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"Chicago Mercantile Exchange Bitcoin Futures: Volatility, Liquidity and Margin"

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Abstract

This paper explores empirically the behavior of the Chicago Mercantile Exchange (CME) bitcoin futures contract. The analysis focuses on the time period between the launch of the CME bitcoin futures contract on December 18, 2017, and September 17, 2018. The behavior of the bitcoin spot market and CME futures market is compared and analyzed along several dimensions: price, volatility and liquidity. By comparing the Garman-Klass volatilities of bitcoin spot and futures prices with those of different assets, we find that both the bitcoin spot and futures markets exhibit relatively high volatility compared to other assets. When the ratio of trading volume over open interest is used to measure liquidity, the bitcoin futures market shows a mid-level liquidity. We also find while the exchange margin is set to meet the normal price volatility that can cover the daily price movements within one standard deviation, the brokerage margin for bitcoin futures is set at beyond two standard deviations. Some brokerage firms impose non-margin requirements such as high net account balance and open position limits in addition to regular margins. We conclude that the brokerage firms' relatively high margin and non-margin requirements impede trading activity such as short-sales and thus, liquidity and efficiency in the bitcoin futures market has been slow to develop.

JEL Classification: G1
Keywords: bitcoin, futures, Garman-Klass, volatility, liquidity, margin

1. Introduction

There is on-going debate on what a cryptocurrency is. It can be viewed as money, security, derivative, gambling tool, computer software, etc. While Brito, Shadab, and Castillo (2014) provide its legal interpretation from various angles and proper regulatory actions for it, Yermack (2015) and Cheah and Fry (2015), for example, conclude that bitcoin is not a currency, but a speculative asset, because it has no intrinsic value. However, there are many who see it as an important asset because it is something that had never appeared in the human history so far and has large unproven value. Consequently, those who view it as an excellent store of value have fueled a rapid increase in its price in 2016 and 2017. Also, those who believe in the technology underlying cryptocurrencies have spread their popularity without clearly defining what they are advocating – currency or technology. In fact, Caginalp and Caginalp (2018) state that a handful of cryptocurrency traders can move the price without the help of their majority and make a strong prediction that cryptocurrencies will have high price volatility without the backing of any underlying asset. Consequently, as their popularity and enthusiasm wax and wane, the public's view of high price volatility has been solidified. In order for investors to hedge against such volatile price movements, two futures exchanges[1] began introducing futures contracts on cryptocurrency – namely, bitcoin – in December 2017.

Despite the very volatile nature of the cryptocurrencies in recent periods, many investors and even, central banks have entertained the idea of incorporating them into their portfolios or a pool of monetary policy tools. For example, Bordo and Levin (2017) endorses a central bank digital currency (CBDC) for money by saying, "[W]e have found that CBDC can serve as a practically costless medium of exchange, secure store of value, and stable unit of account." (2017, P19). Under this overall scheme, Kumhof and Noone (2018) develop three model of CBDC and analyze its implications on balance sheets of central banks and commercial banks. As such, there are positive aspects of cryptocurrencies that can benefit the investment community and the monetary system. However, one of the fundamental questions for a cryptocurrency to be either an investment vehicle or a monetary policy tool or both is its volatility in value[2]. When the underlying asset to a monetary system or an investment portfolio exhibits a great deal of volatility in price, its value as a monetary policy tool or an investment vehicle decreases and can be harmful to the economy. In this spirit, we examine the volatility of a cryptocurrency – especially, the futures contracts on it. We measure the magnitude of bitcoin futures price volatility relative to its underlying spot price and other asset price volatilities along with their levels of liquidity. We also provide a possible answer to the question that Hale, Krishnamurthy, Kudlyak, and Shultz (2018) posed: "Why, then, did the price of bitcoin fall somewhat gradually rather than collapse overnight?" when the introduction of bitcoin futures enabled the short-selling of over-valued bitcoin. We identify and evaluate the bitcoin futures margin requirement as one of the reasons for the reduced liquidity and gradual, not immediate, collapse in bitcoin price.

Section 1 provides brief background information on bitcoin spot[3] and bitcoin futures markets while Section 2 is devoted to the analysis of the bitcoin spot and futures price behavior including descriptive statistics on volatilities observed in various asset classes. The Garman-Klass volatility measure is used for its simple and yet robust nature of incorporating the information included in the open, high, low, and closing prices of the bitcoin spot and futures markets. Also, the relative liquidity of the bitcoin futures contract is compared with other futures contracts. Section 3 examines the degree of bitcoin futures volatility relative to other assets. The study period is divided into the first 3-month period when bitcoin futures was introduced and the cryptocurrency market was volatile, and the next 6-month period when the cryptocurrency volatility was somewhat subdued. Section 4 presents the role of bitcoin

[1] Chicago Board Options Exchange (CBOE) and Chicago Mercantile Exchange (CME) listed them. We chose to study the CME bitcoin futures market in this paper.

[2] Despite the obvious difference, we treat value the same as price in this paper because how to measure the value of a cryptocurrency is still in debate. In fact, Caginalp and Caginalp (2018, p.1131) state that "The value of a cryptocurrency such as Bitcoin is unchartered territory in economics."

[3] Throughout this paper, we use the term, bitcoin spot price or spot market, instead of bitcoin cash price or cash market, to distinguish bitcoin from the bitcoin cash, a variant form of cryptocurrency that was hard-forked from bitcoin.

futures margins on the market liquidity. The level of the margins set by the exchange is compared with that set by the futures brokerage firms. Summary and conclusions are presented in Section 5.

1.1 The Bitcoin Spot Market

The definition of cryptocurrency has not been settled and there are many views on what it is. However, the Bank of International Settlement (BIS) defines it as a currency that is electronic, functions like cash in peer-to-peer transactions and is not the liability of a financial institution. It is created by individuals, not governments or central banks.[4] Bitcoin was the first cryptocurrency. It was created by Satoshi Nakamato in 2009 based on a paper describing a peer-to-peer electronic cash system.[5]

Bitcoin allows peer-to-peer transactions based on a distributed ledger technology known as Blockchain.[6] Bitcoin uses a decentralized database where peer-to-peer transactions are broadcast to a network of users. The transactions are validated by network nodes, miners. The transactions, or blocks, are recorded in the ledger and linked to the previous version of the ledger to form a chain of transactions. This ledger is based on an infrastructure known as the protocol which is supposed to align the incentives of all the participants and insure that all participants adhere to the rules. One of the most important features of the bitcoin protocol is that no more than 21 million bitcoins can exist.[7] Individuals who use bitcoins to pay for goods and services in peer-to-peer cash market transactions may obtain bitcoins on an organized bitcoin exchange. Conversely, individuals who receive bitcoins and want to convert them into cash may sell their bitcoins on an organized bitcoin exchange. Even though there are numerous variant forms of bitcoin such as bitcoin cash, ethereum, ethereum classic, litecoin, ripple, etc., we focus on bitcoin because the Chicago Mercantile Exchange (CME) lists and trades the futures contract on an aggregate index of bitcoin spot prices. During our study period between December 18, 2017 and September 17, 2018, the daily spot market turnover value, bitcoin price times quantity exchanged, averaged $1.034 billion.[8]

1.2 Chicago Mercantile Exchange Bitcoin Futures Market

On December 18, 2017, the Chicago Mercantile Exchange (CME) launched its bitcoin futures contract. Table 1 provides its salient features. The contract size is 5 bitcoins and expires on the March quarterly cycle with first 2 nearby months serially listed.

The CME bitcoin futures contract does not track the price of bitcoin from a single bitcoin exchange. In fact, it follows the Bitcoin Reference Rate (BRR) that is a combination of bitcoin spot prices from a minimum of four bitcoin spot exchanges. The BRR aggregates bitcoin trading activity across major bitcoin spot exchanges between 3:00 p.m. and 4:00 p.m. London time. For example, there are four bitcoin constituent spot exchanges: GDAX, Bitstamp, Kraken and itBit.[9] Calculation rules are geared toward a maximum of transparency

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[4] https://www.bis.org/publ/qtrpdf/r_qt1709f.pdf. Bech, Morten and Rodney Garratt, "Central Bank Cryptocurrencies" BIS quarterly Review, September 2017, p 57.

[5] https://bitcoin.org/bitcoin.pdf "Bitcoin: A Peer-to-Peer Electronic Cash System" Satoshi Nakamoto satoshin@gmx.com, www.bitcoin.org.

[6] https://www.bis.org/publ/qtrpdf/r_qt1709f.pdf. Bech, Morten and Rodney Garratt, "Central Bank Cryptocurrencies" BIS quarterly Review, September 2017, p 58.

[7] https://www.bis.org/publ/arpdf/ar2018e5.htm "Cryptocurrencies: looking beyond the hype." BIS Annual Economic Report, June 17, 2018, p 98.

[8] Aalborg, Molnar, and de Vries (2018), for example, document the patterns of price, volatility, and trading volume of bitcoin spot market in order to identify the factors that influence bitcoin volatility.

[9] David Lerman, "CME Bitcoin Futures: The Basics" Bitcoin Webinar, June 5, 2018.

and real-time replicability in underlying spot markets. The bitcoin futures contract is settled in cash based on the BRR.

Table 1: Salient Features of the Chicago Mercantile Exchange Bitcoin Futures Contract

Contract Unit	5 bitcoin, as defined by the CME CF Bitcoin Reference Rate (BRR)
Minimum Price Fluctuation	Outright: $5.00 per bitcoin = $25.00 per contract. Calendar Spread: $1.00 per bitcoin = $5.00 per contract.
Trading Hours	CME Globex and CME ClearPort: 5:00 p.m. – 4:00 p.m. CT Sunday – Friday.
Listing Cycle	Nearest 2 months in the March Quarterly cycle (Mar, Jun, Sep, Dec) plus the nearest 2 "serial" months not in the March Quarterly cycle.
Termination of Trading	Last Day of Trading is the last Friday of contract month. Trading in expiring futures terminates at 4:00 p.m. London time on Last Day of Trading.
Position Limits	Spot Position Limits are set at 1,000 contracts. A position accountability level of 5,000 contracts will be applied to positions in single months outside the spot month and in all months combined.
Price Limits	Price limits for a given Business Day are made by reference to the most recent Bitcoin Futures settlement price, settled at 3:00 p.m. Central time each Business Day.
	Special price fluctuation limits equal to 7% above and below prior settlement price and 13% above and below prior settlement price and a price limit of 20% above or below the previous settlement price. Trading will not be permitted outside the 20% above and below prior settlement price.
Settlement	Cash settled by reference to Final Settlement Price, equal to the CME CF Bitcoin Reference Rate (BRR) on Last Day of Trading.

Source: CME, CME Bitcoin Futures Frequently Asked Questions

2. Bitcoin Futures Price Trend and Relative Price Volatility

2.1 Price Trend

Figure 1 displays the movements of the bitcoin spot and nearby futures prices during the study period. As well noted in the media, the peak bitcoin price was observed on December 17, 2017, a day before the CME bitcoin futures contract was introduced. Since then, both the spot and futures prices declined in a close, tight relationship.

Figure 1. Daily Closing Prices of Bitcoin Futures and Bitcoin Spot

(12/18/2018-09/17/2018)

The reason for this steady downward movement in bitcoin price was attributed to the short-selling opportunities made available via futures trading. Hale, Krishnamurthy, Kudlyak, and Shultz (2018), however, wonder why this downward price adjustment was gradual, not immediate, given the nature of short-selling.

Table 2 presents the descriptive statistics for the bitcoin spot and CME bitcoin futures price, trading volume and open interest for the study period of December 18, 2017 through September 17, 2018.[10]

We observe that the average bitcoin futures and spot price levels are similar, except for the carrying charge difference, and that their standard deviations also are similar. However, the trading volumes, expressed as number of bitcoins traded, show a drastic difference between the markets where the bitcoin spot market dominates the bitcoin futures market. This observation is not startling, given that the futures contract is at the very infant stage of development. What is interesting is the fact that the large bitcoin spot market size indicates

[10] We focus on the nearby bitcoin futures prices because they are the most liquid bitcoin futures contracts with the greatest volume and open interest.

the growth potential for the bitcoin futures market which has a very small trading volume for now.

Table 2. Descriptive Statistics for Daily Bitcoin Futures and Bitcoin Spot Price, Volume and Open Interest (12/18/2018-09/17/2018)

Variable	Observations	Mean	Std. Dev.	Min	Max
Bitcoin Futures Closing Price	188	8,719.18	2,621.91	5,865.00	19,100.00
Bitcoin Futures Trading Volume	188	15,626	11,014	2,030	57,765
Bitcoin Futures Open Interest	188	1,487	658	139	2,460
Bitcoin Spot Closing Price	188	8,778.93	2,680.01	5,903.44	19,114.20
Bitcoin Spot Trading Volume	188	795,111	229,895	520,466	1,805,494

Source: CME Bitcoin Futures and Bitcoin spot price data from Yahoo Finance BTC-USD.

While the bitcoin spot and nearby futures closing prices move mostly in tandem, there seems to be a noticeable downtrend in both the bitcoin spot and futures prices during the study period. At the start of the bitcoin futures contract in December 2017, the price level was fluctuating around the level of $15,000 per bitcoin. After that, both the spot and nearby futures prices declined to a level close to $7,000 during the spring and summer, 2018. In order to determine if the volatility regime changed during this period, we arbitrarily divided the study period into two subperiods: the first subperiod is an approximate 3-month period between December 18, 2017 and March 31, 2018, and the second subperiod is an approximate 6-month period between April 1, 2018 and September 17, 2018. Figure 1 shows visually the two distinct volatility regimes. The first period shows a high volatility whereas the second period, a relatively low volatility.

2.2 Liquidity

We examine the relative market sizes of the bitcoin spot and futures to analyze the relative liquidity of the futures market to the spot market. In order to measure the size of the spot market, we convert the spot market turnover, price times number of coins traded, into the number of bitcoins by dividing the spot market turnover by the daily closing bitcoin spot price during the study period. For the futures market size, we multiply the daily trading volume by 5 because the size of the CME bitcoin futures contract is five bitcoins.

Figure 2 displays the respective market sizes of the bitcoin spot and the bitcoin futures market in number of bitcoins. Paying attention to the difference in scale between the bitcoin spot market and the nearby bitcoin futures market, we note that during the nine-month study period, the daily spot market bitcoin volume fluctuated between 500,000 and 1,750,000, while the CME nearby futures contracts generated daily volumes between 2,000 and 55,000. The average daily coin volume for the front month, or nearby, bitcoin futures contract was 15,625 coins. Since the average daily coin volume in the bitcoin spot market was 791,685, it means that the CME bitcoin futures market coin volume was only 2% of the bitcoin spot market. The pure size difference indicates that the bitcoin futures market is relatively less liquid than the spot market, holding all else constant.

Figure 2. Daily Trading Volume of Bitcoin Futures and Bitcoin Spot in Number of Bitcoin (12/18/2018-09/17/2018)

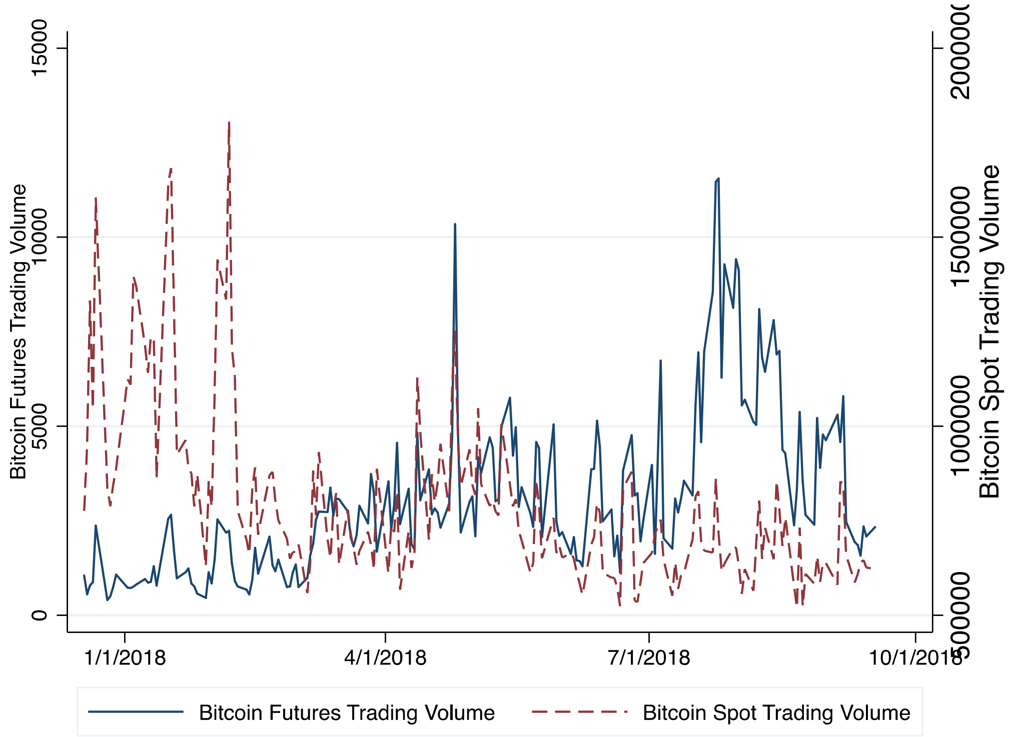


Figure 2 also shows that while the daily bitcoin spot trading volume in number of bitcoins has a downtrend through the spring and summer, 2018, the bitcoin nearby futures trading volume in coins indicates a general uptrend during the same period. This observation is interesting in light of the price trend observed in Figure 1. Combining the two figures, we see that there is a strong inverse relationship between coin price and coin trading volume.[11] This may indicate that investors showed less interest in bitcoin spot market as the price fell while bitcoin futures traders were trying to build up the market while the price was less volatile.

The coin volume metric provides good insight into the differences in trading activity between the bitcoin spot and futures markets, but it does not provide information about the liquidity for the bitcoin futures market relative to other futures markets. Market liquidity can be measured and evaluated in various ways. For example, one can look at the size of the market activity and conclude that the larger the trading volume and open interest, the greater the liquidity. On the other hand, one can look at specific trading characteristics such as the bid-ask spread, and conclude that the narrower the bid-ask spread, the greater the market liquidity. While these measures are good in evaluating liquidity in well-developed markets, they may not be good for measuring the liquidity of new or less-developed markets such as the bitcoin futures market. In such a market, the ratio of trading volume to open interest is a more appropriate liquidity measure because it focuses specifically on the trading activity that creates and supports open interest. A large ratio means that trading volume is large enough to support the willingness of the traders to carry an open position overnight or longer. On the other hand, in a well-established market, this ratio can be small because open interest is often much larger than the trading volume. The large open interest, being associated with a large hedging demand and use, is often found in a well-developed futures market. To understand

[11] This inverse relationship was also observed by Aalborg, Molnar and de Vries (2018, Table 13) in the bitcoin spot market.

the liquidity in the bitcoin futures market, we calculate the ratio of trading volume to open interest, define it as the liquidity ratio, and then plot the ratio's daily values for the time period between December 18, 2017 and September 17, 2018 in Figure 3.

Figure 3. Liquidity Ratio of the Ratio of Daily Volume over Daily Open Interest in Bitcoin Futures (12/18/2018-09/17/2018)

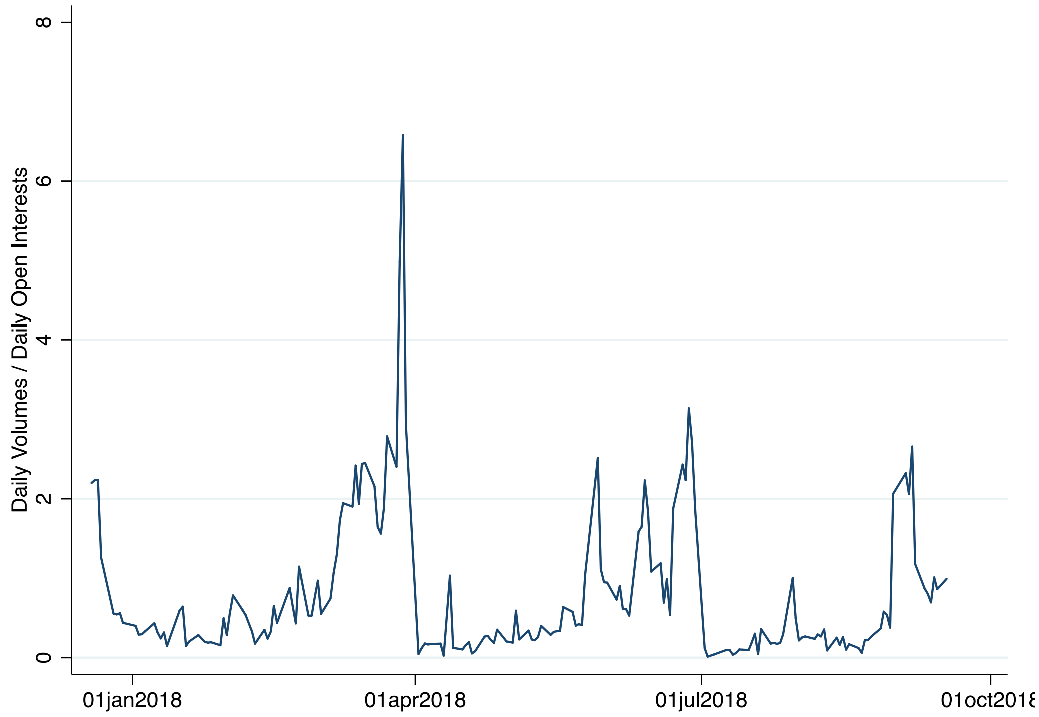


Figure 3 shows that the liquidity ratio increases toward the nearby futures contract expiration and reaches its peak for that contract on the expiration day, the last Friday of the contract month. During the first expiration cycle in March 2018 for bitcoin futures, the liquidity ratio reaches a level greater than 6, indicating that the trading volume is more than 6 times the size of open interest. The ratio drops significantly after the contract expiration but slowly builds up over the following months. For the case of June and September contracts, the ratio reaches a level greater than 2 at expiration. This indicates that the liquidity increases at each contract expiration, making the orderly expiration and settlement possible. Therefore, there has been no significant market disturbance in the bitcoin futures market.

This observation of the bitcoin futures market liquidity can be expanded and compared to other futures contracts as seen in Table 3.

Table 3 shows that the well-developed markets such as E-mini S&P 500 futures and 10-year T-Note futures have the liquidity ratio below 0.5 whereas the euro futures has 0.527. Also, the standard deviations of these markets are relatively small, indicating that they are well-established and stable. However, the gold futures and light sweet crude oil futures show a liquidity ratio greater than bitcoin futures. The ratios of 0.910 and 0.971 for gold futures and crude oil futures, respectively, indicate that their volume is almost equal to the size of open interest. Also, their standard deviations are much larger than E-mini S&P 500 and 10-year T-Note futures, indicating that they are less-developed and somewhat unstable.

Table 3: The Liquidity Ratio of Daily Trading Volume over Open Interest for Selected Futures Contracts (12/18/2018-09/17/2018)

Variable	Mean	Std. Dev.	Min	Max
Bitcoin Futures	0.788	0.918	0.013	6.583
E-Mini S&P 500 Futures	0.485	0.191	0.049	1.419
Gold Futures	0.910	1.904	0.000	22.140
10-year T-Note Futures	0.488	0.391	0.094	2.998
Euro Futures	0.527	0.236	0.054	2.040
LS Crude Oil Futures	0.971	0.777	0.166	3.661

Sources: CME Bitcoin Futures, Yahoo Finance BTC-USD, CME E-Mini S&P 500 Futures, COMEX Gold Futures, CME T-Note Futures, CME Euro Currency Futures, and Light Sweet Crude Oil Futures. All data are daily trading data.

This relatively large liquidity ratio and large standard deviation may mean that these markets attract more speculative interest than E-mini S&P 500 and 10-year T-Note futures markets. As speculative interest rises and falls, the trading volume rises and falls without much change in open interest. Given this observation, we conclude that the bitcoin futures market is less-developed, than the E-mini S&P 500 and 10-year T-Note futures markets. Given the short length of bitcoin futures trading, it is clearly wrong to conclude that the bitcoin futures market is more mature or better established than gold or crude oil futures markets, simply based on the bitcoin futures liquidity ratio of 0.788 being lower than both markets. In fact, given the not-so-insignificant speculative trading present in gold and crude oil, we suspect that the smaller liquidity ratio found in the bitcoin futures market may indicate that it has less speculative interest than the gold futures and crude oil futures markets during this period.

2.3 Relative Price Volatility

There are a few studies that examined the volatility of bitcoin spot and futures prices. For example, Kochling, Muller, and Posch (2018) examine the effect of the bitcoin futures contract on the efficiency of the bitcoin spot market by employing daily closing price data for the CME bitcoin futures contracts and bitcoin spot market. They find that after the CME futures contracts were introduced in December of 2017, the bitcoin spot market became weak-form efficient and the price predictability disappeared. They attribute this bitcoin spot market result to the creation of short positions via the CME bitcoin futures contracts. Kapar and Olmo (2018) also analyze the price discovery function fulfilled by the bitcoin futures contracts, by using daily price data and a vector cointegrated model. They find that the CME futures market dominates the bitcoin spot market in the price discovery process. Corbet, Lucey, Peat, and Vigne (2018), while examining the hedging efficiency of bitcoin futures, conclude that hedging increases spot price volatility and spot market leads the futures market. Aalborg, Molnar and de Vries (2018), on the other hand, examine the factors that determine the bitcoin spot price volatility and conclude that realized volatility can be predicted by the heterogenous autoregressive model. Given the robustness of the Garman-Klass volatility measure, Tan, Chan and Ng (2018) use it to improve volatility prediction and measure the degree of persistence in cryptocurrency prices. They find that the bitcoin spot market exhibited relatively low volatility that was more predictable when compared to the other cryptocurrencies.

While many of these studies dealt with various aspects of bitcoin volatilities, their concentration was on the bitcoin or cryptocurrency spot market, not on the bitcoin futures market. Consequently, we examine closely in this paper the volatility of the bitcoin futures prices in relation to bitcoin spot price and other futures prices. To understand and compare the true nature of price volatility with other assets, we also choose to employ the Garman-Klass (1980) extreme value method, as shown below in Equation (1).

$$\sigma^2 = .5\left(ln\frac{\text{HIGH}}{\text{LOW}}\right)^2 - .39\left(ln\frac{\text{CLOSE}}{\text{OPEN}}\right)^2 \tag{1}$$

Where: HIGH denotes the highest price observed during the trading day;

LOW denotes the lowest price observed during the trading day;

OPEN denotes the opening price at the beginning of the trading day;

CLOSE denotes the closing price at the end of the trading day.

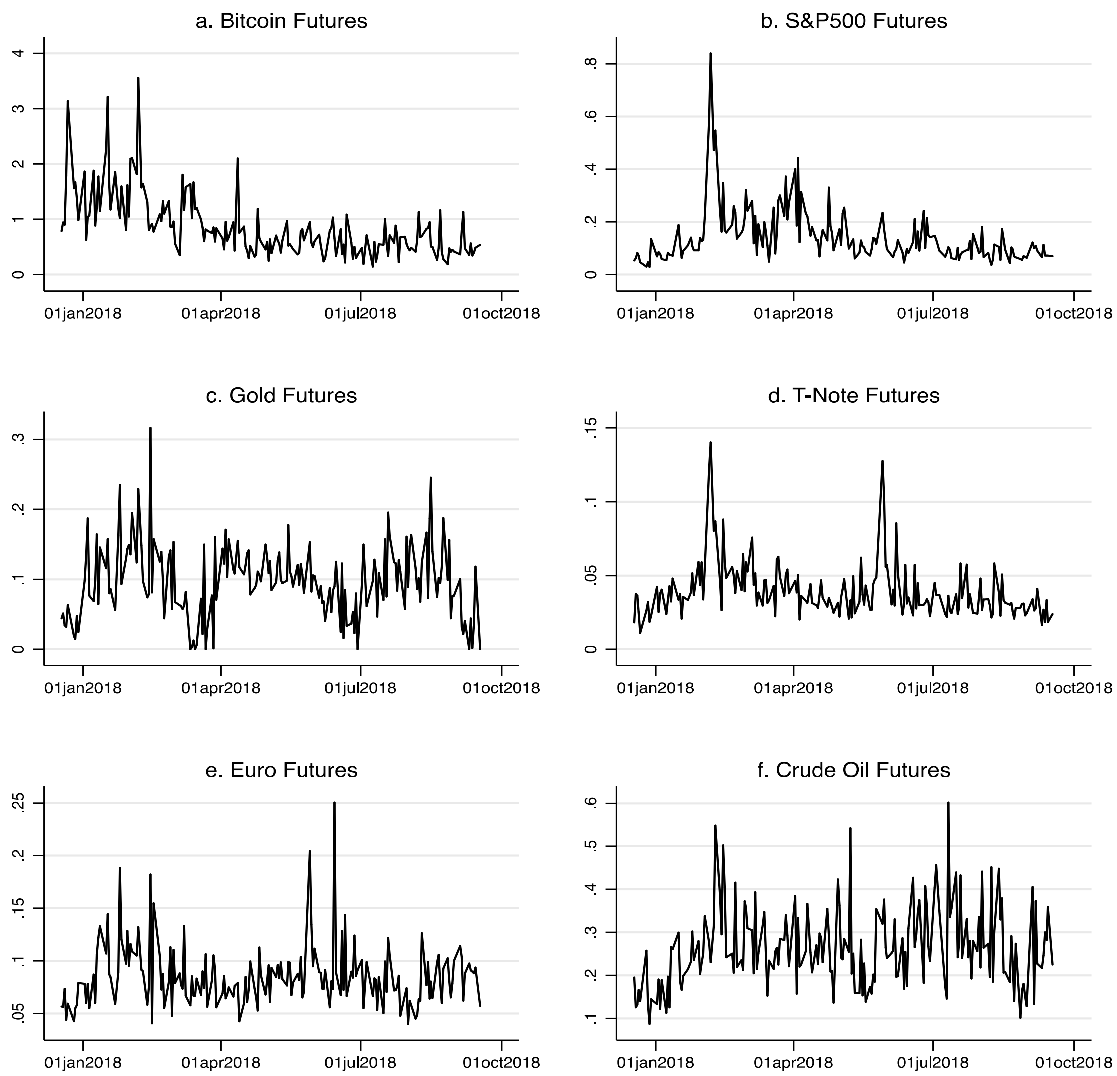
The Garman-Klass formula utilizes 4 pieces of price information observed in a given day: High, low, open and close price. Beckers (1983) has shown that the Garman-Klass volatility is robust and performs better than volatility estimated from historical closing prices. Since Equation 1 generates variances, we take the square root of these values to measure the volatility of the assets included in this study. Table 4 provides descriptive statistics for the Garman-Klass volatilities for the bitcoin spot and futures markets, as well as assets that enjoy active futures markets.

Table 4. Descriptive Statistics of the Garman-Klass Annualized Volatility (12/18/2018-09/17/2018)

Variable	Obs	Mean	Std. Dev.	Min	Max
Bitcoin Futures	184	0.905	0.551	0.144	3.557
Bitcoin Spot	184	0.733	0.561	0.153	3.669
E-Mini S&P 500 Futures	184	0.141	0.104	0.030	0.840
Gold Futures	184	0.097	0.053	0.000	0.316
10 Year T-Note Futures	184	0.039	0.019	0.011	0.140
Euro Futures	184	0.085	0.029	0.040	0.250
LS Crude Oil Futures	184	0.264	0.093	0.087	0.602

Table 4 shows the descriptive statistics on the Garman-Klass annualized volatilities calculated for CME bitcoin futures, bitcoin spot and selected futures prices. It is interesting to note that the mean volatilities of bitcoin futures and bitcoin spot are much higher than those of the E-mini S&P500, gold, 10-year-T-note, euro and crude oil futures contracts during the study period. In fact, the bitcoin futures volatility is about 10 times larger than gold and euro futures, about 6 times larger than the E-mini S&P 500 futures and about 23 times larger than the 10-year T-Note futures.[12] The annualized price volatility of 90.5% for the bitcoin futures contract is striking and is not seen often in the futures market. Also, the higher volatility in bitcoin futures than in bitcoin spot is important and noteworthy because they should exhibit a very similar magnitude.

Figure 4. The Garman-Klass Annualized Volatility of Bitcoin Futures and Selected Futures Contracts (12/18/2018-09/17/2018)



We provide a visual comparison of the Garman-Klass volatilities for the futures contracts via the graphs displayed in Figure 4. This set of graphs shows the Garman-Klass volatility for selected futures contracts which provide a visual comparison of price volatility across different types of futures contracts. Noting that the scale of the bitcoin futures graph dwarfs the other graphs, it shows clearly the extremely large volatility in bitcoin futures as compared to the other futures contracts. However, we find visually a volatility pattern that is similar to all futures contracts. The price volatility is clearly higher before April 1, 2018 than after, except the case of crude oil.

[12] Similarly, Baek and Elbeck (2015) find that bitcoin price is 26 times more volatile than S&P 500.

To quantify and examine the relationship between the bitcoin futures volatility and the other assets volatilities, we calculate the Pearson product-moment correlation coefficients among the selected assets and present them in Table 5.

Table 5. Pearson Product-moment Correlation Coefficients of the Garman-Klass Annualized Volatilities (12/18/2018-09/17/2018)

	Bitcoin Futures	Bitcoin Spot	E-Mini S&P 500 Futures	Gold Futures	10 Year T-Note Futures	Euro Futures	LS Crude Oil Futures
Bitcoin Futures	1.000						
Bitcoin Spot	0.928	1.000					
E-Mini S&P 500 Futures	0.286	0.253	1.000				
Gold Futures	0.045	0.037	0.239	1.000			
10 Year T-Note Futures	0.220	0.169	0.664	0.334	1.000		
Euro Futures	0.078	0.025	0.159	0.314	0.380	1.000	
LS Crude Oil Futures	-0.122	-0.181	0.290	0.155	0.235	0.055	1.000

The correlation coefficients in Table 5 confirm the visual patterns we observed in Figure 4 but reveal that the bitcoin futures volatility behaves very differently from other asset markets. The small positive correlation coefficients with E-mini S&P 500 and 10-year T-Note futures show the small overall market sensitivity linked to bitcoin futures while the near-zero coefficients with gold and euro futures show virtually no relationship with bitcoin futures at all. The negative correlation coefficient with the crude oil futures price volatility may be a reflection of different trading environments where crude oil is closely anchored to the macroeconomic fluctuation but bitcoin is not. Finally, it is not surprising that the bitcoin futures price volatility has the strongest positive correlation with bitcoin spot price volatility.

3. Changing Volatility

In Section 2 we used the graphs in Figures 1 and 4 to identify what appears to be a regime shift in the bitcoin market volatility after April 1, 2018. In this section, we examine the regime shift by dividing the data into two subperiods: December 18, 2017 through March 31, 2018, and April 1, 2018 through September 17, 2018. Using regression analysis, we first explore how the volatilities of the bitcoin spot and futures markets behaved. Then, we examine how the bitcoin futures volatility behaved in relation to the established futures market volatilities during the two subperiods and the whole period.

3.1 Changing Bitcoin Volatility in Three Separate Periods

The following simple regression model, as expressed in Equation (2), is estimated where the bitcoin futures volatility is a function of the bitcoin spot volatility and then regressed on the bitcoin spot volatility. The usual regression estimation assumptions of normally, identically, and independently distributed error term are assumed.

$$\sigma_t^F = \alpha + \beta_F(\sigma_t^C) + e_t \quad (2)$$

where σ_t^F represents the square root of the Garman-Klass variance for the nearby bitcoin futures price, and σ_t^C means the square root of the Garman-Klass variance for the bitcoin spot price at time t with i.i.d errors of e_t.

The statistical significance of the null hypothesis that the slope coefficient, β_F, is equal to 1 will indicate if the change in bitcoin futures volatility is the same as that in bitcoin spot volatility. The magnitude and sign of the intercept term, α, will indicate the presence of a fixed effect.

The entire study period, December 18, 2017 through September 17, 2018, is divided into two subperiods: December 18, 2017 through March 31, 2018, and April 1, 2018 through September 17, 2018. The regression Equation (2) is estimated for the three periods: the first estimation is for the whole study period, the second for the first subperiod, and the third for the second subperiod. Table 6 presents the regression results for these periods to show the changing relationships over time.

Table 6. Simple Regression Output of Bitcoin Futures Price Volatility on Bitcoin Spot Price Volatility

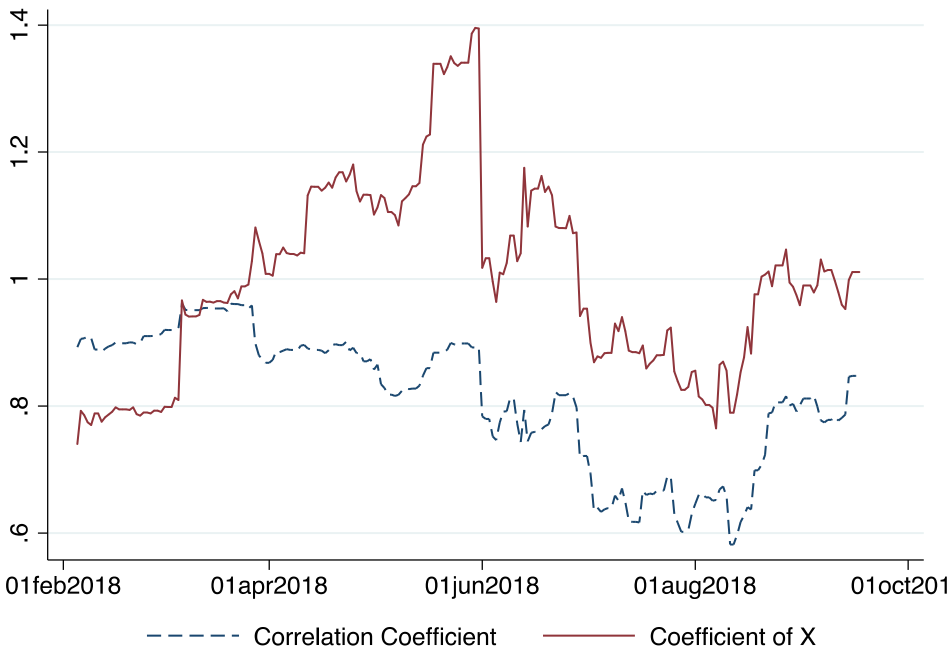
	Whole Period: 12/18/2018-09/17/2018	First Subperiod: 12/18/2018-03/31/2018	Second Subperiod: 04/01/2018-09/17/2018
β_F	0.912***	0.820***	1.064***
	(0.0271)	(0.0438)	(0.0761)
Intercept	0.178***	0.331***	0.080*
	(0.0250)	(0.0596)	(0.0390)
N	184	68	116
R^2	0.862	0.842	0.632

Standard errors in parentheses, * p<0.05, ** p<0.01, *** p<0.001

We note that there is a strong fixed effect present in all three periods when the intercept terms are all positive and significant at the .05 level of significance or lower. This shows that bitcoin futures volatility is generally higher than the bitcoin spot volatility during the December 18, 2017 through September 17, 2018 period. Moreover, all of the slope coefficients are positive and significant at .001 significance level, indicating that the change in bitcoin futures price volatility and spot price volatility have a positive and significant relationship. However, when the slope coefficients were tested against the null hypothesis of 1, the slope coefficients for the whole period and for the first subperiod generated t statistics of -3.24 and -4.11 respectively which meant the null hypothesis had to be rejected. However, the t statistic for the second subperiod slope was 0.841 which meant that the null hypothesis could not be rejected. Thus, these results lead us to conclude that the bitcoin futures volatility was clearly greater than the bitcoin spot volatility during all three periods of our study. However, the slope coefficients being less than one in both the whole study period and the first subperiod indicate that the change in the bitcoin futures volatility was less than the change in the bitcoin spot volatility after netting out the fixed effect. Even though this relationship was not observed during the second period when the bitcoin price became lower and more stable, the overall absolute level of bitcoin futures volatility is higher than that of bitcoin spot volatility in all three periods. To confirm this relationship, we estimate the 50-day rolling window regression coefficients from Equation (2), calculate the corresponding correlation coefficients as shown in Figures 5.

Prior to April 2018, correlation coefficients between bitcoin spot and futures prices were around 0.9, indicating close tandem movements. However, this relationship deteriorated until late August 2018. In the meantime, the regression coefficients peak around late May 2018 and declined thereafter. This indicates that at the initial stage of bitcoin futures trading, the bitcoin futures market was dominated and led by the relatively high bitcoin spot prices in 2017, showing high correlation coefficients above 0.8 and high regression coefficients above 1. However, from June 2018, both the correlation and regression coefficients declined, which indicates the gradual strengthening of the bitcoin futures market and less reliance on the bitcoin spot market.

Figure 5. Rolling Window Coefficient and Correlation Coefficients between Volatilities of Bitcoin Futures Price and Bitcoin Spot Price (Window Size = 50 Trading Days)



In summary, we note that when the bitcoin price was high during the first subperiod, the bitcoin futures price volatility was higher than the bitcoin spot price volatility. However, when the bitcoin price decreased and remained stable during the second subperiod, the sensitivity of changes in bitcoin spot and futures price volatility converged. Overall, for the whole period, the price volatility observed in the first subperiod dominates the bitcoin price volatility observed in the second subperiod. Consequently, its aggregated effect is manifested as the bitcoin futures price volatility being higher than the bitcoin spot price volatility.

3.2 Bitcoin Volatility Relationships to Other Futures Market Volatilities

Earlier in Table 5 we used correlations to document the relationships between the volatilities of the bitcoin markets and other futures markets. Now we use regression analysis for the three periods to examine the robustness of the relationship between the bitcoin futures price volatility and the price volatility of other futures contracts: E-mini S&P 500, Gold, 10-year T-

Note, Euros, and Crude Oil. We estimate the simple regression Equation (3) below under the usual regression assumptions:

$$\sigma_t^F = \alpha + \beta_i(\sigma_t^i) + e_t \quad (3)$$

where σ_t^F represents the square root of the Garman-Klass variance for the nearby bitcoin futures contract, and σ_t^i means the square root of the Garman-Klass variance for the established futures contract i at time t with e_t as errors. i represents one of the following futures contracts: E-mini S&P 500, Gold, 10 Year T-Note, Euros, and Crude Oil.

Table 7. Cochrane-Orcutt autoregressive estimation output of the daily volatility of bitcoin futures on alternative financial futures

	E-Mini S&P 500 Futures	Gold Futures	10-year T-Note Futures	Euro Futures	Crude Oil Futures
	A. Whole Period (12/18/2017-10/17/2018)				
β_i	1.159**	0.329	1.338	0.520	-0.211
	(0.399)	(0.636)	(2.016)	(1.037)	(0.339)
Intercept	0.681***	0.813***	0.792***	0.801***	0.901***
	(0.0936)	(0.101)	(0.112)	(0.119)	(0.120)
N	183	183	183	183	183
R^2	0.045	0.001	0.002	0.001	0.002
	B. First Subperiod (12/18/2018 - 3/31/2018)				
β_i	1.105	0.786	1.454	2.251	-0.794
	(0.618)	(1.141)	(3.750)	(2.166)	(0.873)
Intercept	1.109***	1.234***	1.241***	1.110***	1.507***
	(0.160)	(0.154)	(0.205)	(0.220)	(0.245)
N	67	67	67	67	67
R^2	0.047	0.007	0.002	0.016	0.013
	C. Second Subperiod (4/1/2018-9/17/2018)				
β_i	0.518	0.499	0.609	-0.737	0.0416
	(0.417)	(0.582)	(1.689)	(0.926)	(0.274)
Intercept	0.519***	0.531***	0.559***	0.642***	0.569***
	(0.0564)	(0.0642)	(0.0662)	(0.0829)	(0.0795)
N	115	115	115	115	115
R^2	0.013	0.006	0.001	0.006	0.000

Standard errors in parentheses, * p<0.05, ** p<0.01, *** p< 0.001

Once again, the statistical significance of the null hypothesis that the slope coefficient, β*i*, is equal to 1 will indicate if the change in bitcoin futures volatility is the same as that in other futures volatility. The magnitude and sign of the intercept term, α, will indicate the presence of a fixed effect. We initially assumed *i.i.d.* errors but the residuals indicate very strong positive serial correlations, so we estimate the model using the generalized least-squares method by Prais and Winsten (1954) proposed by Cochrane and Orcutt (1949). Table 7 presents the regression results.

Table 7 shows that there is a very strong positive fixed effect for the whole period. This indicates that bitcoin futures volatility has the highest volatility among the selected futures contracts. Also, when the slope coefficients were tested against the null hypothesis of 1, only the crude oil contract generated a t-statistic that justified rejecting the null hypothesis. This is consistent with the correlations between the bitcoin futures and the crude oil futures reported in Table 5 and with our earlier conclusion that crude oil is anchored to macroeconomic fluctuation while bitcoin is not. Failure to reject the null hypothesis of 1 for the E-mini S&P futures, gold futures, T-Note futures, and euro futures indicates that the change in bitcoin futures price volatility is the same as volatility change in these more established futures contracts. However, this is not the case for bitcoin spot and futures volatilities as observed in Table 6 where it was shown that the bitcoin futures volatility is greater than the bitcoin spot volatility.

Thus, there rises a puzzling question that deals with volatility. Given that the futures and spot markets should behave similarly, the bitcoin futures price volatility should not exceed the bitcoin spot price volatility. But it did, especially during the first subperiod. Can a possible answer lie in the fact that the volatility difference is caused by a lack of liquidity in the bitcoin futures market in comparison to that in bitcoin spot market? Given that the bitcoin spot market is much more liquid than the bitcoin futures market via its pure size difference, we find a possible answer to this question by examining the margin schemes employed by the exchange and the brokerage community.

4. The Role of Margin

The reason why bitcoin futures price volatility seems to be higher than the bitcoin spot price volatility during the study period may be found in the lack of optimal trading activity in the futures market. This is because the bitcoin futures contract is in the infant stage of development and requires an establishment of broad public acceptance which may come with time. That said, we find a possible answer in the margin requirements established by the exchange and more importantly, that practiced by the brokerage community that is represented by the futures commission merchants (FCMs). It is well known that the margins affect the trading volume and open interest. Therefore, we examine the adequacy of exchange margins and the brokerage margins next.

4.1 Exchange Margins

Bitcoin futures contracts are subject to daily price fluctuation limits of 7%, 13% and 20%. These limits apply to both upside and downside price changes relative to the prior day's bitcoin futures settlement price. The Chicago Mercantile Exchange (CME) margin requirements[13] for speculators in bitcoin futures contracts as of December 1, 2017 were 43% of the contract's notional value for the maintenance margin and initial margin set at 1.1 of maintenance margin, or 47.3%. For example, assume that a customer purchased one bitcoin futures contract at $6,230 per bitcoin. Since each contract controls 5 bitcoins, the notional value of the contract was $31,150. Consequently, the initial margin for the position was calculated as 1.1 x 0.43 or 0.473 of $31,150 which equals $14,734, while the maintenance margin, 0.43 of $31,150 which equals $13,394.

Given that the difference between the initial margin and maintenance margin is $1,340, it is about 4.3% of the futures contract's notional value, $31,150. This means that the exchange's maintenance margin is well below the daily price limit of 7% and thus, can work well in periods of normal volatility. Also, the initial margin of $13,394 which is equivalent to $2,678.80 per bitcoin is very similar to the price movement of one standard deviation of

[13] See https://www.cmegroup.com/education/bitcoin/cme-bitcoin-futures-frequently-asked-questions.html

$2,621.91 as observed in Table 2. This means that the initial margin covers about 68% of the daily price movements. Even though a higher margin that can cover 95% of price movements may be desirable, it seems that the exchange's initial and maintenance margins are set reasonably low enough to not hinder the trading activity. While this finding is encouraging to the trading activity, a quite different story is told by the role and impact of actual margins required the customers by brokerage firms.

4.2 Brokerage Margins

It is known that the brokerage community sets their own margins to protect themselves from possible customer defaults. Even if they wish to have a larger volume of trading to generate larger revenue, they must put their financial security over profit. In the case of bitcoin futures, due to the extreme price volatility observed in the bitcoin spot market in 2016 and 2017, brokerage firms decided to set their own customer margins far above those set by the exchange. For example, the margin requirements for a speculative account at a prominent futures brokerage firm based in Chicago were 110% of notional value for initial margin and 94% of notional value for maintenance margin[14]. In addition, the brokerage firm required an account balance of $250,000 and only allowed open positions in 3 bitcoin futures contracts[15]. Therefore, when the notional value of a bitcoin futures contract is $31,150 as in the previous example, a customer must post an initial margin of 1.1 times $31,150 which equals $34,265. The maintenance margin is 0.94 of $31,150 which equals $29,281. These levels of a brokerage firm's margins are more than double the exchange margins and clearly not in line with the risk that the exchange saw. Given that one standard deviation of bitcoin futures price is $2,621.91, which is $13,109.55 per contract, the initial margin of $34,265 per contract can cover 2.6 standard-deviation movements in bitcoin futures price, which corresponds to an approximately 99.5% of all price movements. While it is understandable for the brokerage community to set their own margins higher than those of the exchange in anticipation of their customer default risk, the impact of high brokerage margins on trading volume can be very drastically negative. That is what we suspect to be the cause of reduced liquidity in the bitcoin futures market and the reason behind the slow downward price adjustment in bitcoin price that Hale, Krishnamurthy, Kudlyak, and Shultz (2018) questioned, given the short-sale opportunity made available via the futures market. The brokerage community being afraid of the customers' potential default possibility in trading bitcoin futures have often set a margin at 100% or higher of the notional value of the futures contract. This can clearly hinder the growth of the bitcoin futures trading and in fact, can choke off the market liquidity that is necessary for the market growth. Consequently, the impact of short-sale opportunities on bitcoin price was not allowed to fully propagate during the early stage of bitcoin futures trading, resulting in a gradual downward price adjustment.

5. Summary and Conclusions

This paper explores empirically the behavior of the Chicago Mercantile Exchange (CME) bitcoin futures contract during the time period between the launch of the CME bitcoin futures contract on December 18, 2017, and September 17, 2018. Using the Garman-Klass volatility measure, the price volatility of the CME futures contract is compared with that of the bitcoin spot market. We find that the bitcoin futures market shows a higher price volatility than the bitcoin spot market. Also, the Garman-Klass volatility of bitcoin futures prices is compared

[14] These levels of margin requirements were not unique to this brokerage firm but widely practiced by many other brokerage firms in the industry as confirmed by personal interviews.
[15] Once again, this type of non-margin requirements was not unique to the firm we interviewed. There were wide variations among brokerage houses regarding non-margin requirements for bitcoin futures trading.

with that of different futures contracts such as the E-mini S&P 500, gold, 10-year T-Note, euro, and crude oil futures to examine the relative volatility of the bitcoin futures contract. We find that the bitcoin futures market exhibits a relatively higher volatility than all other futures markets.

When the ratio of trading volume over open interest is used to measure market liquidity, the bitcoin futures market shows a mid-level liquidity of 0.788, indicating that one open interest is supported by 0.788 trading volume. On the other hand, the well-developed and highly-liquid futures markets such as the E-mini S&P 500 and 10-year T-Note show a liquidity ratio below 0.5, indicating that one open interest is supported by less than 0.5 trading volume. This means that open interest is larger than trading volume, which is a characteristic of a well-established futures market. As for the less-developed and less-liquid futures markets such as the gold and crude oil futures, the liquidity ratio is close to 1, indicating that trading volume is as large as the open interest.

When the Garman-Klass volatilities of selected futures markets are analyzed via simple regression models for two subperiods and the whole period of study, we find the bitcoin futures price having the dominantly higher volatility than all the other markets. In particular, contrary to common expectation, the bitcoin futures price volatility is higher than the bitcoin spot price volatility. Also, the short-sale opportunities available via the futures market did not bring about an immediate downward price adjustment in bitcoin. To explain the reason behind these observations, we examine the margin requirements set by the exchange and the brokerage community. We find while the exchange margin is set to meet the normal price volatility that can cover the daily price movements within one standard deviation, the brokerage margin for bitcoin futures is set at beyond two standard deviations. In addition, brokerage firms require customers to meet non-margin requirements such as high net account balance and open position limits. We conclude that these relatively high margin and non-margin requirements of brokerage firms discourage trading activity and thus, dampen the development of liquidity that is needed to build the bitcoin futures market. Consequently, the brokerage margin has room to be adjusted downward to a level that secures the brokerage firms' financial health and at the same time, encourages more active participation of the customers. While there are many studies on the relationship between margins and price volatility, Hardouvelis and Kim (1995), for example, look at the metal futures and conclude that increased exchange margins reduce trading volume but decreased exchange margins have unclear impact on trading volume. We find the conclusions of the Hardouvelis and Kim study and others not applicable to our conclusion because they do not examine the role and impact of brokerage firms' margin and non-margin requirements on the growth of trading volume and liquidity.

Overall, however, we understand the limited scope of this study due to the limited data observed during a very short time period. Despite this shortcoming, we have verified the high volatility of bitcoin futures price relative to selected futures markets and provide a valuable insight into the impact of the brokerage firms' margin and non-margin requirements on the development of the bitcoin futures market.

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