Informed trading in the Bitcoin market

Wenjun Feng, Yiming Wang, Zhengjun Zhang

PII: S1544-6123(17)30699-2
DOI: 10.1016/j.frl.2017.11.009
Reference: FRL 825

To appear in: *Finance Research Letters*

Received date: 7 November 2017
Accepted date: 26 November 2017

Informed trading in the Bitcoin market

Wenjun Feng[a,*], Yiming Wang[a,*], Zhengjun Zhang[b]

[a]*School of Economics, Peking University, No.5 Yiheyuan Road, Beijing, China, 100871*
[b]*Department of Statistics, University of Wisconsin at Madison, 1300 University Avenue, Madison, Wisconsin, 53706*

Abstract

Bitcoin's price sensitivity to the material events makes informed trading very profitable in this new market. We propose a novel indicator to assess the informed trades ahead of cryptocurrency-related events. Using trade-level data of USD/BTC exchange rates, we find evidence of informed trading in the Bitcoin market prior to large events: Quantiles of the order sizes of buyer-initiated (seller-initiated) orders are abnormally high before large positive (negative) events, compared to the quantiles of seller-initiated (buyer-initiated) orders. When examining the timing of the informed trades, we further notice that the informed traders prefer to build their positions two days before large positive events and one day before large negative events. The profits of informed trading in the Bitcoin market are estimated to be considerably large.

Keywords: Bitcoin, cryptocurrency, informed trading
JEL: G10 G14

1. Background and introduction

Bitcoin is the first, largest-capped, and most famous cryptocurrency, which is now accepted as an alternative payment method by many merchants like Subway and Microsoft. At the time of 20:00 pm Nov.6, 2017 (CST), Bitcoin price reached 7113.71 USD/BTC; its total market cap was 118,568,024,632 USD. Bitcoin's growing popularity for investors are partly due to its hedging and diversifying ability for traditional assets (Bouri et al., 2017; Dyhrberg, 2016), and its cost advantage for international transactions (Kim, 2017).

Compared to conventional assets like stocks and bonds, Bitcoin prices are much more volatile (Balcilar et al., 2017) and particularly sensitive to regulatory and market events. For example, China's banning financial institutions from handling Bitcoin transactions on Dec.5 2013, led to a 34.28% Bitcoin price drop in four days. The price sensitiveness of Bitcoin makes informed trading quite profitable, due to the huge benefits of trading ahead of large price appreciations (depreciations).

The lack of supervision and the 24h continuous trading mechanism also encourage informed trading in the Bitcoin market. Unlike the strictly regulated stock markets, there has been no case of legal punishment

*Corresponding Author
Email addresses: fengwenjun@pku.edu.cn (Wenjun Feng), wangyiming@pku.edu.cn (Yiming Wang), zjz@stat.wisc.edu (Zhengjun Zhang)

as yet on informed trading of Bitcoin worldwide. Meanwhile, Bitcoin is available for trading 24h everyday on almost all Bitcoin exchanges, allowing the informed traders to build positions anytime when they get the private information prior to the uninformed investors.

The detection of informed trading in the stock markets are widely discussed in the literature. However, the methods and models designed for the stock markets are not so proper for the Bitcoin market. The information asymmetry models which use quoted bid-ask spreads to measure market markers' cost of trading with informed traders (e.g., Harris, 2017; Huang and Stoll, 1997), and the probability of information-based trading (PIN) method (Easley et al., 1996), are two most widely used methods in empirical researches (e.g., Kim and Lim, 2017; Ormos and Timotity, 2016). However, these methods are designed for quote-driven markets with designated market makers to provide liquidity, while most Bitcoin exchanges, if not all, are order-driven markets.[1] The logistic models and supported vector machine methods are also popular models to analyze informed trading (e.g., Liou, 2008; Summers and Sweeney, 1998), howbeit they require samples of reported informed trading, and there is no such case of Bitcoin. The buy-sell volume imbalance is another candidate to recognize informed trades (e.g., Barber and Odean, 2007; Heston et al., 2010). However, the trading volume is large, volatile, and unstationary in the Bitcoin market (Balcilar et al., 2017), and the informed traders are only a small part of the market participants. Thus the volume imbalance may mot well signify the existence of Bitcoin informed trading.

The main contributions and findings of this paper can be summarized as follows. First, we propose a novel indicator to detect and assess the informed trades ahead of cryptocurrency events, based on the buy-sell trade size imbalances. Second, using trade-level data of USD/BTC exchange rates, we find evidence of informed trading in the Bitcoin market prior to both positive and negative large events. Third, we analyze the timing of the informed trades. The results suggest that the informed traders prefer to build their position two days before large positive events and one day before large negative events. Forth, we estimate the profits of the informed traders. The estimated profits is between 100,922 and 915,455 USD per event, and between 222,973 and 2,367,409 USD per large event,[2] according to the baseline estimation. To the best of our knowledge, this is the first study on informed trading in the cryptocurrency market.

2. The measurement of informed trading

In this section we propose a measurement indicator of Bitcoin informed trading, and describe the motivations behind the indicator construction.

[1]For example, current major Bitcoin exchanges like Bitstamp, BitMEX, Bitfinex, Bithumb, bitFlyer, etc., and some past leading exchanges like Mt.Gox and OKCoin, are all order-driven markets, in which individuals post bids, offers, or market orders.

[2]A positive (negative) event which causes an event-day return of over 5% (less than -5%) is classified as large.

2.1. Motivations

The motivations are based on two facts. First, the informed traders prefer market orders to limit orders (e.g. Baruch et al., 2017; Siikanen et al., 2017). Second, the informed traders in the Bitcoin market especially prefer large-size orders, the reasons are as follows.

(1) It is pointed out by the literature that large-size orders are signals of informed trading (Grundy and McNichols, 1989; Kim and Verrecchia, 1991; Shen et al., 2017).

(2) Compared to the highly regulated stock markets, the lack of supervision and good anonymity in the Bitcoin market make the informed traders have less incentives to break large orders into many smaller ones, to hide their behaviors from the regulators.[3]

(3) The informed traders in the Bitcoin market prefer to use large orders to cut costs. Bitcoin transactions are based on the blockchain technology. Any transaction must be included in 6 blocks by the miners (i.e. transaction verifiers) to get confirmed. Technically, at most 7 transactions can be confirmed within a second, for the whole chain. To achieve faster confirmation, one could pay an extra transaction fee (tip), as the miners sort a transaction' priority by its (absolute) transaction fee (regardless of its trade size). The informed traders who require immediacy to take advantage of their short-lived information, have incentives to pay extra transaction fees,[4] and to place large orders to cut the costs, instead of placing many small orders.

2.2. Measurement of informed trading

With the rationale above, and inspired by the volume imbalance indicator (Easley et al., 2008) in the literature, we propose an order-size based measure to detect informed trading. Our measuring indicator is defined as,

$$OSI_{q,t} = 100 \times \frac{B_{q,t} - S_{q,t}}{B_{q,t} + S_{q,t}}, \tag{1}$$

where $OSI_{q,t}$ is the buy-sell order size imbalance at day $[t-1, t]$, $B_{q,t}$ ($S_{q.t}$) is the size of the q-quantile orders of all buyer- (seller-) initiated orders at day $[t-1, t]$, regarding to the order sizes (in BTC).

When the data of transactions' directions and historical bid-ask quotes are unavailable, a common way to discern a trade's direction is the tick rule (e.g. Bernile et al., 2016). Namely, a trade whose trading price is higher (lower) than the previous trade, will be classified as buyer- (seller-) initiated; a trade whose trading

[3]Admittedly, the insiders still have some incentives to avoid super large orders, to soften implementation shortfalls. This potential incentive is the reason why we choose to use quantiles, and imbalances, not the extreme values, or absolute values to measure informed trading.

[4]For example, supposing there's a material positive news, an informed trader buy Bitcoin prior to the release of the news, and plan to sell it right after the release. If he risks not to pay an extra tip, there's a possibility that the Bitcoins he buys will come into his wallet a week later, when the price probably has dropped.

price is the same as the previous trade will be classified as the same type of the previous trade. This rule is shown to perform remarkably well when order book data are unavailable (Lee and Ready, 1991).

We examine informed trading in the pre-event 3-day window $[d_i - 3, d_i]$, with $[d_i, d_i + 1]$ being the i^{th} event day.[5] We calculate $OSI_{q,t}$ for each day in the pre-event window. We also compute daily $OSI_{q,t}$ for the control periods, namely $[d_i - 15, d_i - 5]$ or $[d_{i-1} + 3, d_i - 5]$, whichever is shorter. Then we run robust regressions to examine the differences between the pre-positive (pre-negative) event windows, and the control periods.

3. Data and event choice

We use the order-level USD/BTC trading data of Bitstamp, a Luxembourg-based Bitcoin exchange. The data period is 09/13/2011-07/17/2017. The choice of Bitstamp is due to its long trading history, its leading role in the market, and its good liquidity.[6] Our data come from Bitcoincharts.com.

We examine 42 events happening in the sample period, which is listed in detail in Table A.1 in the Appendix. All the selected events are exogenous, unscheduled and unanticipated by the public but known to some insiders in advance,[7] material,[8] and happens on a specific traceable date. Table 1 describes the average and median returns on the event days. Table 2 presents some summary statistics of B_q, S_q, and OSI_q (at $q = 90\%$).

4. Empirical results

We focus on the answers to four questions. Is there any evidence of informed trading ahead of material events in the Bitcoin market? Is there asymmetry between the informed trading ahead of positive and negative events, and how to explain that? When do the informed traders trade? And how many profits do they earn from informed trading? We also conduct a robustness check in this section.

4.1. Evidence of informed trading

To assess the differences of the trades in the pre-event windows and the control days, we regress the order size imbalance ratio (OSI) over the dummy variables of *pos_event* (which equals to 1 for the days

[5] As the Bitcoin market is highly volatile, we believe that the informed traders will not build their positions long before the event day.

[6] Bitstamp was one of largest exchanges until 2016, and is still a leading and most famous Bitcoin exchange in 2017. Many of its past rivals have stepped down from the stage of history. For example, Mt.gox has filed for bankruptcy in 2014; OKCoin and Huobi are about to halt all transactions in 2017 due to China's official ban on domestic crypto trading exchanges.

[7] For example, the event that "The Bitcoin price reaches 6000 USD/BTC for the first time" does not meet the requirement.

[8] "Material" requires that, 1. the information is directly related to the cryptocurrency market; 2.the public disclosure of the information are expected to have a positive or negative market impact.

	Positive event	Negative event	Total number of events
Number of events	17	25	42
Mean of event day returns	3.40%	-6.06%	
Median of event day returns	1.11%	-6.38%	
Number of large events[1]	4	16	20
Mean of large event day returns	16.18%	-10.44%	
Median of large event day returns	8.82%	-7.74%	

[1] A large event is defined as an event which causes an appreciation (depreciation) of over 5% (less than -5%) on the positive (negative) event day.

Table 1: Event day returns

		Stats.	N	Mean	Standard deviation	Median	Min	Max	ADF test p-value[1]
Control period	(1)	B_q	369	6.1968	11.0937	3.1014	0.8626	109.2145	0.00
	(2)	S_q	369	5.6432	6.4201	3.3534	0.3900	45.2185	0.00
	(3)	OSI_q	369	-1.0562	16.7519	-1.2352	-52.4600	85.1255	0.00
Pre-positive event	(4)	B_q	51	6.0651	7.2835	3.6918	1.3943	38.5314	0.00
	(5)	S_q	51	5.4159	3.3776	4.1590	1.6571	15.4956	0.01
	(6)	OSI_q	51	-3.0474	16.1209	-4.9758	-33.5827	58.7896	0.00
Pre-neagitve event	(7)	B_q	75	5.5920	7.6037	2.6010	0.8503	47.2806	0.00
	(9)	S_q	75	6.1001	7.6692	2.9963	0.9259	43.8400	0.00
	(9)	OSI_q	75	-4.9796	13.5291	-5.1881	-68.2051	38.1616	0.00

[1] the p-value of the Augmented Dickey-Fuller (ADF) test for a unit root, with the null hypothesis that there's a unit root in a univariate time series.

Table 2: Summary statistics of daily 90%-quantiles of all buy orders, sell orders (in regards to the order sizes), and *OSI*.

		Zooming in on the pre-event windows				Zooming in on the pre-event windows		
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OSI	[-3,0]	[-1,0]	[-2,-1]	[-3,-2]	[-3,0]	[-1,0]	[-2,-1]	[-3,-2]
Panel A: all 42 events.					*Panel B: only 20 large events.*			
Intercept	-1.0562	-1.0562	-1.0562	-1.0562	-0.1910	-0.1910	-0.1910	-0.1910
	(-1.21)	(-1.21)	(-1.21)	(-1.21)	(-0.14)	(-0.14)	(-0.14)	(-0.14)
Pos_event	-1.9911	-2.2661	-0.3482	-3.3592	13.4536	5.5564	25.8141	8.9902
	(-0.83)	(-0.99)	(-0.07)	(-0.76)	(2.30)	(0.96)	(2.61)	(0.88)
Neg_event	-3.9234	-7.0232	1.0409	-5.7878	-3.8882	-6.2402	-1.5971	-3.8274
	(-2.20)	(-2.41)	(0.37)	(-2.33)	(-2.02)	(-3.01)	(-0.60)	(-1.22)

This table reports the robust ordinary least square regressions of the daily buy-sell order size imbalance ratio (OSI) in Bitstamp, on the event indicators. Panel A examined all 42 selected events, while Panel B examined only 20 large events. A large event is an event which leads to an Bitcoin price appreciation (depreciation) of over 5% (less than -5%) on the positive (negative) event day. The samples consist of the three days in the pre-positive-event windows ($Pos\_event = 1, Neg\_event = 0$), the three days in the pre-negative-event windows ($Pos\_event = 0, Neg\_event = 1$), and the days in the control periods ($Pos\_event = 0, Neg\_event = 0$), namely $[d_i - 15, d_i - 5]$ or $[d_{i-1} + 3, d_i - 5]$, whichever is shorter, with $[d_i, d_i + 1]$ being the i_{th} event day. OSI is the daily buy-sell order size imbalance defined by $OSI_{q,t} = 100 \times (B_{q,t} - S_{q,t})/(B_{q,t} + S_{q,t})$, where $B_{q,t}$ ($S_{q.t}$) is the size of the q-quantile orders of all buyer- (seller-) initiated orders at day t, regarding to the order sizes (in BTC). q is set as 90% in this regression. In column (1) of both Panel A and B, the dependent variables are calculated daily in the three-day pre-event window and the in the control days. In column (2)-(4) of both Panel A and B, the dependent variables are calculated daily for a specific pre-event day ([-1,0], [-2,-1], or [-3,-2]), and each days in the control periods. The robust t-statistics are reported in the parentheses.

Table 3: Bitstamp buy-sell order size imbalances (at the 90% quantile), conditional on the pre-event indicators

in the pre-positive-event windows and 0 otherwise) and *neg_event* (which equals to 1 for the days in the pre-negative-event windows and 0 otherwise).

Column (1) in Panel A of Table 3 reports the result of this regression, which indicates strong evidence of the existence of informed trading before negative events, as the *neg_event* coefficient is -3.9234 and statistically significant. Averagely, the 90%-quantile of the sell orders are 10.48% larger than those of the buy orders, before the negative events.[9] The magnitude is economically large, as in the control periods, the 90%-quantile of the sell orders are only 2.13% larger than those of the buy orders averagely. However, overall and averagely, we do not see abnormal patterns of large trades before positive events.

4.2. An explanation for the asymmetry: event magnitudes

A natural question is that why informed trading is only estimated to be significant ahead of negative events rather than positive events? We do not go deep into this problem due to limitation of space. However, here we propose and test one possible explanation, that is, the magnitude and influences of the negative events are evidently higher than the positive ones, as indicated by Table 1. If we classify events as large when the event day return is larger than 5% (less than-5%) for positive (negative) events, 4/17 positive events and 16/25 negative events are large. A small event may not even lead to price appreciation in this volatile market, while large events are supposed to bring higher profits of informed trading. Some of the insiders who get information of the minor events, probably choose not to trade on this information, and only the informed traders of large events build positions before the events.

To test this explanation, following Baruch et al. (2017), we run the basic regression only for the large events, to see the statistical and economic significance in either directions.[10] The regression result as shown in column (1), Panel B, Table 3, clearly indicates significant informed trading ahead of both positive and negative large events. Averagely, before the large positive events, the 90%-quantile of the buy orders are 30.58% larger than the sell orders;[11] And before the large negative events, the 90%-quantile of the sell orders are 8.51% larger than the quantile of the buy orders. In the cases of the large events, the positive large events are even more exposed to pre-event informed trading, compared to the negative large events. This is probably due to short-sell costs, as is widely discussed in the literature (e.g. Marin and Olivier, 2008).

[9] According to the regression result in column (1), Panel A, Table 3, the mean OSI before in the pre-negative event window is (-1.0562)+(-3.9234)=-4.9796. According to the definition that $OSI = 100 \times (B_q - S_q)/(B_q + S_q)$, we have $(S_q - B_q)/B_q = -2 \times OSI/(100 + OSI) = 10.48\%$.

[10] In fact, we also run the regression for the small events, and do not detect informed trading before both positive and negative events. Due to the limitation of space, we do not report the numeric results of small events.

[11] According to the regression result in column (1), Panel B of Table 3, the mean OSI before in the pre-positive event window is (-0.1910)+13.4536=13.2626. According to the definition that $OSI_q = 100 \times (B_q - S_q)/(B_q + S_q)$, we have $(B_q - S_q)/S_q = 2 \times OSI_q/(100 - OSI_q) = 30.58\%$.

Regarding to the large events, the order size imbalances are both in the directions of the upcoming events, showing evidence of private information before the news is widely available. Meanwhile, the magnitudes of the imbalances are economically large before both large positive and large negative events.

4.3. The timing of pre-event trading

To investigate when exactly do the insiders trade, we divide the 3-day pre-event window into three one-day periods, and apply the baseline tests to all the 42 selected events, as well as only to the 20 large events. The regression results are presented in Column (2)-(4) of Panel A and B in Table 3.

Overall, the informed trading is significant on day [-1,0] and day [-3,-2], ahead of negative events. Averagely, on day [-1,0] and day [-3,-2] before the negative events, the 90%-quantile of the sell orders are 17.58% and 14.69% larger than the quantile of the buy orders, respectively.

If we concentrate on the large events which cause over 5% price appreciation (depreciation) on the event day, as shown by column (2)-(4) of Panel B in Table 3, averagely, the OSIs are all in the directions of the upcoming events for all the three days. Significant informed buy orders happens on day $[-2,-1]$ ahead of the large positive events, with the 90%-quantile of the buy orders 68.90% larger than the 90%-quantile of the sell orders; meanwhile, significant informed sell orders happens on day $[-1,0]$ ahead of the large negative events, with the 90%-quantile of the sell orders 13.75% larger than the 90%-quantile of the buy orders.

4.4. Robustness

To assess the robustness of our informed trading measurement and the above findings, we repeat all the above regressions using alternative quantiles of 80%, 85%, and 95%, instead of the 90% quantile in the baseline analysis, when computing the OSI_q. The regression results are presented in Table 4. The main results and inferences of our analysis remain mostly unchanged using the alternative quantiles.

4.5. The profits of Bitcoin informed trading

Inspired by Bernile et al. (2016), we estimated a postulated lower bound and an upper bound of the informed traders' profit. The lower bound assumes that the orders submitted by uninformed traders are well-balanced regarding to the order sizes, while the informed traders only use large market orders, leading to the imbalances between buyer- and seller-initiated orders' sizes in the high quantiles. The upper bound assumes that all the large orders in the pre-event windows are submitted by the informed traders, who use either market orders or limit orders, in the direction of the upcoming events. For simplicity, we hypothetically assume that the informed traders all unwind their positions at time [1], namely the 24:00 of the event day. (or day[2], [3], for robustness check). Mathematically speaking, for event i, define the top $(1-q)$ large size orders among all the orders in the 3 day pre-event windows (whatever it is buyer-initiated or seller-initiated) to be "pre-event large trades". Let $p_{i,j}$ and $q_{i,j}$ be the price (in USD/BTC) and size (in BTC) of the j^{th}

	Zooming in on the pre-event windows					Zooming in on the pre-event windows		
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
OSI	[-3,0]	[-1,0]	[-2,-1]	[-3,-2]	[-3,0]	[-1,0]	[-2,-1]	[-3,-2]
Panel A: q=80%, all 42 events.					*Panel B: q=80%, only 20 large events.*			
Intercept	-0.5125	-0.5125	-0.5125	-0.5125	0.7834	0.7834	0.7834	0.7834
	(-0.6)	(-0.59)	(-0.59)	(-0.59)	(0.56)	(0.56)	(0.56)	(0.56)
Pos_event	-0.7547	-2.2235	1.6581	-1.6989	14.3610	4.9806	27.8444	10.2581
	(-0.29)	(-0.72)	(0.32)	(-0.39)	(2.13)	(0.59)	(2.18)	(1.06)
Neg_event	-3.2906	-4.8851	-1.3626	-3.6244	-4.5784	-3.1136	-5.7587	-4.8630
	(-2.02)	(-1.98)	(-0.51)	(-1.50)	(-2.17)	(-1.35)	(-1.78)	(-1.37)
Panel C: q=85%, all 42 events.					*Panel D: q=85%, only 20 large events.*			
Intercept	-0.7542	-0.7542	-0.7542	-0.7542	-0.2056	-0.2056	-0.2056	-0.2056
	(-0.88)	(-0.88)	(-0.88)	(-0.88)	(-0.15)	(-0.15)	(-0.15)	(-0.15)
Pos_event	-1.7681	-2.9810	0.2263	-2.5496	12.6588	4.7013	23.3224	9.9527
	(-0.75)	(-1.29)	(0.05)	(-0.62)	(2.01)	(0.70)	(1.87)	(1.01)
Neg_event	-2.9855	-4.7094	-0.6058	-3.6413	-2.7925	-3.1168	-3.2835	-1.9772
	(-1.78)	(-1.85)	(-0.24)	(-1.32)	(-1.35)	(-1.33)	(-1.18)	(-0.54)
Panel E: q=95%, all 42 events.					*Panel F: q=95%, only 20 large events.*			
intercept	-0.4614	-0.4614	-0.4614	-0.4614	0.3067	0.3067	0.3067	0.3067
	(-0.50)	(-0.50)	(-0.50)	(-0.50)	(0.21)	(0.21)	(0.21)	(0.21)
pos_event	-2.4901	-6.2413	-0.7995	-0.4294	12.1227	1.7188	25.4545	9.1947
	(-1.05)	(-2.32)	(-0.16)	(-0.12)	(1.99)	(0.26)	(2.47)	(0.94)
neg_event	-4.8019	-8.4953	1.2848	-7.1952	-4.5659	-8.6262	-1.1531	-3.9183
	(-2.45)	(-2.87)	(0.47)	(-2.17)	(-2.05)	(-4.54)	(-0.34)	(-1.02)

This table check the robustness of the results in Table 3, by changing the dependent variable from the OSI ratios conducted at q = 90%, to the OSI ratios conducted at q = 80% (Panel A and B), 85% (Panel C and D), 80% (Panel E and F), respectively. Panel A, C, E examined all 42 selected events, while Panel B, D, F examined only 20 large event. In column (1) of each panel, the dependent variables are calculated daily in the three-day pre-event window and the in the control days. In column (2)-(4) of each panel, the dependent variables are calculated daily for a specific pre-event day ([-1,0], [-2,-1], or [-3,-2]), and each days in the control periods. The robust t-statistics are reported in the parentheses.

Table 4: Robustness check (q=80%, q=85%, q=95%)

pre-event large trade. Then the postulated lower and upper bound of informed trading profits for event i are computed as,

$$Profit_{i,lower} = \sum_j (p_i - p_{i,j}) q_{i,j} \chi_{i,j}, \tag{2}$$

$$Profit_{i,upper} = \phi_i \sum_j (p_i - p_{i,j}) q_{i,j}, \tag{3}$$

where p_i is the price at the time when the informed trader unwind their position; $\chi_{i,j}$ equals to 1 if transaction (i, j) is buyer-initiated and -1 otherwise; ϕ_i equals to 1 if the event is a positive event and -1 otherwise.

Table 5 report the estimated lower bounds and upper bounds of the profits of informed trading in the Bitstamp exchange. For example, using the 90% quantile to discern large orders and assuming the informed traders unwind their position at the end of the event day, the average estimated profit of Bitcoin informed trading is between 100,922 and 915,455 USD per event; and between 222,973 and 2,367,409 USD per large event.

		Average for all events			Average for large events		
q	$Profit$	[1]	[2]	[3]	[1]	[2]	[3]
80%	$Profit_{Lower}$	107,878	33,161	47,203	239,819	68,733	105,256
	$Profit_{Upper}$	1,097,080	844,493	1,188,967	2,829,265	1,886,761	2,339,414
85%	$Profit_{Lower}$	105,060	33,300	47,169	233,199	68,404	104,918
	$Profit_{Upper}$	1,026,280	794,382	1,113,654	2,650,727	1,773,952	2,193,827
90%	$Profit_{Lower}$	100,922	33,177	46,312	222,973	66,934	101,277
	$Profit_{Upper}$	915,455	716,509	995,042	2,367,409	1,595,768	1,963,093
95%	$Profit_{Lower}$	88,183	31,455	41,657	191,973	60,176	89,199
	$Profit_{Upper}$	725,456	578,813	792,255	1,866,421	1,271,789	1,557,011

This table estimate the postulated lower bounds and upper bounds of the informed traders' profits (in USD), with the quantile to discern large orders set to $q = 80\%, 85\%, 90\%, 95\%$, respectively. We hypothetically assume that the informed traders unwind their position at time [1], [2], or [3], with [0] being the 00:00 of the event day and [0,1] being the event day. The first three columns report the average estimated informed trading profits of all 42 events, while the last three columns report the average estimated profits of 20 large events.

Table 5: Estimated profits of the informed traders

5. Conclusions

In this study, we use transaction-level data to investigate the informed trading prior to Bitcoin events. Applying a novel indicator that we design for the cryptocurrency market, we find evidence of informed trading in the Bitcoin market ahead of cryptocurrency-related negative Bitcoin market events, and ahead of large positive events. Quantiles of the order sizes of buyer-initiated (seller-initiated) orders are abnormally high before large positive (negative) events, compared to the quantiles of seller-initiated (buyer-initiated) orders. The insiders of the large positive news prefers to build their position two days before the event, while the insiders of large negative news prefer to trade at the day before the event. The profits of informed trading are between 100,922 and 915,455 USD per event according to the baseline estimation.

The evidence of informed trading in the Bitcoin market suggests that people who get information before it's widely available, profit on their private information, at the cost of other market participants' losses. Our study is relevant for global regulators who's in supervision of the cryptocurrency markets, as the lack of clear regulatory laws and lack of supervision from the regulatory authorities are potential reasons for the existence of informed trading.

Disclosure statement

No potential conflict of interest.

Acknowledgements

This work was supported by China Scholarship Council [grant number 201606010147]; National Natural Science Foundation of China [grant number 709730002]; and National Science Foundation, Division of Mathematical Sciences [grant number 1505367].

References

Balcilar, M., Bouri, E., Gupta, R., Roubaud, D., 2017. Can volume predict Bitcoin returns and volatility? a quantiles-based approach. Econ. Model. 64, 74–81.

Barber, B.M., Odean, T., 2007. All that glitters: The effect of attention and news on the buying behavior of individual and institutional investors. Rev. Financ. Stud. 21, 785–818.

Baruch, S., Panayides, M., Venkataraman, K., 2017. Informed trading and price discovery before corporate events. J. Financ. Econ. 125, 561–588.

Bernile, G., Hu, J., Tang, Y., 2016. Can information be locked up? informed trading ahead of macro-news announcements. J. Financ. Econ. 121, 496–520.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., Hagfors, L.I., 2017. On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? Finance Res. Lett. 20, 192–198.

Dyhrberg, A.H., 2016. Hedging capabilities of Bitcoin. is it the virtual gold? Finance Res. Lett. 16, 139–144.

Easley, D., Engle, R.F., O'Hara, M., Wu, L., 2008. Time-varying arrival rates of informed and uninformed trades. J. Financ. Econometr. 6, 171–207.

Easley, D., Kiefer, N.M., O'hara, M., Paperman, J.B., 1996. Liquidity, information, and infrequently traded stocks. J. Finance 51, 1405–1436.

Grundy, B.D., McNichols, M., 1989. Trade and the revelation of information through prices and direct disclosure. Rev. Financ. Stud. 2, 495–526.

Harris, T., 2017. Earnings announcements and quoted bid-ask spreads of us bank holding companies. Finance Res. Lett. 20, 223–228.

Heston, S.L., Korajczyk, R.A., Sadka, R., 2010. Intraday patterns in the cross-section of stock returns. J. Finance 65, 1369–1407.

Huang, R.D., Stoll, H.R., 1997. The components of the bid-ask spread: A general approach. Rev. Financ. Stud. 10, 995–1034.

Kim, O., Verrecchia, R.E., 1991. Market reaction to anticipated announcements. J. Financ. Econ. 30, 273–309.

Kim, S., Lim, S.C., 2017. Earnings comparability and informed trading. Finance Res. Lett. 20, 130–136.

Kim, T., 2017. On the transaction cost of Bitcoin. Finance Res. Lett. 23, 300–305.

Lee, C., Ready, M.J., 1991. Inferring trade direction from intraday data. J. Finance 46, 733–746.

Liou, F.M., 2008. Fraudulent financial reporting detection and business failure prediction models: a comparison. Manage. Auditing J. 23, 650–662.

Marin, J.M., Olivier, J.P., 2008. The dog that did not bark: Insider trading and crashes. J. Finance 63, 2429–2476.

Ormos, M., Timotity, D., 2016. Market microstructure during financial crisis: Dynamics of informed and heuristic-driven trading. Finance Res. Lett. 19, 60–66.

Shen, D., Li, X., Zhang, W., 2017. Baidu news coverage and its impacts on order imbalance and large-size trade of Chinese stocks. Finance Res. Lett. 23, 210–216.

Siikanen, M., Kanniainen, J., Valli, J., 2017. Limit order books and liquidity around scheduled and non-scheduled announcements: Empirical evidence from nasdaq nordic. Finance Res. Lett. 21, 264–271.

Summers, S.L., Sweeney, J.T., 1998. Fraudulently misstated financial statements and insider trading: An empirical analysis. Account. Rev. , 131–146.

Appendix

Table A.1: Event choice

Date	Event type		Country	Event
12/19/11	Market	Positive	US	The Good Wife announced to air a Bitcoin-themed TV episode "Bitcoin for Dummies", after which investors bet big on the show and drive prices to new highs.[1]
3/1/12	Hacking	Negative	US	Linode, an American privately owned virtual private server provider company, was Hacked. Over 46,000 BTC was stolen.[1]
8/17/12	Crime	Negative	US	Bitcoins Savings & Trust, halted payments, which turned out to be a Ponzi scheme.[1]
9/5/12	Hacking	Negative	US	Bitfloor, which was the fourth largest exchange dealing in US dollars, announced to be hacked. 24,000 BTC was stolen.[2]
3/12/13	Tech.	Negative	-	Bitcoin 0.8 caused a feather hard fork of Bitcoin.[1]
3/25/13	Policy	Positive	CY& EU	The tax haven Cyprus made a deal with the Europe to get €10 billion bailout, conditioning on levying large bank accounts. Many account holders and followers began buying Bitcoin, making Bitcoin double its price in 10 days.[1]
5/14/13	Investigation	Negative	US	The US Homeland Security Investigations (DHS) seized $2,915,507.40 from an account owned by a Mt. Gox subsidiary, with the warrant.[1]

Continued on next page

Table A.1 (continued)

Date	Event type		Country	Event
6/29/13	Policy	Positive	US	The US Financial Crimes Enforcement Network (FinCEN), issued license to Mt. Gox, the largest Bitcoin exchange at that time.[3]
10/2/13	Investigation	Negative	US	The US FBI seized around 26,000 BTC from Silk Road, an online black market, during the arrest of its owner Ross William Ulbricht.[2]
10/23/13	Hacking	Negative	AU	Inputs.io, an Australian Bitcoin wallet provider, was hacked. 4100 Bitcoins (worth over a million USD) was stolen.[2]
11/18/13	Policy	Positive	US	The US Senate held a hearing on Bitcoin. The general consensus is summed up by the director of the FinCEN "We want to operate in a way that does not hinder innovation."[1]
12/5/13	Policy	Negative	CN	The People's Bank Of China (PBOC) declared prohibiting financial institutions from handling Bitcoin transactions, which led to a market panic.[1]
12/18/13	Market	Negative	CN	China's biggest Bitcoin exchange at that time, BTCChina, announced to stop accepting deposits in RMB.[4]
1/8/14	Policy	Positive	CN	The Financial Services and the Treasury of Hong Kong addressed that "Hong Kong at present has no legislation directly regulating Bitcoin and other similar virtual currencies."[5]
1/27/14	Policy	Negative	RU	The Russia Central Bank recommended that Russians and legal entities refrain from dealing with Bitcoins.[6]
2/7/14	Hacking	Negative	-	Mt. Gox, Bitstamp, and BTC-e all experienced a stoppage of trading due to massive DDoS attacks.[1]
2/24/14	Hacking	Negative	JP	Mt. Gox Closed. An alleged leaked internal document showed that over 744,000 BTC were lost by the company.[1]
3/7/14	Policy	Negative	JP	The Japanese government made a cabinet decision, prohibiting banks and securities companies from dealing Bitcoins.[5]
3/26/14	Policy	Negative	US	the US Internal Revenue Service (IRS) declared that Bitcoin is a property subject to tax.[1]
4/10/14	Policy	Negative	CN	The PBOC's restrictions against Bitcoin finally pressured some Chinese banks to issue a deadline against several Bitcoin exchanges, requiring them to close their accounts by 4/15/2014.[1]
7/4/14	Policy	Negative	EU	The European Banking Authority (EBA) recommended that national supervisory authorities discourage financial institutions from dealing visual currencies.[7]
7/18/14	Market	Positive	US	Dell announced to accept Bitcoin.[1]
12/11/14	Market	Positive	US	Microsoft announced to accept Bitcoin.[1]
1/4/15	Hacking	Negative	LU	Bitstamp's operational hot wallets were hacked, and 18,866 BTC was stolen (roughly \$5.2 million).[1]
1/26/15	Market	Positive	US	Coinbase Launched an US Licensed exchange.[1]
2/14/15	Hacking	Negative	CN	BTER, a Chinese top ranking Bitcoin exchange, was hacked. 7,170 BTC (roughly \$2.1million) was stolen.[2]
6/3/15	Policy	Positive	US	New York State announced to release BitLicense application.[1]
8/1/15	Investigation	Negative	JP	Mark Karpeles, the CEO of the failed Bitcoin exchange Mt. Gox, was arrested in Japan on charges of fraud and embezzlement in relation to the collapse of Mt. Gox.[1]
8/15/15	Tech.	Negative	-	Bitcoin XT Fork Released and caused market fear.[1]
9/22/15	Policy	Positive	US	New York State Department of Financial Services (NYDFS) approved the first BitLicense application, to Circle Internet Financial.[1]

Continued on next page

Table A.1 (continued)

Date	Event type		Country	Event
10/22/15	Policy	Positive	EU	European Court of Justice (ECJ), the highest court in Europe, ruled that Bitcoin is a payment method, not a property; buying and selling Bitcoin are tax-free.[1]
10/31/15	Market	Positive	UK	Bitcoin featured on the front page of the magazine The Economist.[1]
1/14/16	Market	Negative	CH	Mike Hearn, who had been heavily involved in the Bitcoin community since the beginning of Bitcoin, announced to quit Bitcoin.[1]
2/24/16	Policy	Positive	JP	Japanese legislators officially proposed virtual currencies to be payment methods.[5]
4/27/16	Market	Positive	US	Steam, a popular gaming platform, announced to accept Bitcoin.[1]
5/25/16	Policy	Positive	JP	Japan officially recognized Bitcoin and digital currencies as "means of payment that is not a legal currency".[5]
8/2/16	Hacking	Negative	CN	Bitfinex was hacked, announcing that 119,756 BTC (around 72 million) was stolen.[2]
11/29/16	Policy	Positive	RU	Russia's Federal Tax Service stated that there is no legal prohibition of cryptocurrencies in a document.[5]
1/11/17	Investigation	Negative	CN	Chinese authorities announced plans to investigate Bitcoin exchanges.[8]
2/9/17	Policy	Negative	CN	Department of Business Administration of the PBOC stated four banning rules on the Bitcoin exchanges. Multiple Chinese Bitcoin exchanges delayed or paused Bitcoin withdraw services.[5]
3/10/17	Policy	Negative	US	The U.S. Securities and Exchange Commission (SEC) rejected the Winklevoss Bitcoin ETF application.[1]
3/24/17	Policy	Positive	JP	The Japans Financial Services Agency (FSA) announced that a new law will be implemented from April.1, 2017, which categorizes Bitcoin as a legal payment method.[9]

[1] https://99bitcoins.com/price-chart-history/ (accessed Nov. 5, 2017).

[2] https://en.wikipedia.org/wiki/History_of_bitcoin (accessed Nov. 5, 2017).

[3] https://en.wikipedia.org/wiki/Mt._Gox (accessed Nov. 5, 2017).

[4] https://www.reuters.com/article/us-bitcoin-china-btcc/chinese-bitcoin-exchange-btcchina-stops-accepting-deposits-idUSKCN1C208G (accessed Nov. 5, 2017).

[5] https://en.wikipedia.org/wiki/Legality_of_bitcoin_by_country_or_territory (accessed Nov. 5, 2017).

[6] http://www.loc.gov/law/foreign-news/article/russia-bitcoin-exchanges-can-be-penalized/ (accessed Nov. 5, 2017).

[7] https://www.eba.europa.eu/documents/10180/657547/EBA-Op-2014-08+Opinion+on+Virtual+Currencies.pdf (accessed Nov. 5, 2017).

[8] https://www.cnbc.com/2017/01/11/bitcoin-falls-5-as-china-plans-to-investigate-firms.html (accessed Nov. 5, 2017).

[9] https://cointelegraph.com/news/japan-is-set-for-massive-explosion-in-bitcoin-acceptance (accessed Nov.5, 2017).