BITCOIN MARKET MICROSTRUCTURE: HOW DOES IT DIFFER FROM STOCK MARKET?

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ABSTRACT

This study analyzes the relationship among bitcoin order imbalances, liquidity, and returns using the BitMEX intraday trading data from April 2017 to July 2018. The bitcoin order imbalances are strongly and positively correlated with both liquidity measures and bitcoin returns. The kurtosis and skewness of bitcoin returns are extremely large compared to those of stock returns, implying large intraday volatility. Variance of bitcoin returns are very high compared to their mean and correlations between microstructure variables also tend to be high. Such patterns in the bitcoin market are much more salient than those in the stock market. However, in contrast to the stock market, autocorrelations in order imbalance measures are nearly zero in the bitcoin market.

KEYWORDS: bitcoin, cryptocurrency, order book, order imbalance, market microstructure

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INTRODUCTION

The size of the bitcoin market is growing fast, at an alarming pace. Unlike equities or fixed income, there is no proper economic model to determine the fundamental price of cryptocurrencies such as bitcoin. Likewise, in contrast to highly regulated stock markets, little is known about how the trading mechanism affects the bitcoin price formation process. Due to a lack of fundamental understanding of the bitcoin market, investors, practitioners, and regulators cannot adequately respond to their objectives. This paper aims to lay the foundation for future research on the bitcoin market by examining trading activity, liquidity, and bitcoin returns with high frequency data.

The bitcoin market has several characteristics that differ from the stock market in terms of trading mechanism. First, bitcoins are traded 24 hours a day, 7 days a week. Second, lack of bitcoin custody services limits institutional investments and hence retail investors account for the large part of order flow in the bitcoin market. Third, policy uncertainty heavily affects bitcoin market volatility. Fourth, there are only a few designated bitcoin market makers. These unique features of the bitcoin market suggest that the market microstructure characteristics of the bitcoin would be different from those of stock markets.

We first examine basic statistical properties of bitcoin order imbalances at one-minute intervals, and then analyze the relationship between order imbalance and market liquidity measures. Next, we study the extent to which bitcoin order imbalances affect bitcoin returns. The main contribution of this paper is to investigate the relationship between bitcoin order imbalances and returns with high frequency data for the first time in the literature.

This paper discusses the market microstructure of bitcoin markets and compares it with the stock market microstructure described in the literature. We organize this paper as follows. First, we explain data and variables. Second, descriptive statistics are presented on four different time periods. Third, we compare the descriptive statistics with those in the stock market. The final section concludes.

DATA AND VARIABLES

This paper uses trade and quote data of bitcoin/US Dollar perpetual swap contract[6] traded in BitMEX, a leading exchange for trading bitcoin futures and swaps. According to CoinMarketCap's statistics, BitMEX is the largest bitcoin exchange in the world, as of July 2018. Table 1 defines variables. We analyze the following variables measured at one minute intervals. OIBNUM is the number of buyer-initiated trades less the number of seller-initiated trades. OIBBIT is the buyer-initiated bitcoins purchased less seller-initiated bitcoins sold. OIBDOL is the buyer-initiated dollars paid less seller-initiated dollars received. OIBNUM, OIBBIT, and OIBDOL are related to trading intensity that might be associated with private information. Positive numbers indicate buying pressure and negative numbers indicate selling pressure. QSPR is the quoted bid-ask spread averaged across all trades. NUMTRANS is the total number of transactions. TVOL is the total dollar volume. QSPR, NUMTRANS, and TVOL are related to asset liquidity. It is well known that order imbalances are negatively correlated with liquidity in stock markets. PRICE is the closing price of bitcoin at each minute. RETURN is the log return of bitcoin over the one minute interval. These variables are commonly referenced in high frequency market microstructure research for traditional financial markets, and this paper directly adopts them to study the microstructural features of the bitcoin market.

The data provide a dummy variable indicating whether a trade is buyer-initiated or seller-initiated. Hence, instead of using the Lee and Ready (1991) algorithm, we use accurate trade direction when computing order imbalance measures. Therefore, our measures are less subject to measurement errors, compared to the measures calculated using typical US equity transaction data, such as the NYSE TAQ.

Table 1: Variable Definitions

We measure all variables per minute. OIBNUM, OIBBIT, and OIBDOL measure order imbalance in number of trades, bitcoin, and dollars. QSPR is a quoted spread averaged across all trades. NUMTRANS and TVOL are the total number of transactions and the total number of dollar volume. PRICE is the closing price of bitcoin in dollar and RETURN represents a log return of bitcoin price.

[6] The swap contract symbol is XBTUSD. Each contract represents the dollar value of one bitcoin. This contract does not have an expiration date, and provides a way for investors to speculate or hedge on the future value of bitcoin.

Panel A: Variables

Concepts	Definitions
OIBNUM	Number of buyer-initiated trades less the number of seller-initiated trades
OIBBIT	Buyer-initiated bitcoins purchased less the seller-initiated bitcoins sold
OIBDOL	Buyer-initiated dollars paid less the seller-initiated dollars received
QSPR	Quoted bid-ask spread averaged across all trades
NUMTRANS	Total number of transactions
TVOL	Total dollar volume
PRICE	Closing price of bitcoin at each minute
RETURN	Log return of bitcoin price over a minute

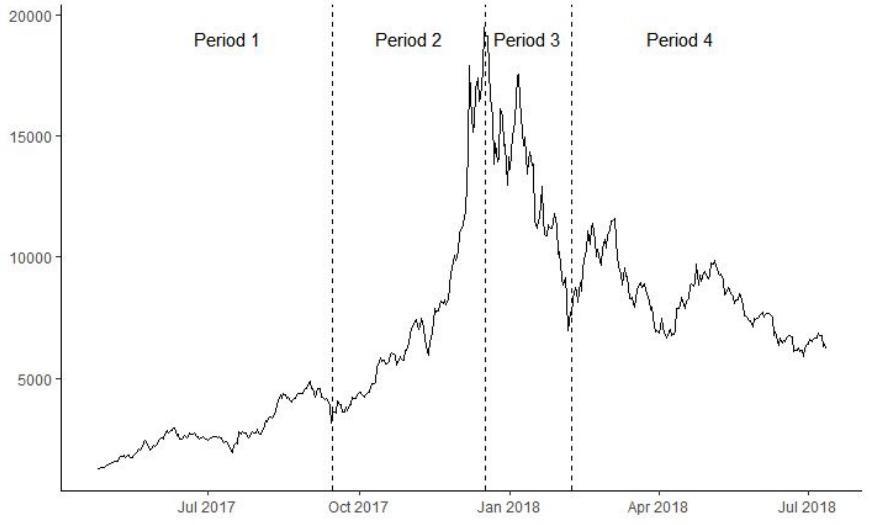
Panel B: Periods

Periods	Definitions
Period 1	25 April 2017 to 15 September 2017 (144 days)
Period 2	16 September 2017 to 17 December 2017 (93 days)
Period 3	18 December 2017 to 7 February (52 days)
Period 4	8 February 2018 to 12 July 2018 (155 days)

Compared to traditional risky assets, bitcoin has relatively short history. Thus, sudden regulatory changes can trigger large intraday volatility, and investor sentiment is an important factor in determining bitcoin price. To analyze such a rapidly changing market, we conduct a sub-period analysis. We divide the sample period into four sub-periods according to the bitcoin price movements, as pictured in Figure 1. In Period 1 (25 April 2017 to 15 September 2017), we observe the development of bitcoin market and the rise of its price albeit low volume. In Period 2 (16 September 2017 to 17 December 2017), the bitcoin market surged with much investor attention. In Period 3 (18 December 2017 to 7 February), bitcoin price plunged. In Period 4 (8 February 2018 to 12 July 2018), bitcoin price was relatively stable.

Figure 1: Behavior of bitcoin Price and Subperiods

X-axis are date(25th, April, 2017 - 12th, July, 2018). Y-axis are price of bitcoin(dollar).



DESCRIPTIVE STATISTICS

Table 2: Summary Statistics

Descriptive statistics are given for order-imbalance measures from BitMEX quote and trade data, over 444 days between April 25th, 2017 and July 12th, 2018. For the analysis, daily data is divided into minute periods, with each day consisting of 1440 observations (638,820 observations in total). The entire period is divided into four sections.

Period 1	N	Mean	St. Dev.	Min	Median	Max
OIBNUM	205,934	0.53	42.26	-583.00	0.00	590.00
OIBBIT	205,934	-214	116,865	-3,555,212	0.0	2,978,033
OIBDOL	205,934	-957,281	419,893,501	-14,884,605,482	0.0	12,433,593,716
QSPR	205,934	3.56	4.52	1.00	2.05	221.69
NUMTRANS	205,934	59.91	80.19	0.00	32.00	1,084.00
TVOL (dollars)	205,934	300,180,098	623,014,928	0.0	95,618,882	18,854,541,410
Bitcoin close price	205,934	2,824.56	938.62	1,263.20	2,593.20	5,008.60
Bitcoin minute returns	205,920	0.00	0.00	-0.03	0.00	0.03

Period 2	N	Mean	St. Dev.	Min	Median	Max
OIBNUM	133,552	2.42	108.69	-1,194.00	1.00	1,423.00
OIBBIT	133,552	1,743	725,676	-18,217,122	2,133	15,866,980
OIBDOL	133,552	14,708,901	8,172,542,618	-264,000,000,000	10,645,768	293,000,000,000
QSPR	133,552	2.60	8.16	1.00	1.34	1393.97
NUMTRANS	133,552	181.48	165.68	0.00	129.00	1709.00
TVOL (dollars)	133,552	6,935,919,753	12,366,220,857	0.0	2,500,818,497	303,000,000,000
Bitcoin close price	133,552	7,609.40	3,953.31	3,476.10	6,211.85	20,090.50
Bitcoin minute returns	133,548	0.00	0.00	-0.07	0.00	0.06

Period 3	N	Mean	St. Dev.	Min	Median	Max
OIBNUM	74,880	0.23	110.32	-1,056.00	1.00	1,446.00
OIBBIT	74,880	-6,654	865,398	-13,052,114	-413	22,228,441
OIBDOL	74,880	-76,511,168	11,270,512,665	-196,000,000,000	-4,031,380	270,000,000,000
QSPR	74,880	3.45	5.63	1.00	2.10	764.55
NUMTRANS	74,880	236.54	145.40	0.00	206.00	1815.00
TVOL (dollars)	74,880	11,959,012,499	14,046,362,156	0.0	7,687,475,899	331,000,000,000
Bitcoin close price	74,880	12,902.63	2,749.58	5,875.50	13,407.00	19,366.00
Bitcoin minute returns	74,879	0.00	0.00	-0.03	0.00	0.08

Period 4	N	Mean	St. Dev.	Min	Median	Max
OIBNUM	220,197	-2.63	255.38	-6,967.00	0.00	6,919.00
OIBBIT	220,197	-19,308	1,852,839	-56,141,095	-169	57,299,540
OIBDOL	220,197	-152,352,687	15,099,952,675	-468,000,000,000	-935,114	382,000,000,000
QSPR	220,197	1.44	2.33	-182.30	1.03	205.08
NUMTRANS	220,197	311.74	300.56	0.00	238.00	7,661.00
TVOL (dollars)	220,197	15,055,538,178	19,824,470,803	0.0	9,206,683,271	510,000,000,000
Bitcoin close price	220,197	8,183.12	1,392.42	5,773.50	8,151.50	11,760.50
Bitcoin minute returns	220,189	0.00	0.00	-0.03	0.00	0.05

Table 2 presents descriptive statistics for bitcoin order-imbalance and other measures regarding liquidity and trading activity. In period 1, the medians of all three order-imbalance

measures are roughly zeros. The mean of OIBNUM is positive (0.53) while those of OIBBIT and OIBDOL are negative (-214, -957281). These statistics imply that investors spread their trades when building inventories, while liquidating their inventories with a large sell. Such trading pattern is similar to pump and dump trading, but trader level data is necessary to verify whether pump and dump trading actually occured in the bitcoin market during this period. The average quoted spread is 3.56 dollars, and the average number of transactions is 59.91. The standard deviation of bitcoin price at period 1 is 938.62 dollars, smaller than those of other periods.

In period 2, we see that the bitcoin price rapidly rose, and that all three order-imbalance measures have positive means and medians. The average quoted spread is 2.60 dollars, and the average number of transactions is 181.48. The standard deviation of bitcoin price is 3953.31 dollars, largest among all four periods.

Period 3 is when the bitcoin price plunged. During this period, OIBNUM has positive mean and median, but OIBBIT and OIBDOL have negative means and medians. The average quoted spread is 3.45 dollars and the average number of transactions is 236.54. The standard deviation of bitcoin price is 2749.58 dollars.

Finally, in period 4, all three order-imbalance measures have negative means. OIBBIT and OIBDOL have negative medians. The average of quoted spread is 1.44 dollars. The average number of transactions is 311.74, which is larger than those of other periods. The standard deviation of bitcoin price is 1392.42 dollars during this period.

Table 3: Correlation Table

Correlations are given for order-imbalance measures from BitMEX quote and trade data, over 444 days between April 25th, 2017 and July 12th, 2018. For the analysis, daily data is divided into minute intervals, with each day consisting of 1440 observations (638,820 observations in total). The entire period was divided into four sub-periods. The correlation shown below are concurrent correlations (t-statistics in parentheses).

Period 1	OIBNUM	OIBBIT	OIBDOL	QSPR	NUMTRANS	TVOL	Bitcoin Price
OIBBIT	0.672						
	(412.12)						
OIBDOL	0.655	0.972					
	(393.83)	(1861.64)					
QSPR	-0.017	-0.054	-0.053				

	(-7.68)	(-24.50)	(-24.24)				
NUMTRANS	-0.015	-0.065	-0.064	0.462			
	(-6.99)	(-29.47)	(-28.97)	(236.15)			
TVOL	-0.027	-0.097	-0.101	0.378	0.846		
	(-12.24)	(-44.06)	(-46.23)	(185.04)	(719.27)		
Bitcoin Price	0.009	-0.003	-0.002	-0.083	0.302	0.374	
	(4.28)	(-1.17)	(-0.86)	(-38)	(143.81)	(182.90)	
Bitcoin Returns	0.598	0.662	0.586	-0.017	-0.025	-0.034	0.0004
	(338.32)	(401.26)	(328.06)	(-7.56)	(-11.34)	(-15.48)	(0.19)

Period 2	OIBNUM	OIBBIT	OIBDOL	QSPR	NUMTRANS	TVOL	Bitcoin Price
OIBBIT	0.821						
	(525.39)						
OIBDOL	0.699	0.927					
	(357.58)	(901.65)					
QSPR	-0.014	-0.048	-0.046				
	(-5.21)	(-17.65)	(-16.78)				
NUMTRANS	-0.010	-0.049	-0.05	0.293			
	(-3.53)	(-17.97)	(-18.38)	(111.93)			
TVOL	-0.021	-0.077	-0.092	0.368	0.738		
	(-7.58)	(-28.17)	(-33.64)	(144.58)	(400.11)		
Bitcoin Price	0.007	0.001	0.002	0.094	0.307	0.543	
	(2.59)	(0.45)	(0.59)	(34.36)	(118.06)	(236.10)	
Bitcoin Returns	0.795	0.722	0.660	0.015	-0.033	-0.044	0.005
	(478.42)	(381.66)	(321.28)	(5.34)	(-12.15)	(-16.04)	(1.98)

Period 3	OIBNUM	OIBBIT	OIBDOL	QSPR	NUMTRANS	TVOL	Bitcoin Price
OIBBIT	0.815						
	(385.37)						
OIBDOL	0.788	0.973					
	(350.24)	(1160.52)					
QSPR	-0.003	-0.016	-0.019				
	(-0.92)	(-4.52)	(-5.29)				
NUMTRANS	-0.025	-0.044	-0.042	0.521			
	(-6.87)	(-12.01)	(-11.43)	(167.07)			
TVOL	-0.025	-0.056	-0.058	0.559	0.755		
	(-6.78)	(-15.47)	(-16)	(184.28)	(315.35)		
Bitcoin Price	-0.003	0.006	0.003	-0.102	-0.234	0.134	
	(-0.74)	(1.55)	(0.89)	(-28.19)	(-65.96)	(37.11)	
Bitcoin Returns	0.837	0.721	0.679	0.021	-0.017	-0.011	0.007
	(417.81)	(285.02)	(253.32)	(5.78)	(-4.52)	(-2.97)	(1.82)

Period 4	OIBNUM	OIBBIT	OIBDOL	QSPR	NUMTRANS	TVOL	Bitcoin Price
OIBBIT	0.912						
	(1043.71)						
OIBDOL	0.888	0.987					
	(905.33)	(2866.49)					
QSPR	-0.003	-0.011	-0.017				
	(-1.38)	(-5.13)	(-8.11)				
NUMTRANS	-0.079	-0.089	-0.088	0.331			
	(-38.43)	(-43.09)	(-42.58)	(164.53)			
TVOL	-0.08	-0.105	-0.109	0.396	0.886		
	(-38.60)	(-50.32)	(-52.37)	(202.20)	(899.98)		
Bitcoin Price	0.011	0.004	0.002	0.088	0.053	0.198	

	(5.06)	(1.74)	(1.16)	(41.40)	(24.76)	(94.65)	
Bitcoin Returns	0.734	0.695	0.703	0.023	-0.019	-0.022	0.005
	(507.70)	(454.20)	(463.55)	(10.83)	(-8.90)	(-10.44)	(2.19)

Table 3 reports correlations. In all periods, three measures of order imbalance are strongly and positively correlated with returns. Interestingly, table 3 indicates that there exists significant correlations between returns and traditional trading activity indicators, e.g. total number of transactions and dollar volume. However, the magnitude of the correlation between order imbalance measures and traditional trading activity indicators was much lower. Hence, order imbalance exerts a greater influence on returns than other traditional trading activity indicators do.

Table 4: Autocorrelation

Autotorrelations are given for order-imbalance measures from BitMEX quote and trade data, over 444 days between April 25th, 2017 and July 12th, 2018. For the analysis, daily data is divided into minute intervals, with each day consisting of 1440 observations (638,820 observations in total). The entire period was divided into four sub-periods. We examine the autocorrelations of data lagged by up to 5 minutes for each variable.

Lag minutes: Period 1	OIBNUM	OIBBIT	OIBDOL	Returns	DQSPR	DOIBNUM
1	0.289	0.274	0.273	0.092	-0.343	-0.397
	(137.132)	(129.231)	(129.016)	(41.792)	(-165.769)	(-195.952)
2	0.142	0.088	0.093	-0.015	-0.09	-0.072
	(65.297)	(40.113)	(42.302)	(-6.632)	(-41.177)	(-32.548)
3	0.097	0.017	0.023	-0.029	-0.033	-0.016
	(44.428)	(7.912)	(10.493)	(-13.204)	(-14.965)	(-7.063)
4	0.075	-0.001	0.005	-0.028	-0.007	-0.012
	(33.909)	(-0.512)	(2.117)	(-12.74)	(-3.397)	(-5.688)
5	0.069	0.006	0.009	-0.025	-0.006	-0.001
	(31.475)	(2.654)	(4.212)	(-11.099)	(-2.657)	(-0.474)

Period 2	OIBNUM	OIBBIT	OIBDOL	Returns	DQSPR	DOIBNUM
1	0.202	0.251	0.236	0.026	-0.343	-0.387
	(75.204)	(94.72)	(88.602)	(9.415)	(-133.231)	(-153.117)
2	0.021	0.05	0.035	-0.029	-0.074	-0.088
	(7.509)	(18.192)	(12.913)	(-10.566)	(-26.998)	(-32.207)
3	-0.02	-0.005	-0.02	-0.04	-0.029	-0.027
	(-7.425)	(-1.834)	(-7.437)	(-14.799)	(-10.761)	(-9.692)
4	-0.018	-0.007	-0.016	-0.033	-0.020	-0.010
	(-6.689)	(-2.609)	(-5.941)	(-12.287)	(-7.407)	(-3.912)
5	0.000	0.003	-0.002	0.001	-0.008	0.015
	(0.181)	(1.056)	(-0.552)	(0.48)	(-2.846)	(5.441)

Period 3	OIBNUM	OIBBIT	OIBDOL	Returns	DQSPR	DOIBNUM
1	0.172	0.210	0.211	0.018	-0.342	-0.400
	(48.498)	(59.641)	(60.403)	(5.031)	(-100.215)	(-120.348)
2	0.007	0.017	0.025	-0.035	-0.084	-0.09
	(2.048)	(4.997)	(7.606)	(-9.75)	(-23.615)	(-24.8)
3	-0.009	-0.004	-0.006	-0.026	-0.036	-0.017
	(-2.757)	(-1.217)	(-2.154)	(-7.363)	(-9.806)	(-4.843)
4	0.002	0.012	0.019	0.003	-0.011	0.005
	(0.349)	(2.982)	(4.168)	(0.771)	(-2.869)	(1.251)

5	0.005	0.01	0.015	-0.005	-0.004	0.001
	(1.371)	(2.342)	(3.007)	(-1.228)	(-1.372)	(0.475)

Period 4	OIBNUM	OIBBIT	OIBDOL	Returns	DQSPR	DOIBNUM
1	0.221	0.265	0.267	-0.035	-0.211	-0.389
	(105.522)	(127.352)	(129.042)	(-16.911)	(-101.457)	(-199.006)
2	0.05	0.065	0.065	-0.017	-0.170	-0.094
	(23.442)	(29.811)	(30.038)	(-8.013)	(-81.118)	(-43.832)
3	0.025	0.024	0.025	-0.001	-0.054	-0.007
	(11.896)	(10.899)	(11.698)	(-0.559)	(-25.239)	(-3.187)
4	0.012	0.012	0.013	-0.002	-0.020	-0.008
	(5.479)	(5.44)	(5.881)	(-0.973)	(-9.495)	(-3.815)
5	0.011	0.011	0.013	-0.006	-0.010	0.001
	(4.882)	(5.03)	(6.066)	(-2.845)	(-4.48)	(0.168)

Table 4 reports autocorrelations. In all periods, all three order imbalance measures exhibit positive autocorrelations at lags of one and two minutes, but autocorrelation decays quickly. The bitcoin returns measured at one minute interval show some autocorrelation, but the direction is not consistent across all periods. DQSPR, defined as changes in QSPR, presents negative autocorrelation at one minute lag across all time periods. DOIBNUM, defined as changes in OIBNUM, shows strong negative autocorrelation for one minute lag in all time periods.

Table 5: Normality test, skewness and kurtosis of bitcoin returns

All statistics are significant; P-values on X-squared tests are nearly zero for all statistics.

	Period 1	Period 2	Period 3	Period 4
Jarque-Bera Normality statistic	2335900	18826000	796620	11043000
Mean x 10^6	4.89	12.34	-12.42	-1.19
Standard Deviation x 10^6	1525.07	1788.19	2757.92	1248.93
Skewness	0.3	1.12	0.39	0.44
Kurtosis	19.49	61.14	18.82	37.69

Table 5 presents the distribution of bitcoin returns measured at one-minute interval. In each period, we observe positive skewness in the bitcoin return distribution and all kurtosis are much larger than 3, the reference value of normal distribution. Since there exist several positive outliers as bitcoin price surges in period 2, we observe the largest skewness of 1.12 and kurtosis of 61.14 in that specific period. Jarque-Bera test, the goodness-of-fit test of whether skewness and kurtosis match a normal distribution, strongly rejects the null hypothesis that bitcoin return is normally distributed. Interestingly, skewnesses are positive in all sub-periods in contrast to stock returns.

Figure 2: Density plot of bitcoin returns

Figure 2 presents density plots of bitcoin returns for each period. X-axis and Y-axis represent bitcoin return and its frequency, respectively. Dotted lines are density of bitcoin returns, and solid lines are normal distribution which has same mean and variance of each period.

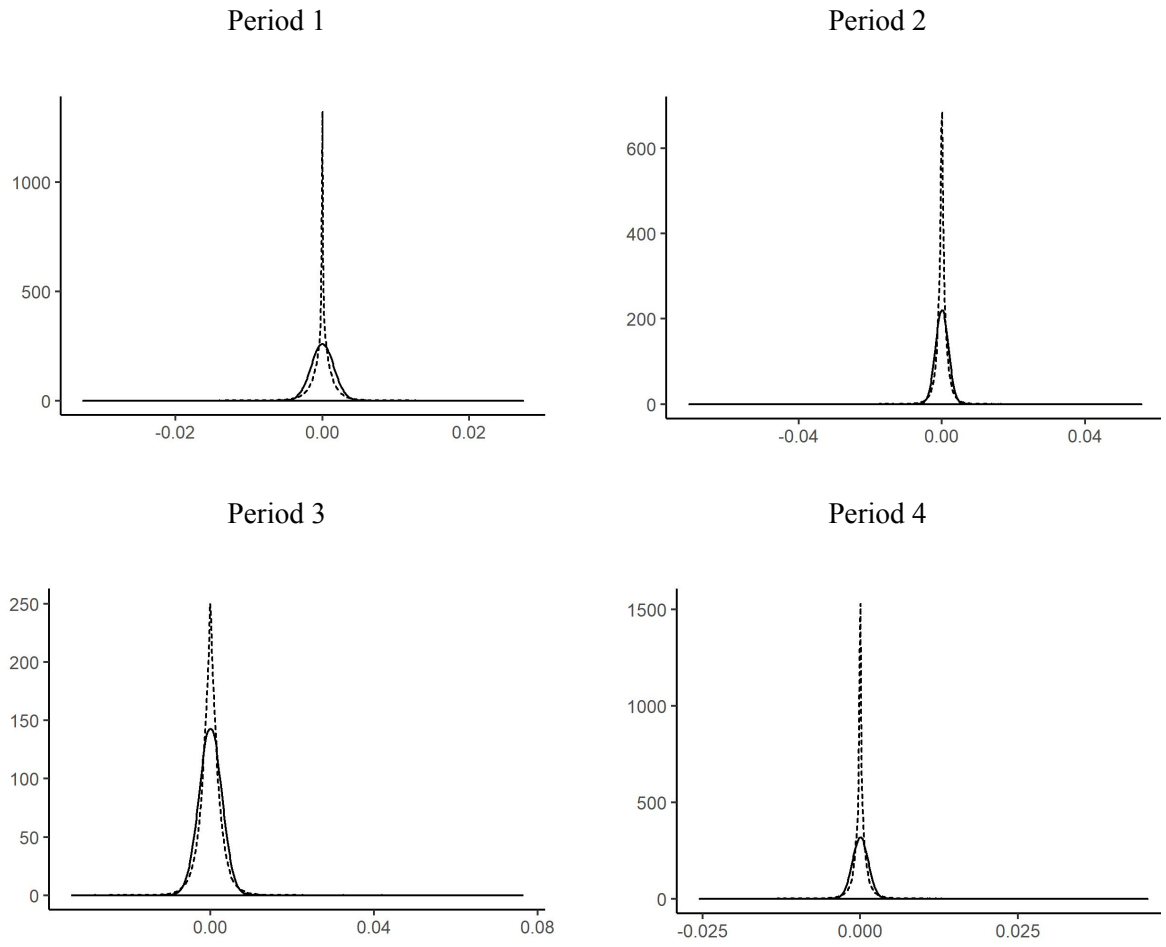


Figure 2 shows the histogram of bitcoin returns. X-axis and Y-axis represent bitcoin return and its frequency, respectively. We can verify results of Table 5 by observing large fat tails.

Figue 3: QQ plot of returns
X-axis are theoretical quantiles under normality. Y-axis are sample quantiles.

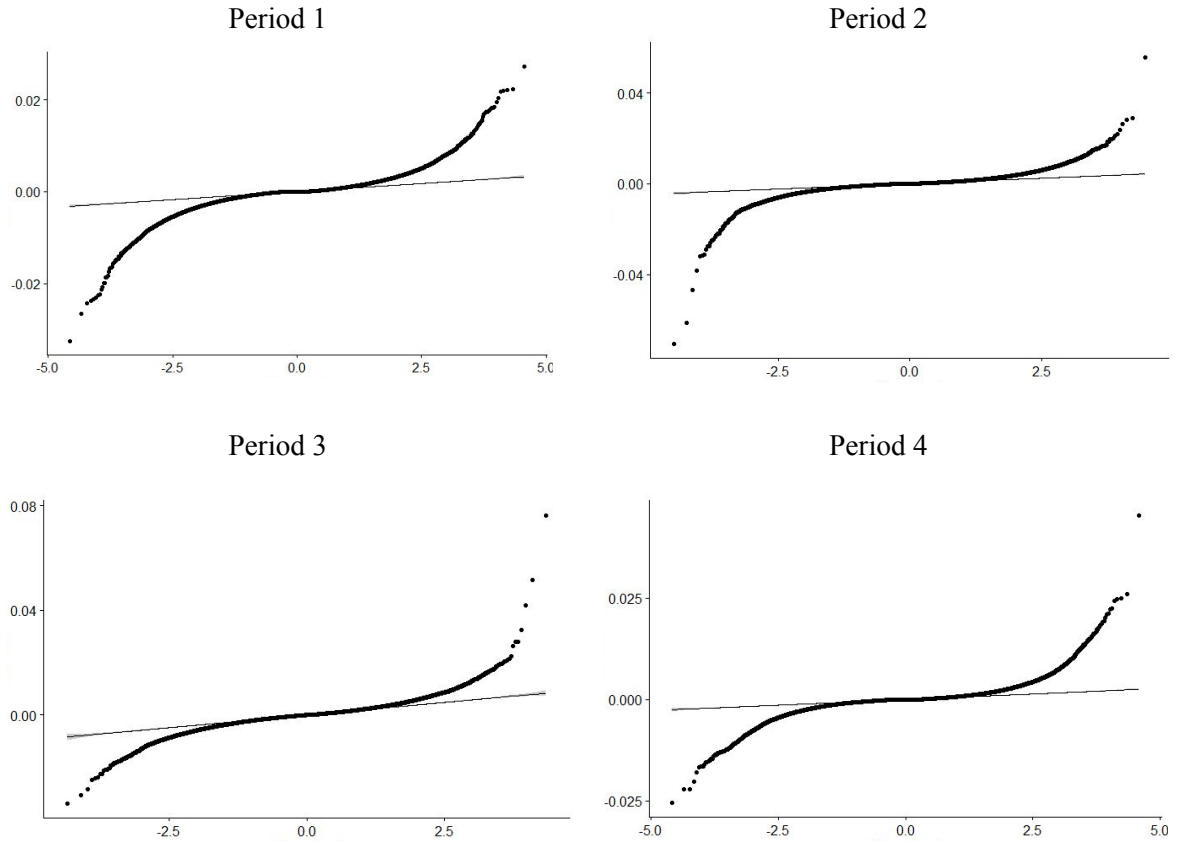


Figure 3 is the QQ plot of bitcoin returns visualizing the results of Jarque-Bera test in Table 5. X-axis means theoretical quantiles under normality. Y-axis represents sample quantiles. By investigating the distance between tails and a straight line in the middle, we can visually assess the extent that bitcoin returns deviates from the normal distribution. Also, the figure confirms large positive skewness and kurtosis of the bitcoin returns.

DIFFERENCE FROM STOCK MARKETS

Then, how does bitcoin market differ from the stock market? We compare our findings of the bitcoin market with Chordia et al (2002), which studied the S&P 500 market from 1988 to 1998. First, for all measures on order imbalance and trading activities, and the ratio of standard deviation to mean (CV: coefficient of variation) are generally larger in the bitcoin market than those in the stock market. In the bitcoin market, we adjust the value of CV by

multiplying 0.026 to change the minute-by-minute properties to daily. The CV of OIBNUM at bitcoin market is from 1.18 (minimum) in period 2 to 12.64 (maximum) in period 3 depending on sub-periods while that of stock market is 1.65. Only the CV of period 2 is lower than that of stock market but the mean value of OIBNUM in that period is the largest among all periods. It means that the imbalance scale itself is large even if the CV seems small.

Second, the CVs of total number of transactions and total dollar volume in bitcoin market are smaller than those found in the stock market. In the stock market, NUMTRANS and TVOL are 0.61 and 0.72, respectively. In bitcoin market, NUMSTRAN ranges from 0.016 in period 3 to 0.035 in period 1. TVOL ranges from 0.031 in period 3 to 0.055 in period 1. However, the CV of QSPR is larger than that in stock market. We do not adjust the CV of QSPR due to the concept of QSPR. QSPR ranges from 1.27 to 3.14 in the bitcoin market while QSPR is 0.16 in stock market.

Third, the relationship between variables tends to be tighter in the bitcoin market. In the bitcoin market, the correlations between returns and order-imbalance measures are greater. The correlation between returns and OIBNUM in bitcoin market ranges from 0.598 to 0.837 depending on subperiods while the correlation in the stock market is 0.408. The correlation between returns and OIBBIT ranges from 0.662 to 0.722 while that in stock market is 0.599. Lastly, the correlation between returns and OIBDOL in bitcoin market ranges from 0.586 to 0.793 while it is 0.528 in stock market.

The correlations among order-imbalance measures are also greater. The correlation between OIBNUM and OIBBIT ranges from 0.672 to 0.912, the correlation between OIBNUM and OIBDOL ranges from 0.655 to 0.888, and the correlation between OIBBIT and OIBDOL ranges from 0.927 to 0.987 while those in stock market are 0.522, 0.531, and 0.966, respectively. On the other hand, the correlations between returns and trading activities are negative in the bitcoin market. In bitcoin market, the correlation between returns and NUMTRANS ranges from -0.033 to -0.019, and the correlation between returns and TVOL is from -0.044 to -0.011 while those in stock market are 0.012 and 0.024 respectively.

Fourth, the autocorrelations in order imbalance measures are lower in bitcoin market. In stock market, order imbalance measures show autocorrelation up to five days but in the bitcoin market, we can only see weak one-minute autocorrelation.

In sum, bitcoin market is more volatile than stock market as the sample standard deviation compared to the sample mean is much higher in bitcoin market. Correlations among order imbalance measures are stronger in bitcoin market, while autocorrelations of order imbalance measures are much weaker in bitcoin market.

CONCLUSION

How is the bitcoin market different from the stock market in terms of market microstructure? First, order imbalances in bitcoin market are strongly correlated with bitcoin returns, and the order imbalances have stronger correlations with each other. Second, bitcoin returns are highly volatile even after adjusting average returns. Third, bitcoin order imbalance measures do not show serial correlation even at the minute level while stock order imbalance measures exhibit serial correlation that lasts up to days. For future research, we suggest the following. What determines the market microstructure characteristics, and how trading activities and policies affect the bitcoin market.

REFERENCE

Chordia, T., Roll, R., & Subrahmanyam, A. (2002). Order imbalance, liquidity, and market returns. *Journal of Financial economics*, *65*(1), 111-130.

Chordia, T., & Subrahmanyam, A. (2004). Order imbalance and individual stock returns: Theory and evidence. *Journal of Financial Economics, 72(3)*, 485-518.

Lee, C. M., & Ready, M. J. (1991). Inferring trade direction from intraday data. *The Journal of Finance*, *46*(2), 733-746.

APPENDIX

Table 1: Marketwide order imbalance - summary statistics and correlation

This table shows order imbalances and trading activity measures of the traditional stock market. This table is described in Chordia et al (2002).

Descriptive statistics are given for average daily order imbalance measures from NYSE stocks belonging to the S&P500 over 1988–1998 inclusive (2779 observations). Trades are signed using the Lee and Ready (1991) algorithm. OIBNUM, OIBSH, and OIBDOL measure the value-weighted order imbalance in number of transactions, shares, and dollars, respectively. $VOL, NUMTRANS, and QSPR are the value-weighted averages of dollar volume (in millions of dollars), number of transactions, and the average daily quoted spread, respectively. The value weights are proportional to market capitalization at the end of the previous calendar year. The variables DQSPR and DOIBNUM denote the daily percentages and the daily first differences in QSPR and OIBNUM, respectively. S&P500 is the daily return on the Standard & Poor's 500 Index. Values in bold face (Panel C) are significantly nonzero with an asymptotic *p*-value less than 0.00001.

Panel A: Summary statistics

	Mean	Median	Standard deviation
OIBNUM	34.89	27.22	57.48
OIBSH/1×10^3	59.71	45.40	97.12
OIBDOL/1×10^6	4.167	2.830	6.498
|OIBNUM|	90.33	78.61	52.71
|OIBSH|/1×10^3	168.0	147.0	86.04
|OIBDOL|/1×10^9	9.628	7.560	6.165
QSPR	0.182	0.187	0.030
NUMTRANS	658.0	534	399.0
$VOL	58.37	40.17	42.17
|DQSPR(%)|	2.66	1.98	2.63

Panel B: Correlations

	OIBNUM	OIBSH	OIBDOL	NUMTRANS	$VOL
OIBSH	0.522				
OIBDOL	0.531	0.966			
NUMTRANS	0.533	0.468	0.562		
$VOL	0.476	0.509	0.608	0.971	
S&P500	0.408	0.599	0.528	0.012	0.024

Panel C. Autocorrelations

Lag (days)	OIBNUM	OIBSH	OIBDOL	S&P500	DQSPR	DOIBNUM
1	**0.539**	**0.376**	**0.465**	0.005	**−0.321**	**−0.420**
2	**0.470**	**0.322**	**0.421**	−0.023	**−0.096**	**−0.074**
3	**0.469**	**0.297**	**0.400**	−0.032	−0.022	**−0.037**
4	**0.434**	**0.290**	**0.399**	−0.018	−0.022	−0.016
5	**0.414**	**0.271**	**0.384**	−0.023	−0.018	**0.034**

Source: Chordia et al(2002)