Emotions drive Actions: Sentiment and Cryptocurrency Market Reactions to Macroeconomic News Announcements

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Abstract

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Key words: Cryptocurrency; Investor sentiment; macroeconomic announcements; Crypto market efficiency; Intraday data

JEL Classification: G02; G14; G15

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"For some reason, because of the way investor psychology works, people switch from only seeing the good to seeing only the bad."

Howard Stanley Marks

1 Introduction

Digital assets, such as cryptocurrencies, have experienced precipitous growth in recent years regarding market capitalization and popularity in the global financial markets (Liu et al., 2022; Smales, 2022). Despite the relatively brief history of cryptocurrencies with the invention of Bitcoin in 2009, there are more than 23,000 traded cryptocurrencies in March 2023, with a total market capitalization of over US$1.1 trillion[1]. As decentralized digital currencies admit direct payments without financial intermediaries, cryptocurrencies increasingly attract attention from institutional and retail investors, policymakers, social media, and academic research (Liu et al., 2022). As a nature of decentralized assets, cryptocurrencies demonstrate characters that make them particularly attractive to "amateur" retail traders who elucidate accessible information differently to institutional investors that control the equity markets (Al Guindy, 2021; Lucey et al., 2022). This divergence in information processing among market participants, often referred to as 'noise' traders, can help explain why cryptocurrency prices frequently deviate significantly from their fundamental values (De Long et al., 1990). While some earlier studies argue that the cryptocurrency market aligns with the efficient market hypothesis (Jiang et al., 2018; Urquhart, 2016; Vidal-Tomás and Ibañez, 2018), the prevailing consensus in the literature leans toward characterizing the cryptocurrency market as relatively inefficient (Baur et al., 2018; Corbet et al., 2019).

Considered a primary indicator of the ongoing economic environment, macroeconomic news announcements and the reactions of the financial markets have been put more emphasis (Anderson et al., 2003; Evans, 2011; Huang, 2018). Further, given those unique features of the cryptocurrency market, a growing research area of behavioral

[1]See: https://www.forbes.com/advisor/investing/cryptocurrency/different-types-of-cryptocurrencies/

finance has added to its scope the investor behavior in, in terms of investor behaviors (Gurdgiev and O'Loughlin, 2020; Huynh and Phan, 2023; Mai et al., 2018). Studying the effects of fundamental factors on cryptocurrency prices, a few studies investigate the reactions of cryptocurrencies to macroeconomic news and find inconsistent evidence. For instance, Corbet et al. (2020a) and Ben Omrane et al. (2021) uncover substantial reactions of cryptocurrencies to U.S. monetary policy announcements. Conversely, Vidal-Tomás and Ibañez (2018) report insignificant responses of cryptocurrencies to monetary policy events from major economies. Moreover, the true effects of macroeconomic announcements can be subject to various biases, with interpretation heavily influenced by investor sentiment levels, which are often proxied by optimism or pessimism. Given the extant literature on behavioral finance in the cryptocurrency market, the reactions of the crypto market to macroeconomic new announcements shaped by the stages of investor sentiment remain unanswered. This paper examines whether and how bullish sentiment modifies the potential impacts of released macroeconomic information on crypto market reactions. Specifically, this paper seeks to solve the following questions:

(i) *Do cryptocurrencies experience abnormal returns and trading volume to the U.S. macroeconomic news announcements? And are any types of news more prominent than others?*

(ii) *To what extent the bullish sentiment can modify the cryptocurrency market reactions?*

In this study, we utilize the intraday data (5-minute intervals) of the top 100 cryptocurrencies and data on 32 major macroeconomic announcements in the United States from 1st January 2014 to 31st December 2021. Employing the approach of Balduzzi et al. (2001) to estimate the announcement surprises, we find that the majority of the U.S macroeconomic announcements have considerable impacts on the aggregate cryptocurrency return and trading volume. Those reactions significantly depend on the nature and types of news, which can generate positive or negative effects. Next, we focus on the potential impacts of investor sentiment on the cryptocurrency market

response to macro news. We employ the daily MarketPysch Indices (TRMI) for the cryptocurrencies offered by Thomson Reuters[2] to compute a daily aggregate sentiment index for the cryptocurrency market. We document pervasive evidence that bullish sentiment can weaken the cryptocurrency market reactions to announcements of macro news for both market returns and turnover ratio. This modified effect is significant for aggregate specification and individual evaluation that separates among announcement forms. Regarding the economic significance, bullish sentiment can weaken 40% to 50% of the crypto market reactions to the news, which remains significant for both good and bad macroeconomic information.

To further confirm our findings, we propose a battery of robustness checks and sensitivity analyses to control the endogeneity issue. Using the sub-sample analyses, we find market reactions driven by coins' characteristics, economic stages, and political bias, while the weakening effect of sentiment remains unchanged. Further, our findings hold, regardless of changing event windows, supporting the hypothesis of pre-announcement drift. We can also reinforce the influences of investor sentiment before the macro news announcement to contend with potential endogeneity concerns. Utilizing alternative measures of investor sentiment, our results are relatively unchanged with differences in magnitude for equity markets' sentiment. In addition, our results remain robust when controlling for additional factors that could initiate time-varying reaction of these crypto markets to news such as macroeconomic situations, expected volatility and aggregate uncertainties. To provide broader findings, we also consider the reactions to macroeconomic announcements in European Union (EU), China, Japan, and Germany. We observe that the cryptocurrency market only compellingly reacts to macro news in the EU and China with a significant weakening effect of sentiment.

Our research makes substantial contributions to the existing finance literature on multiple fronts. Firstly, it enriches the domain of literature concerned with the state-dependent connection between asset prices and macroeconomic fundamentals, with a

[2]MarketPysch Indices are the standard for machine-learning sentiment assessments that analyses more than 55,000 news sites and 4.5 million social media sites, blogs and tweets. See: www.economist.com/graphic-detail/2012/06/28/the-mood-of-the-market

specific focus on the cryptocurrency market. While prior studies have extensively explored the effects of macroeconomic news on traditional stock markets, as documented by Boyd et al. (2005) and Kurov and Stan (2018), our study sheds light on the distinctive reactions of the cryptocurrency market to various categories of macroeconomic news announcements, an aspect that has remained relatively unexplored in the existing literature.

Second, to be best of our knowledge, this is the first study to confirm the impact of investor sentiment on cryptocurrency market reactions to macroeconomic announcements. In the domain of behavioral finance, the role of investor sentiment within the cryptocurrency market has been the subject of active evaluation (Anamika et al., 2023; Gaies et al., 2021; Gurdgiev and O'Loughlin, 2020; Huynh and Phan, 2023). Our analysis significantly advances the understanding of how investor sentiment reshapes the relationship between fundamental factors and the cryptocurrency market's reactions, particularly in terms of returns and trading volume. In this context, our findings align with those of Gu et al. (2021), who reached a similar conclusion for the U.S. stock market. Consequently, our results help paint a complete picture and provide valuable insights into the efficiency of market behavior within decentralized asset markets. Further, the availability of the specific sentiment scores for the cryptocurrency market employed in this study lets us split the sentiment-return/volume feedback loops from more exceptional perception. Also, our study distinguishes itself from prior research by utilizing high-frequency data with short intraday intervals (5-minute intervals) around the release of macroeconomic news. Such investigations are essential given the growing prominence of high-frequency trading in the dominion of price discovery.

From the starting point of this study, our findings are of great importance for practitioners and academia in exploiting potential profit when trading on macroeconomic news. By comprehending the role of sentiment in shaping the relationship between the cryptocurrency market and macroeconomic surprises, traders can better anticipate market responses to news events when they endeavor to estimate the magnitude of

these announcements. It would be useful to consider the momentous impacts of sentiment stages on the reactions of cryptocurrency markets to scheduled global and local macroeconomic news. In reality, our results offer valuable insights that can aid both investors and managers of multinational corporations in effectively managing risk through cryptocurrency inclusion in their portfolios, leveraging high-frequency trading strategies.

The remainder of the paper is organized as follows. Section 2 briefly summarizes the related literature. Section 3 depicts the data, variable constructions, and baseline methods. Section 4 presents the main results and supporting evidence. Section 5 reports the robustness checks and additional analyses and Section 6 concludes the study.

2 Literature Review

Behavioral finance is a research area that has been growing over the years, and more recently, added to its scope the investor behaviour in the cryptocurrency market. Therefore, this literature strand has been addressing several topics, such as investor sentiment in the cryptocurrency market (Akyildirim et al., 2021; Anamika et al., 2023; Huynh and Phan, 2023), herding behaviour in the cryptocurrency market (da Gama Silva et al., 2019; Gurdgiev and O'Loughlin, 2020; Papadamou et al., 2021), news effects in crypto investors' behaviour (Chu et al., 2019; Domingo et al., 2020; Li et al., 2021), and investor attention (Katsiampa et al., 2019; Smales, 2022). Consequently, the aggregation and synthesis of existing knowledge produced so far, as well as the identification of literature gaps are of extreme significance (Corbet et al., 2019) for the literature strand on investor behaviour in the cryptocurrency market.

There are also indications that the crypto market has a complex sentiment component (Jo et al., 2020) and that its prices and trading activity are driven by popularity, emotion, and sentiment (Goczek and Skliarov, 2019; Hou et al., 2020). Variations in optimism shape the cryptocurrency return such that when positive news is released, the returns dispersion decreases (Caferra, 2020). Thus, optimism leads to the convergence of expectations and high prices, revealing that investors' sentiment influences cryptocurrency prices and that cryptocurrencies' volatility is based on investors' emotions and behaviour (Caferra, 2020). As such, investor sentiment significantly impacts the cryptocurrency market. From that point, several studies highlight a robust relationship between sentiment and the cryptocurrency market. A pioneering study by Glaser et al. (2014) identifies behavioural biases like overconfidence and sensation-seeking as influential on Bitcoin market sentiment and trading behaviour. Kristoufek (2015) found a positive correlation between Bitcoin-related Google searches and price, suggesting that public sentiment and attention can impact market movements. Utilising the sentiment extracted from news, Chen et al. (2018) prove that news sentiment significantly drives cryptocurrency returns, especially in less prominent coins. Conversely, Biais

et al. (2019) demonstrate that social media sentiment is predictive of cryptocurrency returns, particularly for Bitcoin and Ethereum. Smith and Svec (2019) indicated that extreme sentiments amplify cryptocurrency market volatility, underscoring the profound effect sentiment has across various aspects of cryptocurrency trading and valuation. However, this impact varies with microeconomic and macroeconomic sentiments. It is revealed that the microeconomic sentiment, which shows everyday concerns (job search, unemployment), has a bigger effect than the macroeconomic sentiment (Burggraf et al., 2021; Corbet et al., 2020b). Furthermore, in the Bitcoin market, when investor sentiment is pessimistic, returns decline, and in times of increased sentiment, investors tend to adopt risk-averse behaviour (Burggraf et al., 2021). Additionally, in the presence of fear and bearish sentiment in equity markets, investors turn to the cryptocurrency market, increasing cryptocurrency prices (Gaies et al., 2021; Huynh and Phan, 2023).

On the one hand, the predictability of the cryptocurrency market is remarkable because according to the Efficient Market Hypothesis (EMH), a predictable market is informationally inefficient as the available information is not fully reflected in market prices (Fama, 1970). Due to the lack of intrinsic value and the prices of cryptocurrencies being driven by speculation, there is no way for cryptocurrencies to be valued fundamentally, making the market irrational. The cryptocurrency market also offers limited instruments and opportunities for investors to communicate a downward price potential, contributing to an inefficient market (Hossain, 2021). Previous papers on cryptocurrency's market efficiency have proposed mixed findings on the reactions of crypto assets to information. Gandal et al. (2018) also confirm that regulation declarations related to the perceptions and actions within the cryptocurrency markets significantly influence both market sentiment and transaction volumes. Several studies have explored the impact of fundamental factors on cryptocurrency valuations, with a focus on the response to macroeconomic announcements yielding mixed results. Dyhrberg (2016) evaluates the sensitivities of macroeconomic variables on Bitcoin and shows that its price reacts significantly to the Federal Funds rate. Furthermore, positive shocks increase the volatility of Bitcoin returns by more than negative shocks while

the opposite asymmetry is observed for other assets. Considering the reactions to four major US macroeconomic news announcements, Corbet et al. (2020a) confirm that only unemployment and durable goods have significant effects on Bitcoin daily returns. The volatility spillover and feedback effects are also obtained by Corbet et al. (2020b) when they consider the reactions of digital assets including cryptocurrencies, protocols, and decentralized applications to Federal funds rate and quantitative easing announcements. Likewise, Pyo and Lee (2020) confirm the effects of Federal Open Market Committee (FOMC) statements and macroeconomic disclosures on the valuation of Bitcoin. Ben Omrane et al. (2021) found that cryptocurrencies exhibit notable reactions to announcements of U.S. monetary policy. On the other hand, Vidal-Tomás and Ibañez (2018) observed that cryptocurrency markets show negligible reactions to monetary policy events from the world's leading economies.

Overall, macroeconomic announcements reveal three types of information relevant for valuing the asset prices, including information about future interest rates, risk premium, and future earnings (Boyd et al., 2005). Good news signals a healthy economy and has a direct positive effect on the stock market through the change in expectations of corporate earnings. It also has an indirect effect through the increase in interest rates and the equity premium due to the expected tightening reaction of monetary policy (Bernanke and Kuttner, 2005). In other words, information is impounded into asset prices in different economic environments. The inter-temporal rational expectations equilibrium model of Veronesi (1999) shows that uncertainty about the state of the economy causes stock market investors to overreact to bad news in good economic times and underreact to good news in bad economic times.

3 Data and method

3.1 Cryptocurrency data

We collect data on the top 100 cryptocurrencies covering the period from 01 January 2014 to 31 December 2021 based on the market capitalization by the end of 2021. Hence, our sample can include both booms and busts in the cryptocurrency markets. The trading data is collected from Coinmarketcap.com, considered as the leading source of cryptocurrency data that has been employed in prior literature (Gkillas and Katsiampa, 2018; Liu et al., 2022; Subramaniam and Chakraborty, 2020; Zhang et al., 2021). This platform can overcome the weaknesses of other sources (such as Kaiko and Bitcoincharts.com) by providing price data by taking the volume-weighted average of all prices reported in each market. In addition, we can alleviate concerns about survivorship bias by including both active and deceased cryptocurrencies (Liu et al., 2022). Overall, our sample accounts for more than 90% of the total value of the market capitalization, which can entirely manifest the overall picture of the cryptocurrency market. We eliminate cryptocurrencies that are classified as tokens or stablecoins, and those with less than 1 year of data (i.e., issued after Dec 2020).

In this study, we utilize the 5-minute interval (tick-by-tick) trade data to explore the immediate market reaction to announcements of macroeconomic news. Following prior studies on the intraday frequency in the cryptocurrency markets, the 5-min sampling offers a better balance between low and high frequencies (Akyildirim et al., 2021; Aslan and Sensoy, 2020; Ben Omrane et al., 2021; Hasan et al., 2021). Further, Yarovaya and Zieba (2022) and Aslan and Sensoy (2020) also confirm that, in high-frequency cryptocurrency research, the 5-min data provides optimal interval for investors to react to new information and instantly accommodate their asset holdings. To capture the reactions of crypto investors on macro news, we rely on two indicators of returns and turnover. The returns for each currency are computed from the 5-min price as: $RET_{i,t} = ln(Price_{i,t}/Price_{i,t-1})$. Following Dong et al. (2022); Youssef (2022) and Brauneis and Mestel (2018), the turnover ratio is defined as dollar volume divided by market cap to

capture the trading intensity.

3.2 Macroeconomic news data

We examine 32 scheduled U.S. macroeconomic announcements from 01 January 2014 to December 2021 to be consistent with the development of cryptocurrency market. We employ the data of the US economy as the leadership role played by the U.S. financial market. Given the finance literature, the announcements of U.S. macroeconomic news are unarguably one of the focal attention of investors worldwide, both in U.S. and non-U.S. stock markets (Hammoudeh et al., 2016; Nikkinen et al., 2006). Further, the current literature also consistently confirms that US macroeconomic announcements exert stronger impacts on the trading behaviour and asset prices than national events (Anderson et al., 2003; Balcilar et al., 2019; Jäggi et al., 2019). As such, the U.S. macroeconomic news are strongly relevant for investors in the cryptocurrency market.

In this study, we utilize the data on scheduled macroeconomic news announcements of the US economy, obtained from Bloomberg and coordinated in the UTC time zone[3]. Following the works of (Anderson et al., 2003; Jäggi et al., 2019; Omrane and Savaşer, 2017) and Lyócsa et al. (2020), we select 32 relevant news and sorted into the following eight macroeconomic announcement groups: (I) Real Economic Activity; (II) Consumption ; (III) Investment; (IV) Government; (V) Trade; (VI) Price indices; (VII) Monetary Policy; and (VIII) Forward-Looking indicators[4]. Those announcements are organised and publicised by 14 organisations, including the Federal Reserve Board (FRB), Bureau of the Census (BC), Bureau of Economic Analysis (BEA), U.S. Department of Treasury (USDT), Bureau of Labor Statistics (BLS), Conference Board (CB), Federal Reserve Bank of Philadelphia (FRBP), Institute for Supply Management (ISM), Federal Reserve Bank of New York (FRBNY), Thomson Reuters and University of Michigan (TRUM), National Association of Purchasing Management (NAPM), Automatic Data Processing, Inc. (ADP), and National Association of Purchasing Management (NAPM).

[3]Data on coinmarketcap.com is also collected, recorded, and reported in UTC time unless otherwise specified. See Table 1 for the released times (EST) and corresponding UTC times.

[4]Those indicators comprise information integrating market expectations about future economic development and situation (Andersen et al., 2003).

In our sample, there are 31 announcements are released on monthly basis, while the Initial unemployment (jobless claims) is announced weekly. An overview of this classification is reported in Table 1. We also collect data on the macroeconomic announcements in the European Union, Germany, Japan, and China to broadly explore the impacts on macro news around the world, which is consistent with the nature of cryptocurrency market.

– Insert Table 1 about here –

Following Balduzzi et al. (2001) and Gu et al. (2021), we calculate the news surprises as the difference between the actual published values and the anticipated values of macroeconomic indicators. The standardized surprises ($SP_{j,t}$) for each indicator are computed as follows:

$$SP_{j,t} = \frac{AM_{j,t} - FV_{j,t}}{\sigma_{j,t}} \tag{1}$$

where $AM_{j,t}$ is the actual value of macroeconomic indicator j, $FV_{j,t}$ is the anticipated median value of the Bloomberg forecast for indicator j, and $\sigma_{i,t}$ is the sample standard deviation of $(AM_{j,t} - FV_{j,t})$. We use the news surprises ($SP_{j,t}$) to investigate the stock market response to macroeconomic news in the 10-minute/20-minute intervals from five/ten minutes before to five/ten minutes after the announcements. This approach can standardize the surprise and is straightforward to compare the findings across different announcement types.

3.3 Sentiment measures

Given the current literature, there are two approaches (i.e., direct approach and indirect approach) to capture investor sentiment in the financial markets. The indirect method uses data from financial markets, which can reflect the trading behaviour of the economic agents (Baker and Wurgler, 2006). The direct method mainly utilises surveys data questioning consumers or investors about their predisposition of future economic conditions and investment plans (Qiu and Welch, 2004; Wang et al., 2021). To consider

the modified impacts of investor sentiment on the macroeconomic news reaction, we rely on the sentiment indicators provided by Refinitiv MarketPsych Analytics[5]. Using machine learning and textual analyses, Thomson Reuters Marketpsych Indices (TRMI) collects sentiment data by quantifying economic, social, political, and other country-level news into meaningful sentiment indices. TRMI covers more than 2,000 news sources, including prominent specialised financial news presses and content such as *The Wall Street Journal, The Financial Times, The New York Times, Thomson Reuters News Feed Direct, Factiva News*, and *Google News* on a real-time basis and over a 24-hour rolling window. The data also comprise updated information scraped from millions of stock message boards, social media sites, and blogs from *StockTwits, Yahoo!Finance*, and *Seeking Alpha*. In the current behavioural literature on cryptocurrencies, several studies have confirmed the validity of the textual sentiment measures provided by TRMI, such as Akyildirim et al. (2021); Entrop et al. (2020); Kalyvas et al. (2021) and Kalyvas et al. (2020). Overall, TRMI can overcome the restrictions of traditional sentiment measures as the indices are more comprehensive, efficient, and reliable (Gan et al., 2020; Huang et al., 2018).

In this study, we focus on the TRMI Cryptocurrency Sentiment indices that comprise a number of emotional and topical items across more than 2,000 global news and 800 social media sites in real-time, yielding 43 themes and sentiments on the top 100 cryptocurrencies that may drive investor behaviours in cryptocurrency markets[6]. We combine two components of social and news cryptocurrency sentiment that quantifies news stories' content on a continuous scale in the range from -1 (extremely negative tone) to 1 (extremely positive tone), with a sentiment score of 0 representing neutral tonality. In other words, the higher value indicates that investors are more bullish about the cryptocurrency market. We construct a daily composite cryptocurrency sentiment index from the daily value-weighted averages of Sentiment by using the market capitalization

[5]Refinitiv MarketPsych Analytics provide sentiment data covering 100,000+ companies, 150+ indices and ETFs, 44 commodities, 45 currencies, 200+ country macroeconomics, fixed income instruments for 60 countries and 500+ cryptocurrencies, which are available from January 1998.

[6]TRMI Cryptocurrency Sentiment indices are launched in 2018 with the historical data dates back to 2009.

of all coins in the index. For the robustness checks, we also obtain several alternative sentiment measures, including (1) Refinitiv MarketPsych equity market indices; (2) American Association of Individual Investors (AAII) sentiment; (3) Baker and Wurgler (2006) sentiment index; (4) Bekaert et al. (2022) Risk Aversion Index; (5) Investor Attention from Google Search Volume data, which are comprehensively considered in Section 5.6 and Appendix C.1. In Appendix C.2, we also provide the graphical description for the TRMI Cryptocurrency Sentiment index on weekly basic, which is computed from the daily data employed in our main analyses.

3.4 Baseline Models

In this study we utilise two main indicators of abnormal returns and turnover to capture the reactions of crypto market. Initially, we compute the normal returns for each cryptocurrency by using the data of the estimation window by using the market model with Ordinary Least Square (OSL) (Dyckman et al., 1984). The normal/expected return - $E(Ret_{i,t})$ is computed as follows:

$$Ret_{i,t} = \alpha_i + \beta_i Ret_{m,t} + \epsilon_{i,t} \tag{2}$$

where, $Ret_{m,t}$ is the return of the benchmark index of the value-weighted crypto market return on period t. Then, the abnormal return, $AR_{i,t}$ is calculated using below given formula:

$$AR_{i,t} = Ret_{i,t} - E(Ret_{i,t}) \tag{3}$$

Where, $AR_{i,t}$ shows the abnormal return on coin i on time t. $Ret_{i,t}$ shows the actual return on coin i on time t. We estimated the cumulative abnormal return (CARs) for coin i over the event window from time t1 to t2 by using continuously compounded abnormal returns as follows:

$$CAR_{i(t1-t2)} = \sum_{t=t1}^{t2} AR_{i,t} \tag{4}$$

To consider the impacts on trading intensity around the event, we use the turnover ratio as dollar volume divided by market capitalization. This approach allows us to initially verify the reactions of cryptocurrency market around the macro new announcements, which is reported in Section 4.1 – Table 2.

To comprehensively consider the market reactions, we follow Akyildirim et al. (2021) and Nguyen et al. (2020), we construct 5-min interval equal-weighted indices for all cryptocurrencies by the average of scaled returns and turnover of each cryptocurrency over the same sample period[7]. This approach can overcome the issue of emphasizing weights on large coins, which may reduce the effects of noisy movements created by small ones. Furthermore, Nguyen et al. (2020) also confirm that the diversification in cryptocurrency investment can be realistically and certainly accomplished by means of an equal weighting of cryptocurrencies. We then examine the effect of macroeconomic announcements on the stock market during an intraday window around the releases of macroeconomic news using the following regressions:

$$Y_t = \alpha_0 + \sum_{j=1}^{k} \beta_j SP_{j,t} + \epsilon_{j,t} \tag{5a}$$

$$Y_t = \alpha_0 + \beta_i SP_t + \epsilon_t \tag{5b}$$

where Y_t, include Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information[8]. $SP_{j,t}$ is the standardized surprise corresponding to announcement j at time t. This first specification - Equation (5a) accounts for all the k macro announcements that are released at the same time specified by $\sum_{j=1}^{k} \beta_j SP_{j,t}$. In

[7]In unreported results, we also estimate the results for the value-weighted indices for all cryptocurrencies. The results remain statistically significant but with lower levels of economic significance.

[8]It is common to use a narrow intraday window, around 5 to 10 minutes around the event, to immediately capture the reaction to macroeconomic news (Anderson et al., 2003; Gu et al., 2021), since the macro-related information can be incorporated in the trading behavior immediately after announcements.

Equation (5b), we consider overall cryptocurrency market responses to macroeconomic news by treating all announcements the same in the aggregate specification. We estimate Equations (5a) and (5b) from January 2014 to December 2021 by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors.

To explore whether and how investor sentiment modifies the cryptocurrency market reactions to macroeconomic news, we construct two following specifications:

$$Y_t = \alpha_0 + \sum_{j=1}^{k} \beta_j SP_{j,t} + \gamma SENT_t + \sum_{j=1}^{k} \delta_j (SP_{j,t} \times SENT_t) + \epsilon_{j,t} \tag{6a}$$

$$Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta (SP_t \times SENT_t) + \epsilon_t \tag{6b}$$

where, $SENT_t$ is the sentiment indicator proxied by the daily TRMI Cryptocurrency Sentiment. We utilize three forms of SENT as (i) a dummy variable taking values of one when the sentiment measure is in its top quartile, and zero otherwise; (iii) a dummy variable taking values of one when the daily sentiment measure is above the sample median, and zero otherwise; and (iii) the standardized sentiment over the entire sample period. The interaction term of $SP_t \times SENT_t$) indicates how the cryptocurrency market responds to adjustments of macroeconomic news, subject to different levels of investor sentiment. If the estimated coefficient of is negative, we can conclude that the increase in sentiment can weaken the market reaction to macro news.

4 Empirical results

4.1 Preliminary results: Cryptocurrency market reaction to Macroeconomic News

Initially, we consider the cryptocurrency market reaction to macroeconomic news by utilizing the event study approach. Following a study of Di Tommaso et al. (2023), we carry out two different non-parametric tests: bootstrapped standard errors and the Wilcoxon test to assess if the reaction of the cryptocurrency abnormal returns (AR) and turnover ratio (TURN), on average, significantly different from zero. The results are reported in Table 2. In Panel A, the cryptocurrency returns are positive and significant during the window time t until 10 minutes after the announcements. Interestingly, the results also indicate that cryptocurrency investors also reacted before the announcements with negative and significant AR within the 10-min interval before the events. The results of cumulative abnormal return (CAR) also exhibit positive and statistically significant from time t to t+30. In Panel B, we also obtain similar results for the turnover (TURN) and cumulative turnover ratio (CTURN). Overall, these preliminary results indicate the significant reactions of the cryptocurrency market to the announcement of U.S. macro news.

– Insert Table 2 about here –

We consider turnover and abnormal return for two intervals of [-5;+5] and [-10;+10] around the release of macroeconomic news in Table 2. The results for individual and aggregate events are reported in Panel A and B by utilizing Equations (5a) and (5b), respectively. In Panel A, the results indicate that most macroeconomic announcements have a considerable impact on the cryptocurrency market. For instance, the return increases substantially for both intervals when the *Gross Domestic Product (GDP)* growth is higher than the pre-announcement compromises. The declared GDP higher than the anticipated value denotes the optimistic performance of the economy, which is a positive sign for investors in the cryptocurrency market. Regarding two indicators

of unemployment, *Initial unemployment (jobless claims) and Unemployment rate*, we find negative reactions of returns to those surprises. In other words, higher actual unemployment indicates unfavorable information for cryptocurrency investors. All other "Real Economic Activity" indicators exhibit significant impacts on the crypto returns, except for *Capacity Utilization, Consumer credit* and *Personal Income*. Also, the optimistic revelations for *Personal spending, Durable goods orders*, and *Factory orders* are relatively pleasant information for the cryptocurrency market, which is also exhibited for two indicators of Trade. Our results also indicate that announcements under the category of *Price indices* and *FOMC rate decisions*, positive disclosures are adverse news for investors. Further, we find that 5 out of the 9 *Forward-looking indicators* positively affect the returns of the cryptocurrency market.

In terms of the Turnover ratio, we find that 24 out of 32 announcements exhibit positive and significant impacts on the trading intensity of investors in the cryptocurrency market, while the number for Return is 20. In the last rows of Panel A, we employ the joint Wald test with the null hypothesis of no significant β_i in Equation (5a) for i equals to 1 to 32. The results are statistically significant for all four dependent variables, confirming that the cryptocurrency market has considerable responses to the scheduled U.S macroeconomic proclamations. In Panel B, the regression results for all events by using Equation (5b) also reveal substantial reactions of the cryptocurrency market to macroeconomic news. For instance, the coefficient for [-5;+5] return (turnover) is 0.098 (0.179), revealing that one standard deviation rise in macroeconomic information results in about 9.8 (179) basis points increase in cryptocurrency return (trading volume).

– Insert Table 3 about here –

4.2 Sentiment and market reaction to macroeconomic news

To examine whether and how investor sentiment affects the cryptocurrency market response to macroeconomic news, we utilize the aggregate model - Equation (6a) and report the results in Table 4. From Column (1) to (3), we use three forms of daily SENT as: (i) the standardized sentiment over the entire sample period; (ii) a dummy variable taking values of one when sentiment measure is in its top quartile, and zero otherwise; and (iii) a dummy variable taking values of one when daily sentiment measure is above the sample median, and zero otherwise, respectively. With the standardized sentiment, the estimated coefficients β_i are positive and statistically significant, while of the interaction terms ($SP_t \times SENT_t$)) are significant and negative for both return and turnover across all considered intervals. Hence, bullish investor sentiment can weaken market reactions to macroeconomic announcements. Regarding economical magnitude, one standard deviation rise in investor sentiment would reduce the extent of reactions by 3.7 bps for return and 7.5bps for turnover ratio. In other words, the return (turnover) reactions are reduced by about 38% (42%)[9], corresponding to the overall reactions to news assessed over the whole sample period (Panel B of Table 3).

– Insert Table 4 about here –

In column (2), when investor sentiment dummies for the top quartile are included in the models, we find significant positive coefficients estimate on the macroeconomic surprises and negative estimated coefficients of the interaction terms. The opposing sign of the two coefficients implies that the cryptocurrency market reactions to announcements are weakened when investors are with a more bullish sentiment. Regarding the economic significance, one standard deviation increase in macroeconomic surprises initiates an average variation of 12.8 bps (16.8 bps) in the [-5;+5] return (turnover) during bearish sentiment periods, compared to a change of 6.4 bps (7.2 bps) during bullish

[9]For Return [-5;+5], it is computed by -0.037 (δ in column (1) of Table 4) divided by 0.098 (β_i in Panel B of Table 3). For Turnover [-5;+5], it is computed by -0.075 (δ in column (1) of Table 4) divided by 0.179 (β_i in Panel B of Table 3).

sentiment periods. In other words, the cryptocurrency market's sensitivity to surprising macroeconomic news during high bullish sentiment periods is only about 40 to 50% of the reactions during low sentiment stages. In column (3), our results remain qualitatively unchanged when we consider the median dummies of sentiment.

– Insert Table 5 about here –

In Table 5, we further examine the effects of sentiment on the cryptocurrency market reactions to individual announcements by employing Equation (6a). For these analyses, we only use one form of SENT as the standardized sentiment over the entire sample period attributable to consistent results in Table 4. For both return intervals, we find 29 out of 32 estimated coefficients of the interaction terms - δ_i have opposing signs compared with the corresponding β_i, and 18 out of 32 δ_i are statistically significant. Regarding the turnover ratio, we can obtain 17 out of 32 δ_i are statistically significant, with also 29 opposing coefficient pairs. Therefore, the results on individual events also support our prior findings that bullish sentiment can significantly reduce the responses of cryptocurrency market to the notices of macro news. The economic significance is also considerable for each type of announcement. For instance, one standard deviation increase in sentiment would reduce the extent of reactions to "*Industrial Production*" news by 61% (-0.47/0.076) of abnormal returns and 48% (-0.074/0.155) of turnover ratio. Also, sentiment can reduce 25% abnormal returns and 32% turnover that reacted to the surprises of "*Unemployment rate*". In addition, the Wald test results in the last column further confirm the substantial impacts of sentiment of that cryptocurrency market reactions to macro news.

Given the extant psychology and financial literature, investors with highly optimistic sentiments tend to rely more on heuristic information handling; therefore, they are less sensitive to fundamental information (Gu et al., 2021; Kurov and Stan, 2018). Alternatively, investors tend to systematically process new information when they have more pessimism sentiment. Consistent with the human behavior literature, individuals encounter more heuristics rather than systematically treating new information when they confront optimistic emotions Mackie and Worth (1989); Tiedens and Linton (2001).

Further, Shen et al. (2017) show that high investor sentiment weakens the usual positive risk-return compromise as macro-related risk factors exhibit lower returns in phases of high sentiment. Therefore, our findings collaborate with prior premises that the reactions to new information, such as macroeconomic announcements, are less significant during periods of high optimistic sentiment.

In Appendix A, we also consider the impacts of macroeconomic announcements in other major economies and the modified impacts of investor sentiment. We collect the macroeconomic announcements data in European Union (EU), China, Japan, and Germany. We summarize all considered events with time conversions in Table A.1 and re-estimate the results using Equations (6a) and (6b) in Table A.2. Overall, we find that the cryptocurrency market strongly reacts to macro news in EU and China only, while it is insignificant for Japanese and German updates. However, the economic significance of impacts is relatively lower compared to the reactions to the U.S news. Investor sentiment also exerts a weakening effect on the market responses to news in EU and China.

5 Additional analyses and robustness checks

To strengthen our findings, we employ various robustness tests with alternative variables and econometric approaches in this section.

5.1 Asymmetric impacts: market reaction to good and bad macroeconomic news

Given the extant literature, cryptocurrency investors behave differently to diverse kinds of information, such as good versus bad information (Corbet et al., 2020b; Rognone et al., 2020). Studies on the stock markets by Barberis et al. (1998) and Veronesi (1999) confirm that market reacts stronger to unfavourable news, which modifies by the stages of the economy (Conrad et al., 2002). Considering the impacts of macroeconomic news, Anderson et al. (2003) document that the foreign exchange market exhibits stronger reactions to bad news. Studies on the cryptocurrency market also confirm that reactions significantly depend on the nature of information, such as good or bad news (Caferra, 2020; Cheikh et al., 2020; Hashemi Joo et al., 2020). Therefore, we explore how sentiment affects the cryptocurrency market response to good and bad news by setting apart good from bad macroeconomic announcements. Following the approaches of Gu et al. (2021), we transpose the signs of the announcements that negative (positive) shocks are good (bad) information as the outcomes in Table 3 to confirm that positive (negative) shocks denote good (bad) news for the cryptocurrency market. We independently replicate the results from Equation (6b) for good and bad news and report the results in Table 6.

– Insert Table 6 about here –

Overall, our results indicate that negative macro news exerts stronger impacts on the cryptocurrency market than more positive ones, for both return and turnover. For instance, the bad news can reduce 12.9bps of [-5;+5] returns compare to 10.6bps of good ones. Regarding the impacts of investor sentiment, the interaction terms ($SP_t \times SENT_t$) are significant and negative for both return and turnover across all considered intervals,

indicating that the bullish sentiment can reduce market reactions to different categories of news. When we consider the absolute values of the coefficients, those moderated effects are more significant in magnitude for positive news than negative ones. To some extent, our findings are consistent with previous literature (i.e., Hashemi Joo et al. (2020); Rognone et al. (2020); and Corbet et al. (2020b)) that investors' reactions to news are considerably driven by their sentiment.

5.2 Sentiment and time-varying response to macroeconomic news

Next, we assess the time-varying sensitivity of cryptocurrencies to the announcements of macroeconomic news regarding returns and trading volume. Following the approach of Swanson and Williams (2014) and Kurov and Stan (2018), we address the small-sample bias from the traditional procedure of rolling windows by assuming that the comparative magnitudes of the response coefficients in Eq. (5a) and (5b) are persistent over time . As such, we can pool the shocks for all macroeconomic announcements in a one estimation. First, we utilize a major event of cryptocurrency market – 2017/18 cryptocurrency price crash on 22 December 2017, which exhibit a negative sentiment shock of investors during our examined period Cross et al. (2021); Yaya et al. (2019). In Appendix C.2, the graph also exhibit a significant devastation of cryptocurrency sentiment around this event. Initially, we run the regression by simultaneously using Eq. (5a) for both returns and turnover for the period before 22 December 2017 and saving the estimated coefficients. Then, these values are employed to calculate the normalized announcement surprises as for the 20 and 24 significant announcements for returns and turnover, respectively. As some of these announcements arise at the same time, we condense all normalized surprises for announcements that happened at the same time into a single variable. Subsequently, the regression in Eq. (5a) is simplified to the following specification:

$$Y_t = \alpha_0 + \beta \widehat{SSP_t} + \epsilon_t \tag{7}$$

where Y_t, include Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five minutes before to five minutes after the release of a macroeconomic information. $\widehat{SSP_t} = \sum_{j=1}^{k} \beta_j SP_{j,t}$ is the sum of the normalized surprises for announcements that happened in that period. As stated by Kurov and Stan (2018), this approach could lower the small-sample puzzle in the rolling regression since it is not essential to calculate individual reaction coefficient for each announcement form. With our alteration of announcement surprises, the β coefficient in Eq. (7) has a mean value of unity from the start of the sample period to 22 December 2017. In other words, shifts in the β coefficient after 22 December 2017 indicate that the reactions to news changes in an extent of increased bearish sentiment in the cryptocurrency. With the rolling window of corresponding to an approximately six-month period, we re-run the Eq. (7) with total 362 observations. Finally, we plot all obtained β coefficients for both return and turnover in Figure (1) and (2). Regarding the time-varying responses of returns, the estimated coefficients increase significantly after the cryptocurrency price crash in December 2017 before accompanying a marked fall in 2019. The return reactions also increase during the COVID period (2020-2021) depicted by higher bearish sentiment. With more stable patterns, the time-varying responses in trading volume also increase following Dec 2017 and Jan 2020. Overall, during the periods of elevated bearish sentiment, cryptocurrency markets mostly react stronger to macroeconomic news. Although it does not directly support our regression results on bullish sentiment in Table 5, our findings can confirm that the time-varying sensitivity of cryptocurrencies to macroeconomic news is driven by investor sentiment.

– Insert Figure 1 and 2 about here –

Prior studies also confirm that other factors could initiate time-varying reaction of investors to macroeconomic news, such as macroeconomics and policy uncertainty (Husted et al., 2016; Kurov and Stan, 2018), risk aversion and expected market volatility Drechsler et al. (2018), and business cycle Forni et al. (2017); Kurov and Stan (2018). As such, we further include several factors to control for the macroeconomics and market

conditions, including Cryptocurrency Uncertainty Index (CUI) by Lucey et al. (2022), CBOE Volatility Index - VIX, Economic Policy Uncertainty index – EPU by Baker et al. (2016) and the Aruoba–Diebold–Scotti (ADS) business conditions index by Aruoba et al. (2009). We estimate the average effect of investor sentiment on the crypto market reaction to news with controls by using the following regression:

$$Y_t = \alpha_0 + b_{SENT} SENT_t + b_X X_t + b_{SP} \sum_{j=1}^{k} \hat{\beta}_j SP_{j,t} + b_S \sum_{j=1}^{k} \hat{\beta}_j (SP_{j,t} \times SENT_t) + c_X \sum_{j=1}^{k} \hat{\beta}_j (SP_{j,t} \times X_t) + \epsilon_t \tag{8}$$

Where $X_t$is a control variable, that accounts for the CUI, VIX, EPU, and ADS indices, which are reported for both return and turnover in Panel A – D of Table 7, respectively. After controlling for those factors, our results remain robust that bullish sentiment weakens the reactions of cryptocurrency market to macroeconomic news with negative and significant coefficients (b_S). In addition, the estimated coefficients of $SP_{j,t} \times X_t$ (c_X) are positive and significant for CUI, VIX, and EPU for both return and turnover. Overall, the higher levels of uncertainties and expected volatilities, the stronger the crypto market reaction to macroeconomic news.

– Insert Table 7 about here –

5.3 Sub-sample analyses

The existing finance literature advocates that the efficiency of the cryptocurrency market is not a permanent phenomenon, which is substantially twisted by market conditions and crisis periods (Bourghelle et al., 2022; Fernandes et al., 2022; Wang and Wang, 2021). Hence, we further assess whether economic stages, such as the COVID-19 pandemic, have substantial effects on the cryptocurrency market reactions to macroeconomic surprises. Utilizing the event of the COVID-19 pandemic at the beginning of 2020, we split our sample into two sub-periods: 01 Jan 2014 to 31 Dec 2019 and 01 Jan 2020 to 31 Dec 2022. We independently replicate the results from Equation (6b) for each

sub-periods and report the results in Table 8. Our results indicate that the reactions of the crypto market to macro news, for both return and turnover, are more visible during the pandemic period. This finding is in line with prior studies by Philippas et al. (2020) and Fernandes et al. (2022) that investors exhibit more forms of panicked reactions to informative signals such as macro news. However, considering the interaction terms ($SP_t \times SENT_t$), we can also confirm that bullish sentiment reduces market reactions. The relative ratios (δ to β) are identical for both sub-periods; therefore, the deteriorating forces of sentiment on market responses are comparable for both periods.

– Insert Table 8 about here –

In the next sub-sample analysis, we consider the different characteristics of cryptocurrencies. Following Cheng and Yen (2020) and Yao et al. (2021), we divide our sample into Large versus Small size and Old versus Young cryptocurrencies based on the median of market capitalization and listing months in a given month[10]. We then re-estimate the results for each sub-sample using Equation (6b) and report the results in Table 8. WWe construct 5-min interval equal-weighted indices for each sub-sample by the average of scaled returns and turnover of each cryptocurrency over the same sample period. We then re-estimate the results for each sub-sample using Equation (6b) and report the results in Table 9. Regarding the market capitalization, the estimated coefficients on market reactions are all significantly positive. The absolute values of the larger coins are considerably higher than smaller coins, indicating the larger coins exhibit stronger responses to macro news. For the two groups of ages, older coins also significantly react to news compared to younger ones. This is in line with the fact that more mature coins usually have higher market values, and attract more attention from investors (Yao et al., 2021). The interaction terms $SP_t \times SENT_t$ are significant and negative across all reflected intervals, demonstrating that the optimistic sentiment can lower market reactions to macro announcements. Considering the ratios (δ to β), the

[10]In unreported results, we also consider sub-samples by excluded bitcoin and top 5 coins by market cap. Overall, the results are qualitatively similar to Table 9.

results also indicate the modified drives of sentiment are comparable for both groups of market capitalization.

– Insert Table 9 about here –

In the Appendix B.1, we further consider the differences on traditional coins (our sample) and stable coins[11]. By further collecting data of top 20 stable coin by market capitalization from Coinmarketcap.com, we also construct 5-min interval equal-weighted indices for stablecoins over the same sample period. Overall, we can reconfirm that traditional coin exhibit stronger reactions to macro news than stablecoins in terms of returns, while it is identical for turnover ratio. The modified impacts of investor sentiment are only more visible for returns of traditional coins, while it is consistent for turnover.

In Appendix B.2, we consider the potential political bias on the releases of macroeconomic information. Prior studies suggest that newspaper headlines are likely more pessimistic during the Republican presidencies (Corbet et al., 2020b; Lott Jr and Hassett, 2014). As such, we also partition our sample by the U.S. President is a Republican or Democratic and re-estimate the results using Equation (5b) and (6b) for [-5+5] interval returns and turnover. Overall, cryptocurrency market reveals stronger reactions to macro news when the U.S. President is a Republican, which is consistent with the more negative newspaper headlines released. The effects of investor sentiment remain unchanged for two sub-samples.

[11]Several studies confirm that stablecoins can serve as safe havens in terms of an effective diversifier as their low conditional correlations between stablecoins with cryptocurrency portfolios (Baur and Hoang, 2021; Díaz et al., 2023; Wang et al., 2020).

5.4 Sentiment before announcements and cryptocurrency market reaction

To alleviate potential endogeneity concerns about our data, we also consider the impacts of investor sentiment before the macro news announcement. We modify our prior models by including the lagged values of our sentiment measure as follows:

$$Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_{t-\tau} + \delta(SP_t \times SENT_{t-\tau}) + \epsilon_t \tag{9}$$

Where, $SENT_{t-\tau}$ captures the value of the TRMI Cryptocurrency Sentiment released the one day and average three day prior to each macroeconomic announcement. We report the estimated results in Table 10. Overall, the estimated coefficients of SP_t are all positive and significant, indicating that our results on cryptocurrency market reactions remain robust. The coefficients of $SP_t \times SENT_{t-\tau}$ also exhibit negative and significant values across all variables, indicating that market reactions to macroeconomic news are less significant when investors demonstrate more bullish sentiment.

– Insert Table 10 about here –

5.5 Alternative Event Windows

Initially, our study utilizes the trading data over narrow windows from five to ten minutes intervals around the official releasing times of macroeconomic news. To provide more robust evidence, we further examine the market reactions with several alternative windows up to 30 minutes around the announcement release time. By re-estimating the results from Equation (6b) for new windows, we report the results in Table 11. Overall, our findings are robust for various event windows with positive estimated coefficients for standardized surprises. The interaction term ($SP_t \times SENT_t$) also maintains negative and significant coefficients for all the intervals considered. In other words, the modified impacts of bullish sentiment still embrace, even after we expand the event window from 10 to 60 minutes around the events. Consider the absolute values of the SP_t coefficients,

we find that the magnitude of reactions less significant prior to the release times. Hence, our results collaborate the pre-announcement drift findings by Kurov et al. (2019) and Marmora (2022) regarding the patterns of information leakage and superior forecasting featuring private data[12].

– Insert Table 11 about here –

5.6 Alternative Measures of Investor Sentiment

In the final robustness checks, we utilize several alternative indicators of investor sentiment and re-estimate the results from Equation (6b) in Table 12. Following the current behavioral finance and cryptocurrency literature, we employ four alternative measures of investor sentiment, including Thomson Reuters Marketpsych Country Index (RMI)[13]; Baker and Wurgler (2006) investor sentiment index (BW); Risk aversion index (RAI) by Bekaert et al. (2022)[14]; and the American Association of Individual Investors (AAII) sentiment index. To consider the potential impacts of investor attention on crypto market reactions, we also obtain the Investor Attention from Google Search Volume data (GSVI). The detailed descriptions are reported in Appendix C. The frequencies for sentiment dummies for are varying among different alternative indicators due to the data availability.

– Insert Table 12 about here –

Our results are reliable with those based on RMI, RAI, BW and AAII sentiment all consistent with prior findings that cryptocurrency market responses to news are substantially weaker when positive sentiment increases. When using the proxy of investor attention, we obtain significant and positive coefficients of the interaction term across all variables. In other words, crypto market response to macroeconomic news is

[12]In this study, our study does not seek explanations for the market reactions over different intervals, but rather explore the power of sentiment affects for both pre-drifts and post-announcement.

[13]We compute the RMI index by taking the GDP-weighted average values of G20 countries.

[14]To be consistent with hypothesis on bullish sentiment, we utilize the bottom quartile of the RAI in the interaction term of $SP_t \times SENT_t$ in Equation (6b).

substantially stronger in periods of higher investor attention. This finding congruous with the theoretical model proposed by Andrei and Hasler (2015) that greater attention admits information to incorporated into asset prices more promptly, inducing stronger reactions of cryptocurrencies to the macro news. In addition, crypto investors are more likely to buy attention-grabbing assets Barberis and Huang (2008); Smales (2022); therefore, cryptocurrencies exhibit stronger responses to macroeconomic information, with higher returns and trading volume, during higher attention period.

5.7 Alternative approach: Weighted Least Squares

A possible concern about our results is that the intraday data in our regressions are heteroskedastic caused by the intraday periodicity of prices and feasibly diverse influences of different announcement classes on volatility and volatility clustering (Andersen and Bollerslev, 1997; Kalev et al., 2004). Generally, we utilize the regressions with heteroskedasticity consistent standard errors, which provide statistically significant results in prior sections. However, to address the potential data issue and enhance estimation efficiency, we utilize the Weighted Least Squares (WLS) estimation technique as in Andersen et al. (2007). First, we employ the OLS regression with $\widehat{SSP}_t$ is the sum of the normalized surprises for announcements that happened in that period as in Eq.(7) in the following equation:

$$Y_t = \alpha_0 + b_{SENT} SENT_t + b_{SP} \widehat{SSP}_t + \delta_S (\widehat{SSP}_t \times SENT_t) + \epsilon_t \tag{10}$$

Consistent with our prior analyses, we use the standardized sentiment over the entire sample period for $SENT_t$. Then, we use the residuals obtained from of Eq. (10) to estimate the following volatility model:

$$ln(\hat{\epsilon}_t^2) = \beta ln(\hat{\epsilon}_{t-1}^2) + \sum_{n=1}^{N} \delta_n D_n + \theta_1 \left|\widehat{SSP}_t\right| + \theta_2 SENT_t + \theta_3 (\left|\widehat{SSP}_t\right| \times SENT_t) + \mu_t \tag{11}$$

In this equation, include the first lag of volatility $(ln(\hat{\epsilon}_{t-1}^2)))$ to capture the possible volatility clustering. We also add a dummy variable of D_n to capture systematic

differences in volatility across different times of trading day in the US. We choose the six points of time (N = 6 and 8:15 am, 8:30 am, 9:45 am, 9:55 am, 10:00 am, and 2:00 pm) according to the release times of the macroeconomics news. After obtaining the estimated volatility $ln(\hat{\epsilon}^2_{t-1}) - \hat{\mu}_t$ from Eq. (11), we employ the WLS estimation with the estimated volatility in Eq. (10) and report the results in Table 13. We also report the baseline results from OLS as in Table 4 for comparison with WLS coefficients. As expected, the coefficient standard errors are smaller than the baseline values for both return and turnover. Hence, although our results remain unchanged, the conclusion is consistent that the presence of more bullish sentiment can weaken the reactions of crypto market to macroeconomic news.

– Insert Table 13 about here –

6 Conclusion

This paper intends to enrich the understanding of how investor sentiment modifies reactions of the cryptocurrency market to the announcement of macroeconomics news. Utilizing the high-frequency dataset of top 100 cryptocurrencies and 32 scheduled U.S macroeconomic announcements from 2014 to 2021, we find that the cryptocurrency market significantly responds to that news. The extent and magnitude of this effect depend on the kind of released information. We also document that bullish sentiment can weaken 40 to 50% of the crypto market reactions to the news, which remains significant for both good and bad macroeconomic information. Under a battery of robustness checks and sensitivity analyses to control the endogeneity issue, our findings remain robust. Overall, this study proposes valuable implications for academics, practitioners, and investors in crypto asset allocations and exploiting profit with market-timing. Overall, our findings also suggest that investors, multinational corporation managers, and institutional asset managers with digital currency holdings may find it useful to consider the significant effect of macroeconomic news on the seasonal volatility of cryptocurrency markets. To improve risk management practices associated with cryptocurrency transactions, these market participants would benefit from adjusting their portfolio positions to account for the effects of the day of the week and the impact of scheduled news on the seasonal volatility component.

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Tables and Figures

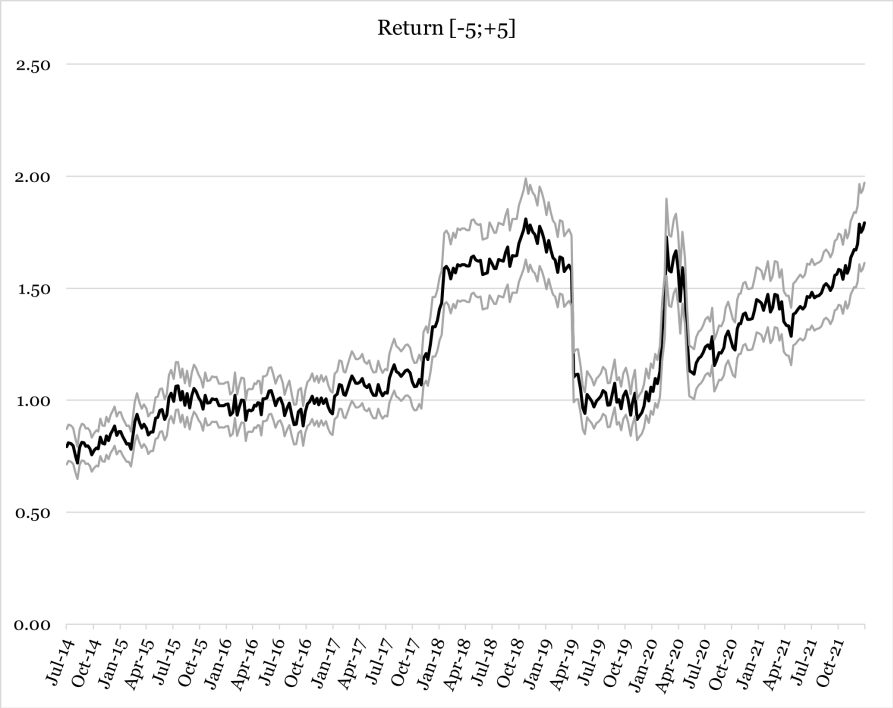

Figure 1: Time-varying response of cryptocurrencies returns to macroeconomic news.

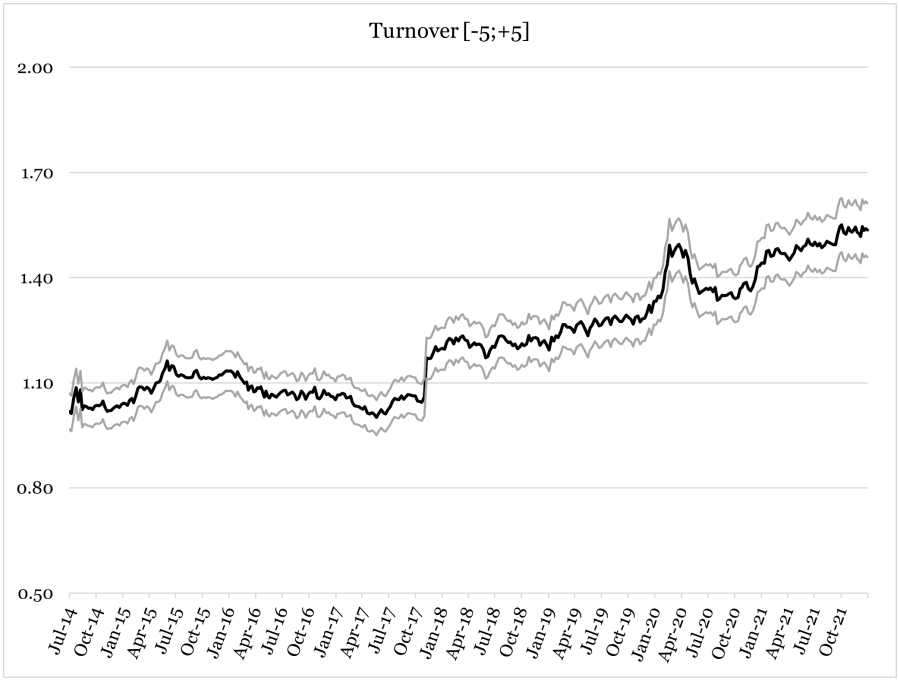

Figure 2: Time-varying response of cryptocurrencies turnover to macroeconomic news.

Table 1: U.S. Macroeconomic News Announcements

This table reports the data from January 2014 to December 2021 for 32 relevant news and sorted into the following eight macroeconomic announcement groups: (I) Real Economic Activity; (II) Consumption ; (III) Investment; (IV) Government; (V) Trade; (VI) Price indices; (VII) Monetary Policy; and (VIII) Forward-Looking indicators. Those announcements are organised and publicised by 14 organisations, including the Federal Reserve Board (FRB), Bureau of the Census (BC), Bureau of Economic Analysis (BEA), U.S. Department of Treasury (USDT), Bureau of Labor Statistics (BLS), Conference Board (CB), Federal Reserve Bank of Philadelphia (FRBP), Institute for Supply Management (ISM), Federal Reserve Bank of New York (FRBNY), Thomson Reuters and University of Michigan (TRUM), National Association of Purchasing Management (NAPM), Automatic Data Processing, Inc. (ADP), and National Association of Purchasing Management (NAPM). All times are reported at U.S. Eastern Time (EST) and corresponding UTC time.

Announcement	Source	Obs	Frequency	EST	UTC
(I) Real Economic Activity					
(1) Gross Domestic Product	BEA	90	monthly	8:30 AM	12:30 PM
(2) Nonfarm payroll employment	BLS	95	monthly	8:30 AM	12:30 PM
(3) Retail sales advance	BC	80	monthly	8:30 AM	12:30 PM
(4) Industrial production	FRB	95	monthly	9:15 AM	1:15 PM
(5) Capacity utilization	FRB	94	monthly	9:15 AM	1:15 PM
(6) Personal income	BEA	95	monthly	8:30 AM	12:30 PM
(7) Consumer credit	FRB	95	monthly	3:00 PM	7:00 PM
(8) Initial unemployment (jobless claims)	ETA	460	weekly	8:30 AM	12:30 PM
(9) Unemployment rate	BLS	95	monthly	8:30 AM	12:30 PM
(10) ADP employment	ADP/MALLC	55	monthly	8:15 AM	12:15 PM
(II) Consumption					
(11) Personal consumption expenditures	BEA	95	monthly	8:30 AM	12:30 PM
(12) Personal spending	BEA	95	monthly	8:30 AM	12:30 PM
(13) New home sales	BC	95	monthly	10:00 AM	10:00 AM
(III) Investment					
(14) Durable goods orders	BC	95	monthly	8:30 AM	12:30 PM
(15) Construction spending	BC	68	monthly	10:00 AM	2:00 PM
(16) Factory orders	BC	95	monthly	10:00 AM	2:00 PM
(17) Business inventories	BC	92	monthly	10:00 AM	2:00 PM
(IV) Government					
(18) Government budget deficit	BEA	95	monthly	8:30 AM	12:30 PM
(V) Trade					
(19) Balance of trade	BEA	95	monthly	8:30 AM	12:30 PM
(20) Current account	BEA	95	monthly	8:30 AM	12:30 PM
(VI) Price indices					
(21) Consumer price index	BLS	95	monthly	8:30 AM	12:30 PM
(22) Producer price index	BLS	83	monthly	8:30 AM	12:30 PM
(VII) Monetary policy					
(23) FOMC Rate Decision	FRB	95	monthly	2:00 PM	2:00 PM
(VIII) Forward-looking indicator					
(24) Consumer confidence	CB	95	monthly	10:00 AM	2:00 PM
(25) U. of Michigan Confidence	TRUM	95	monthly	9:55 AM	1:55 PM
(26) U. of Michigan current business conditions	TRUM	95	monthly	9:55 AM	1:55 PM
(27) NAPM/ISM index - Manufacturing	ISM	95	monthly	10:00 AM	2:00 PM
(28) NAPM/ISM index - Non-manufacturing	ISM	52	monthly	10:00 AM	2:00 PM
(29) Housing starts	BC	95	monthly	8:30 AM	12:30 PM
(30) Index of leading indicators	CB	95	monthly	10:00 AM	2:00 PM
(31) Philadelphia Fed Business Outlook	FRBP	95	monthly	10:00 AM	2:00 PM
(32) Chicago Purchasing Manager Index	NAPM	95	monthly	9:45 AM	1:45 PM

Table 2: Abnormal returns and trading volume on around the events.

This table reports the preliminary results of cryptocurrency market reactions of announcements of macroeconomic news from January 2014 to December 2021. We carry out two different non-parametric tests: bootstrapped standard errors and the Wilcoxon test to assess if the cryptocurrency abnormal returns (AR) and turnover ratio (TURN), on average, are significantly different from zero. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Return						
Period	**AR**	**Bootstrap (p-value)**	**Wilcoxon (p-value)**	**CAR**	**Bootstrap (p-value)**	**Wilcoxon (p-value)**
t-30	0.227	0.043**	0.047**	0.227	0.567	0.529
t-25	0.143	0.067*	0.078*	0.476	0.369	0.343
t-20	-0.071	0.357	0.362	0.405	0.424	0.394
t-15	0.03	0.645	0.688	0.435	0.393	0.365
t-10	-0.087	0.066*	0.058*	0.348	0.497	0.462
t-5	-0.13	0.045**	0.051*	0.218	0.628	0.584
t	0.648	0.003***	0.000***	0.866	0.040**	0.035**
t+5	0.384	0.008***	0.005***	1.25	0.014**	0.012**
t+10	0.25	0.037**	0.028**	1.393	0.009***	0.005***
t+15	-0.039	0.758	0.705	1.354	0.010**	0.009***
t+20	-0.017	0.825	0.767	1.337	0.018**	0.017**
t+25	0.033	0.587	0.546	1.37	0.008***	0.008***
t+30	0.019	0.893	0.869	1.39	0.008***	0.007***
Panel B: Trading volume - Turnover						
Period	**TURN**	**Bootstrap (p-value)**	**Wilcoxon (p-value)**	**CTURN**	**Bootstrap (p-value)**	**Wilcoxon (p-value)**
t-30	0.147	0.784	0.763	0.147	0.651	0.607
t-25	0.242	0.574	0.559	0.388	0.386	0.359
t-20	-0.165	0.536	0.522	0.223	0.398	0.37
t-15	0.156	0.751	0.731	0.379	0.397	0.369
t-10	-0.147	0.615	0.598	0.232	0.412	0.383
t-5	0.318	0.088*	0.075*	0.55	0.091*	0.082*
t	1.67	0.000***	0.000***	2.22	0.065*	0.059*
t+5	0.825	0.002***	0.001***	3.045	0.017**	0.015**
t+10	0.59	0.059*	0.047**	3.635	0.002***	0.003***
t+15	0.161	0.729	0.678	3.796	0.000***	0.000***
t+20	-0.069	0.864	0.804	3.727	0.002***	0.002***
t+25	-0.12	0.797	0.741	3.607	0.005***	0.006***
t+30	-0.105	0.855	0.832	3.502	0.009***	0.010**

Table 3: Regression results: cryptocurrency reaction to macroeconomic news

This table reports the regression results from two models: $Y_t = \alpha_0 + \sum_{j=1}^{k} \beta_j SP_{j,t} + \epsilon_{j,t}$ (5a) and $Y_t = \alpha_0 + \beta_i SP_t + \epsilon_t$ (5b) in Panel A and B, respectively. Y_t includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Individual macroeconomic news - β_i				
Announcement	**Return**		**Turnover**	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
(I) Real Economic Activity				
(1) Gross Domestic Product (GDP)	0.164***	0.156***	0.310***	0.390***
(2) Nonfarm payroll employment	0.194***	0.182***	0.309***	0.245**
(3) Retail sales advance	0.172***	0.102**	0.215**	0.204**
(4) Industrial production	0.076**	0.060**	0.155**	0.118*
(5) Capacity utilization	-0.011	-0.012	0.022	0.021
(6) Personal income	0.03	0.027	0.067	0.064
(7) Consumer credit	0.063	0.026	0.108*	0.102
(8) Initial unemployment (jobless claims)	-0.190***	-0.167***	0.296***	0.231**
(9) Unemployment rate	-0.241***	-0.247***	0.301***	0.226**
(10) ADP employment	0.192***	0.153***	0.274**	0.211**
(II) Consumption				
(11) Personal consumption expenditures	0.035	0.028	0.068	0.051
(12) Personal spending	0.068*	0.061*	0.104*	0.072
(13) New home sales	0.05	0.042	0.087	0.069
(III) Investment				
(14) Durable goods orders	0.128**	0.101*	0.185*	0.139
(15) Construction spending	0.056	0.039	0.086	0.059
(16) Factory orders	0.104**	0.083*	0.130*	0.103
(17) Business inventories	0.019	0.015	0.12	0.095
(IV) Government				
(18) Government budget deficit	0.024	0.019	0.077	0.061
(V) Trade				
(19) Balance of trade	0.091**	0.072*	0.114*	0.09
(20) Current account	0.108**	0.086**	0.167**	0.133*
(VI) Price indices				
(21) Consumer price index	-0.138***	-0.096**	0.311***	0.247**
(22) Producer price index	-0.109**	-0.086*	0.271***	0.216**
(VII) Monetary policy				
(23) FOMC Rate Decision	-0.128***	-0.089**	0.319***	0.254***
(VIII) Forward-looking indicator				
(24) Consumer confidence	0.210***	0.167**	0.304***	0.242***
(25) U. of Michigan Confidence	0.051	0.035	0.129*	0.09
(26) U. of Michigan current business conditions	0.059	0.04	0.148**	0.103
(27) NAPM/ISM index - Manufacturing	0.143***	0.128**	0.207***	0.144**
(28) NAPM/ISM index - Non-manufacturing	0.120**	0.083	0.150**	0.104*
(29) Housing starts	0.118	0.105	0.177**	0.123*
(30) Index of leading indicators	0.064	0.044	0.093	0.065
(31) Philadelphia Fed Business Outlook	0.157***	0.140***	0.284***	0.198**
(32) Chicago Purchasing Manager Index	0.101**	0.090*	0.194**	0.135*
Wald test (p-value)	0.000***	0.000***	0.000***	0.000***
Observations	3,325	3,325	3,325	3,325
Adj-R^2 (%)	19.63	17.57	18.16	12.62
Panel B: Aggregate specification				
$\beta(SP_t)$	0.098***	0.078***	0.179***	0.124**
Observations	3,325	3,325	3,325	3,325
Adj-R^2 (%)	10.21	9.14	11.49	7.98

Table 4: Aggregate regression results: cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent	**[-5, +5]**			**[-10, +10]**		
variable: Return	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
	Standardized	**Top Quartile**	**Median**	**Standardized**	**Top Quartile**	**Median**
SP_t	0.234***	0.128***	0.091**	0.208***	0.103**	0.094**
	(0.019)	(0.022)	(0.064)	(0.019)	(0.022)	(0.019)
$SENT_t$	0.012	0.031	0.027	0.051*	0.046*	0.041
	(0.015)	(0.019)	(0.013)	(0.025)	(0.031)	(0.029)
$SP_t \times SENT_t$	-0.037***	-0.064***	-0.024**	-0.033***	-0.057***	-0.023**
	(0.006)	(0.001)	(0.015)	(0.007)	(0.003)	(0.017)
Constant	-0.005	-0.003	-0.008	-0.01	-0.009	-0.008
	(0.012)	(0.009)	(0.014)	(0.010)	(0.009)	(0.007)
Observation	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	10.95	9.8	8.77	9.73	8.71	7.79
Dependent	**[-5, +5]**			**[-10, +10]**		
variable: Turnover	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
	Standardized	**Top Quartile**	**Median**	**Standardized**	**Top Quartile**	**Median**
SP_t	0.312***	0.168***	0.099**	0.287***	0.136***	0.077**
	(0.003)	(0.008)	(0.014)	(0.004)	(0.008)	(0.016)
$SENT_t$	0.009	0.023	0.02	0.038	0.036	0.033
	(0.012)	(0.007)	(0.008)	(0.004)	(0.004)	(0.005)
$SP_t \times SENT_t$	-0.075***	-0.096***	-0.044***	-0.071***	-0.116***	-0.040***
	(0.003)	(0.001)	(0.006)	(0.003)	(0.000)	(0.007)
Constant	-0.007	-0.006	-0.011	-0.014	-0.012	-0.011
	(0.025)	(0.019)	(0.024)	(0.020)	(0.019)	(0.023)
Observation	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	8.95	8.01	7.17	7.95	7.12	6.37

Table 5: Regression results: cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6a): $Y_t = \alpha_0 + \sum_{j=1}^{k} \beta_j SP_{j,t} + \gamma SENT_t + \sum_{j=1}^{k} \delta_j (SP_{j,t} \times SENT_t) + \epsilon_{j,t}$. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Announcement	**Return [-5, +5]**		**Return [-10, +10]**		**Turnover [-5, +5]**		**Turnover [-10, +10]**	
	SP_t	$SP_t \times SENT_t$	SP_t	$SP_t \times SENT_t$	SP_t	$SP_t \times SENT_t$	SP_t	$SP_t \times SENT_t$
(I) Real Economic Activity								
(1) Gross Domestic Product	0.184***	-0.026	0.146**	-0.020	0.285***	-0.040	0.214***	-0.030
(2) Nonfarm payroll employment	0.482***	-0.098**	0.383***	-0.078**	0.747***	-0.152***	0.560***	-0.114***
(3) Retail sales advance	0.122	0.005	0.097	0.004	0.189*	0.008	0.142*	0.006
(4) Industrial production	0.258***	-0.047**	0.205***	-0.038**	0.399***	-0.074**	0.300***	-0.055*
(5) Capacity utilization	-0.109	0.015	-0.087	0.012	0.169*	-0.024	0.127	-0.018
(6) Personal income	0.099**	-0.021**	0.079**	-0.017*	0.153***	-0.033**	0.115**	-0.025
(7) Consumer credit	0.180**	-0.045**	0.143	-0.036**	0.278***	-0.071*	0.209**	-0.053*
(8) Initial unemployment (jobless claims)	-0.197***	0.038***	-0.157***	0.030***	-0.305***	0.059**	-0.229**	0.044**
(9) Unemployment rate	-0.397***	0.061***	-0.316***	0.049**	-0.615***	0.095***	-0.461**	0.071**
(10) ADP employment	0.246***	-0.034**	0.196**	-0.027**	0.381***	-0.053**	0.286***	-0.040**
(II) Consumption								
(11) Personal consumption expenditures	0.045	0.006	0.036	0.005	0.070	0.010	0.052	0.007
(12) Personal spending	0.087	-0.012	0.069	-0.010	0.135	-0.019	0.101	-0.014
(13) New home sales	0.147**	-0.038**	0.117**	-0.031**	0.228***	-0.060***	0.171**	-0.045**
(III) Investment								
(14) Durable goods orders	0.330***	-0.071***	0.262***	-0.056**	0.380***	-0.081***	0.285**	-0.061**
(15) Construction spending	0.113	-0.013	0.090	-0.010	0.138	-0.016	0.103	-0.012
(16) Factory orders	0.199**	-0.023*	0.158**	-0.018	0.197*	-0.022*	0.148	-0.017
(17) Business inventories	-0.057	0.008	-0.045	0.006	0.281	0.039	0.211	0.030
(IV) Government								
(18) Government budget deficit	0.094	-0.010	0.075	-0.008	0.243	-0.025	0.182	-0.019
(V) Net export								
(19) Balance of trade	0.202***	-0.063***	0.161***	-0.050***	0.201***	-0.063**	0.151***	-0.047**
(20) Current account	0.172	-0.018	0.137	-0.014	0.212	-0.022	0.159	-0.017
(VI) Price indices								
(21) Consumer price index	-0.221**	0.031**	-0.175**	0.025**	0.395***	-0.055***	0.296***	-0.041**
(22) Producer price index	-0.063	0.007	-0.050	0.005	0.125	-0.013	0.094	-0.010
(VII) Monetary policy								
(23) FOMC Rate Decision	-0.135***	0.023**	-0.107**	0.011*	0.268***	-0.027**	0.201**	-0.020**
(VIII) Forward-looking indicator								
(24) Consumer confidence	0.357***	-0.044**	0.284***	-0.035**	0.411***	-0.051***	0.308***	-0.038**
(25) U. of Michigan Confidence	0.051	0.005	0.041	0.004	0.103	0.011	0.077	0.008
(26) U. of Michigan current business conditions	0.059	-0.008	0.047	-0.007	0.118	-0.017	0.088	-0.012
(27) NAPM/ISM index - Manufacturing	0.232***	-0.087***	0.184**	-0.069***	0.267***	-0.100***	0.200***	-0.075**
(28) NAPM/ISM index - Non-manufacturing	0.135	-0.014	0.108	-0.011	0.134	-0.013	0.101	-0.010
(29) Housing starts	0.027	-0.004	0.021	-0.003	0.032	-0.004	0.024	-0.003
(30) Index of leading indicators	0.068	-0.007	0.054	-0.006	0.079	-0.008	0.059	-0.006
(31) Philadelphia Fed Business Outlook	0.310***	-0.063***	0.247***	-0.050***	0.447***	-0.091***	0.335***	-0.068**
(32) Chicago Purchasing Manager Index	0.243***	-0.037**	0.193**	-0.030*	0.372***	-0.057**	0.279**	-0.043*
Wald test (p-value)	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
Observations	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	17.45	15.62	16.14	11.22	14.93	10.38	13.81	9.60

Table 6: Asymmetric impacts: sentiment and reaction to good and bad macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for two groups of good versus bad news. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Return	Good news		Bad news	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.106***	0.097***	0.129***	0.115***
	(0.023)	(0.029)	(0.017)	(0.020)
$SENT_t$	0.042**	0.038**	-0.026*	-0.021
	(0.005)	(0.006)	(0.006)	(0.007)
$SP_t \times SENT_t$	-0.042***	-0.034***	-0.031***	-0.027**
	(0.004)	(0.006)	(0.011)	(0.012)
Constant	-0.095*	-0.087*	0.103**	0.092*
	(0.013)	(0.017)	(0.008)	(0.009)
Observation	1,831	1,831	1,875	1,875
Adj-R^2 (%)	5.78	5.17	9.80	8.77
Dependent variable: Turnover	Good news		Bad news	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.088**	0.080**	0.107***	0.096***
	(0.017)	(0.018)	(0.010)	(0.012)
$SENT_t$	0.038**	0.035**	-0.025*	-0.019
	(0.007)	(0.006)	(0.010)	(0.012)
$SP_t \times SENT_t$	-0.057***	-0.046***	-0.041***	-0.037***
	(0.002)	(0.003)	(0.004)	(0.004)
Constant	-0.034**	-0.031**	0.037**	0.033**
	(0.019)	(0.019)	(0.007)	(0.009)
Observation	1,831	1,831	1,875	1,875
Adj-R^2 (%)	4.46	3.99	7.56	6.77

Table 7: Average effect of investor sentiment on the crypto market response to macroeconomic news (with controls).

This table reports the regression results from Equation (8): $Y_t = \alpha_0 + b_{SENT} SENT_t + b_X X_t + b_{SP} \sum_{j=1}^{k} \hat{\beta}_j SP_{j,t} + b_S \sum_{j=1}^{k} \hat{\beta}_j (SP_{j,t} \times SENT_t) + c_X \sum_{j=1}^{k} \hat{\beta}_j (SP_{j,t} \times X_t) + \epsilon_t$. X_t is a control variable, that accounts for the CUI, VIX, EPU, and ADS indices, which are reported for both return and turnover. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	CUI		VIX		EPU		ADS	
Return	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.072***	0.064***	0.061**	0.055**	0.082***	0.073***	0.085***	0.076**
	(0.015)	(0.013)	(0.012)	(0.011)	(0.016)	(0.014)	(0.016)	(0.014)
$SP_t \times SENT_t$	-0.061***	-0.055***	-0.052***	-0.046**	-0.069***	-0.062***	-0.072***	-0.065***
	(0.011)	(0.010)	(0.009)	(0.008)	(0.012)	(0.011)	(0.012)	(0.010)
$SP_t \times X_t$	0.089**	0.080**	0.310**	0.278**	0.136***	0.122***	-0.142	-0.127
	(0.023)	(0.021)	(0.018)	(0.016)	(0.025)	(0.022)	(0.024)	(0.022)
Constant	-0.015	-0.014	-0.016	-0.015	-0.018	-0.015	-0.019	-0.016
	(0.012)	(0.009)	(0.008)	(0.010)	(0.009)	(0.011)	(0.008)	(0.010)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R2 (%)	15.30	13.69	12.26	10.97	17.73	15.86	17.56	15.72
Dependent variable:	CUI		VIX		EPU		ADS	
Turnover	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.098***	0.088***	0.083***	0.075**	0.111***	0.099***	0.116***	0.104***
	(0.005)	(0.007)	(0.005)	(0.007)	(0.006)	(0.007)	(0.005)	(0.007)
$SP_t \times SENT_t$	-0.087***	-0.078**	-0.070**	-0.062**	-0.093***	-0.083**	-0.089***	-0.080**
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
$SP_t \times X_t$	0.028**	0.025**	0.148**	0.132**	0.197***	0.176***	-0.047	-0.042
	(0.023)	(0.021)	(0.018)	(0.016)	(0.025)	(0.022)	(0.024)	(0.022)
Constant	-0.020	-0.018	-0.022	-0.018	-0.021	-0.018	-0.021	-0.020
	(0.011)	(0.009)	(0.009)	(0.008)	(0.012)	(0.009)	(0.008)	(0.010)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R2 (%)	10.10	9.04	8.09	7.24	10.78	9.65	10.68	9.56

Table 8: Sub-period analysis: Investor sentiment and reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for two sub-periods: 01 Jan 2014 to 31 Dec 2019 and 01 Jan 2020 to 31 Dec 2022. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Return	Jan 2014 - Dec 2019		Jan 2020 - Dec 2022	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.093**	0.085**	0.220***	0.197***
	(0.012)	(0.015)	(0.005)	(0.007)
$SENT_t$	0.023	0.021	0.057*	0.045*
	(0.006)	(0.006)	(0.003)	(0.004)
$SP_t \times SENT_t$	-0.042***	-0.034**	-0.098***	-0.096***
	(0.005)	(0.007)	(0.002)	(0.002)
Constant	-0.014	-0.013	-0.015	-0.014
	(0.007)	(0.007)	(0.006)	(0.007)
Observation	2,793	2,793	931	931
Adj-R^2 (%)	8.68	7.77	13.13	11.75
Dependent variable: Turnover	Jan 2014 - Dec 2019		Jan 2020 - Dec 2022	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.112***	0.102**	0.214***	0.191***
	(0.008)	(0.009)	(0.003)	(0.004)
$SENT_t$	0.019	0.017	0.050*	0.045*
	(0.008)	(0.008)	(0.002)	(0.003)
$SP_t \times SENT_t$	-0.062***	-0.054***	-0.113***	-0.106***
	(0.007)	(0.007)	(0.001)	(0.001)
Constant	-0.009	-0.008	-0.010	-0.009
	(0.005)	(0.005)	(0.006)	(0.005)
Observation	2,793	2,793	931	931
Adj-R^2 (%)	10.24	9.16	13.65	12.22

Table 9: Sub-sample analysis: Investor sentiment and reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for Large versus Small size and Old versus Young cryptocurrencies based on the median of market capitalization and listing months in a given month. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent	**Large cap**		**Small cap**		**Old**		**Young**	
variable: Return	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.095***	0.087***	0.073**	0.061**	0.098***	0.087***	0.087***	0.086***
	(0.009)	(0.010)	(0.013)	(0.015)	(0.005)	(0.007)	(0.005)	(0.007)
$SENT_t$	0.054*	0.049*	0.034	0.030	0.033	0.035	0.031	0.028
	(0.002)	(0.002)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
$SP_t \times SENT_t$	-0.045***	-0.040***	-0.034**	-0.032*	-0.039***	-0.037***	-0.040***	-0.038***
	(0.004)	(0.004)	(0.006)	(0.007)	(0.003)	(0.003)	(0.004)	(0.003)
Constant	-0.011	-0.010	-0.012	-0.011	-0.013	-0.011	-0.014	-0.012
	(0.008)	(0.008)	(0.007)	(0.008)	(0.006)	(0.008)	(0.006)	(0.006)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	9.68	8.66	7.75	6.94	11.72	10.49	11.62	10.40
Dependent	**Large cap**		**Small cap**		**Old**		**Young**	
variable: Turnover	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.107***	0.098***	0.086***	0.082***	0.100***	0.090**	0.109***	0.097***
	(0.005)	(0.007)	(0.005)	(0.007)	(0.006)	(0.007)	(0.005)	(0.007)
$SENT_t$	0.047*	0.043*	0.030	0.026	0.034	0.036	0.032	0.030
	(0.008)	(0.009)	(0.011)	(0.011)	(0.009)	(0.009)	(0.010)	(0.010)
$SP_t \times SENT_t$	-0.069***	-0.062***	-0.036**	-0.034**	-0.060***	-0.056***	-0.061***	-0.058***
	(0.003)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)
Constant	-0.010	-0.009	-0.011	-0.010	-0.012	-0.010	-0.012	-0.011
	(0.006)	(0.006)	(0.005)	(0.006)	(0.005)	(0.006)	(0.005)	(0.005)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	11.24	10.06	9.00	8.06	12.00	10.74	11.89	10.64

Table 10: Sentiment before announcements and reaction to macroeconomic news

This table reports the regression results from Equation (9): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_{t-\tau} + \delta(SP_t \times SENT_{t-\tau}) + \epsilon_t$ for investor sentiment before the macro new announcements. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Return	Prior day		Prior three days	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.196***	0.173***	0.105**	0.084**
	(0.002)	(0.002)	(0.003)	(0.004)
$SENT_{t-\tau}$	-0.027	-0.023	-0.016	-0.014
	(0.009)	(0.011)	(0.013)	(0.014)
$SP_t \times SENT_{t-\tau}$	-0.040***	-0.035***	-0.025**	-0.021**
	(0.008)	(0.009)	(0.011)	(0.012)
Constant	-0.023	-0.020	0.023	0.019
	(0.012)	(0.014)	(0.012)	(0.014)
Observation	3,325	3,325	3,325	3,325
Adj-R^2 (%)	8.90	7.96	13.45	12.04
Dependent variable: Turnover	Prior day		Prior three days	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.202***	0.179***	0.198***	0.159***
	(0.004)	(0.005)	(0.004)	(0.005)
$SENT_{t-\tau}$	-0.019	-0.016	-0.012	-0.010
	(0.007)	(0.008)	(0.010)	(0.011)
$SP_t \times SENT_{t-\tau}$	-0.031***	-0.027***	-0.020**	-0.016**
	(0.007)	(0.008)	(0.010)	(0.011)
Constant	0.058	0.049	0.056	0.047
	(0.019)	(0.023)	(0.020)	(0.024)
Observation	3,325	3,325	3,325	3,325
Adj-R^2 (%)	8.26	7.39	6.62	5.92

Table 11: Alternative event windows: Sentiment and cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for different alternative event windows. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Return	**[-30, 0]**	**[-15, 0]**	**[-30, +30]**	**[0, +15]**	**[0, +30]**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
SP_t	0.029*	0.034**	0.097***	0.116***	0.074***
	(0.017)	(0.015)	(0.009)	(0.007)	(0.010)
$SENT_t$	0.016	0.030	0.024	0.022	0.014
	(0.008)	(0.007)	(0.004)	(0.003)	(0.005)
$SP_t \times SENT_t$	-0.012**	-0.018**	-0.043***	-0.045***	-0.034***
	(0.007)	(0.006)	(0.002)	(0.002)	(0.003)
Constant	-0.012	-0.010	0.025	0.013	0.019
	(0.005)	(0.006)	(0.005)	(0.006)	(0.006)
Observation	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	8.90	7.96	13.45	12.04	13.32
Dependent variable: Turnover	**[-30, 0]**	**[-15, 0]**	**[-30, +30]**	**[0, +15]**	**[0, +30]**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
SP_t	0.072**	0.086***	0.154***	0.185***	0.119***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.004)
$SENT_t$	0.026	0.031	0.025	0.023	0.015
	(0.011)	(0.012)	(0.013)	(0.014)	(0.016)
$SP_t \times SENT_t$	-0.030**	-0.045**	-0.107***	-0.113***	-0.087***
	(0.015)	(0.014)	(0.005)	(0.004)	(0.006)
Constant	-0.009	-0.008	0.018	0.010	0.014
	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)
Observation	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	8.90	7.96	13.45	12.04	13.32

Table 12: Alternative Sentiment proxies: Sentiment and cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ by using the alternative investor sentiment indicators and investor attention. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable: Return	RMI (daily)		BW (monthly)		RAI (daily)		AAII (weekly)		GSVI (weekly)	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.084***	0.074***	0.060***	0.048**	0.067***	0.056***	0.075***	0.063***	0.066***	0.055**
	(0.007)	(0.008)	(0.009)	(0.007)	(0.010)	(0.009)	(0.010)	(0.008)	(0.009)	(0.007)
$SENT_t$	0.024*	0.020*	0.006	0.005	0.017	0.014	0.011	0.010	0.005	0.004
	(0.01)	(0.014)	(0.017)	(0.013)	(0.019)	(0.016)	(0.018)	(0.015)	(0.016)	(0.013)
$SP_t \times SENT_t$	-0.042***	-0.037**	-0.029**	-0.026**	-0.066***	-0.056***	-0.040**	-0.033**	0.036***	0.029***
	(0.004)	(0.005)	(0.013)	(0.011)	(0.004)	(0.004)	(0.005)	(0.004)	(0.042)	(0.035)
Constant	-0.020	-0.016	0.019	0.016	-0.022	-0.019	-0.021	-0.018	-0.056	-0.047
	(0.007)	(0.008)	(0.010)	(0.008)	(0.014)	(0.012)	(0.014)	(0.012)	(0.035)	(0.030)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	7.75	6.94	11.72	10.49	11.62	10.40	9.68	8.66	3.84	3.43
Dependent variable: Turnover	RMI (daily)		BW (monthly)		RAI (daily)		AAII (weekly)		GSVI (weekly)	
	[-5, +5]	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.094***	0.083***	0.067***	0.059***	0.082***	0.069***	0.092***	0.078***	0.081***	0.068***
	(0.005)	(0.006)	(0.007)	(0.006)	(0.008)	(0.007)	(0.008)	(0.006)	(0.007)	(0.006)
$SENT_t$	0.033	0.027	0.031	0.026	0.030	0.025	0.029	0.024	0.020	0.017
	(0.003)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.005)	(0.004)	(0.007)	(0.006)
$SP_t \times SENT_t$	-0.102***	-0.086***	-0.047**	-0.043**	-0.094***	-0.079***	-0.090***	-0.075***	0.024**	0.020**
	(0.001)	(0.002)	(0.008)	(0.006)	(0.002)	(0.002)	(0.002)	(0.002)	(0.014)	(0.012)
Constant	-0.008	-0.006	-0.009	-0.008	-0.011	-0.009	-0.010	-0.008	-0.018	-0.015
	(0.005)	(0.006)	(0.007)	(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.012)	(0.010)
Observation	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325	3,325
Adj-R^2 (%)	9.08	8.13	13.74	12.29	13.61	12.18	11.34	10.15	4.49	4.02

Table 13: Sentiment and cryptocurrency market reaction to macroeconomic news: OLS and Weighted Least Squares (WLS) estimations

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for the OSL and Equation (10) $Y_t = \alpha_0 + b_{SENT} SENT_t + b_{SP} \widehat{SSP}_t + \delta_S(\widehat{SSP}_t \times SENT_t) + \epsilon_t$ for WLS. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the weighted least squares (WLS) and Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	[-5, +5]		[-10, +10]	
Return	**(1) Baseline OSL**	**(2) WLS**	**(1) Baseline OSL**	**(2) WLS**
SP_t	0.234***	0.213***	0.208***	0.190***
	(0.019)	(0.013)	(0.019)	(0.015)
$SENT_t$	0.012	0.011	0.021*	0.019
	(0.015)	(0.013)	(0.025)	(0.022)
$SP_t \times SENT_t$	-0.037***	-0.030***	-0.033***	-0.027***
	(0.006)	(0.005)	(0.007)	(0.005)
Constant	-0.005	-0.005	-0.006	-0.005
	(0.012)	(0.011)	(0.010)	(0.009)
Observation	3,325	3,325	3,325	3,325
Adj-R2 (%)	10.95	9.80	15.77	14.11
Dependent variable:	[-5, +5]		[-10, +10]	
Turnover	**(1) Baseline OSL**	**(2) WLS**	**(1) Baseline OSL**	**(2) WLS**
SP_t	0.312***	0.247***	0.287***	0.227***
	(0.003)	(0.002)	(0.004)	(0.003)
$SENT_t$	0.009	0.008	0.016	0.014
	(0.012)	(0.011)	(0.004)	(0.004)
$SP_t \times SENT_t$	-0.075***	-0.051**	-0.071***	-0.034**
	(0.003)	(0.001)	(0.003)	(0.001)
Constant	-0.007	-0.006	-0.008	-0.007
	(0.025)	(0.022)	(0.020)	(0.018)
Observation	3,325	3,325	3,325	3,325
Adj-R2 (%)	8.95	8.01	11.13	9.96

APPENDIX

Appendix A – CRYPTOCURRENCY MARKET REACTIONS TO MACRO ANNOUNCEMENTS IN MAJOR ECONOMIES

Table A1: Macro announcements in European Union (EU), China, Japan and Germany

EU	**Obs**	**Frequency**
(I) Real Economic Activity		
Gross Domestic Product	90	monthly
Industrial production	95	monthly
Unemployment rate	95	monthly
Retail sales	80	monthly
(II) Monetary policy		
ECB: Monetary policy	62	every six weeks
(III) Price indices		
Consumer price index	95	monthly
(VI) Forward-looking indicator		
Consumer confidence	95	monthly
Business confidence	96	monthly
China		
(I) Real Economic Activity		
Gross Domestic Product	23	Quarterly
Manufacturing purchasing manager index	92	monthly
Industrial production	94	monthly
(II) Consumption		
Retail sales	95	monthly
(III) Investment		
Fixed assets investment	95	monthly
(IV) Trade		
Balance of trade	95	monthly
(VI) Price indices		
Consumer price index	95	monthly
Producer price index	88	monthly
(VII) Monetary policy		
M2 Money Supply	95	monthly
(VIII) Forward-looking indicator		
PMI Manufacturing	90	monthly
Japan		
(I) Real Economic Activity		
Gross Domestic Product	23	Quarterly
Unemployment	95	monthly
Industrial Production	95	monthly
(II) Consumption		
Households' expenditure	90	monthly
Retail sales	90	monthly
(III) Price indices		
Consumer price index	95	monthly
(IV) Trade		
Balance of trade	92	monthly
(IV) Monetary policy		
Money supply (M2 + CD)	92	Quarterly
(V) Forward-looking indicator		
Tankan (large manufacturing)	80	monthly
Tankan (large non-manufacturing)	80	monthly
Germany		
(I) Real Economic Activity		
Gross Domestic Product	23	Quarterly
Industrial Production	95	monthly
Unemployment claims	92	monthly
(II) Consumption		
Retail sales	90	monthly
(III) Price indices		
Consumer price index	95	monthly

Table A2: Sentiment and cryptocurrency market reactions to macroeconomic announcements in European Union, China, Japan and Germany

Dependent variable:	EU		Germany		China		Japan	
Return	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
SP_t	0.037**	0.033**	0.012	0.010	0.034**	0.020*	0.013	0.011
	(0.010)	(0.011)	(0.009)	(0.007)	(0.003)	(0.002)	(0.009)	(0.007)
$SENT_t$		0.024		0.020		0.006		0.005
		(0.012)		(0.014)		(0.017)		(0.013)
$SP_t \times SENT_t$		-0.018**		-0.009		-0.022**		-0.009
		(0.008)		(0.009)		(0.006)		(0.005)
Constant	-0.096	-0.080	0.092	0.077	-0.088	-0.074	-0.084	-0.071
	(0.019)	(0.023)	(0.027)	(0.022)	(0.030)	(0.025)	(0.029)	(0.024)
Observation	728	728	420	420	895	895	815	815
Adj-R^2 (%)	8.95	6.71	5.28	3.96	8.91	6.69	7.98	5.98
Dependent variable:	EU		Germany		China		Japan	
Turnover	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
SP_t	0.052**	0.046**	0.008	0.007	0.027*	0.023	0.005	0.005
	(0.003)	(0.004)	(0.006)	(0.005)	(0.002)	(0.001)	(0.006)	(0.005)
$SENT_t$		0.024		0.012		0.015		0.010
		(0.012)		(0.014)		(0.017)		(0.013)
$SP_t \times SENT_t$		-0.022**		-0.006		-0.016*		-0.003
		(0.005)		(0.006)		(0.009)		(0.004)
Constant	-0.044	-0.037	0.042	0.035	-0.040	-0.034	-0.039	-0.032
	(0.023)	(0.027)	(0.022)	(0.018)	(0.025)	(0.021)	(0.029)	(0.024)
Observation	728	728	420	420	895	895	815	815
Adj-R^2 (%)	10.25	7.69	6.04	4.53	10.21	7.66	9.14	6.85

Appendix B.1 – SUB-SAMPLE ANALYSES

Table B1: Stable versus traditional cryptocurrencies: Investor sentiment and cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for two groups of traditional coins versus stablecoins. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	Traditional coins		Stable coins	
Return	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.099***	0.093***	0.024*	0.022
	(0.006)	(0.006)	(0.018)	(0.018)
$SENT_t$	0.038	0.035	0.009	0.007
	(0.003)	(0.003)	(0.006)	(0.006)
$SP_t \times SENT_t$	-0.045***	-0.037***	-0.013	-0.012
	(0.005)	(0.006)	(0.009)	(0.009)
Constant	-0.008	-0.010	-0.011	-0.010
	(0.005)	(0.006)	(0.006)	(0.006)
Observation	3,325	3,325	3,325	3,325
Adj-R^2 (%)	11.64	10.42	7.18	6.43
Dependent variable:	Traditional coins		Stable coins	
Turnover	**[-5, +5]**	**[-10, +10]**	**[-5, +5]**	**[-10, +10]**
SP_t	0.103***	0.094***	0.109***	0.098***
	(0.006)	(0.007)	(0.005)	(0.006)
$SENT_t$	0.043*	0.039	0.047*	0.037
	(0.005)	(0.006)	(0.005)	(0.006)
$SP_t \times SENT_t$	-0.051***	-0.042***	-0.054**	-0.051**
	(0.007)	(0.008)	(0.011)	(0.011)
Constant	-0.013	-0.012	-0.014	-0.013
	(0.006)	(0.006)	(0.005)	(0.005)
Observation	3,325	3,325	3,325	3,325
Adj-R^2 (%)	9.96	8.91	8.47	10.07

Appendix B.2 – SUB-SAMPLE ANALYSES: POLITICAL BIAS

In this sub-sample analysis, we partition our sample by the U.S. President is a Republican or Democratic and re-estimate the results using Equation (5b) and (6b) for [-5+5] interval returns and turnover.

- Republican – Donald Trump (20 Jan 2017 – 20 Jan 2021)
- Democratic: Barack Obama (1 Jan 2014 – 20 Jan 2017) and Joe Biden (20 Jan 2017 – 31 Dec 2021)

Table B2: Political bias: Investor sentiment and cryptocurrency reaction to macroeconomic news

This table reports the regression results from Equation (6b): $Y_t = \alpha_0 + \beta_i SP_t + \gamma SENT_t + \delta(SP_t \times SENT_t) + \epsilon_t$ for two sub-periods of Republican or Democratic presidencies. Y_t, includes Ret_t and $Turn_t$ are the continuously compounded turnover and abnormal return from five/ten minutes before to five/ten minutes after the release of a macroeconomic information. $SP_{j,t}$ is the standardized surprise corresponding to announcement i at time t. $SENT_t$ is the sentiment indicator proxied by the daily Thomson Reuters Marketpsych (TRMI) Cryptocurrency Sentiment. The sample is from January 2014 to December 2021. The reported coefficients are obtained by using the Ordinary Least Squares with Newey and West (1987)'s heteroscedasticity and autocorrelation consistent standard errors. The descriptions of all announcements are reported in Table 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Dependent variable:	Republican		Democratic	
Return	**(1)**	**(2)**	**(1)**	**(2)**
SP_t	0.088***	0.086***	0.069**	0.055**
	(0.004)	(0.005)	(0.004)	(0.003)
$SENT_t$		0.016		0.013
		(0.010)		(0.012)
$SP_t \times SENT_t$		-0.029**		-0.020**
		(0.008)		(0.009)
Constant	0.023	0.019	0.022	0.018
	(0.009)	(0.011)	(0.013)	(0.010)
Observation	1,680	1,680	1,645	1,645
Adj-R^2 (%)	8.44	6.33	4.98	3.73
Dependent variable:	Republican		Democratic	
Turnover	(1)	(2)	(1)	(2)
SP_t	0.066***	0.059***	0.047***	0.046***
	(0.014)	(0.017)	(0.013)	(0.011)
$SENT_t$		0.022		0.018
		(0.010)		(0.012)
$SP_t \times SENT_t$		-0.025**		-0.017**
		(0.008)		(0.009)
Constant	0.044	0.037	0.042	0.035
	(0.019)	(0.023)	(0.025)	(0.020)
Observation	1,680	1,680	1,645	1,645
Adj-R^2 (%)	9.45	7.09	5.57	4.18

Appendix C.1 –ALTERNATIVE SENTIMENT MEASURES

Table C1: Descriptions of alternative investor sentiment and attention indicators

Sentiment measures	Description	Frequency	Prior studies
Thomson Reuters Marketpsych Country Index (RMI)	There are 187 countries or regions being scored that analyze news and social media in real-time to convert the volume and variety of professional news and the internet into manageable information flows that drive sharper decisions. The indices are delivered as real-time data series that can easily be incorporated into your investment and trading decision processes – quantitative or qualitative. In this study, we utliize the GDP-weighted index of G20 economies.	Daily	Gan et al. (2020); Kalyvas et al. (2021)
Baker and Wulger (2006) sentiment index (BW)	Baker and Wurgler (2006) utilise the first component of principal component analysis (PCA)to constructed an sentiment index from the six market-wide proxies: Closed-end fund discount (CFED), Trading volume on NYSE (TURN), The share of equity in the new issue (SEI), Number of initial public offerings (IPO), Average first-day return of IPOs (RIPO), Dividend premium (DP). The data is available: http://people.stern.nyu.edu/jwurgler	Monthly	Anamika et al. (2023); Jiang et al. (2023)
Investor Risk aversion Index (RAI)	Risk Aversion Index (RAI) developed by Bekaert et al. (2022) that measure the time-varying risk aversion that ultimately can be calculated from observable financial information at high frequencies. The risk aversion coefficient is utility-based, reflecting the time-varying relative risk aversion coefficient of the representative agent in a generalized habit-like model with preference shocks. The data is available: https://www.nancyxu.net/risk-aversion-index	Daily	Alam et al. (2023); Huynh and Phan (2023)
American Association of Individual Investors (AAII) sentiment index	The AAII index is conducted weekly surveys to measure the percentage of individual investors who are bullish, bearish, or neutral on the financial market for the coming six months. The results are published monthly on AAII Journal by evenly splitting with 36% of all responses neutral, 28% bearish, and 36% bullish. The data is available: https://www.aaii.com/sentimentsurvey	Weekly	Güler (2021); Jo et al. (2020)
Investor Attention from Google Search Volume (GSVI)	The Internet search-based investor attention from the search volume of Google Trends (http://www.google.com/trends), which provides detailed data on the frequency of term searches. the search volume index (GSVI) obtained by the searcher is from 0 to 100. As for our study, the search area that we selected is global, and the search term that we selected belongs to the "cryptocurrency" market.	Weekly	Smales (2022); Subramaniam and Chakraborty (2020)

Appendix C.2 – MARKETPSYCH CRYPTOCURRENCY INDEX

The monthly Thomson Reuters Marketpsych Cryptocurrency Index (TRMI) crypto sentiment is computed using daily sentiment during the period 01 Jan 2014 to 31 Dec 2021.

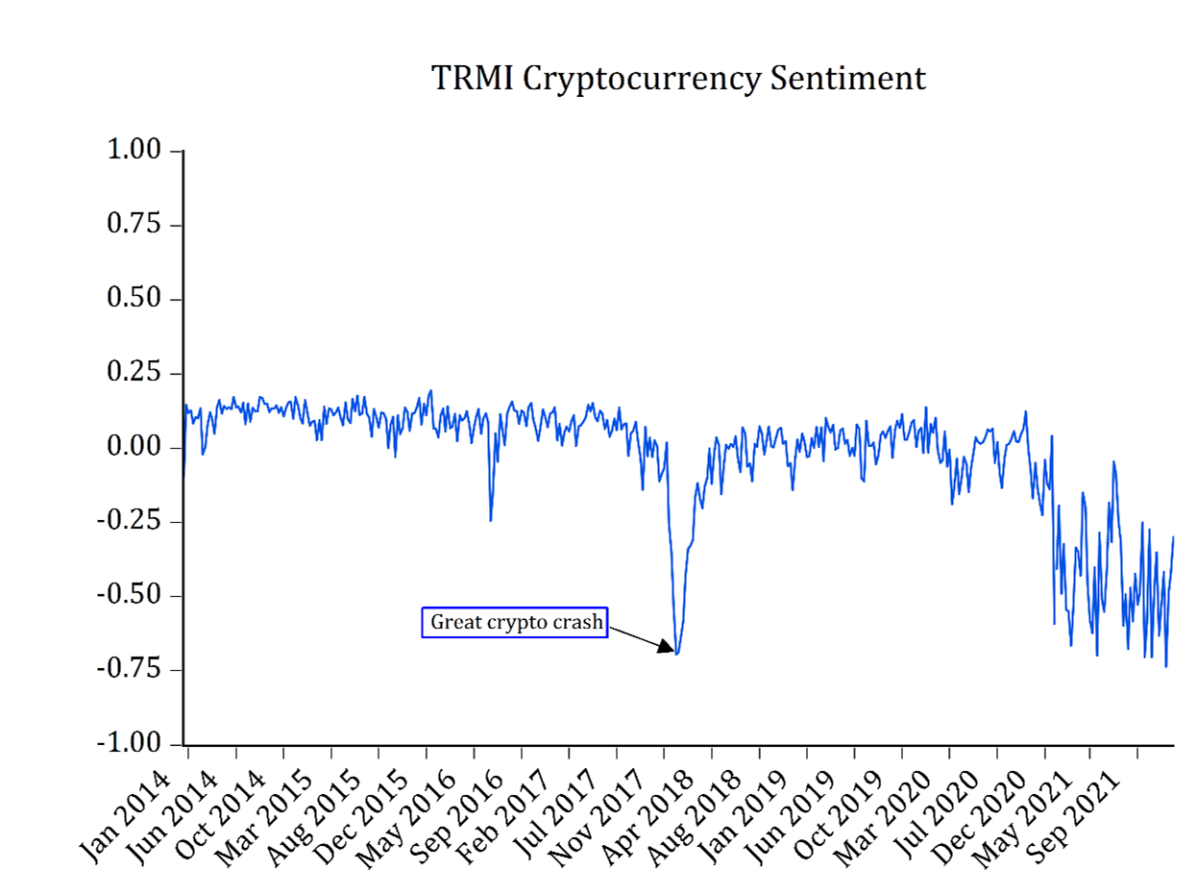

Figure 3