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Intraday reaction of cryptocurrencies to centralized monetary policies: An event study analysis on Bitcoin

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Abstract

The borderless and decentralised nature of Bitcoin, allied with its controversial increasing visibility and recognition in the financial markets, is putting pressure on policymakers to understand the extent to which Bitcoin behaves as the remaining assets. This is the first paper to employ high-frequency Bitcoin data to analyse its sensitivity to monetary policy decisions. The present analysis of its volatility and trading activity patterns reveal that Bitcoin does not significantly react to announcements on monetary decisions released by FED, ECB and BOE[1], even when a change in policy occurs. These results suggest Bitcoin's independence of centralised monetary authorities, which carries implications for investors, as they can benefit from diversification by investing in Bitcoin as an alternative asset class. These results are also valid for different exchanges and time periods, which reveals a certain level of market efficiency.

Keywords: Intraday data, Cryptocurrencies, Monetary policy announcements, Bitcoin.

Disclaimer

This paper should be deemed as containing the author's unique views rather than as reflecting those of the European Central Bank.

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1. Introduction

First introduced by Satoshi Nakamoto in 2008, Bitcoin is a peer-to-peer virtual currency that has been widely popularised by its unique deflationary nature, its innovative and technology-driven cash system and its major price swings. The pioneers of Bitcoin proposed it as an

[1] FED: Federal Federal Reserve System, ECB: European Central Bank, BOE: Bank of England.

open-source currency independent of centralized policies and free from the control of any monetary authorities, including central banks. An alternative financial system has been proposed in which the supply is limited to 21 million bitcoins and where a trusted third party is not required; instead, the blockchain technology and distributed ledger enable users to directly interact among each other and collectively approve the transactions.

The growing interest in Bitcoin has triggered the creation of at least 2072 cryptoassets, resulting in a market of $131 billion (CoinMarketCap, 2018). These competitors continue to emerge at a rapid pace with improved technology and efficiency, and to focus on solutions beyond the scope of online payments. Nevertheless, after almost 10 years of existence, Bitcoin is the oldest and most well-established cryptocurrency, acting as a benchmark for the remaining coins and assuming a dominant position with a share of 52% and market capitalization of $68 billion (CoinMarketCap, 2018). However, Bitcoin's price development has been far from running smoothly throughout the years (as shown in Appendix A1), and it has experienced large price jumps driven by speculation and momentum (Corbet et al., 2018). In fact, Bitcoin reached a peak valuation of $327 billion and has a current daily volatility of 5% (The Bitcoin Volatility Index, 2018), which is much higher than those of traditional assets and currencies (see Appendix A2 for the evolution of Bitcoin's volatility). In addition, this instability and immaturity make the technology less appealing to end consumers, who are accustomed to products with great user experience and convenient features—aspects that are lacking in the cryptosphere. Therefore, there is a sceptical sentiment surrounding cryptocurrencies' potential to replace fiat currencies. Even though they can act as a means of payment, at their current state they cannot be considered an adequate store of value or unit of account; the only cryptocurrency with potential to function as a store of value would be Bitcoin, given its credible reputation and resilience. Nevertheless, research shows Bitcoin has not been used much as a currency but mainly as an alternative asset.

The increased popularity of digital assets, the uncertainty surrounding their role in the financial market and the regulation disorientation create the need to further analyse their behaviour. The introduction of Bitcoin futures in late 2017 and the potential creation of more Bitcoin-related products would create additional linkages with the financial system which—accompanied by a potential loss of trust in its market—could generate instability in the financial system. In that sense, it is crucial to monitor Bitcoin's developments and understand to what extent the currently available policy toolbox is capable of influencing this market. More specifically, given the alleged freedom of Bitcoin from centralised monetary authorities, it is of great relevance for policymakers whether cryptocurrencies are vulnerable to their public announcements. It is also relevant to investors whether central banks are able to influence Bitcoin through such instruments, as this provides insights into whether investing in Bitcoin as an alternative asset class delivers diversification benefits. Therefore, the purpose of this paper is to evaluate whether central banks' monetary policy decisions are promptly successful in Bitcoin's market. To assess if and how Bitcoin's market reacted to the release of centralised monetary policies in the US, the Euro area and the UK from March 2013 to June 2018, the intraday volatility and trading activity patterns were analysed on a five-minute basis, by comparing a sample of announcement days with a sample of non-announcement days. It was also examined if Bitcoin's reaction depends on whether policies were changed.

In the rest of the paper, Section 2 introduces the topic and its corresponding literature. Section 3 details the methodology employed, and the data to be used are summarized in Section 4. Section 5 presents the major findings and its implications, and Section 6 closes the paper.

2. Literature Review

Since its launch in January 2009, Bitcoin has been the focus of many research papers across a wide range of fields, including economics, finance, law and computer science. Regardless of

the expanding body of relevant literature in recent years, cryptocurrencies still remain an immature research field with high-quality peer reviewed papers being hard to find. This review focuses on peer-reviewed financial studies, published in official journals and platforms alike, on the underexplored topics of Bitcoin's price sensitivity to regulatory and market events and other financial themes such as diversification benefits and market efficiency.

The attention received by Bitcoin on its volatile price movements triggered an investigation on the existence of a speculative bubble in the market. Although Cheah & Fry (2015) confirm this, Corbet et al. (2017a) report no clear evidence of a persistent bubble. The authors also conclude the fundamental drivers of the short-term price of Bitcoin and Ether are blockchain position, hashrate and liquidity. Baek & Elbeck (2015) argue Bitcoin price is internally determined by buyers and sellers instead of fundamental economic elements, thus concluding Bitcoin resembles a speculative investment asset rather than a currency. Baur et al. (2017a) support this view, taking into account Bitcoin's unique risk-return characteristics, volatility and non-correlation with other assets. On the other hand, Dyhrberg (2016) places Bitcoin between gold (commodity) and USD (currency), ranging from a pure medium of exchange to a pure store of value. Baur et al. (2017b) provide insights into the distribution of Bitcoin holders, reporting that one-third are investors and only a minority use it as a medium of exchange. They also highlight the potential diversification benefits of Bitcoin by showing its non-correlation with the traditional assets both in bull and bearish periods. It then becomes evident that the continually expanding popularity on Bitcoin has generated an on-going debate regarding its behaviour either as an asset or as a currency. Nevertheless, some papers focus on the diversification, hedging and safe haven[2] properties of Bitcoin. Bouri et al. (2017) evaluated the hedging capabilities of Bitcoin for various asset classes, revealing its effectiveness as a diversifier but not as a hedge or safe haven. On the contrary, Guesmi et al.

[2] An asset acts as a diversifier if shows low correlation with other assets, as a strong hedge if shows negatively correlation, and as a strong safe heaven if this negative correlation is also verified during moments of market turmoil.

(2018) emphasize that a long position in Bitcoin can be a useful hedging tool for all different financial assets and that a hedging strategy composed of Bitcoin, gold, oil and emerging stock markets significantly decreases a portfolio's volatility as compared to the same portfolio without Bitcoin. Urquhart & Zhang (2018) employ hourly returns to confirm Bitcoin acts as a hedge and diversifier at multiple periods of time and as a safe haven for CAD, CHF and GBP. The employment of an intraday analysis is a rare case in the literature, but it is a more appropriate approach than the standard daily data, given the high-frequency trading activity and intraday volatility of Bitcoin (Corbet et al., 2018).

Regarding Bitcoin's efficiency, the literature is in its infancy, with Urquhart (2016) being the first to show strong significance of inefficiency, although in recent times Bitcoin seems to have become more efficient as more investors trade it. By using transactional-level USD/BTC exchange rates, Feng et al. (2017) showed the presence of insider trading in the Bitcoin market prior to large cryptocurrency-related events. They reveal that orders initiated by buyers (sellers) are abnormally high two (one) days ahead of positive (negative) events. They point to the absence of supervision from regulatory authorities as a reason for the insider trading and a sign of concern given the high profitability of such trading. Auer & Claessens (2018) presented consistent results by showing that regulatory actions affect Bitcoin prices several hours before their release. They discovered that the intensity of the impact depends on the type of regulatory event, with cryptocurrencies' specific events having the greatest effect and general bans on money laundering and financing of terrorism having a lower impact. Even though they were the first to quantify the impact of regulatory actions on Bitcoin's price, it is not surprising that Bitcoin reacts to the release of new regulations, especially if they are oriented towards digital currencies.

On the other hand, the price sensitivity of Bitcoin to other government-centred actions—such as macroeconomic, macroprudential and monetary policy decisions—is not so intuitive.

Given the decentralized nature of Bitcoin, it is pertinent to study whether this allegedly decentralized currency is vulnerable to governmental instruments outside the scope of regulation and if governments have the power to control Bitcoin via the same channels they influence asset prices and overall economic conditions. The study of the effect of such policies on cryptocurrencies is a field that has received little attention by academics. In fact, Corbet et al. (2017b) were the first and only researchers so far to address the impact of monetary policies by various central banks on Bitcoin: they developed a GARCH model to find evidence that quantitative easing decisions significantly affect Bitcoin's return volatility. Given the high contribution of their paper to the literature and the room for improvement, the next part of this section is dedicated to a review of this paper.

First, it is questionable whether the end-of-the-day volatility based on the closing price alone is suitable to represent an intraday event, given the high-speed reaction of Bitcoin to the news. In a more recent paper, the same authors report that almost all studies on cryptocurrencies have examined their dynamics at a daily frequency and emphasise the urgent need for high-frequency intraday analysis, which is more appropriate for Bitcoin given the high intensity of intraday transactions (Corbet et al., 2018). Consistent with this view, Latif et al. (2017) argue that Bitcoin and Litecoin are immediately and sensitively affected by new information.

The second limitation of the work by Corbet et al., (2017b) is the fact that, although they controlled for international crises and terrorism events, they failed to account for cryptocurrency-specific events, including regulatory actions, which are known to dramatically impact cryptocurrencies' volatility and transaction volumes (Auer & Claessens, 2018). Given the daily nature of the used dataset, it is crucial to ensure that events with such an enormous impact on Bitcoin's volatility do not systematically match the days of the monetary policy decisions. Because the authors failed to account for the presence of concurrent and overlapping events, the interpretation of the significance of their results might be distorted.

Given the high relevance of the topic first explored by Corbet et al. (2017b), this paper accounts for some of its limitations and contributes to the existent literature in several ways.

First, this paper marks the first high-frequency intraday event analysis of Bitcoin's reaction to monetary policy announcements—which is pertinent because high-frequency observations are a more accurate measure of Bitcoin's reaction than daily observations. Intraday analysis is not common in the literature; however, it allows the investigation of the intraday volatility pattern of Bitcoin and the assessment of how rapidly the market digests monetary policy announcements. By including a robustness test for a different exchange, this analysis is also suitable for drawing conclusions on the degree of Bitcoin's market efficiency. If Bitcoin reacts to announcements in a similar way in both exchanges, then Bitcoin's market may be deemed to function in an efficient fashion. On the other hand, if investors of a certain exchange significantly incorporate the new publicly available information into Bitcoin's price, whereas on another exchange there is no evidence of such significant reaction, then Bitcoin's market can be considered as inefficient.

Second, the present analysis also constitutes an improvement on approaches in the existing literature by neutralising the effect of cryptocurrency-specific shocks in the analysis and ensuring the observed significance is stimulated by actual monetary policy decisions instead of cryptocurrencies-related events such as regulatory disorientation, hacking attacks to exchanges and technological shocks. Removing such overlapping events from the analysis ensures the analysis is not contaminated by the effects of events not related to monetary policy indeed only reflects the reaction of Bitcoin to monetary decisions.

Third, researchers mostly use returns and volatility as measures of market impact in Bitcoin, but they fail to investigate trading activity, which is especially relevant because its lack of physical form enables it to be transitioned at increasingly high velocities. In fact, the rapidity at which Bitcoin can be transitioned influences its liquidity profile, which—allied with market

characteristics—is expected to change the most as the market matures (Burniske & Tatar, 2018). Therefore, this paper adds to the literature by being the first to examine the intraday trading activity pattern of a cryptocurrency's reaction to monetary policy decisions.

Traditional bonds and stocks typically see their intraday volatility and trading volume induced by monetary policy announcements (Andersson, 2007). If Bitcoin reacts to such announcements in the same direction as traditional financial assets, one would question its usefulness as a diversification tool; however, if it reacts in the opposite direction or does not react at all, investors might consider holding Bitcoin in their portfolio as an alternative asset class, as it would then constitute a good source of diversification to mitigate risk. Therefore, this paper contributes to the understanding of the potential diversification and hedging benefits of cryptocurrencies to investors—which is an underexplored topic in the literature (Corbet et al., 2018). In addition, tentative explanations of the repercussions of such reaction will be provided not only for investors but also for users of Bitcoin and policy makers.

Finally, because data on cryptocurrencies is expanding every day and their volatility is so high, Corbet et al. (2018) have pointed out that results found at a certain point in time might completely differ from results found two years later. This becomes more evident upon the realisation that researchers have been analysing the behaviour of a market in its early stages, wherein change is unavoidable with the size of Bitcoin's investments and transactions increasing relative to other assets. The data used by Corbet et al. (2017b) covers the period until April 2016, in which each Bitcoin was worth $446. Today's price of $3,888 per Bitcoin (CoinMarketCap, 2018) shows the need to assess the new developments in its behaviour, and thus this paper accommodates for this gap by using the most recent available data to continue the above-mentioned research.

3. Methodology

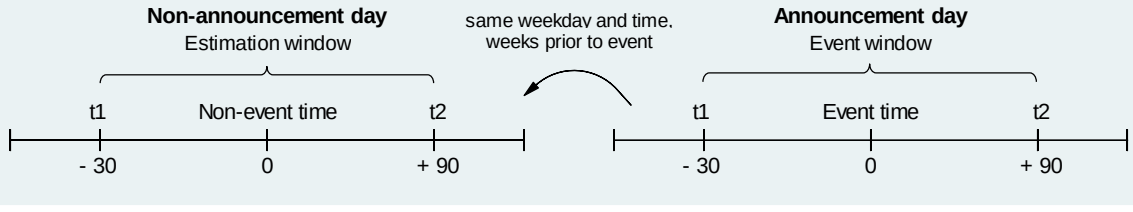
The event study methodology is widely used to evaluate the reaction of assets around a certain announcement and test if and how quickly the market participants incorporate the new information. Given the high-frequency character of the data analysis, the methodology of Andersson (2007) is used as a baseline.

3.1. Event definition: An event is defined as an announcement on monetary policy decisions taken by central banks, including both conventional (e.g. interest rates) and non-conventional (e.g. quantitative easing and quantitative tightening) policies. To account for the detachment of Bitcoin from a specific country, a varied range of central banks is selected according to their level of worldwide influence and the suitability of their announcements for an intraday event study. The most suitable are those announcements pre-scheduled for a precise timing, unambiguously defined, and released to the public at the same time (i.e. no information available prior to the release). In an analysis with announcements from more than one central bank, it is also crucial that all of them release approximately the same amount of information; otherwise, investors' reaction will be delayed as more information needs to be processed. Because the monetary policies of the FED, ECB, People's Bank of China (PBOC), Bank of Japan (BOJ) and BOE are the most relevant for international economic stability (Caproasia Institute, 2017), ideally the announcements of all of them would be analysed. However, PBOC was excluded because of two reasons: first, its announcements are released in the format of a report with dozens of pages, which is difficult for the market to absorb within a narrow intraday time frame; second, in 2017 many important Chinese exchanges were excluded from domestic transactions (Feng et al., 2017). BOJ was also removed because its press releases occur at different timings, depending on the meeting duration, causing investors to be disoriented regarding the precise time of the release. Therefore, events are restricted to the release of monetary policy announcements by FED, ECB and BOE.

This selection is also appropriate when considering the geographical distribution of Bitcoin's nodes[3], where the USA and Germany are the two biggest countries with a share of 24% and 19%, respectively (Appendices A3 and A4). This distribution of miners throughout various countries contributes to the argument that Bitcoin is not at the mercy of a single nation's government (Burniske & Tatar, 2018). As announcements from three central banks are examined, their different time zones are converted into the same time zone—UTC—to achieve data consistency. The event hour is also corrected for the summer/winter time differences.

3.2. Event window: The selection of the period over which the event is supposed to have an effect on the stock returns is highly debated in the literature. Nevertheless, a narrower window is preferable for assets that react very fast to news because it is long enough to capture most of the effect of the policy surprise without being contaminated by unrelated events that could lead to biased estimations. Also, short-horizon event studies are considered reliable in terms of specification (Kothari & Warner, 2008).

Fig. 1 - Timeline of event study



Using a 120-minute window, Auer & Claessens (2018) found cryptocurrencies react very fast to announcements on regulatory actions. Under the assumption that Bitcoin also incorporates monetary policy announcements almost instantly into its prices, the event window was set to be 120 minutes long, starting 30 minutes before and ending 90 minutes after the announcement: $(t_1, t_2) = (-30, +90)$.

[3] A Bitcoin node is a point of connection to the network; that is, a location where the Bitcoin software has been downloaded and its blockchain is being maintained (Burniske & Tatar, 2018).

The exact timing of each announcement's release is time 0. It is worth noting that the likelihood of leakages is very low, thus eliminating the necessity of adopting a large window prior to the event. To sum up, the assumption of the instant incorporation of information by cryptocurrencies, along with a good knowledge of the precise timing of the announcement, allows the establishment of a very narrow event window (Gürkaynak & Wright, 2013).

3.3. Measures of market impact: The effect of monetary policy announcements on Bitcoin was assessed by analysing the volatility and trading activity at five-minute intervals. This is an adequate frequency for Bitcoin because it is frequent enough to account for the high speed of its trades but not too noisy (Liu et al., 2012). As for examining the behaviour of the intraday volatility pattern, the classical measure of squared returns is too noisy and biased by microstructure effects such as the bid–ask bounce (Gatheral & Oomen, 2010). Therefore, it does not constitute an appropriate measure of realized intraday volatility, and the same applies to the use of closing prices alone. Alternatively, measures including the open, high, low and close prices are more informative and efficient relative to the classical return-based estimators. Parkinson (1980) and Garman-Klass (1980) provide two examples of price range estimators which, relative to the classic measure, are 2.5–5 and 7.4 times more efficient, respectively (Chou et al., 2009). Although these two methods are efficient only when the drift term is null, due to the lack of a better intraday measure, the estimator by Garman-Klass (1980) was used, as it already constitutes a major improvement relative to the standard method. The volatility V_t at time t is given by

$$V_t = \frac{1}{2}[ln(H_t) - ln(L_t)]^2 - [2\,ln\,2 - 1][ln(C_t) - ln(O_t)]^2, \qquad (1)$$

where H_t is the high price, L_t is the low price, C_t is the close price and O_t is the open price. Turning to the intraday trading activity pattern, the standard proxy is the volume, which can be measured in terms of the number of trades, the number of shares exchanged and the

monetary value of such shares. The chosen measure is the total monetary value of the Bitcoin's shares traded in a particular moment, T_t, which corresponds to the sum of the value of individual transactions (Alabed & Al-Khouri, 2008):

$$T_t = \sum_{i=1}^{NT_t} P_i TS_i \quad with \quad NT = \sum_{i=1}^{n} q_i, \tag{2}$$

where NT_t is the number of transactions from time $t-1$ to t, TS_i refers to the amount of shares in trade i, P_i is the price of transaction i and q_i corresponds to trade i.

3.4. Measure of abnormal reaction: Andersson (2007) argues that a review of expectations by market participants following a monetary policy announcement must lead to a higher volatility in comparison to the volatility in a period without such announcement. A similar approach was employed to compare the behaviour of two datasets: the first sample is constituted by the announcement days, and the second contains observations for days free of announcements. This second dataset represents the normal market conditions, that is, the volatility or trading activity expected in days where no announcements are made. Because there is no consensus regarding the valuation of cryptocurrencies, except for the orders investors place on the market (Corbet et al., 2018), this is the best valid benchmark for the expected performance of Bitcoin in a regular day. Thus, the impact of each announcement can be measured as the ratio between the volatility or trading activity observed on the announcement day and that observed on an equivalent non-announcement day. These ratios are termed the abnormal volatility $AV_{i,t}$ and abnormal trading activity $AT_{i,t}$ and are defined as

$$AV_{i,t} = \frac{V_{i,t,announcement}}{V_{i,t,non-announcement}} \tag{3}$$

$$AT_{i,t} = \frac{T_{i,t,announcement}}{T_{i,t,non-announcement}}. \tag{4}$$

A ratio of more than one means the announcement has, on average, an impact—either positive or negative—on Bitcoin and that its market participants are reacting to the new information. Because Bitcoin investors might react differently to a change in the monetary policy decision

compared to when it remains unchanged, with a similar methodology, Bitcoin's market reaction was decomposed based on whether the monetary policy has changed:

$$AV_{i,t,change} = \frac{V_{i,t,change}}{V_{i,t,non-announcement}} \quad (5) \qquad AT_{i,t,change} = \frac{T_{i,t,change}}{T_{i,t,non-announcement}}. \quad (6)$$

3.5. Cross-sectional aggregation: For the total number of days where a monetary policy decision was taken, given by $i = 1, 2, \ldots, N$, the market impact of Bitcoin was aggregated across all event dates to give the average abnormal volatility AAV_t and trading activity AAT_t:

$$AAV_t = \frac{1}{N}\sum_{i=1}^{N} AV_{i,t} \quad (7) \qquad AAT_t = \frac{1}{N}\sum_{i=1}^{N} AT_{i,t}. \quad (8)$$

3.6. Time series aggregation: In order to analyse the overall average effect on Bitcoin's market over the 120-minute event window, the cumulative average abnormal volatility $CAAV(t_1, t_2)$ and trading activity $CAAT(t_1, t_2)$ were computed:

$$CAAV(t_1, t_2) = \sum_{t=t_1}^{t2} AAV_t \quad (9) \qquad CAAT\ (t_1, t_2) = \sum_{t=t_1}^{t2} AAT_t. \quad (10)$$

3.7. Control measures: The volatility and trading activity change over the course of the trading day and are higher at the opening and closing hours. Even though this might not be so evident for Bitcoin, as it is available for trading 24/7 in almost all (online) exchanges, this factor has to be neutralized in the analysis, as exchanges denominated in fewer currencies are more subject to use by local traders and dips in the trading activity (Brandvold et al., 2015). By selecting on non-announcement days the five-minute intervals at the same time of day on the same weekday as on announcement days, the sample is controlled for both intraday and weekday effects (Andersson, 2007). Another important issue to address is the confounding effect—cases where multiple announcements occur in close proximity might contaminate the results. Thus, days where two or more different central banks released a monetary policy

announcement—overlapping events—were eliminated from the sample. Also removed are days where cryptocurrency-specific extreme events occurred. These include hacking attacks to cryptocurrency exchanges, regulatory actions, improvements in the technology underlying the cryptocurrency and any other events that constitute a shock to the cryptocurrencies market and are known to significantly affect their price.

3.8. Test for normality: A significance test is only correctly specified if its assumptions regarding the statistical properties of the data are correct. Therefore, before defining the significance test to be used, this paper tests the normality of the data using the skewness and kurtosis test for a time series of Bitcoin's daily returns. This test only requires a minimum of eight observations to be valid[4] and assesses the distribution of the returns by combining the third and fourth standardized moments into an overall test statistic.

The daily closing prices are converted into logarithmic returns by taking the log of the ratio of the price of the previous day, P_{t-1}, to the price of the current day, P_t:

$$R_t = ln\left(\frac{P_t}{P_{t-1}}\right). \quad (11)$$

3.9. Significance test: To assess the reaction of Bitcoin surrounding monetary policy decisions, the announcement sample was tested against the non-announcement sample by determining if they come from populations with the same distribution. If Bitcoin can be considered normally distributed, the appropriate significance test is the t-test; otherwise, the non-parametric Wilcoxon rank-sum test (also called the Mann–Whitney test) must be used. The hypotheses are as follows:

- **H1:** Monetary policy announcements affect Bitcoin's volatility: $AAV_t \neq 1$;
- **H2:** Monetary policy announcements affect Bitcoin's trading activity: $AAT_t \neq 1$;
- **H3:** Bitcoin's abnormal volatility is conditional to a policy change: $AAV_{t,change} \neq 1$;

[4] The remaining tests for normality available on Stata are invalid, because they have an upper boundary of 5000 observations.

- **H4:** Bitcoin's abnormal tr. activity is conditional to a policy change: $AAT_{t,change} \neq 1$.

For a p-value smaller than 10%, the null hypothesis is rejected at the 90% confidence level, and the abnormal volatility/trading activity is significantly different from one. In the case of significance, it can be concluded whether investors are negatively or positively affected, on average, by the announcements.

3.10. Robustness validation: Some particular cases of the baseline model were applied. The first robustness test disaggregates the data into each central bank and tests the observations for each of them. This shows if the origin of the announcement makes a difference when it comes to triggering a reaction in Bitcoin's market. As a second robustness check, the methodology was repeated using a different exchange, as there are potential differences in terms of trading activity—and the investors are not the same either. This reveals whether the characteristics of the exchange (trade-off between security and access) where Bitcoin is traded affect how investors react to the announcements. The efficiency of Bitcoin can also be extrapolated: if the effects of the announcements differ from one exchange to the other, then Bitcoin's market is not operating in an efficient manner. As a final check, it was tested whether the same results prevail for different intervals of time, which reveals whether the sensitiveness and efficiency of Bitcoin are changing/maturing over time. To have a balanced analysis, the data is randomly subdivided into two periods of time of the same duration.

4. Data

Events: All dates and exact timings of the monetary policy announcements decisions were gathered directly from each central banks' official websites. Each of the three central banks currently holds eight pre-scheduled meetings during a year, but at different hours. FOMC has released implementation notes at 14:00 EDT/EST since March 2013, ECB's Governing

Council has published a press release at 13:45 CET/CEST since April 1999, and BOE's Monetary Policy Committee releases decision summaries at 12:00 UTC/BST the day after a meeting. Accordingly, a total of 150 event dates were identified between March 2013 and June 2018, of which 38 are overlapping announcements. From the resultant 112 event dates, 11 occur in the same day as cryptocurrency extreme events and one is missing, which results in a total of 100 announcement dates. The cryptocurrency-specific event dates were identified and collected from four different sources including previous papers such as Feng et al. (2017) and Vidal-Tomás & Ibañez (2018) and webpages on cryptocurrency news such as DeCenter and Hackernoon. The aggregated list of crypto-related events can be found in Appendix B1. In the final sample of announcements, listed in appendix B2, 27 announcements correspond to ECB, 34 to BOE and 39 to FED. A summary table can be found in Appendix B3. The non-announcement sample is composed of 100 events as well, and it can assume values of either one, two or three weeks before the corresponding announcement date.

Bitcoin: The data employed in this study comprises data for the trading volume, close, open, high and low prices of Bitcoin in USD at a five-minute frequency (consult Appendix C1 for general descriptive statistics). The data were collected from Bitstamp, and the time span is subject to data availability. Even though the Bitstamp data have been available since the creation of Bitstamp, until early 2013 high-frequency data was not easily available and there were many missing intraday observations for five-minute observations. For that reason, the dataset covers the period from March 01, 2013, to June 31, 2018. This comprises a total of 25,000 five-minute observations over the 120-minute event window, considering volume and all prices for all 200 dates. Bitstamp was selected among more than 200 Bitcoin exchanges because it is the oldest active exchange in the industry—it started operations in August 22, 2011. It is a reliable exchange with a controlled operational risk, as it chooses to only give access to cryptocurrencies with a certain degree of maturity (Burniske & Tatar, 2018). This is

why the largest fraction of its volume (49%) is originated in Bitcoin trades, as shown in Appendix C2. Besides being one of the largest and most liquid exchanges (see the evolution of its volume in Appendix C3), it is also one of the most popular and credible because it is regulated as a payment institution and able to operate in all EU countries, as it is based in Luxembourg (Nasdaq, 2018). This is especially relevant in a context where many exchanges have been closed throughout the years, including Mt. Gox, which used to be the largest exchange until its bankruptcy in early 2014 (Feng et al., 2017).

To test the normality of Bitcoin's returns, the daily closing prices were collected from the same source, with a total of 2368 observations (December 31, 2011, to June 27, 2018). The Stata descriptive statistics on the time series of Bitcoin's log returns are presented in Appendix C4. Finally, to validate the robustness, data were collected from Coinbase. However, the time span is smaller (January 29, 2015, to June 31, 2018) because this exchange started its operations later, totalling 152 dates and 19,000 observations.

5. Results and discussion

Table 1 – General statistics of AV_t and AT_t, five-minute observations

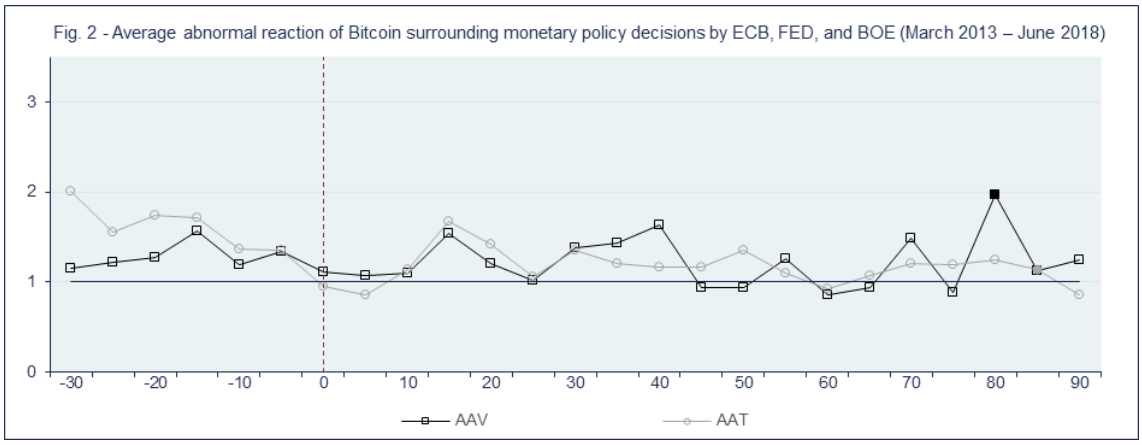
	Total sample $(N = 100)$		**Change sample** $(N = 16)$	
	AV_t	AT_t	$AV_{t,change}$	$AT_{t,change}$
Mean	1,21	1,25	1,10	1,29
Max	2,39	1,67	0,71	1,80
Min	1,00	2,21	1,00	1,65
Skew	2,45	1,19	0,58	1,20
Kurt	5,67	1,61	0,29	1,59
Obs.	2500	2500	400	400

5.1. Evidence of high non-normality

The skewness and kurtosis test rejects the hypothesis of the normality of Bitcoin's returns, as confirmed by the Stata output in Appendix C5. See also Appendix C6 for a comparison of the distribution of Bitcoin log returns and the normal bell curve. Given the non-normality of the data, the statistical significance of the market impact at each five-minute interval was assessed

through the Wilcoxon rank-sum test, where the filled dots imply a statistically significant ratio with at least a 10% significance level, and empty dots suggest insignificance. The p-values of such significance test can be found in Appendix D, and the average results decomposed by announcement and non-announcement samples are given in Appendix E.

5.2. No evidence of significant reaction of Bitcoin



As a first conclusion, Fig. 2 suggests the release of monetary policy announcements does not induce a significant impact on either volatility or trading activity of Bitcoin. Overall, both the volatility and trading activity are at the same level in a period of monetary policy decisions as those in periods without such decisions (also see Table 1). This lack of incorporation of monetary policy decisions into Bitcoin's price supports the contrasting behaviour of Bitcoin relative to traditional assets and implies its independence from a centralised monetary authority, as policymakers fail to affect Bitcoin. On one hand, these results are surprising, as they highly contrast with those of the daily analysis by Corbet et al. (2017b); on the other hand, these results are reasonable because the target of monetary policy decisions is to maintain the price stability of their own currency rather than Bitcoin's (which proposes itself as an alternative currency).

A potential explanation for the lack of significance might be that the reaction of Bitcoin is conditional to a change in the policy.

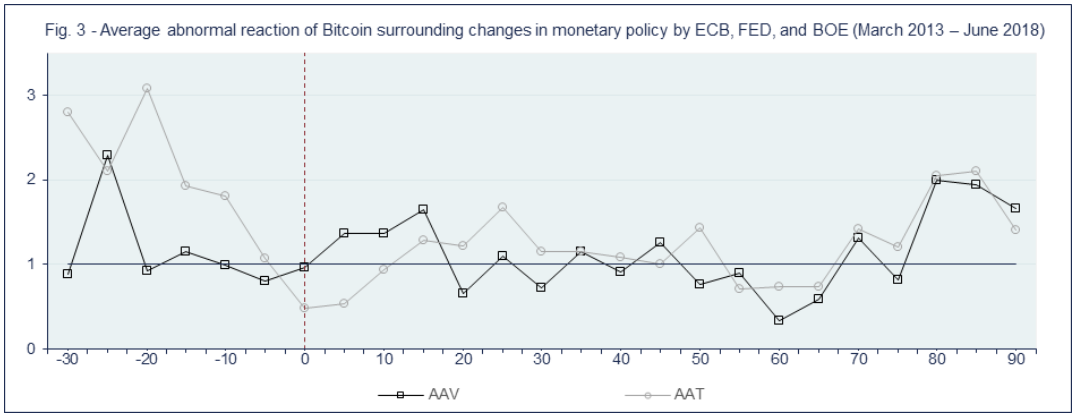
Table 2 – Values of $\mathrm{AAV_t}$ and $\mathrm{CAAV}\ (-30, +90)$, ***p<0,01; **p<0,05; *p<0,1

	AAV_t							
t	Total	ECB	FED	BOE	2013-15	2016-2018	Coinbase	Change
-30	1,155	0,955	0,967	1,724	1,475	1,004	1,622	0,884
-25	1,224	1,596	0,883	1,454	1,065*	1,389	1,516	2,295
-20	1,278	0,897	1,233	1,734	1,182	1,369	1,960	0,928
-15	1,564	1,407	2,395	1,156	1,756	1,407	1,718*	1,147
-10	1,197	0,549	2,140	1,077	1,143	1,246	0,534	0,991
-5	1,344	1,017	1,550	1,465	1,373	1,316	1,011	0,808
0	1,112	1,117	1,100	1,130	1,048	1,188	1,157	0,966
5	1,069	0,755	1,946*	0,832	1,016	1,121	1,144	1,371
10	1,101	0,793	1,016	1,533	0,789	1,539	1,156	1,373
15	1,544	1,488	1,298	1,890	1,437	1,608	1,415	1,655
20	1,206	1,317	1,252	1,044	1,284	1,145	0,836	0,658
25	1,018	1,181	1,100	0,838	0,722	1,359	0,794	1,102
30	1,381	1,069	1,558	1,435	2,027	0,987	1,366	0,729
35	1,431	1,322	1,976	1,124	1,464	1,400	1,458	1,156
40	1,639	0,896	2,640	1,395	3,000	0,923	1,407	0,912
45	0,942	0,920	0,899	1,005	0,932	0,951	1,299	1,265
50	0,937	0,970	0,961	0,885	0,739	1,338	1,017	0,763
55	1,258	1,042	1,692	1,250	1,027	1,506	1,441	0,893
60	0,853	0,700	1,044	0,842	0,718	1,067	0,849	0,331
65	0,939	0,685	0,837	1,431	1,017	0,850	1,129	0,592
70	1,488	0,754	2,650	0,937	1,871	1,072	1,144	1,315
75	0,886	0,658	0,673	1,753	0,811	0,989	1,106	0,816
80	1,973*	1,425	2,035	2,894*	2,355	1,542	1,396	1,992
85	1,128	1,172	1,656	0,752	1,198	1,054	0,967	1,946
90	1,249	0,913	2,025	0,778	1,100	1,491*	1,001	1,661
CAAV	1,6221	1,6864	1,5580	1,6444	1,5818	1,6550	2,0659	1,9103

Table 3 – Values of $\mathrm{AAT_t}$ and $\mathrm{CAAT}\ (-30, +90)$, ***p<0,01; **p<0,05; *p<0,1

	AAT_t							
t	Total	ECB	FED	BOE	2013-2015	2016-2018	Coinbase	Change
-30	2,015	1,039	2,547	2,598	1,424	2,082	2,415	2,795
-25	1,552	0,705	1,913	2,821	0,887	1,619	1,723	2,105
-20	1,744	0,887	2,022	2,583	0,733	1,938	3,313	3,081
-15	1,719	0,964	1,272	3,515	1,440	1,748	1,471	1,925
-10	1,373	1,303	1,315	1,547	0,766	1,504	1,193	1,806
-5	1,358	1,601	1,016	1,447	1,354	1,358	0,920	1,066
0	0,948	0,895	0,690	2,240	1,177	0,930	1,161	0,482
5	0,861	0,961	0,747	0,922	0,709	0,878	0,782	0,541
10	1,144	0,490	0,760	4,818	0,785	1,190	0,723	0,941
15	1,677	1,847	0,868	3,097	1,700	1,675	0,874	1,291
20	1,425	3,266	0,895	0,885	0,774	1,475	0,686	1,219
25	1,056	0,883	1,125	1,237	0,596	1,106	1,241	1,678
30	1,349	2,058	0,822	1,408	0,875	1,427	0,927	1,155
35	1,212	1,380	1,017	1,259	0,746	1,297	1,275	1,154
40	1,167	1,029	0,802	1,928	0,788	1,216	1,266	1,092
45	1,164	0,806	1,026	1,628	0,699	1,264	1,423	1,011
50	1,350	0,994	1,364	1,859	0,762	1,433	0,848	1,439
55	1,093	1,161	0,448	2,042	0,832	1,118	0,598	0,717
60	0,926	0,894	0,741	1,268	0,704	0,966	0,700	0,744
65	1,066	1,126	0,684	1,459	1,065	1,066	0,773	0,736
70	1,200	1,186	1,148	1,258	0,987	1,239	0,931	1,416
75	1,189	1,283	0,848	1,455	1,159	1,194	0,718	1,204
80	1,247	0,964	1,564	1,254	0,682	1,350	0,895	2,047
85	1,145*	0,842	1,504*	1,261	1,969***	1,060	0,766	2,101
90	0,854	0,788	0,695	1,087	0,349	0,955	0,768	1,406
CAAT	1,7476	1,4256	1,5770	2,1991	1,6494	1,8280	1,5783	1,4296

In Fig. 3, intraday patterns seem to be of a larger magnitude when a change in the monetary policy decision occurs. In particular, it seems that, on average, changes in monetary policy increase Bitcoin's volatility for the first 15 minutes after the announcement. On the other hand, Bitcoin's trading activity consecutively decreases until the time of the announcement, and immediately starts increasing afterwards. However, the investors did not absorb the publicly available information into the price, because this higher-than-normal impact is not statistically significant.



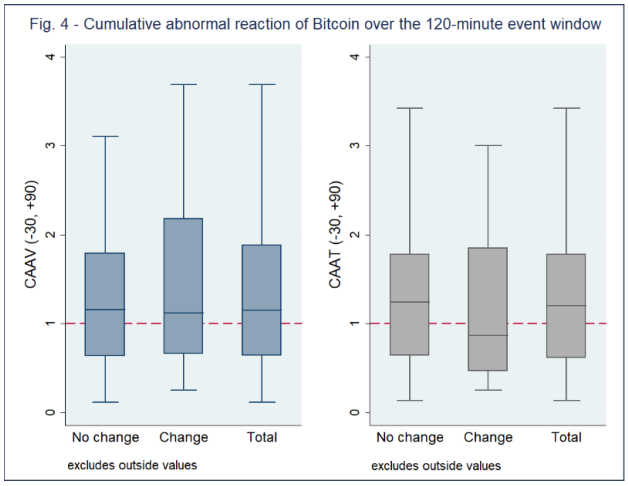
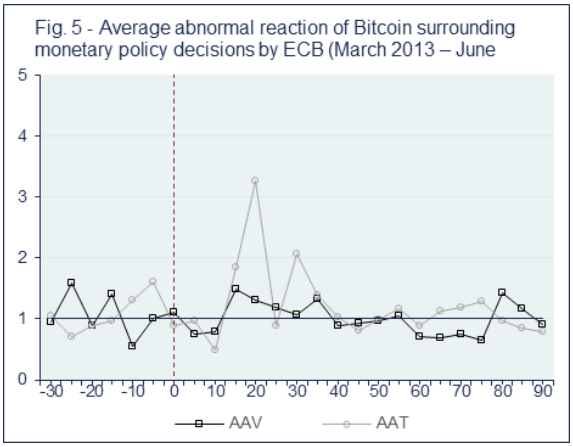
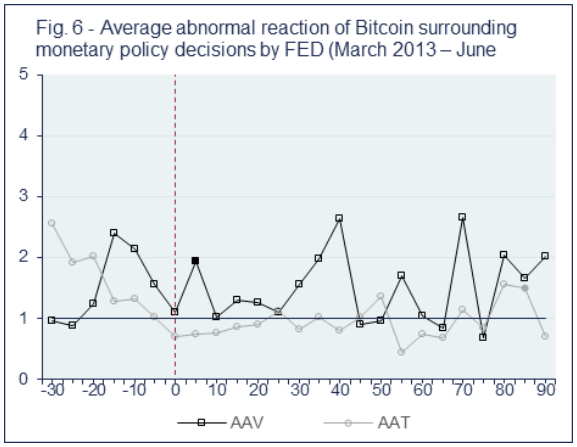


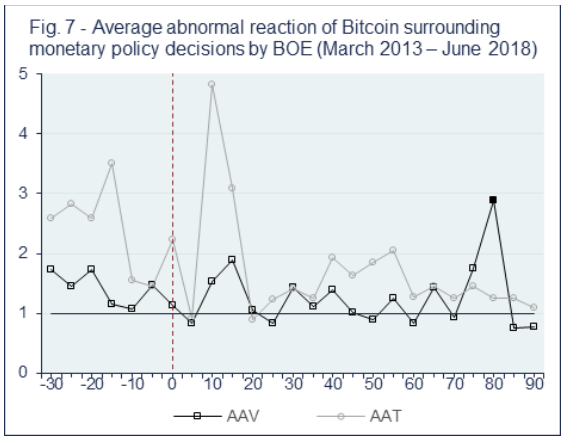
Fig. 4 shows that the median cumulative abnormal reaction of Bitcoin is close to one in all cases. This implies that roughly 50% of the announcements induce a higher-than-normal volatility and trading activity over the event window, whereas the remaining half induces lower-than-normal volatility and trading activity. Again, there is no evidence of Bitcoin having a significant reaction, as the reaction goes in opposite directions with approximately the same likelihood. However, it is worth noting that Bitcoin's reaction to announcements

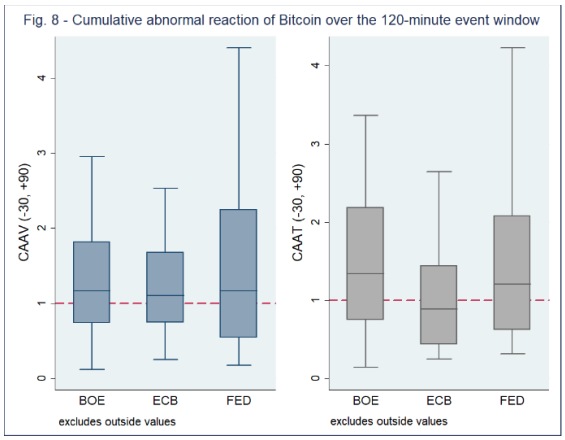
where a change occurred assumes a wider range of abnormal values, when compared to the "total" sample (that is, mean abnormality is larger than median).

5.3. Robust insignificance of the results





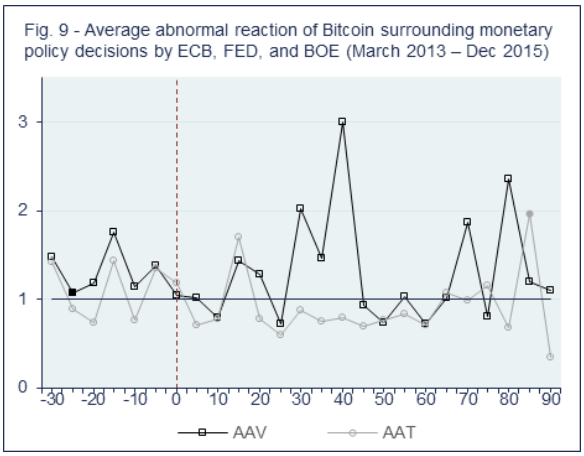


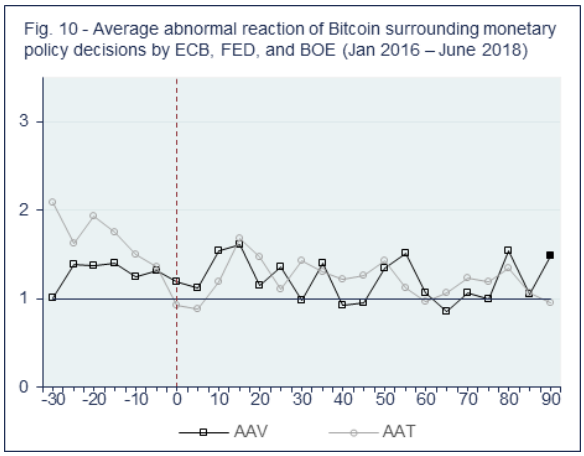


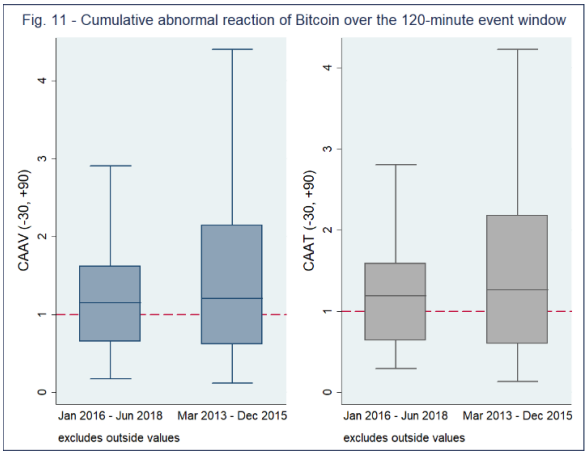
The isolation of Bitcoin's reaction to ECB's announcements (Fig. 5) reveals that the intraday volatility and trading activity patterns are not conditional on monetary policy announcements, as no significance was detected at any moment in the window.

Regarding FED (Fig. 6), the volatility is statistically significant in the five-minute interval following the announcements. However, this significantly higher-than-normal volatility does not persist over the window. In Fig. 8, Bitcoin's reaction seems to show a larger dispersion for FED's announcements than for the remaining central banks because the volatility and activity can be up to four times higher than normal (excluding outliers). This could imply a higher influence of FED over Bitcoin; however, almost 50% of FED's announcements did not induce abnormality. Therefore, it is more reasonable to conclude Bitcoin's reaction is random.

For decisions taken by BOE (Fig. 7), the volatility is in line with the aggregated results, but the volume traded in Bitcoin's market is particularly pronounced, being on average almost five times larger in the 10 minutes following the announcements. Even though it seems that higher volumes of Bitcoin are traded surrounding BOE's announcements than other central banks', this conclusion is not valid given the lack of statistical significance.



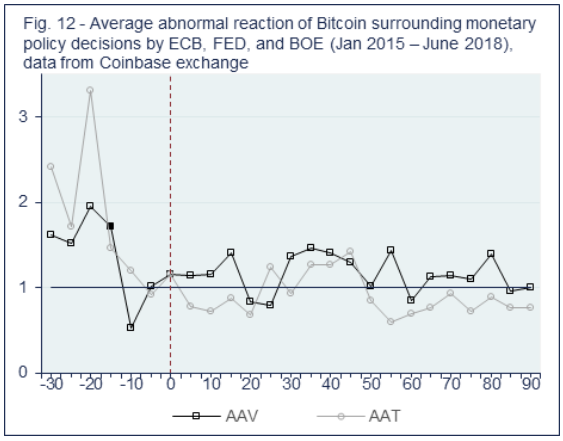


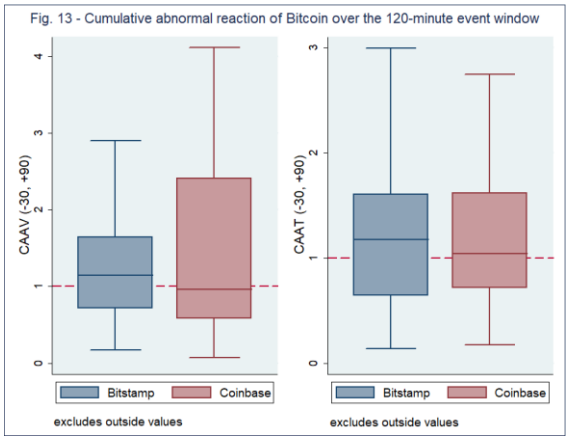


As another measure of the robustness of the results, the sample was divided in two periods. Because Bitcoin does not have a significant reaction surrounding the announcements in any of the periods, the volatility swings in the first half of the sample (Fig. 9) are likely due not to monetary policy announcements but to the newness of the market, as fewer investors, less frequent trading and smaller orders drive a higher volatility (Burniske & Tatar, 2018).

The abnormal reaction of Bitcoin seems more controlled for the second half of the sample (Fig. 10), thus suggesting the increasing maturity of the market. This leads to the question of

whether Bitcoin's efficiency will increase over time and start responding to monetary policy as Bitcoin becomes more widely used, either as a currency or as an investment asset.





The findings are also robust to a different exchange, as evidenced by the lack of significance in the market reaction of Bitcoin and the median cumulative average abnormality being again very close to one. Because no evidence of a significant reaction was found in any of the exchanges, the results suggest a certain degree of efficiency in Bitcoin's market. This also supports the argument that the characteristics of the exchange do not affect this result.

To sum up, the robustness checks performed herein indicate the robustness of the results to different specifications. To be more precise, the lack of reaction of Bitcoin to monetary policy announcements is independent of the central bank, time frame and exchange characteristics.

5.4. Implications for policymakers, users and investors

First, the results show that policymakers from major central banks do not currently have the power to significantly influence Bitcoin's market through the announcement of monetary policy decisions, which gives emphasis to the lack of control on Bitcoin. Policymakers should be aware that their tools are not having a significant impact on Bitcoin's investors and users.

Second, the lack of a significant reaction suggests that the users of Bitcoin share the same line of thought as its creators, who aimed at a decentralised anti-banking system based on a cryptocurrency that would replace fiat currencies. This being the case, it is not surprising that Bitcoin's users do not closely follow centralised monetary policy decisions. These results also

suggest the nature of Bitcoin is free from national borders by virtue of its lack of attachment to the monetary policies of specific countries.

Finally, such an insignificant reaction seems to come from the fact that non-institutional investors, speculators and noise traders who place buy and sell orders in the market without the use of fundamental data account for the majority of the trades (Hayes, 2015). These kinds of investors, wishing to take advantage of the momentum of the market, rely on technical analysis instead of fundamental analysis such as monetary policies. Most of them intend to hold Bitcoin only in the short term, speculating and trying to make a big profit as the early Bitcoin's investors did. Even though the CME introduced Bitcoin indices (2016) and futures (2017)[5], thereby providing institutional investors with more exposure to this market, they still account for a small proportion of the total volume traded. Even though some transparency resulted from this initiative, for Bitcoin to become a mature market, it has to be accepted by the broader capital markets. Nevertheless, its utility value, that is, its usefulness as a safe, quick and efficient electronic payment system, should not be judged upon the speculation surrounding its trading[6] (Burniske & Tatar, 2018).

Furthermore, the lack of Bitcoin's significant reaction contrasts with the behaviour of fiat currencies, thus suggesting its appropriateness for portfolio diversification. However, such (alternative) investment should be small and accompanied by a fundamental analysis of the market, given Bitcoin's high risk and newness. Investors should carefully evaluate the risk–return profile of Bitcoin and its technological characteristics before deciding to invest in such asset. Moreover, because the correlation between Bitcoin and other assets is expected to increase with the overlap of entities investing in both types of assets (Burniske & Tatar, 2018), Bitcoin's current contrasting behaviour should not be taken for granted in the future nor for a potential economic shock.

[5] NYSE also introduced NYXBT, a Bitcoin pricing index, in May 2015 (Burniske & Tatar, 2018).
[6] Two types of value are placed by the community of any cryptoasset: utility value and speculative value.

6. Conclusion

The questions of whether Bitcoin reacts to monetary policy announcements and if such a reaction is conditional to a change in monetary policy were assessed through the analysis of the intraday volatility and trading activity patterns. This paper provides a major contribute to the literature by suggesting that Bitcoin is not vulnerable to news on centralised monetary policies. The independence of Bitcoin to policies that typically influence traditional assets has several implications for users, investors and policymakers. The intervention of central banks is not recognised by Bitcoin's market, which validates its potential diversification gains. Nevertheless, investors should not completely depend on Bitcoin to act as a diversifier, as its status might change as its market matures. Moreover, neither should Bitcoin's technological disruptive potential for users be judged upon its unstable price dynamics over the last years.

From a critical perspective, although an intraday event study is a suitable methodology to evaluate the overall influence of monetary policy decisions on the Bitcoin's market and whether investors were surprised by the news, causality cannot be extrapolated (Karadi, 2017). Another limitation comes from the potential increase of Bitcoin's use and acceptance by institutional investors, as its ecosystem continues to grow. If this scenario materializes, these results would need to be further assessed, as Bitcoin starts to be traded in traditional vehicles and further developed into new products. A suggestion for further research is to study whether the results are the same for the most influential Altcoins. For this, historical tick data for the remaining cryptocurrencies at the five-minute frequency needs to become available for long storage periods of time, and the sample size of events should be large. Because the most important Altcoin, Ether, was launched only in mid-2015, for the time being the data—if available—would still be too small for such analysis. Because this is a market highly characterised by speculative trading, it could also be interesting to investigate other policies with the potential to affect and have an effective control over Bitcoin.

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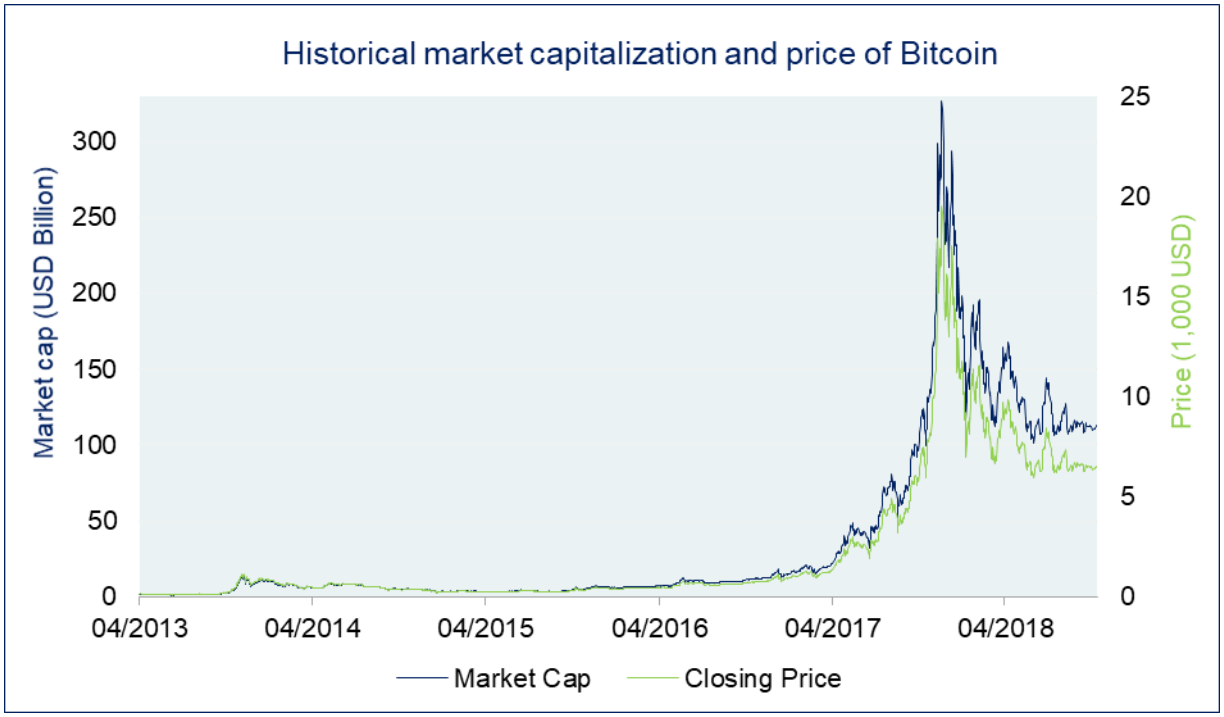
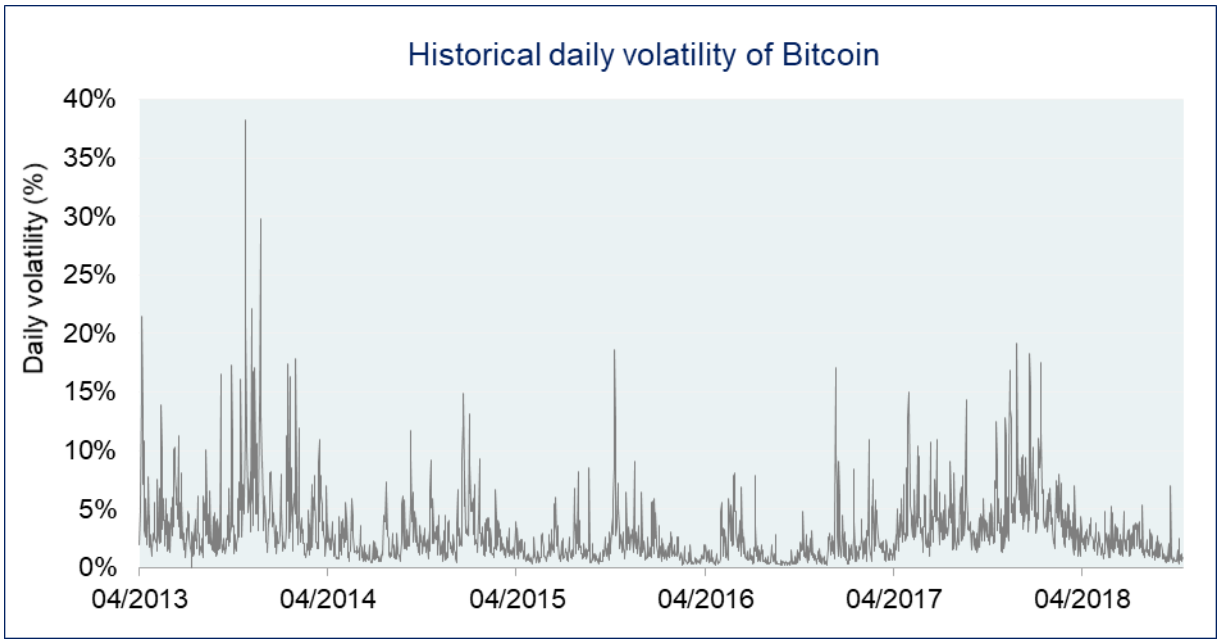
Appendix A – General characterisation of Bitcoin

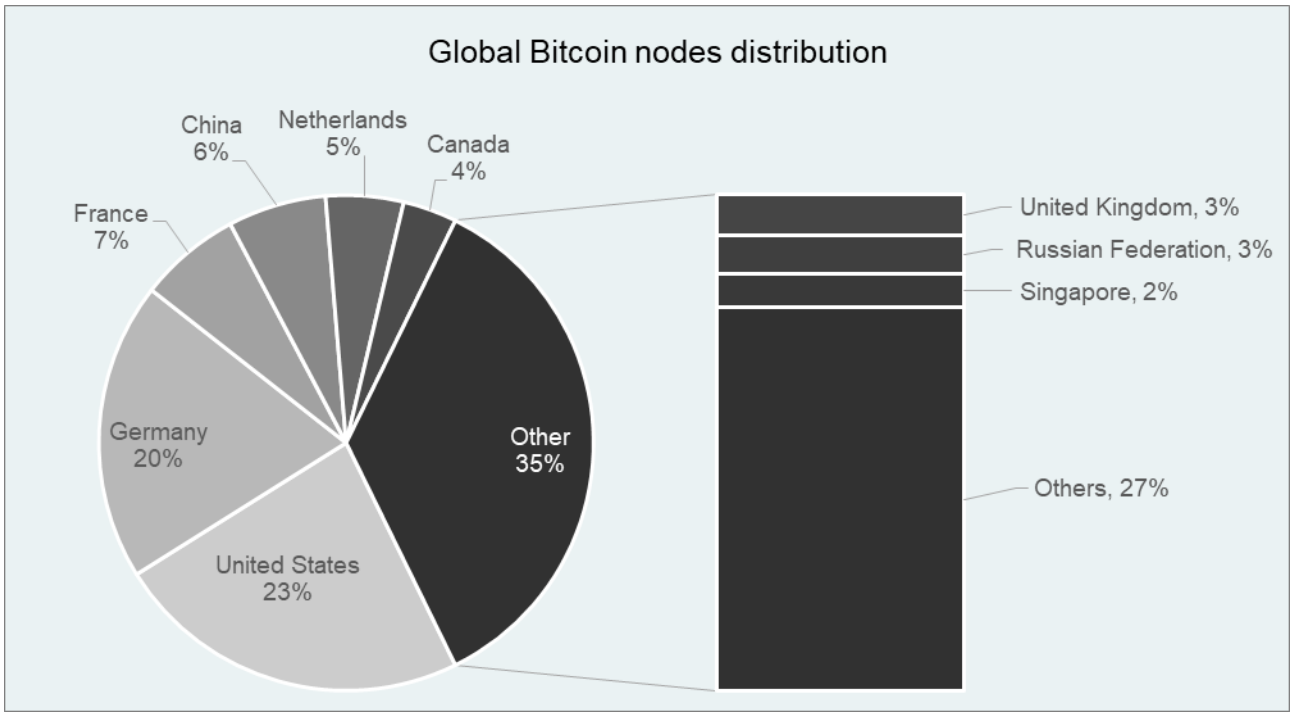
Appendix A1 – Evolution of Bitcoin's price and market capitalization from April 2013 to November 2018. Adapted from https://coinmarketcap.com (November 8, 2018).



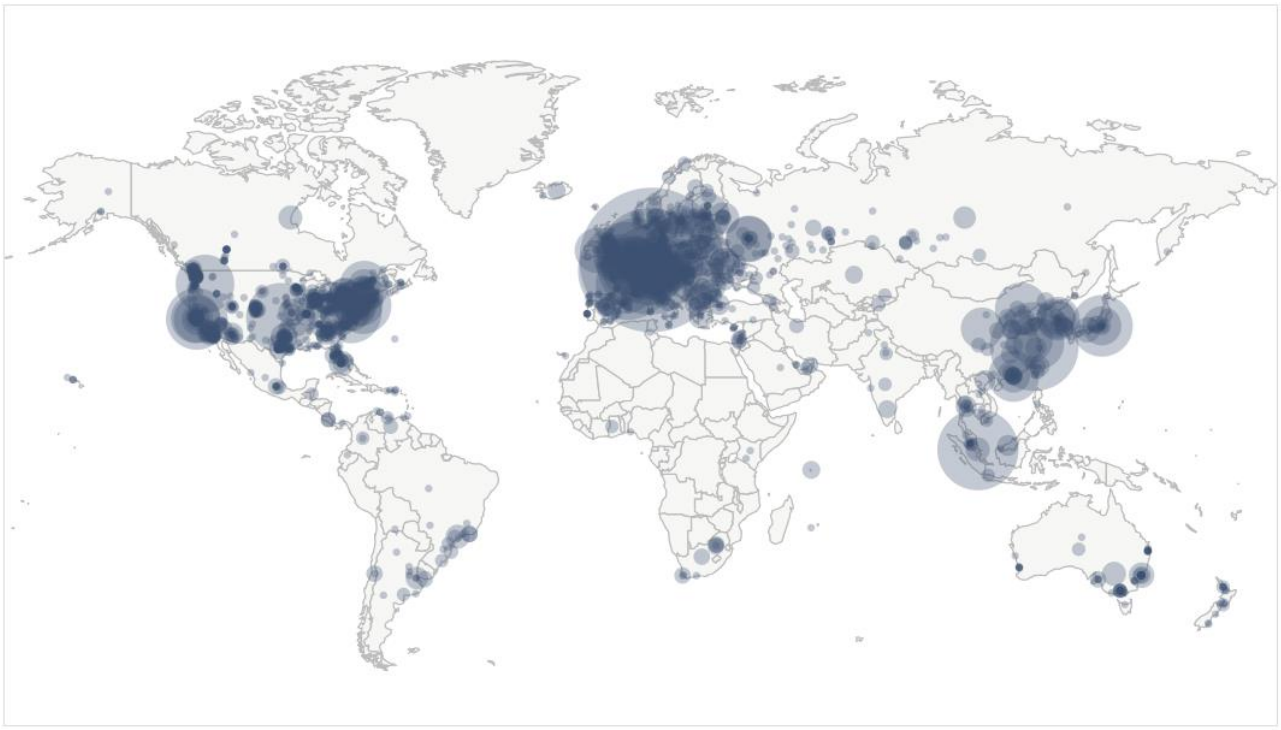
Appendix A2 – Evolution of Bitcoin's daily volatility from April 2013 to November 2018. Adapted from https://coinmarketcap.com (November 8, 2018).



Appendix A3 – Geographical distribution of reachable Bitcoin nodes by country. Adapted from https://bitnodes.earn.com (November 9, 2018).



Appendix A4 – Geographical concentration of reachable Bitcoin nodes. Adapted from https://bitnodes.earn.com (November 9, 2018).



Appendix B – General information on announcement data

Appendix B1 – Cryptocurrency-specific events from March 2013 to June 2018.

Date	Description of the event affecting the Bitcoin's market
26/06/2018	China explores the potential creation of a digital currency.
14/06/2018	Cryptocurrencies are classified as digital rights in Russia.
13/06/2018	India admits the investigation for the cryptocurrency ban was limited.
03/06/2018	IMF recognizes the appeal of cryptoassets.
17/05/2018	The first public cryptocurrency rations are released in China.
16/05/2018	A fake ICO website is created by SEC to educate investors.
11/05/2018	South Korea raids largest cryptocurrency exchange.
11/05/2018	Japan creates a template for cryptocurrency regulation.
30/04/2018	SEC does not rule out ICOs.
27/04/2018	Cryptocurrencies are classified as moveable property by France.
25/04/2018	St. Louis FED recognizes similarities of bitcoin with fiat currency.
25/04/2018	South Korea admits the crypto market is growing exponentially and stabilizing.
25/04/2018	Nasdaq considers including cryptocurrencies.
16/04/2018	IMF acknowledges the potential benefits of cryptocurrencies.
10/04/2018	Coinbase talks with SEC to become a registered brokerage firm.
09/04/2018	Malta becomes the Binance headquarters.
22/03/2018	SEC announces a probe to examine +100 cryptocurrency's hedge funds.
22/03/2018	UK launches a cryptocurrency task force.
13/03/2018	IMF alerts for the cryptoassets' potential for money laundering.
13/03/2018	Winklevoss propose non-profit association on self-regulation.
07/03/2018	SEC issues a warning to exchanges facilitating unregistered securities trades.
06/03/2018	FinCen suggests higher standards of KYC and AML laws to ICOs.
06/03/2018	Brazilian is tokenizing its national currency.
28/02/2018	SEC announces the launch of a cryptocurrency probe.
28/02/2018	CFTC allows employees to trade cryptocurrencies.
27/02/2018	Attempt to block access to overseas trading options.
27/02/2018	Israeli prohibits banks from restricting crypto activity in landmark decision.
16/02/2018	Japan's cryptocurrency industry to set up self-regulatory body.
10/02/2018	Arizona considers accepting taxes in Bitcoin.
05/02/2018	China plans to prevent all cryptocurrency trading by blocking all websites.
31/01/2018	South Korea reveals preference for regulate cryptocurrencies.
30/01/2018	SEC freezes cryptoassets of $600m ICO.
30/01/2018	Facebook bans cryptocurrency related ads.
28/01/2018	Coincheck – large Japanese cryptocurrency exchange – is hacked in $500m.
26/01/2018	China might remove the ICO ban.
26/01/2018	Launch of Korean blockchain association.
19/01/2018	CFTC files charges against two cryptocurrency fraud cases.
22/12/2017	Belarus legalizes cryptocurrencies.
18/12/2017	CME launches Bitcoin futures trading.
11/12/2017	SEC has not approved exchange-traded products holding cryptocurrencies.
10/12/2017	CBOE launches bitcoin futures trading.
07/12/2017	Lightning 1.0 protocol was tested on the Bitcoin network.
04/12/2017	CBOE announces bitcoin futures.
01/12/2017	US authorizes the exchange of derivatives for Bitcoin.

19/11/2017	Hacking of $30.95m from Tether wallet.
13/11/2017	CME announces potential trading of Bitcoin futures.
29/09/2017	Japan grants 11 licenses for digital currency exchanges.
12/09/2017	BitKan, a Chinese OTC service for cryptocurrencies, is suspended by regulators.
04/09/2017	China banns ICOs.
02/08/2017	CBOE announces potential launch of cryptocurrency derivatives.
07/07/2017	Poland alerts banks and consumers for cryptocurrency risks.
14/04/2017	Creation of first blockchain journal in the US.
13/04/2017	Russia does not guarantee Bitcoin's legal recognition.
01/04/2017	Japan authorizes the use of digital currency as a method of payment.
31/03/2017	Japan's Bitcoin law goes into effect in the next day.
24/03/2017	Japan announces classification of Bitcoin as a legal payment method.
10/03/2017	SEC rejects the Winklevoss Bitcoin ETF application.
09/02/2017	PBOC states four banning rules on the Bitcoin exchanges.
03/02/2017	Venezuela announces Petro.
11/01/2017	China announces plans to investigate Bitcoin exchanges.
11/01/2017	South Korea confirms ban on all cryptocurrencies exchanges.
29/11/2016	Russia acknowledges the legality of cryptocurrencies.
02/08/2016	Hacking of 119,756 BTC ($72m) in Bitfinex.
25/05/2016	Japan classifies cryptocurrencies as means of payment but not as currencies.
27/04/2016	Steam, a large gaming distributor, announces to accept bitcoin.
24/02/2016	Japan proposes virtual currencies as payment methods.
14/01/2016	Mike Hearn, heavily involved in Bitcoin community, announces to quit bitcoin.
31/10/2015	Bitcoin features on the front page of The Economist.
22/10/2015	European Court of Justice classifies Bitcoin as a tax-free payment method.
22/09/2015	NY approves its first regulation framework for cryptocurrencies.
15/08/2015	Launch of XT Fork, an attempt to overcome the size limit of Bitcoin's blocks.
01/08/2015	CEO of the failed Mt. Gox is arrested and accused of fraud.
03/06/2015	NY announces to release Bitlicense application.
14/02/2015	Hacking of 7170 BTC ($2.1m) from Bter, a Chinese large bitcoin exchange.
26/01/2015	Coinbase launches an US licensed exchange.
04/01/2015	Hacking of 18,866 BTC ($5.2m) from Bitstamp.
11/12/2014	Microsoft announces to accept Bitcoin.
18/07/2014	Dell announces to accept bitcoin.
04/07/2014	EBA discourages financial institutions from trading virtual currencies.
10/04/2014	Chinese banks demand many Bitcoin exchanges to shut down their accounts.
26/03/2014	US IRS considers Bitcoin as a taxable property.
07/03/2014	Japan prohibits banks and security firms from handling bitcoins.
24/02/2014	Mt. Gox closes. Over 744,000 BTC were lost.
07/02/2014	Three leading exchanges (Bitstamp, Mt. Gox and BTC-e) go offline.
27/01/2014	Russia recommends legal entities to avoid trading bitcoins.
08/01/2014	Hong Kong admits the lack of regulation on virtual currencies.
18/12/2013	China's biggest exchange, Btcchina, stops accepting deposits in RMB.
05/12/2013	PBOC prohibits financial entities from trading bitcoins.
18/11/2013	US senate manifests its intent of not being an obstacle to innovation.
23/10/2013	4,100 BTC ($1m) are stolen from Inputs.io, an Australian wallet supplier.
02/10/2013	FBI collects 26k BTC upon shutting down Silk Road (online black market).
29/06/2013	US Financial Crimes Enforcement Network (FinCEN) allows Mt. Gox to operate.
14/05/2013	US homeland security seizes $2m from Mt. Gox.
25/03/2013	€10b bailout of Cyprus with Europe.
12/03/2013	Bitcoin 0.8 is released with various problems, making users demand previous version.

Appendix B2 – Final sample of announcements dates (i.e. after control measures) from March 2013 to June 2018, where change assumes a value of 1 if the announcement implied a change in the policy and a value of 0 otherwise.

#	Bank	Date	Day	Time	Change
1	FED	20/03/2013	Wed	18:00	0
2	FED	01/05/2013	Wed	18:00	0
3	ECB	02/05/2013	Thu	11:45	1
4	BoE	09/05/2013	Thu	11:00	0
5	FED	19/06/2013	Wed	18:00	0
6	FED	31/07/2013	Wed	18:00	0
7	FED	18/09/2013	Wed	18:00	0
8	BoE	10/10/2013	Thu	11:00	0
9	FED	30/10/2013	Wed	18:00	0
10	FED	29/01/2014	Wed	19:00	0
11	FED	19/03/2014	Wed	18:00	0
12	ECB	03/04/2014	Thu	11:45	0
13	FED	30/04/2014	Wed	18:00	0
14	FED	18/06/2014	Wed	18:00	0
15	ECB	03/07/2014	Thu	11:45	0
16	BoE	10/07/2014	Thu	11:00	0
17	FED	30/07/2014	Wed	18:00	0
18	FED	17/09/2014	Wed	18:00	0
19	ECB	02/10/2014	Thu	11:45	0
20	BoE	09/10/2014	Thu	11:00	0
21	FED	29/10/2014	Wed	18:00	1
22	FED	17/12/2014	Wed	19:00	0
23	ECB	22/01/2015	Thu	12:45	1
24	FED	28/01/2015	Wed	19:00	0
25	BoE	05/02/2015	Thu	12:00	0
26	FED	18/03/2015	Wed	18:00	0
27	BoE	09/04/2015	Thu	11:00	0
28	ECB	15/04/2015	Wed	11:45	0
29	FED	29/04/2015	Wed	18:00	0
30	BoE	11/05/2015	Mon	11:00	0
31	BoE	04/06/2015	Thu	11:00	0
32	FED	17/06/2015	Wed	18:00	0
33	BoE	09/07/2015	Thu	11:00	0
34	ECB	16/07/2015	Thu	11:45	0
35	FED	29/07/2015	Wed	18:00	0
36	BoE	06/08/2015	Thu	11:00	0
37	ECB	03/09/2015	Thu	11:45	0
38	BoE	10/09/2015	Thu	11:00	0
39	FED	17/09/2015	Thu	18:00	0
40	BoE	08/10/2015	Thu	11:00	0
41	FED	28/10/2015	Wed	18:00	0
42	BoE	05/11/2015	Thu	12:00	0
43	ECB	03/12/2015	Thu	12:45	1
44	BoE	10/12/2015	Thu	12:00	0
45	FED	16/12/2015	Wed	19:00	1
46	ECB	21/01/2016	Thu	12:45	0
47	FED	27/01/2016	Wed	19:00	0
48	BoE	04/02/2016	Thu	12:00	0
49	ECB	10/03/2016	Thu	12:45	1
50	FED	16/03/2016	Wed	18:00	0
51	BoE	17/03/2016	Thu	12:00	0
52	BoE	14/04/2016	Thu	11:00	0
53	ECB	21/04/2016	Thu	11:45	0
54	BoE	12/05/2016	Thu	11:00	0
55	ECB	02/06/2016	Thu	11:45	0
56	FED	15/06/2016	Wed	18:00	0
57	BoE	16/06/2016	Thu	11:00	0
58	BoE	14/07/2016	Thu	11:00	0
59	ECB	21/07/2016	Thu	11:45	0
60	FED	27/07/2016	Wed	18:00	0
61	BoE	04/08/2016	Thu	11:00	1
62	ECB	08/09/2016	Thu	11:45	0
63	BoE	15/09/2016	Thu	11:00	0
64	FED	21/09/2016	Wed	18:00	0
65	ECB	20/10/2016	Thu	11:45	0
66	FED	02/11/2016	Wed	18:00	0
67	BoE	03/11/2016	Thu	12:00	0
68	ECB	08/12/2016	Thu	12:45	1
69	FED	14/12/2016	Wed	19:00	1
70	BoE	15/12/2016	Thu	12:00	0
71	ECB	19/01/2017	Thu	12:45	0
72	FED	01/02/2017	Wed	19:00	0
73	BoE	02/02/2017	Thu	12:00	0
74	ECB	09/03/2017	Thu	12:45	0
75	FED	15/03/2017	Wed	18:00	1
76	BoE	16/03/2017	Thu	12:00	0
77	ECB	27/04/2017	Thu	11:45	0
78	FED	03/05/2017	Wed	18:00	0
79	BoE	11/05/2017	Thu	11:00	0
80	ECB	08/06/2017	Thu	11:45	0
81	FED	14/06/2017	Wed	18:00	1
82	BoE	15/06/2017	Thu	11:00	0
83	ECB	20/07/2017	Thu	11:45	0
84	FED	26/07/2017	Wed	18:00	0
85	BoE	03/08/2017	Thu	11:00	0
86	ECB	07/09/2017	Thu	11:45	0
87	BoE	14/09/2017	Thu	11:00	0
88	FED	20/09/2017	Wed	18:00	1
89	ECB	26/10/2017	Thu	11:45	1
90	FED	01/11/2017	Wed	18:00	0
91	BoE	02/11/2017	Thu	12:00	1
92	FED	13/12/2017	Wed	19:00	1
93	ECB	25/01/2018	Thu	12:45	0
94	BoE	08/02/2018	Thu	12:00	0
95	ECB	08/03/2018	Thu	12:45	0
96	FED	21/03/2018	Wed	18:00	1
97	ECB	26/04/2018	Thu	11:45	0
98	FED	02/05/2018	Wed	18:00	0
99	BoE	10/05/2018	Thu	11:00	0
100	BoE	21/06/2018	Thu	11:00	0

Appendix B3 – Total number of events before and after the employment of the methodology described in Section 3, from March 2013 to June 2018.

Total number of events	**150**
Overlapping events excluded	*38*
Crypto-specific events excluded	*11*
Missing data	*1*
Total number of events after control measures (N)	**100**
of which are from ECB	*27*
of which are from FED	*39*
of which are from BOJ	*34*
of which the monetary policy changed	*16*
of which the monetary policy remained the same	*84*
of which took place in March 2013 – December 2015	*45*
of which took place in January 2016 – June 2018	*55*

Appendix C – General information on Bitcoin data

Appendix C1 – General descriptive statistics of open, high, low and close prices (USD), Garman volatility (%) and trading volume (USD), five-minute observations (March 2013 – June 2018). *Note:* All observations over the 120-minute event window for the total 200 event and non-event dates are included.

Announcement: total sample $(N = 100)$						
	O_t	H_t	L_t	C_t	V_t	T_t
Mean	1753	1755	1752	1754	0,078%	23972
Max	16334	16341	16312	16341	4,094%	1094126
Min	63,93	63,93	63,93	63,93	0,000%	2,95
Skew	2,56	2,56	2,55	2,55	10,98	7,02
Kurt	6,46	6,46	6,44	6,45	205,86	69,21
Obs.	2500	2500	2500	2500	2500	2500

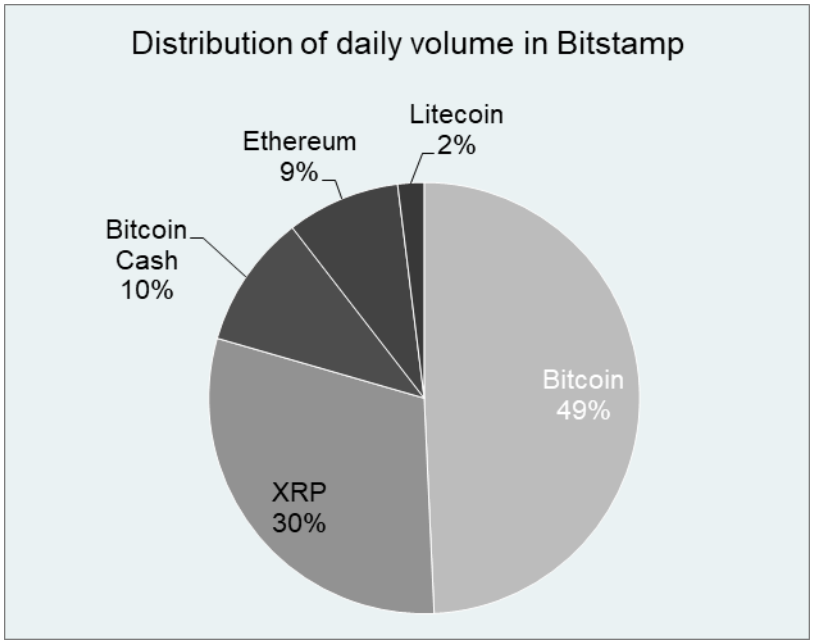
Non-announcement: total sample $(N = 100)$						
	O_t	H_t	L_t	C_t	V_t	T_t
Mean	1691	1692	1689	1690	0,065%	19103
Max	13178	13179	13165	13175	1,715%	654606
Min	46,34	46,34	46,34	46,34	0,000%	1,34
Skew	2,39	2,39	2,38	2,39	4,47	5,89
Kurt	4,86	4,87	4,86	4,86	36,32	43,09
Obs.	2500	2500	2500	2500	2500	2500

Announcement: change sample $(N = 16)$						
	O_t	H_t	L_t	C_t	V_t	T_t
Mean	3106	3110	3102	3107	0,101%	54065
Max	16334	16341	16312	16341	1,223%	957171
Min	109,36	109,36	109,14	109,14	0,000%	60,46
Skew	1,83	1,83	1,83	1,83	2,85	4,10
Kurt	2,71	2,70	2,70	2,70	12,07	21,38
Obs.	400	400	400	400	400	400

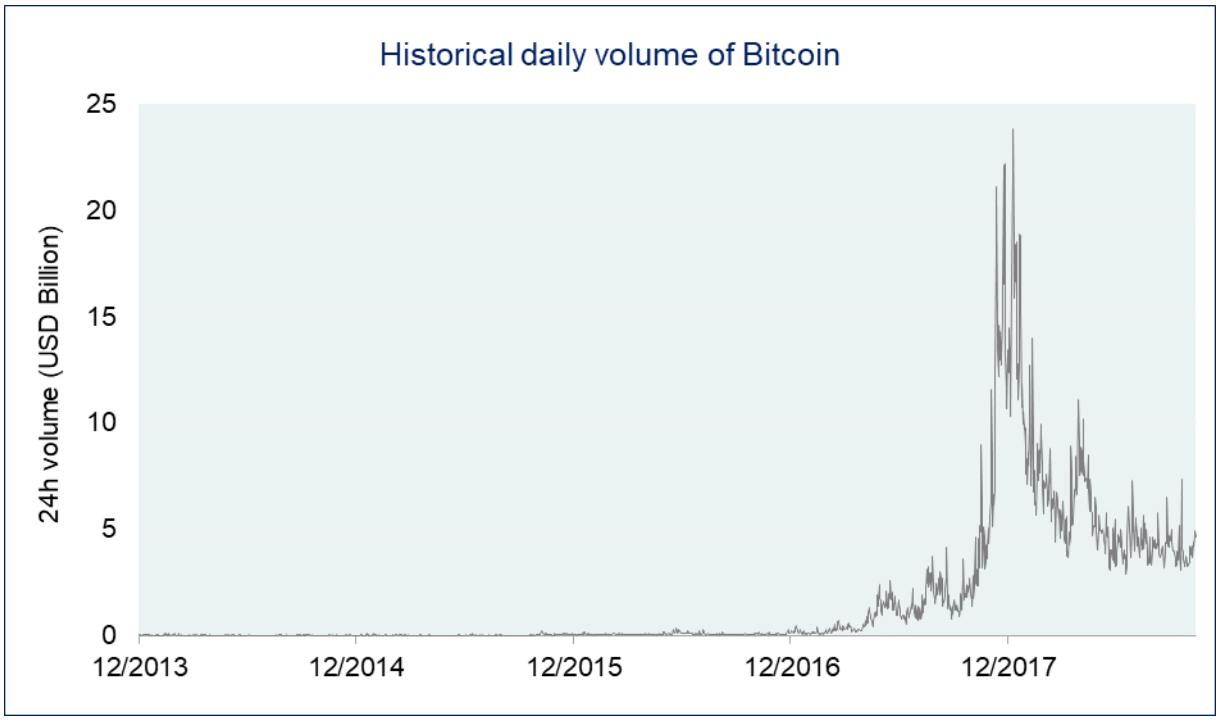
Non-announcement: change sample $(N = 16)$						
	O_t	H_t	L_t	C_t	V_t	T_t
Mean	2754	2757	2751	2754	0,093%	41906
Max	13178	13179	13165	13175	1,715%	531440
Min	91,04	91,18	91,02	91,02	0,000%	36,61
Skew	1,63	1,63	1,63	1,63	4,95	3,41
Kurt	1,84	1,84	1,84	1,85	41,66	13,46
Obs.	400	400	400	400	400	400

Appendix C2 – Volume distribution of Bitstamp by cryptocurrency traded. Adapted from *https://coinmarketcap.com/exchanges/bitstamp* (November 9, 2018).

Note: Approximately 41% correspond to BTC/USD trades and 9% to BTC/EUR trades.



Appendix C3 – Evolution of Bitcoin's volume from December 2013 to November 2018. Adapted from https://coinmarketcap.com (November 8, 2018).



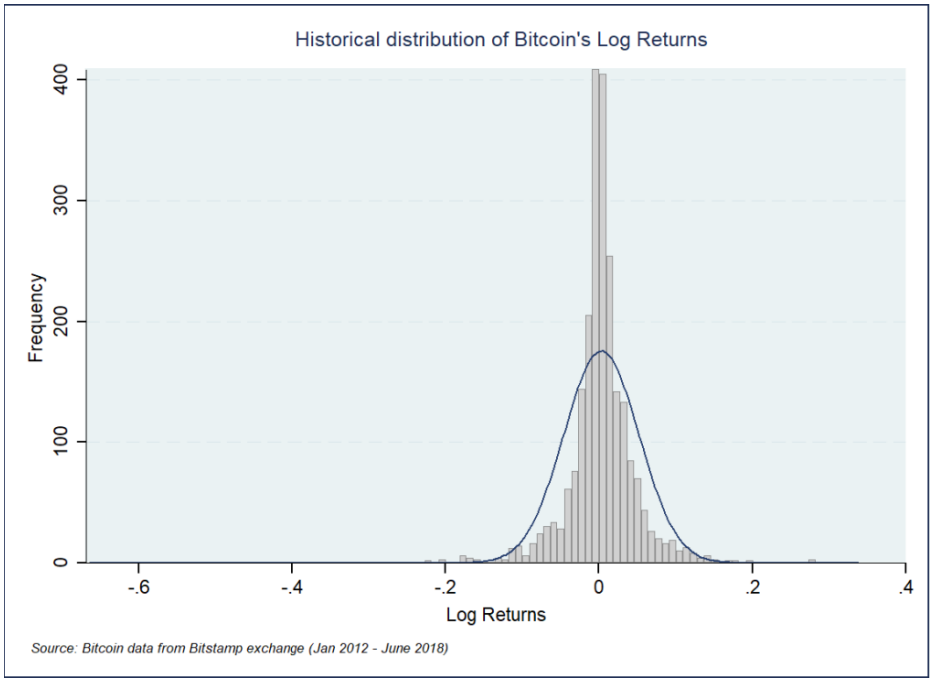
Appendix C4 – General descriptive statistics of the time series of Bitcoin's log returns from December 2011 to June 2018, daily observations, built within Stata.

```
. summarize log_return, detail

                        log_Return
-------------------------------------------------------------
      Percentiles      Smallest
 1%    -.1616149      -.663948
 5%      -.06791      -.3589057
10%    -.0388103      -.3461257       Obs                2368
25%    -.0116741      -.2808917       Sum of Wgt.        2368

50%     .0023579                      Mean            .003054
                       Largest        Std. Dev.       .0489338
75%     .0200551       .27559
90%     .0484242       .2759226       Variance        .0023945
95%     .0722165       .2787571       Skewness       -1.322011
99%     .1382359       .3374862       Kurtosis        25.13491
```

Appendix C5 – Skewness and Kurtosis joint test for normality, daily observations.

```
. sktest log_return

                    Skewness/Kurtosis tests for Normality
                                                      ------ joint ------
    Variable |   Obs   Pr(Skewness)   Pr(Kurtosis)  adj chi2(2)   Prob>chi2
-------------+-------------------------------------------------------------
  log_return |  2.4e+03    0.0000         0.0000            .        0.0000
```

Appendix C6 – Historical distribution of Bitcoin's log returns and its comparison with the normal distribution curve.



Appendix D – Detailed results of the Wilcoxon rank-sum significance test

P-values of the significance test on AAV_t and $CAAV\ (-30, +90)$								
t	**Total**	**ECB**	**FED**	**BOE**	**2013-2015**	**2016-2018**	**Coinbase**	**Change**
-30	0,8635	0,7069	0,5000	0,4346	0,8311	0,8832	0,4159	0,7605
-25	0,1191	0,4382	0,1730	0,6248	0,0655*	0,5775	0,8317	0,2128
-20	0,1809	0,9023	0,3258	0,2408	0,1708	0,4964	0,4584	0,8796
-15	0,1402	0,1506	0,1543	0,8227	0,4684	0,1894	0,0811*	0,7057
-10	0,9940	0,1451	0,3208	0,9796	0,3766	0,4839	0,3470	0,5639
-5	0,2652	0,4403	0,5454	0,4265	0,1776	0,7781	0,6951	0,4502
0	0,5572	0,6018	0,5077	0,1832	0,9380	0,4613	0,2286	0,8792
5	0,4058	0,9023	0,0963*	0,9258	0,6390	0,4372	0,2683	0,4502
10	0,5526	0,2950	0,6989	0,4788	0,4218	0,9831	0,5006	0,9699
15	0,1450	0,2595	0,4289	0,5399	0,6513	0,1250	0,8016	0,4362
20	0,5464	0,5417	0,5363	0,7545	0,4792	0,8915	0,5446	0,3521
25	0,9872	0,5363	0,7051	0,4769	0,7211	0,5370	0,2365	0,7316
30	0,4598	0,4805	0,7799	0,7191	0,6487	0,6105	0,5874	0,6914
35	0,4259	0,2686	0,2089	0,5117	0,5267	0,6366	0,8075	0,2735
40	0,6850	0,8141	0,9073	0,6046	0,5522	0,9376	0,4075	0,4282
45	0,5530	0,9860	0,4904	0,6256	0,4700	0,8870	0,8767	0,5530
50	0,6882	0,9512	0,6125	0,8626	0,7884	0,6404	0,5053	0,5818
55	0,3920	0,6251	0,9796	0,6297	0,7324	0,3490	0,1485	0,4055
60	0,8593	0,5774	0,7292	0,7937	0,7250	0,8867	0,5870	0,1169
65	0,8593	0,4192	0,7920	0,3179	0,9385	0,9016	0,3118	0,5171
70	0,8167	0,6722	0,9399	0,7901	0,9772	0,6802	0,3937	0,5711
75	0,8453	0,9582	0,4931	0,4042	0,3972	0,7131	0,1915	0,4495
80	0,0680*	0,5842	0,5038	0,0609*	0,2112	0,1445	0,6269	0,3521
85	0,8168	0,7871	0,3839	0,4274	0,7563	0,5025	0,6367	0,2996
90	0,1430	0,6740	0,1095	0,9411	0,7431	0,0774*	0,9750	0,4953
CAAV	0,3129	0,4014	0,4936	0,7129	0,4953	0,4713	0,3706	0,4510

P-values of the significance test on AAT_t and $CAAT\ (-30, +90)$								
t	**Total**	**ECB**	**FED**	**BOE**	**2013-2015**	**2016-2018**	**Coinbase**	**Change**
-30	0,2769	0,9793	0,3010	0,5726	0,3555	0,3715	0,5383	0,9699
-25	0,4144	0,9793	0,9085	0,2021	0,1544	0,8459	0,9794	0,8802
-20	0,7750	0,3918	0,3104	0,9902	0,4751	0,9833	0,5704	0,5465
-15	0,4532	0,8559	0,3450	0,5560	0,8941	0,4531	0,6852	0,7063
-10	0,9942	0,6343	0,8848	0,6857	0,9839	0,9167	0,8857	0,6511
-5	0,3738	0,9793	0,7758	0,2390	0,1953	0,6998	0,7653	0,6511
0	0,6904	0,2645	0,3501	0,5397	0,6140	0,7627	0,8712	0,4510
5	0,7434	0,3637	0,6138	0,3512	0,7807	0,5051	0,6111	0,9699
10	0,7049	0,3370	0,7911	0,7685	0,6369	0,8788	0,2170	0,8505
15	0,1426	0,3918	0,5454	0,2439	0,4701	0,1539	0,6583	0,6242
20	0,9357	0,5391	0,8690	0,6500	0,8433	0,6778	0,6215	0,6511
25	0,3048	0,1134	0,9562	0,8830	0,9325	0,3557	0,8193	0,3657
30	0,8508	0,5622	0,9641	0,7967	0,9710	0,9881	0,5530	0,7919
35	0,9805	0,8968	0,4811	0,5316	0,8056	0,7856	0,8308	0,7919
40	0,8584	0,8695	0,8690	0,9316	0,8686	0,5480	0,6372	0,5718
45	0,7881	0,8153	0,8377	0,3906	0,8877	0,7627	0,6852	0,6511
50	0,4328	0,9242	0,1603	0,9804	0,3190	0,6346	0,7153	0,8802
55	0,3532	0,8968	0,3399	0,4693	0,5749	0,4388	0,8021	0,7063
60	0,8508	0,5277	0,7835	0,8157	0,1664	0,3495	0,9383	0,6242
65	0,7994	0,8695	0,6565	0,7967	0,9775	0,7042	0,4611	0,9399
70	0,7231	0,9793	0,4269	0,8157	0,6896	0,7265	0,5190	0,5977
75	0,7397	0,9242	0,7153	0,8540	0,8244	0,6517	0,4931	0,3271
80	0,6565	0,6843	0,7989	0,2696	0,7015	0,6474	0,8828	0,6785
85	0,0981*	0,9242	0,0652*	0,2971	0,0195***	0,8459	0,7681	0,2582
90	0,4089	0,9655	0,2567	0,7405	0,9069	0,3526	0,8799	0,9399
CAAT	0,6372	0,5165	0,5454	0,4618	0,4652	0,8647	0,6744	0,8802

***p<0,01; **p<0,05; *p<0,1

Appendix E – Average results on the volatility and trading activity patterns

Appendix E1 – Average results of V_t and T_t on the announcement sample.

Announcement sample: V_t								
t	Total	ECB	FED	BOE	2013-2015	2016-2018	Coinbase	Change
-30	0,064%	0,059%	0,061%	0,071%	0,058%	0,068%	0,035%	0,065%
-25	0,075%	0,096%	0,065%	0,070%	0,074%	0,076%	0,052%	0,160%
-20	0,075%	0,055%	0,081%	0,084%	0,075%	0,076%	0,043%	0,083%
-15	0,079%	0,068%	0,086%	0,080%	0,089%	0,071%	0,034%	0,087%
-10	0,076%	0,048%	0,103%	0,066%	0,076%	0,075%	0,025%	0,075%
-5	0,081%	0,078%	0,090%	0,073%	0,089%	0,074%	0,031%	0,093%
0	0,083%	0,074%	0,104%	0,066%	0,094%	0,074%	0,041%	0,084%
5	0,075%	0,074%	0,084%	0,066%	0,078%	0,073%	0,029%	0,149%
10	0,081%	0,066%	0,075%	0,099%	0,075%	0,086%	0,031%	0,147%
15	0,075%	0,065%	0,068%	0,091%	0,058%	0,089%	0,050%	0,132%
20	0,070%	0,082%	0,073%	0,056%	0,072%	0,068%	0,032%	0,074%
25	0,063%	0,069%	0,062%	0,059%	0,053%	0,071%	0,028%	0,087%
30	0,076%	0,061%	0,086%	0,075%	0,093%	0,061%	0,047%	0,058%
35	0,093%	0,089%	0,097%	0,091%	0,103%	0,084%	0,035%	0,087%
40	0,087%	0,068%	0,126%	0,058%	0,122%	0,059%	0,025%	0,102%
45	0,070%	0,070%	0,063%	0,076%	0,077%	0,064%	0,040%	0,074%
50	0,070%	0,068%	0,074%	0,067%	0,082%	0,060%	0,034%	0,070%
55	0,067%	0,093%	0,053%	0,063%	0,063%	0,071%	0,039%	0,073%
60	0,068%	0,070%	0,063%	0,074%	0,078%	0,060%	0,025%	0,033%
65	0,072%	0,076%	0,055%	0,088%	0,092%	0,056%	0,031%	0,083%
70	0,096%	0,053%	0,154%	0,062%	0,139%	0,060%	0,034%	0,109%
75	0,072%	0,086%	0,051%	0,085%	0,085%	0,062%	0,033%	0,140%
80	0,124%	0,120%	0,148%	0,099%	0,174%	0,083%	0,035%	0,229%
85	0,082%	0,100%	0,083%	0,067%	0,099%	0,069%	0,035%	0,146%
90	0,082%	0,066%	0,117%	0,053%	0,099%	0,068%	0,035%	0,093%

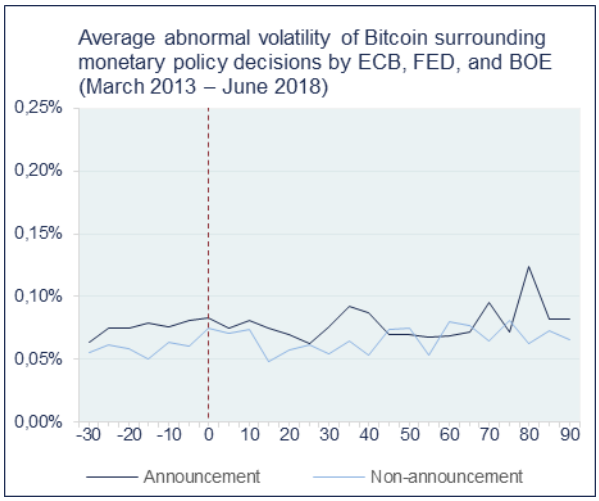
Announcement sample: T_t								
t	Total	ECB	FED	BOE	2013-2015	2016-2018	Coinbase	Change
-30	33578	23199	39644	34861	5351	56672	51855	110593
-25	35475	28628	31393	45594	4087	61155	51115	108062
-20	30194	23167	23750	43166	4553	51174	60724	106020
-15	31795	29589	17574	49858	5476	53328	33408	62524
-10	21727	24644	21784	19345	4769	35601	26918	54482
-5	22582	43389	15756	13889	4806	37127	23501	36360
0	20243	22969	20865	17364	3955	33570	31721	35886
5	21519	25316	19844	20425	4040	35820	23590	45011
10	24403	15191	20233	36501	4217	40918	26579	66550
15	28542	30278	18616	38549	4561	48162	32622	60839
20	29781	57000	15114	24991	2560	52053	25616	42052
25	26929	35449	19723	28430	3285	46274	30377	69447
30	23575	33092	13879	27139	4821	38919	23868	42857
35	21486	25873	15435	24943	4506	35379	27119	37265
40	21524	23977	15309	26705	3654	36145	27364	43750
45	16796	14168	12176	24182	3973	27288	30419	29655
50	26490	32964	15878	33522	4106	44805	28777	38734
55	25435	47735	8862	26736	3724	43198	24482	39128
60	20089	26720	15862	19671	5234	32243	26473	41300
65	19314	22198	12102	25297	5357	30733	23334	32970
70	15547	20756	11027	16596	4422	24649	21976	27460
75	19828	22643	12936	25497	6358	30848	25461	43904
80	24472	21235	20432	31678	4595	40735	25391	67032
85	19566	22531	16721	20474	6991	29854	22265	55813
90	18407	21332	12804	22511	2772	31200	24387	53919

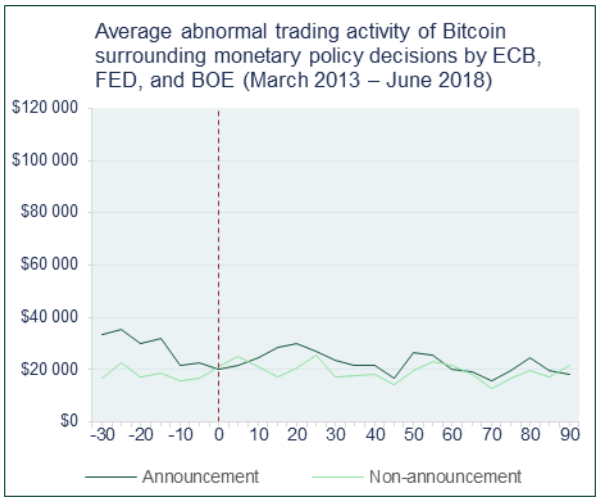
Appendix E2 – Average results of V_t and T_t on the non-announcement sample.

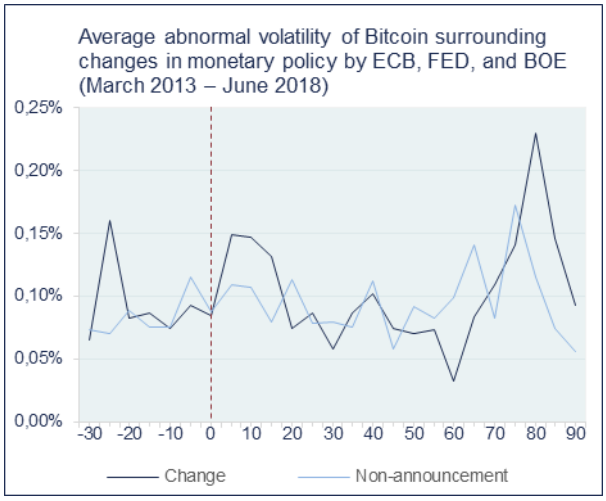
Non-announcement sample: V_t								
t	Total	ECB	FED	BOE	2013-2015	2016-2018	Coinbase	Change
-30	0,055%	0,062%	0,063%	0,041%	0,039%	0,068%	0,022%	0,074%
-25	0,061%	0,060%	0,074%	0,048%	0,069%	0,055%	0,034%	0,070%
-20	0,059%	0,062%	0,066%	0,049%	0,064%	0,055%	0,022%	0,089%
-15	0,051%	0,049%	0,036%	0,069%	0,050%	0,051%	0,020%	0,075%
-10	0,063%	0,087%	0,048%	0,061%	0,067%	0,060%	0,047%	0,075%
-5	0,060%	0,076%	0,058%	0,049%	0,065%	0,056%	0,031%	0,115%
0	0,075%	0,066%	0,095%	0,059%	0,090%	0,063%	0,035%	0,087%
5	0,070%	0,099%	0,043%	0,079%	0,077%	0,065%	0,025%	0,109%
10	0,073%	0,084%	0,074%	0,064%	0,095%	0,056%	0,027%	0,107%
15	0,049%	0,044%	0,052%	0,048%	0,040%	0,055%	0,036%	0,080%
20	0,058%	0,062%	0,059%	0,054%	0,056%	0,059%	0,038%	0,113%
25	0,062%	0,058%	0,056%	0,071%	0,073%	0,052%	0,035%	0,079%
30	0,055%	0,057%	0,055%	0,052%	0,046%	0,062%	0,034%	0,080%
35	0,065%	0,067%	0,049%	0,081%	0,070%	0,060%	0,024%	0,075%
40	0,053%	0,076%	0,048%	0,042%	0,041%	0,063%	0,018%	0,112%
45	0,074%	0,077%	0,070%	0,076%	0,082%	0,067%	0,031%	0,058%
50	0,075%	0,071%	0,077%	0,076%	0,112%	0,045%	0,034%	0,092%
55	0,054%	0,089%	0,031%	0,051%	0,062%	0,047%	0,027%	0,082%
60	0,080%	0,100%	0,060%	0,088%	0,109%	0,057%	0,029%	0,099%
65	0,077%	0,111%	0,066%	0,061%	0,090%	0,065%	0,028%	0,141%
70	0,064%	0,070%	0,058%	0,067%	0,074%	0,056%	0,030%	0,083%
75	0,081%	0,130%	0,076%	0,049%	0,104%	0,063%	0,030%	0,172%
80	0,063%	0,084%	0,073%	0,034%	0,074%	0,054%	0,025%	0,115%
85	0,073%	0,085%	0,050%	0,089%	0,082%	0,065%	0,037%	0,075%
90	0,065%	0,072%	0,058%	0,068%	0,090%	0,045%	0,035%	0,056%

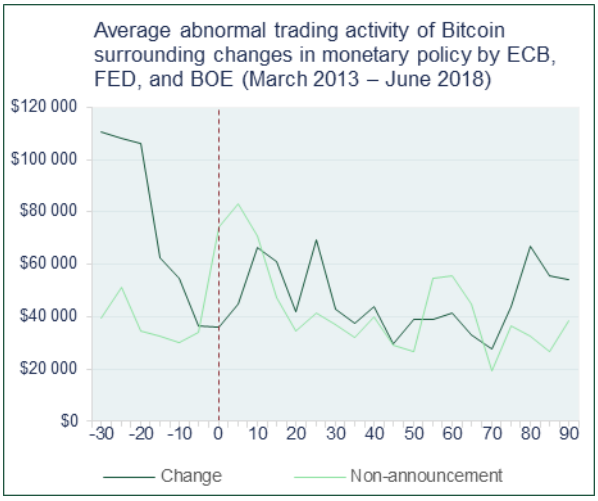
Non-announcement sample: T_t								
t	Total	ECB	FED	BOE	2013-2015	2016-2018	Coinbase	Change
-30	16662	22335	15564	13418	3757	27222	21474	39566
-25	22854	40586	16411	16163	4609	37782	29665	51347
-20	17313	26111	11746	16713	6208	26399	18329	34410
-15	18495	30687	13811	14185	3802	30516	22719	32480
-10	15820	18912	16566	12509	6226	23670	22565	30165
-5	16629	27094	15511	9601	3550	27330	25551	34107
0	21364	25662	30255	7754	3360	36096	27330	74464
5	25007	26348	26560	22161	5700	40804	30169	83240
10	21330	31003	26626	7575	5374	34386	36786	70750
15	17021	16389	21444	12449	2683	28751	37343	47124
20	20897	17452	16884	28237	3310	35287	37353	34508
25	25493	40145	17539	22980	5516	41837	24478	41375
30	17480	16077	16886	19276	5512	27272	25752	37100
35	17722	18746	15184	19820	6039	27280	21267	32297
40	18441	23299	19078	13851	4640	29732	21608	40057
45	14429	17587	11869	14857	5681	21585	21371	29343
50	19624	33159	11639	18035	5386	31273	33920	26910
55	23271	41126	19783	13093	4478	38647	40947	54601
60	21700	29901	21411	15519	7439	33368	37834	55502
65	18117	19721	17683	17341	5032	28823	30188	44793
70	12955	17496	9606	13191	4478	19891	23605	19392
75	16678	17652	15261	17528	5486	25835	35438	36459
80	19632	22023	13065	25267	6740	30181	28356	32754
85	17086	26767	11119	16242	3551	28160	29076	26559
90	21548	27087	18436	20719	7938	32683	31734	38355

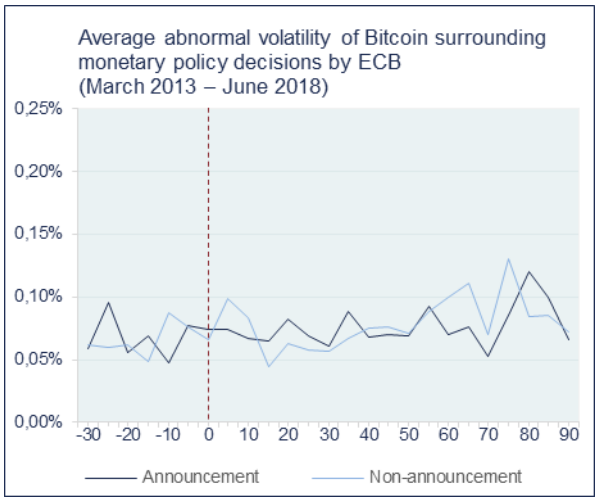
Appendix E3 – Average results of V_t and T_t on announcement and non-announcement samples throughout the event window.

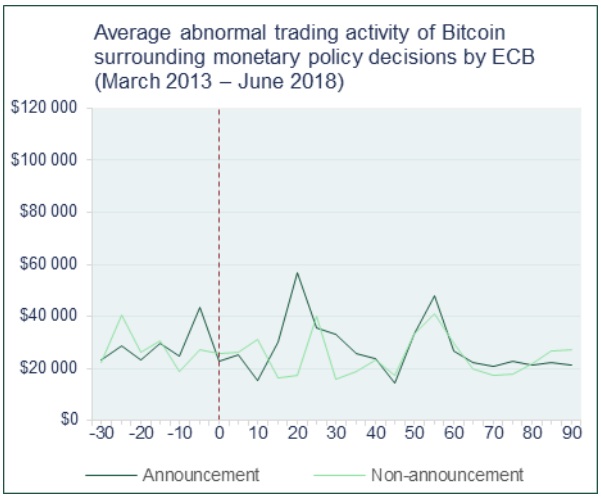


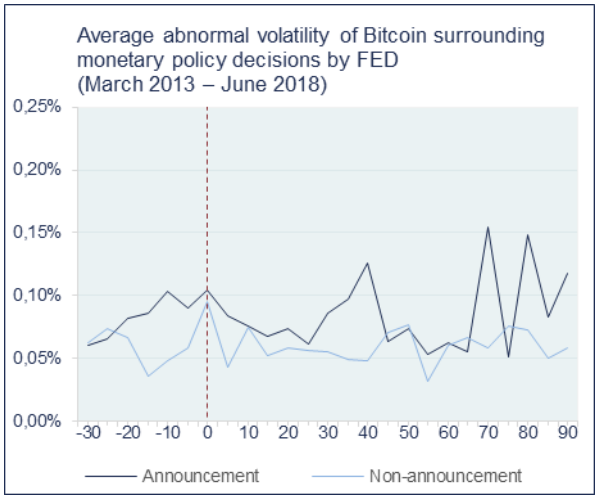


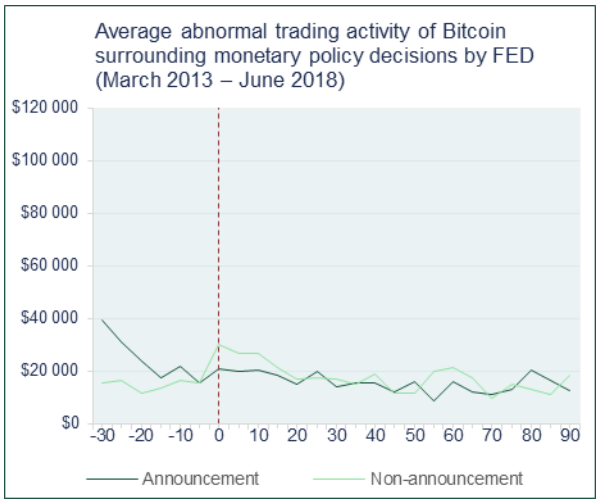


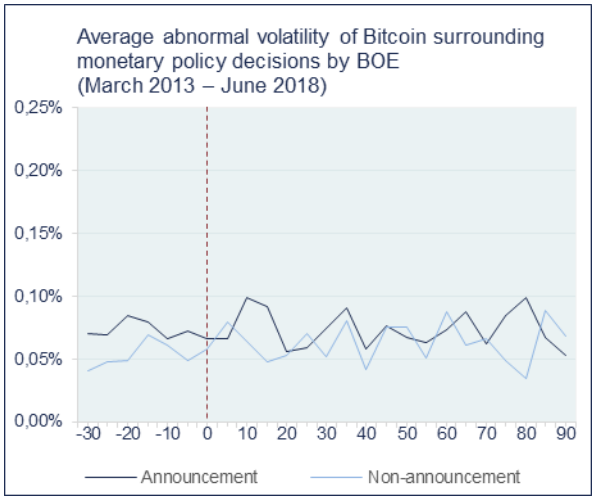


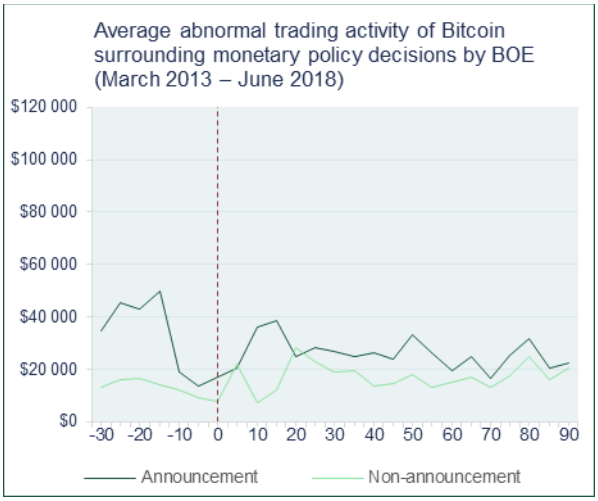


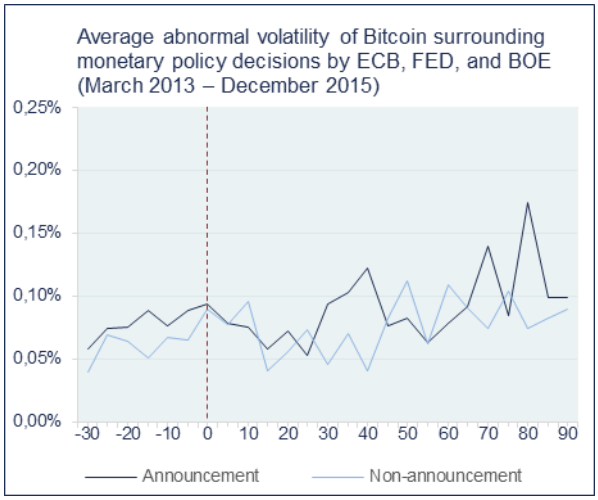


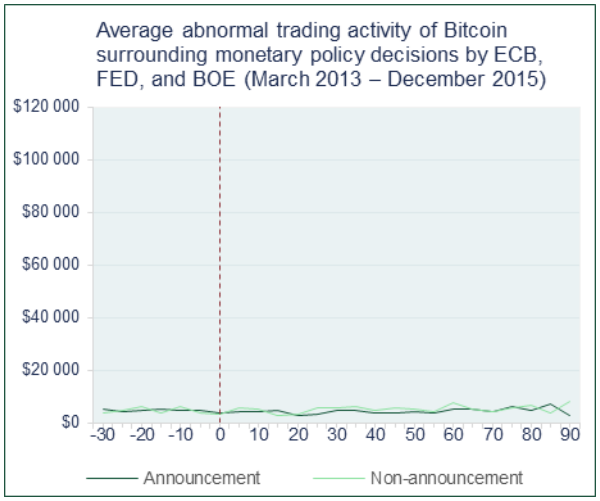

Average abnormal volatility of Bitcoin surrounding monetary policy decisions by FED (March 2013 – June 2018)
0,25%
0,20%
0,15%
0,10%
0,05%
0,00%
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement

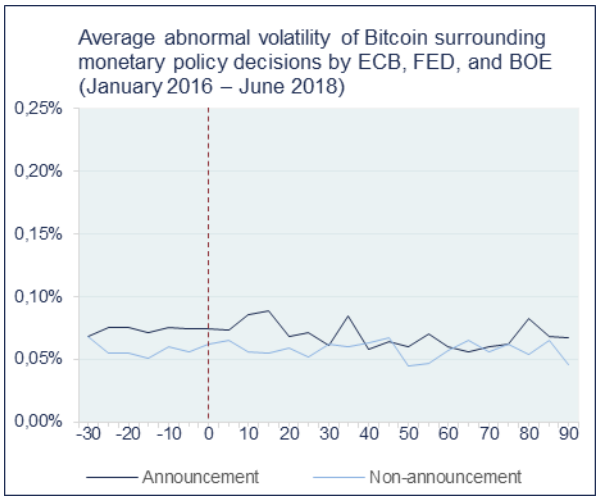

Average abnormal trading activity of Bitcoin surrounding monetary policy decisions by FED (March 2013 – June 2018)
$120 000
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement

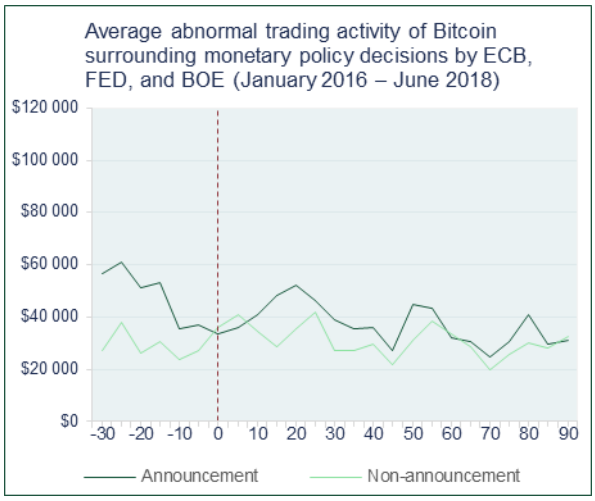

Average abnormal volatility of Bitcoin surrounding monetary policy decisions by BOE (March 2013 – June 2018)
0,25%
0,20%
0,15%
0,10%
0,05%
0,00%
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement

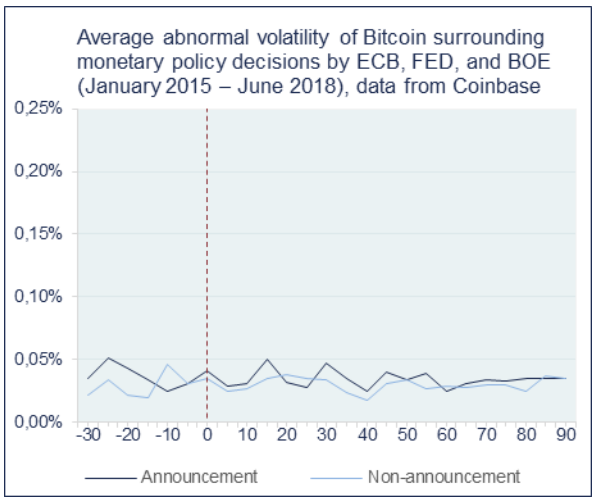

Average abnormal trading activity of Bitcoin surrounding monetary policy decisions by BOE (March 2013 – June 2018)
$120 000
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement

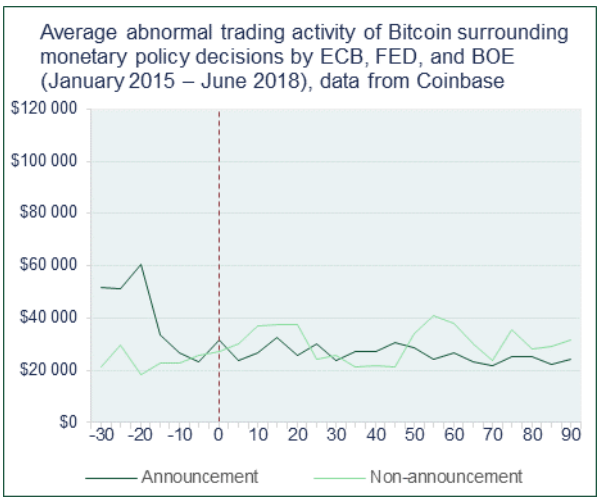

Average abnormal volatility of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (March 2013 – December 2015)
0,25%
0,20%
0,15%
0,10%
0,05%
0,00%
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement


Average abnormal trading activity of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (March 2013 – December 2015)
$120 000
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement


Average abnormal volatility of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (January 2016 – June 2018)
0,25%
0,20%
0,15%
0,10%
0,05%
0,00%
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement


Average abnormal trading activity of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (January 2016 – June 2018)
$120 000
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement


Average abnormal volatility of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (January 2015 – June 2018), data from Coinbase
0,25%
0,20%
0,15%
0,10%
0,05%
0,00%
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement


Average abnormal trading activity of Bitcoin surrounding monetary policy decisions by ECB, FED, and BOE (January 2015 – June 2018), data from Coinbase
$120 000
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-30 -20 -10 0 10 20 30 40 50 60 70 80 90
Announcement
Non-announcement