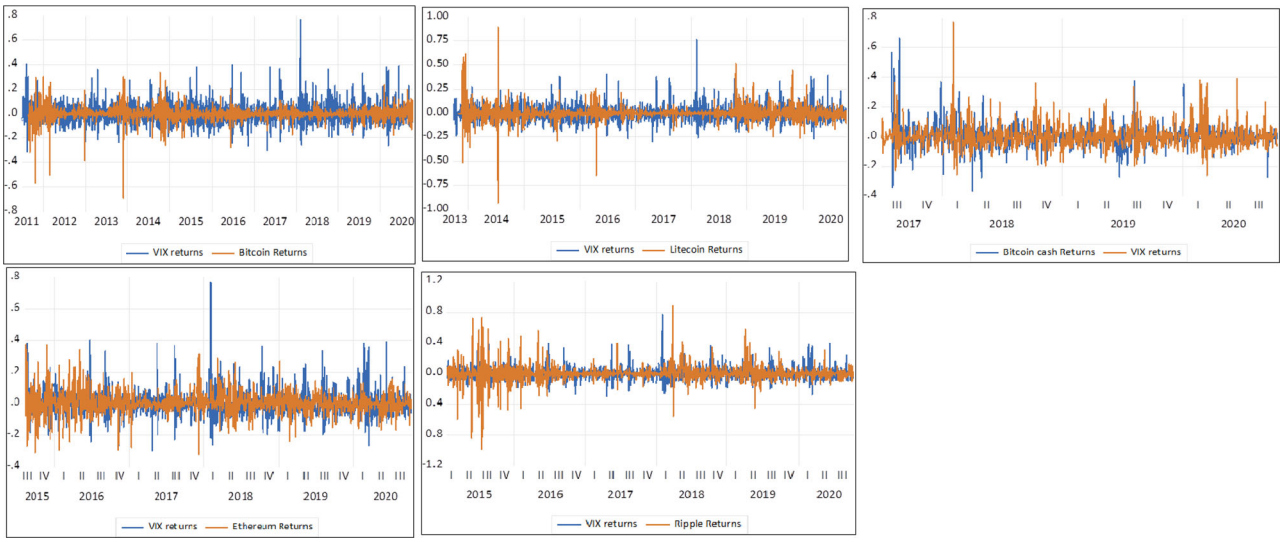

Figure A2. Illustration of movement of cryptocurrency returns with Equity market Sentiment VIX.

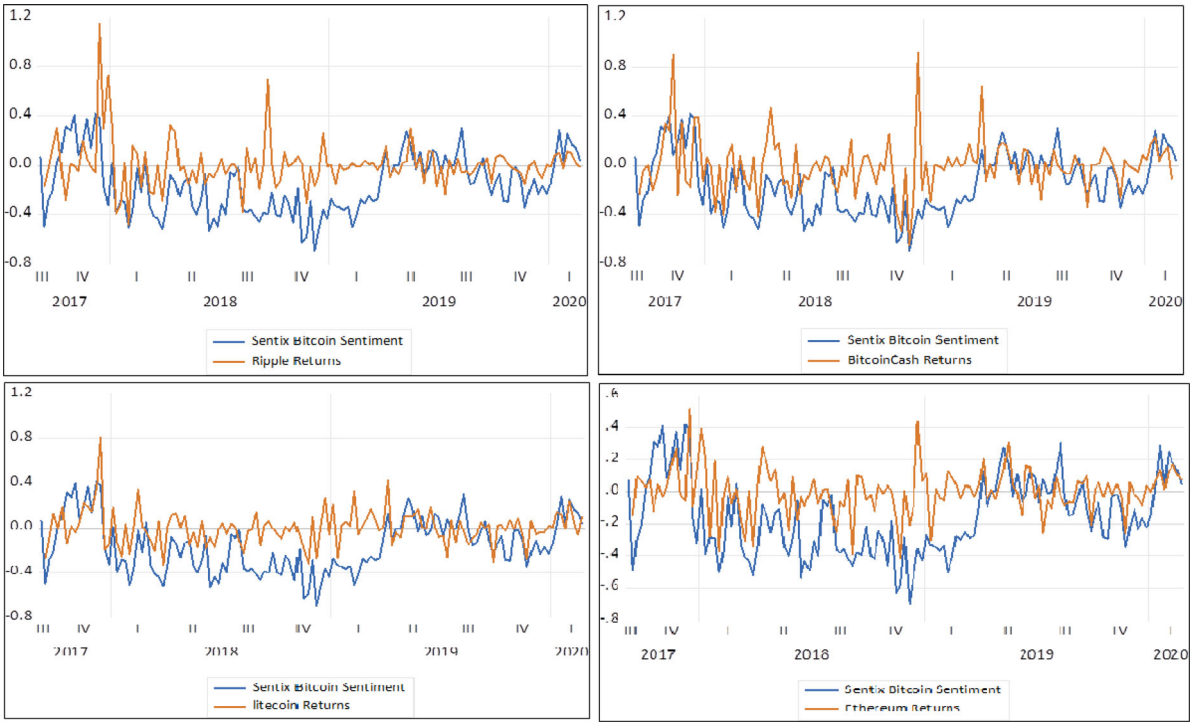

Figure A3. Illustration of movement of Altcoin returns with weekly survey based Sentix Bitcoin Sentiment Index.