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Price Discovery in the Bitcoin Spot and Derivatives Markets

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Executive Summary:

The purpose of this study is to determine the relationship between unregulated spot and derivatives Bitcoin markets, and which market leads the other in pricing. The conclusions from our study showed that derivatives market more frequently lead price discovery of Bitcoin. However, further analyses showed the spot market is more likely to indicate the direction of price movement while the derivatives market indicates the magnitude of the price movement. Since these may seem contradictory on the surface, we discuss areas for further study later in the paper. In an effort to expand upon the initial question and study the relationships between the spot and derivatives markets, we completed several arbitrage studies and concluded that frequent arbitrage opportunities exist both within and across markets.

In order to reach these conclusions, we performed field research with individuals both in traditional financial markets and in crypto markets, as well as studied tick-by-tick data from unregulated exchanges for the period of one year. The overarching opinion of our interviewees is that derivatives lead pricing during periods of high optimism, but that the relationship does not hold true during downturns. Most of our traders operate in the derivative space. Derivatives offer the opportunity to take a view on the asset class in a capital-efficient manner (high leverage), thereby inviting mostly retail investors to speculate on the price of Bitcoin and generating greater liquidity for the spot markets. On the data analysis side, we obtained tick level trading data from Kaiko, a digital assets provider. In total, we analyzed data from 25 spot exchanges and 10 derivative exchanges, 2 of which are futures exchanges and 8 of which are perpetual swaps. We performed several analyses on this data including summary statistics, lead-lag analysis, a deep dive into May 17, 2019, arbitrage index within markets, arbitrage profits within markets, and arbitrage profits across markets.

From the summary statistics, we found that within our dataset, BeQuant, Huobi, and Quoine have the largest value traded in the spot markets. On the derivatives side, OkEX and BitMEX dominate the futures and perpetual swaps markets respectively.

The chief analysis we leveraged to produce our findings was the lead-lag analysis, which directly supports that the derivatives market more frequently leads the nexus of price discovery of Bitcoin. Specifically, OkEX has received the highest score on our lead-lag analysis. Furthermore, the study shows that the spot market plays an important role in price discovery. As we see in our deep-dive on the May 17th flash crash of 2019, there is evidence that the spot market signals the direction of Bitcoin price discovery towards a higher or lower price. Following that direction, in moments of high volatility, the derivatives markets then lead the magnitude of price discovery and determine how large the moves in price are. We found that this was the case in the May 17th flash crash and it led to the overall Bitcoin price crashing down within a matter of seconds.

Moving into the arbitrage studies, we found that the spot market has a much higher arbitrage index than the derivatives market, suggesting that the price spread is larger across spot exchanges than derivative exchanges. Within derivative markets however, futures have a higher arbitrage index than perpetual swaps. Apart from an arbitrage index, we also looked at arbitrage profits in order to quantify the magnitude of the arbitrage opportunities. We found that the profits in the derivatives market are much larger than the spot market, but they are also much less frequent. For the final step in the arbitrage study, we looked at opportunities across markets. We found that frequent arbitrage opportunities exist across markets, with slightly larger profits in the spot to perpetual swaps market. Furthermore, we investigated how these arbitrage opportunities are most likely executed, and what we found is that it is most common to short the spot and long the derivative.

We acknowledge that this study is not fully encompassing of all exchanges in the spot markets and derivatives markets, and in addition we are unable to take into consideration the potential fake volumes being reported on tick-by-tick trading data. We discuss these and other limitations at the end of the paper along with a series of interesting follow-ups to this study that could make for very impactful findings towards the institutionalized trading of Bitcoin.

Project Problem and Scope:

We were tasked with trying to determine whether price discovery occurs in the unregulated bitcoin spot market or bitcoin derivatives market, specifically focusing on futures and perpetual swaps. In general, we concluded that derivatives market more frequently lead price discovery of Bitcoin. Further analyses showed the spot market is more likely to indicate the direction of price movement while the derivatives market indicates the magnitude of the price movement. Finally, we also concluded that frequent arbitrage opportunities exist both within and across markets.

To arrive at these conclusions, we conducted primary research through interviews with traders in traditional and cryptocurrency derivatives markets as well as secondary research to understand the unique aspects of a perpetual swap, a derivative unique to bitcoin. These insights were used to better understand the cryptocurrency market and determine how to structure our analysis. During our research, we found two analysis methodologies that we believed would help determine where price discovery occurred as well as the relationship between markets: creating and analyzing a lead/lag analysis of price moves greater than $100 and an arbitrage index. To complete these analyses, we used tick level trading data from Kaiko, a digital assets data provider. In total, we have data from 25 spot exchanges and 10 derivative exchanges, 2 of which are futures and 8 of which are perpetual swaps. The data includes the time of the trade, instrument, price, and amount and covers March 1, 2019 to March 1, 2020. In this paper, we will discuss the insights from traders, the mechanisms of a perpetual swap, and the findings of our data analysis to explain how we arrived at these conclusions.

Research Findings:

Trader Insights

As part of our market research, the team conducted numerous interviews with traders both in the crypto markets and in the broader financial markets; these traders have either a research or trading career in the crypto space or simply a personal interest in crypto. The purpose of these interviews was three-fold: 1) to develop our understanding of perpetual swaps (elaborated in the following 'Perpetual Swaps' section), 2) to understand how to best express a view in the crypto space, especially when related to available arbitrage opportunities, and 3) to ask the traders where they thought price discovery happened given their experience. We will now detail our findings related to points two and three from our conversations.

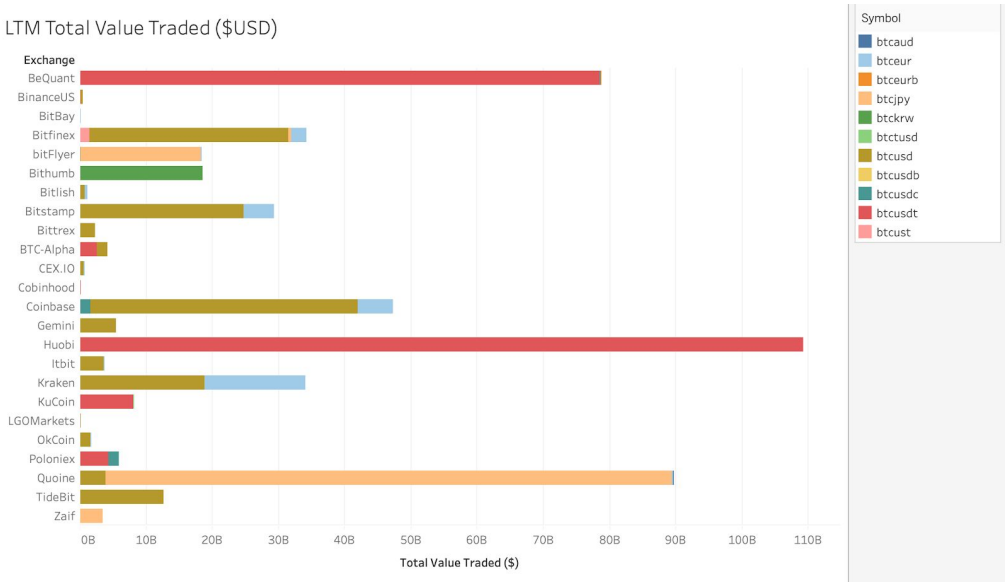
In asking traders to give an overview of both the regulated and unregulated crypto markets, the different mechanics between these two markets was immediately highlighted. In particular, regulated markets kept being referred to as "clunky" - in other words, operationally difficult platforms to trade on. The regulated US markets are clunky given a limited pool of participants and limited liquidity partially brought on by lower available leverage. Traders have to trade cash and derivative instruments on separate exchanges - for example, cash on Coinbase and futures on the CME. Lastly, unlike the unregulated markets, traders do not have 24/7 liquidity on regulated exchanges. All of the traders we addressed trade mostly on unregulated derivatives exchanges.

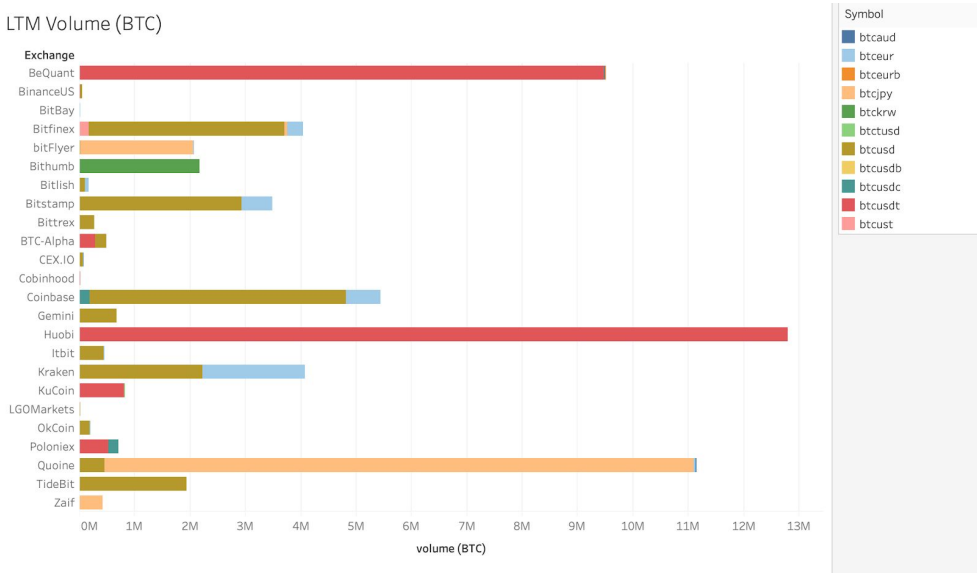
When we inquired as to the types of trades their respective funds placed, most of the traders stated that they were currently active in the derivative space. This was not the case in 2016 and 2017, when their firms traded mostly spot to capitalize on the available arbitrage opportunities. One such arbitrage opportunity was the "kimchi premium" of 2017, when traders purchased BTC on US exchanges such as Coinbase and sold for a higher price in South Korean exchanges. As per their commentary, the frequency of these arbitrage opportunities has begun to diminish as the industry has matured ultimately leading to the predominant use of derivatives to express a view on the market. In spite of the increased liquidity, currently it is still hard to deploy more than $5mm or $10mm in any coin other than Bitcoin and Ether. This is expected to change as the industry continues to grow and as institutional investors join the market. The large players

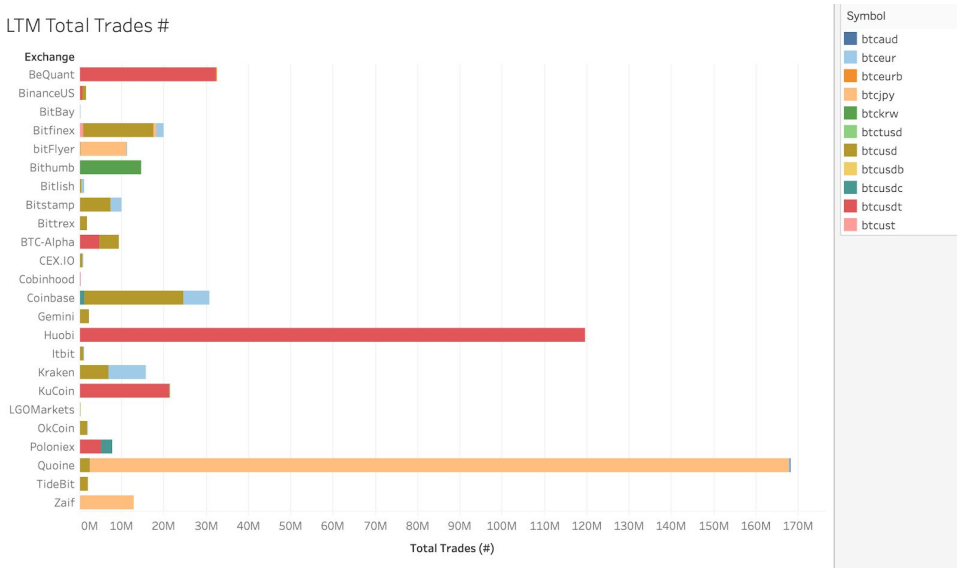
that usually take positions in regular cash markets over a long period of time (asset managers, pension funds, etc) are currently not active in the crypto space - volumes in crypto markets are driven by speculators and fast money. In recent news, as of March 30th 2020 some of Renaissance Technologies's funds, a $75bn hedge fund, are now "permitted to enter into bitcoin futures transactions" (CME futures only) (Source: SEC). Another reason as to the diminished arbitrage in cash markets is the first-mover advantage of quant-traders; quant-traders have been faster than fundamental traders to enter the crypto space, and as such have helped narrow the arbitrage gaps.

Derivatives are capital-efficient; cash is required as collateral, and this collateral requirement varies depending on the exchange and the available leverage (can reach up to 100x). Given the low capital requirement, derivatives attract a greater trading population (mostly retail) and help provide robust liquidity to cash markets. While the traders did not openly comment on their existing positions, they walked us through curve trades - contango, when futures are higher than spot (you short the future and you go long the spot) and backwardation, when spot is higher than futures - and perpetual swap trades. Due to the highly volatile nature of the asset class, trade horizons were mentioned to be any time from hours to longer term days or months.

All of the traders agreed that in their personal experience, they have seen derivatives markets lead the price action. In particular, derivatives really lead pricing during bullish periods, while the opposite holds true during downturns. There were two key insights that we were able to draw from the conversations: 1) cash exchanges, especially the less liquid ones, are still able to move the market, and 2) the relationship between cash and derivative markets might have shifted post the March 12th, 2020 crash. The crypto market is still extremely susceptible to large orders. To illustrate this point, one of the traders referred to the May 17th 2019 Bitstamp event. As can be seen on the graph below, Bitstamp is not the largest exchange by volume or by # of trades (all volumes below converted to USD).


LTM Total Value Traded ($USD)
Exchange
BeQuant
BinanceUS
BitBay
Bitfinex
bitFlyer
Bithumb
Bitlish
Bitstamp
Bittrex
BTC-Alpha
CEX.IO
Cobinhood
Coinbase
Gemini
Huobi
Itbit
Kraken
KuCoin
LGOMarkets
OkCoin
Poloniex
Quoine
TideBit
Zaif
0B
10B
20B
30B
40B
50B
60B
70B
80B
90B
100B
110B
Total Value Traded ($)
Symbol
btcaud
btceur
btceurb
btcjpy
btckrw
btctusd
btcusd
btcusdb
btcusdc
btcusdt
btcust


LTM Volume (BTC)
Exchange
BeQuant
BinanceUS
BitBay
Bitfinex
bitFlyer
Bithumb
Bitlish
Bitstamp
Bittrex
BTC-Alpha
CEX.IO
Cobinhood
Coinbase
Gemini
Huobi
Itbit
Kraken
KuCoin
LGOMarkets
OkCoin
Poloniex
Quoine
TideBit
Zaif
0M
1M
2M
3M
4M
5M
6M
7M
8M
9M
10M
11M
12M
13M
volume (BTC)
Symbol
btcaud
btceur
btceurb
btcjpy
btckrw
btctusd
btcusd
btcusdb
btcusdc
btcusdt
btcust



Nonetheless, a large sell order on the platform caused the price of BTC/USD to drop ~20% in less than 30 minutes and led to a liquidation of $250 million long positions on the BitMEX exchange (Source: CoinTelegraph, Twitter). Like in any asset class (Emerging Markets bonds and stocks), the lack of liquidity and of transparency made the price gap lower in the presence of a large order (or headlines).

The potential break in the pricing relationship between spot and derivatives after the March 12th, 2020 flash crash was highlighted by one of the traders. While he did not provide factual information to support his point, he speculated that after the Bitmex flash crash the risk-appetite of crypto investors has changed. These behavioral changes are: 1) a decreased desire for leverage and 2) an increased awareness of the counterparty risk of some of these exchanges. While there is no data to uphold these claims, another trader did claim that he had reassessed his trading and positions on Bitmex following the flash crash.

Perpetual Swaps

As part of our research, we looked at the largest and most liquid bitcoin derivative, perpetual swaps. In order to determine where price discovery occurs, we needed to understand what a perpetual swap is, how it's pricing, the mechanism behind its trading and who the biggest players in the market are. We focused our analysis of perpetual swaps on the bitcoin-U.S. dollar

swap from the largest perpetual swap exchange, BitMex. Below are our findings on perpetual swaps.

What is a Perpetual Swap?

A perpetual swap is a form of futures contract with no expiration date. A perpetual swap allows investors to trade cryptocurrencies against fiat currencies without having to own the underlying fiat currency. Contracts at BitMEX are $1 in size and the contracts use bitcoin as collateral and settlement currency.

Differences from Traditional Futures

Perpetual swaps have a number of key differences from traditional futures. First, perpetual swaps have no expiration date versus traditional futures which have contracts with expiration throughout the year. A trader can use stop orders to close perpetual swaps based on price but must manually close their position if they only want to trade for a specific time period. Traditional futures must be rolled at expiry to maintain a position.

Perpetual swaps are structured as inverse future contracts which creates a different payoff structure from traditional futures. Below is the payoff formula for a perpetual swap position:

$$\left(\frac{1}{Entry\ Price} - \frac{1}{Exit\ Price}\right) \times Number\ of\ Contracts$$

Traditional futures payoff is calculated as:

$$(Exit\ Price - Entry\ Price) \times Number\ of\ Contracts$$

Perpetual swaps have intra-day exchanges of bitcoin, called funding, with BitMEX's contract settling every eight hours at 12am, 8am and 4pm EST. At each of these times, longs and shorts exchange bitcoin based on a defined funding rate dependent upon the premium or discount relative to the spot price in the last eight hours. Without expiry, there is no settlement and a trader must close their position to receive realized gains or losses. Traditional futures do not have periodic payments and only have settlement at expiry or the close of the contract when gains or losses are disbursed.

Perpetual swaps typically trade very close to the spot price of bitcoin due to the funding rate mechanism. The funding rate changes based on whether the perpetual swap traded above or below the spot price in the last eight-hour settlement period. If the perpetual swap traded at a

premium, the funding rate is set at a level that hopes to draw shorts into the market and vice versa for trading at a discount. Traditional futures differ from spot prices and the difference is called basis. Futures prices differ primarily due to the time gap between spot and contract expiry but can also differ due to factors such as quality of the underlying commodity, delivery location, etc.

Perpetual swaps trade exclusively in unregulated markets, mostly offshore, which allow for significantly higher use of leverage. BitMEX only requires a 1% initial margin which means that up to 100x leverage is possible on positions. Regulated futures, such as the CME's bitcoin futures contracts require a 43% initial margin which equates to a maximum leverage level of ~2.3x.

Finally, we believe that the composition of participants in perpetual swap markets and traditional futures markets differ. The perpetual swap market attracts users of large amounts of leverage and a higher percentage of retail investors, a position reiterated based on our conversations with traders in the market. Traditional futures, particularly those in the regulated markets, are used primarily by institutional investors due to restrictions put in place by regulators.

Mechanics of a Perpetual Swap – Position Marking

BitMEX perpetual swaps are marked according to the fair price marking method. This mark price is used to determine unrealized profit/loss and liquidation prices. Below are the formulas used in the fair price marking method:

$$Funding\ Basis = Funding\ Rate \times \frac{Time\ Until\ Funding}{Funding\ Interval}$$

$$Fair\ Price = Index\ Price \times (1 + Funding\ Basis)$$

The funding basis is the percentage of the funding rate that a trader entering the contract at that moment will pay or receive at the end of a funding interval. The funding rate calculation is discussed in the next section. The time until funding is the next settlement point (12am, 8am or 4pm EST) minus the current time as a percentage of the eight-hour interval (e.g., if there were three hours left, the time until funding would be three divided by eight or 0.375). For BitMEX, the funding interval is three which represents the three eight-hour intervals where funding is exchanged. With the funding basis calculated, BitMEX determines the fair price by the above

formula such that the fair price is a combination of the spot price and the funding that must be paid or received at the time of pricing. The index price is determined based on spot prices from five indices: Coinbase (~45%), Bitstamp (~25%), Kraken (~20%), Gemini (~5%), Itbit (~3%) and Bittrex (~3%).

The mark price differs from the price at which perpetual swaps contracts are actually traded. The use of mark pricing helps protect traders from market manipulation and trading errors on the BitMEX platform. Since the fair price is determined solely based on the spot market prices and funding rates, it is not impacted by manipulation of perpetual swap pricing from large price swings. This protects traders from auto-liquidation processes should BitMEX perpetual pricing experience volatility. Perpetual swap traders are still exposed to large swings in the spot market that may be disconnected from pricing in the perpetual swap market.

Mechanics of a Perpetual Swap – Funding Rate

BitMEX uses a funding rate mechanism to keep perpetual swap prices in-line with the spot price. Funding rates are set based on interest rates and the price premium or discounts to the spot markets based on trading in the last funding interval. Funding rates can be positive or negative. If the funding rate is positive, longs pay shorts. If the funding rate is negative, shorts pay longs.

The interest rate component is a function of the base currency, bitcoin, and the quote currency, U.S. dollar. The interest rate, I, is calculated as:

$$Interest\ Rate\ (I) = \left(\frac{Interest\ Quote\ Index - Interest\ Base\ Index}{Funding\ Interval} \right)$$

The interest quote index is the cost of borrowing U.S. dollars and is a trade-weighted average price from the previous eight-hours interval. The interest base index is the cost of borrowing bitcoin and is a trade-weighted average price from the previous eight-hour interval. The funding interval is equal to three which represent the three eight-hour intervals where funding is exchanged.

The premium index component is a function of the fair price of the perpetual swap, the spot price, the bid price and the ask price. The premium index, P, is calculated as:

$$Premium\ Index\ (P) = \frac{Max(0, Impact\ Bid\ Price - Mark\ Price) - Max(0, Mark\ Price - Impact\ Ask\ Price)}{Spot\ Price} + Funding\ Basis\ Used\ in\ Ma$$

The impact bid and impact ask prices are the average price, across the five indices discussed in the prior section, to fill a ten-bitcoin order on the bid and ask side respectively. The spot price is the average spot price across the five indices discussed in the prior section. The funding basis calculation and description was discussed in the previous section. If perpetual swaps are trading at a premium to spot price, the premium index will be positive and longs will pay shorts (incentivizing shorts to join the market). If perpetual swaps are trading at a discount to the spot price, the premium index will be negative and the level of the premium index minus the interest rate will determine whether or not the funding rate is positive or negative. The premium index attempts to mitigate fluctuations between the perpetual swap price and the underlying bitcoin spot price.

Putting this all together, the total funding rate for the next eight-hour interval is calculated as:

$$Funding\ Rate\ (F) = Premium\ Index\ (P) + clamp(Interest\ Rate\ (I) - Premium\ Index\ (P),\ 0.05\%,\ -0.05\%)$$

If the premium index minus the interest index is between -0.05% and 0.05%, then the funding rate is equal to the interest rate. If the premium index is outside of that range, the funding rate is equal to the premium index plus 0.05% or minus 0.05% depending upon whether the interest rate minus the premium index is positive or negative. Below are some examples, from BitMEX, of funding rate calculations.

Interest Rate (I)	Premium Index §	Funding Rate (F)
0.03%	0.00%	0.03%
0.03%	0.06%	0.03%
0.03%	0.15%	0.10%

In the first two scenarios, the interest rate minus the premium index is between -0.05% and 0.05% making the funding rate equal to the interest rate. In the third scenario, the interest rate minus the premium rate is outside the bounds at -0.12%. In this scenario, the funding rate is then equal to 0.10% which is the premium index of 0.15% minus 0.05% since the interest rate minus the premium index is negative.

Mechanics of a Perpetual Swap – Margin

Initial margin is the minimum amount of bitcoin needed to be deposited to open a perpetual swap position. Initial margin rates for BitMEX perpetual swaps are 1% of the notional size of the trade in their account to open a position. In opening and closing a position with a market order, traders must pay an entry taker fee and an exit taker fee. Taker fees are currently 0.075% on BitMEX. For example, if a trader wants to enter into a trader worth 100 bitcoin, the trade must deposit 1.15 bitcoin into their account.

Maintenance margin levels for BitMEX are 0.40%, down from 0.50% at the beginning of 2020. If a trader's margin falls below the maintenance margin levels, they must either add margin to their account or have their position liquidated.

BitMEX allows for specification of margin within a trader's account. This means that traders can specify how much margin to apply to specific trades without it impacting the remaining bitcoin in their account. For example, let's assume a trader has ten bitcoins in their account and wants to enter a trade that requires an initial margin of one bitcoin. The trader adds one bitcoin of margin specifically to that trade and the remaining nine bitcoins are unaffected. When BitMEX looks for maintenance margin levels, it only looks at the bitcoin specified to the individual contract rather than using the remaining bitcoin in the account for maintenance margin calculations.

Mechanics of a Perpetual Swap – Liquidation

If a trader's margin levels fall below the maintenance margin levels, BitMEX will ask for more margin to protect the position. If the trader cannot, or will not, add margin to the trade, BitMEX begins looking for ways to get the trader up to the necessary maintenance margin levels. First, BitMEX cancels any open orders in the contract in an attempt to avoid a full liquidation of the traders. If the trader still cannot make margin after cancelling open orders, BitMEX will liquidate the positions.

BitMEX considers two prices for liquidation: the liquidation price and the bankruptcy price. The liquidation price is the price of the perpetual swap at which liquidation proceedings begin. The bankruptcy price is the price at which margin no longer exists. When liquidation

begins, BitMEX tries to close the position above the bankruptcy price. If BitMEX is able to close above the bankruptcy price, any remaining margin is taken by the exchange and added to the insurance fund. If BitMEX cannot close the position above the bankruptcy price, money is taken from the insurance fund to lower the bankruptcy price and try to close the position. For example, if a trade's bankruptcy price is $7,500 and BitMEX cannot close the position, they will take $50 from the insurance fund and attempt to execute a limit order at $7,450. When the insurance fund for a particular contract is depleted, auto-deleveraging occurs. At the time of this paper, the perpetual swap insurance fund was ~36,000 bitcoins.

Mechanics of a Perpetual Swap – Auto-Deleveraging

Auto-deleveraging is BitMEX's mechanism to maintain liquidity and solvency of their market. If positions are unable to be liquidated, and the insurance fund for the contract is depleted, auto-deleveraging will occur. Auto-deleveraging systematically deleverages opposing traders' positions (e.g., shorts if the longs have depleted the insurance fund). More profitable and higher leveraged traders are liquidated first as BitMEX believes that high leverage traders cause deleveraging events and should be the ones to pay in auto-deleveraging scenarios.

Priority ranking for auto-deleveraging is calculated as:

$$Ranking = PNL\ Percentage \times Effective\ Leverage\ (if\ PNL > 0)$$
$$Ranking = \frac{PNL\ Percentage}{Effective\ Leverage}\ (if\ PNL < 0)$$

Below are the calculations for the components of the ranking formula:

$$Effective\ Leverage = \frac{abs(Mark\ Value)}{(Mark\ Value - Bankrupt\ Value)}$$
$$PNL\ Percentage = \frac{Mark\ Value - Avg.\ Entry\ Value}{abs(Avg.\ Entry\ Value)}$$
$$Mark\ Value = Position\ Value\ at\ Mark\ Price$$
$$Bankrupt\ Value = Position\ Value\ at\ Bankruptcy\ Price$$
$$Avg.\ Entry\ Value = Position\ Value\ at\ the\ Average\ Entry\ Price$$

Traders are made aware of their auto-deleveraging ranking on BitMEX's website. When a trader is deleveraged, they are notified of the change and any open orders are cancelled. After being deleveraged, a trader is free to re-enter the market at current market rates. Auto-deleveraging events are intended to be a last resort but the reported $500mm notional liquidation in bitcoin and Ethereum futures show the potential for outsized impact.

Data Analysis: Summary Statistics

Before starting the data analysis, we computed a variety of summary statistics in order to learn more about our dataset. For each market, we looked at total number of trades, total value traded, average trade size, daily number of trades, and daily value traded. For the spot market, we also looked at the total volume traded in BTC. The table below shows the statistics for the spot market. Note that all dollar amounts have been converted to USD.

Exchange	symbol	total trades (#)	volume (BTC)	total value traded ($)	average trade size ($)	daily trades (#)	daily value traded ($)
BTC-Alpha	btcusd	4640376	191620.59	1674021039.81	360.7511632	14190	5119330.40
BTC-Alpha	btcusdt	4570818	291241.60	2536445347.00	554.9215364	13563	7526544.06
BeQuant	btceurb	2310	105.28	1016378.67	439.9907642	36	15880.92
BeQuant	btcusdb	10451	258.62	2312012.77	221.2240718	43	9673.69
BeQuant	btcusdc	95948	9029.21	78894164.30	822.2596021	262	215557.83
BeQuant	btcusdt	32268989	9486513.04	78544567027.36	2434.057262	89140	216973942.06
BinanceUS	btcusd	942772	34792.68	293882150.34	311.7213391	6831	2129580.80
BinanceUS	btcusdt	680395	14483.49	123171536.83	181.0294562	4930	892547.37
BitBay	btceur	83399	18836.84	154656057.73	1854.411417	230	427226.68
BitBay	btcusd	37323	1981.34	17340296.44	464.6008208	103	47901.37
Bitfinex	btceur	1773107	283521.75	2291632211.71	1292.43876	4844	6261290.20
Bitfinex	btcjpy	572612	54400.72	472715837.79	825.5430165	1564	1291573.33
Bitfinex	btcusd	16569956	3534180.83	29947706238.57	1807.349774	45149	81601379.40
Bitfinex	btcust	952395	165947.20	1475901150.34	1549.67335	2675	4145789.75
Bithumb	btckrw	14692560	2179652.61	18558480539.31	1263.120963	41271	52130563.31
Bitlish	btceur	542806	66306.12	459468330.26	846.4687757	1605	1359373.76
Bitlish	btcusd	511021	105040.52	718384946.17	1405.78361	1494	2100540.78
Bitstamp	btceur	2686321	566462.97	4627304109.18	1722.543251	7441	12818016.92
Bitstamp	btcusd	7252971	2924970.39	24735330530.70	3410.372181	20091	68518921.14
Bittrex	btcusd	1771990	269262.55	2258529329.64	1274.572277	4841	6170845.16
CEX.IO	btceur	220173	15312.65	119220553.35	541.4858014	601	325739.22
CEX.IO	btcusd	743824	73605.60	620346513.36	833.9963666	2032	1694935.83

Cobinhood	btcusdt	101249	13478.98	74961084.80	740.3637053	568	421129.69
Coinbase	btceur	6234348	632976.91	5301815053.06	850.4201326	17033	14485833.48
Coinbase	btcusd	23526334	4632778.56	40371395850.02	1716.008786	64279	110304360.25
Coinbase	btcusdc	1073465	181085.02	1625084238.99	1513.867931	2932	4440120.87
Gemini	btcusd	2233656	666391.03	5490291421.03	2457.984319	6102	15000796.23
Huobi	btcusdt	119586749	12797956.29	109246998939.95	913.5376608	326739	298489068.14
Itbit	btceur	10474	5620.87	47748951.92	4558.807706	33	151583.97
Itbit	btcusd	984263	444455.40	3549314261.07	3606.062872	2689	9697579.95
Kraken	btceur	8749543	1848168.05	15186240175.10	1735.660957	23905	41492459.49
Kraken	btcjpy	15866	505.87	4102124.40	258.5481154	44	11587.92
Kraken	btcusd	6827228	2225093.07	18846780424.35	2760.531862	18653	51493935.59
Kraken	btcusdc	8772	416.85	3976403.08	453.3063244	165	75026.47
Kraken	btcusdt	17343	1285.54	11539050.42	665.3433902	237	158069.18
KuCoin	btctusd	212283	2390.67	20874841.15	98.33496396	649	63837.43
KuCoin	btcusdt	21180969	808831.51	8079559019.20	381.4537012	64773	24708131.56
LGOMarkets	btcusd	37994	22141.15	189946204.42	4999.373702	463	2316417.13
OkCoin	btceur	8545	952.91	7790406.59	911.6918181	40	37097.17
OkCoin	btcusd	1815243	178524.86	1561786584.74	860.373286	5000	4302442.38
Poloniex	btcusdc	2587400	186243.70	1587962393.50	613.7289918	7050	4326873.01
Poloniex	btcusdt	5093713	518015.69	4363490495.74	856.6423934	13879	11889619.88
Quoine	btcaud	25991	1677.63	11703047.48	450.2730746	75	34020.49
Quoine	btceur	236420	24977.13	200537762.04	848.2267238	645	547917.38
Quoine	btcjpy	165234062	10652090.30	85518153034.86	517.5576512	450229	233019490.56
Quoine	btcusd	2433773	444847.11	3848885452.30	1581.448004	6631	10487426.30
Quoine	btcusdc	67160	2198.60	21243570.71	316.3128456	201	63603.51
TideBit	btcusd	2018836	1940752.49	12691753180.00	6286.668744	7917	49771581.10
Zaif	btcjpy	12845070	419228.67	3454000846.94	268.8970046	35095	9437160.78
bitFlyer	btceur	60587	8765.13	68042355.50	1123.052066	166	187444.51
bitFlyer	btcjpy	10938324	2037938.06	18072291263.28	1652.199301	29886	49377844.98
bitFlyer	btcusd	224222	15677.78	131262349.45	585.4124459	612	358640.30

Next we have the summary statistics for the futures market. Again, all dollar amounts have been converted to USD.

Exchange	symbol	total trades (#)	total value traded ($)	average trade size ($)	daily trades (#)	daily value traded ($)
Huobi Derivative Market	btccq	76984655	4830430922.00	62.74537337	587669	36873518.49
Huobi Derivative Market	btcnw	3930780	205899570.00	52.38135179	30005	1571752.44
OkEX	btcusd190927	159472	4664718.00	29.25101585	159472	4664718.00
OkEX	btcusd191004	736524	28210702.00	38.30248845	92065	3526337.75
OkEX	btcusd191011	887665	44362349.00	49.97645396	63404	3168739.21
OkEX	btcusd191018	834025	41676932.00	49.9708426	59573	2976923.71
OkEX	btcusd191025	822441	39705713.00	48.27788619	58745	2836122.36
OkEX	btcusd191101	1599201	56968535.00	35.62312367	114228	4069181.07
OkEX	btcusd191108	563531	25399968.00	45.07288508	56353	2539996.80
OkEX	btcusd191115	591526	21163579.00	35.77793537	59152	2116357.90
OkEX	btcusd191122	770630	32887665.00	42.67633624	55045	2349118.93
OkEX	btcusd191129	1197272	41254617.00	34.45718016	85519	2946758.36
OkEX	btcusd191227	41350577	732096378.00	17.70462303	469892	8319277.02
OkEX	btcusd200117	398586	8692272.00	21.80777047	132862	2897424.00
OkEX	btcusd200124	822930	27361557.00	33.24894827	82293	2736155.70
OkEX	btcusd200131	1020280	37945188.00	37.19095542	72877	2710370.57
OkEX	btcusd200207	1018557	38725319.00	38.01978583	72754	2766094.21
OkEX	btcusd200214	1234331	36208846.00	29.33479431	82288	2413923.07
OkEX	btcusd200221	1570342	38800727.00	24.7084565	104689	2586715.13
OkEX	btcusd200228	1360198	38351650.00	28.19563769	90679	2556776.67
OkEX	btcusd200306	649339	28044773.00	43.18972524	72148	3116085.89
OkEX	btcusd200313	56747	3773840.00	66.50289883	28373	1886920.00
OkEX	btcusd200327	26665649	552483163.00	20.7189093	567354	11754960.91
OkEX	btcusd200626	24026	380769.00	15.84820611	12013	190384.50

OkEX	btcusdnextweek	11646572	411504554.00	35.33267592	45494	1607439.66
OkEX	btcusdquarter	121656689	2535369504.00	20.84036254	475221	9903787.13
OkEX	btcusdt	98599162	19739047.65	0.200194883	269396	53931.82
OkEX	btcusdthisweek	26788853	815997460.00	30.46033587	104643	3187490.08
OkEX	btcusdthisweek	26788853	815997460.00	30.46033587	104643	3187490.08

Finally, below are the summary statistics for the perpetual swaps market with all dollar values converted to USD.

Exchange	**symbol**	**total trades (#)**	**total value traded ($)**	**average trade size ($)**	**daily trades (#)**	**daily value traded ($)**
Binance Futures	btcusdt	30463458	19098923.36	0.626945351	232545	145793.31
BitMEX	xbtusd	220996350	924906981471.00	4185.168585	603815	2527068255.39
Bitfinex	btcf0ustf0	279382	33313.53	0.119240072	1275	152.12
Bybit	btcusd	9322705	57828266198.00	6202.949273	127708	792168030.11
CryptoFacilities	pixbtusd	3360857	14096335477.00	4194.268152	10373	43507208.26
Deribit	btcperpetual	22066234	32000475122.00	1450.201023	60956	88399102.55
FTX	btcperp	754530	1268008.67	1.680527841	16402	27565.41
OkEX	btcusdperpetual	20190600	634933572.00	31.4469888	125407	3943686.78
OkEX	btcusdtswap	5326411	18015122503.00	3382.225386	81944	277155730.82

Data Analysis: Lead Lag Analysis

The lead lag study we performed is an examination into the price behavior of the universe of data we analyzed. Here is a detailed explanation of how we performed the study. Between the dates of March 1st, 2019 to March 1st, 2020, for every pair on every exchange, we looked at every 5-minute window that resulted in a price change of over $100. To further reduce the set of these windows, we exclude all events with low trading volume, which we define to be 30 trades within the 5-minute window. The total number of events we analyzed is 59,718. See below for the breakdown on the events, through the months.

Universe of Events from March 2019 to February 2020

Months	Mar-2019	Apr-2019	May-2019	June-2019	July-2019	Aug-2019
Events	18	2,687	8,037	5,862	7,722	7,223
Months	Sep-2019	Oct-2019	Nov-2019	Dec-2019	Jan-2020	Feb-2020
Events	971	722	3,954	369	13,806	8,347

We then created another subsect of the data, limiting events to have at least 5 exchanges that fit the criteria aforementioned. From these events, we found the price at the start, price five minutes later, and the price movements in between. In each event, we ranked the exchanges based on their correlations (at least 0.5), the biggest price move up or down, and the best price at a given time (each having equal weighting on the rank). We then gave, for each rank, a score; the first rank scored 1 point, the 2nd rank scored 0.5 points, the 3rd rank scored 0.33 points and the 4th rank scored 0.25 points. We then added the scores for each exchange and added them together to create a lead/lag score. Below are the overall results, and in the Appendix we have listed the results, by each month.

Rank	Exchange	Score
1	OkEX	149.33
2	Coinbase	105.33
3	Bitstamp	103.25
4	Quoine	102.42
5	Bitfinex	96.58
6	Kraken	61.17
7	BitMEX	45.25
8	bitFlyer	32.33
9	Zaif	29.58
10	Poloniex	29.33
11	KuCoin	27.75
12	BTC-Alpha	25.92
13	BeQuant	25.58
14	Huobi	25.33
15	Deribit	24.58

Rank	Exchange	Score
16	Bithumb	22.58
17	Gemini	19.17
18	CryptoFacilities	14.42
19	Huobi Derivativ	12.17
20	Bittrex	8.17
21	CEX.IO	7.58
22	OkCoin	6.17
23	TideBit	4.58
24	Itbit	4.42
25	FTX	2.58
26	Binance Futures	2.17
27	BinanceUS	1.50
28	Bybit	1.25
29	BitBay	1.00
30	Bitlish	0.25
30	LGOMarkets	0.25

The results are a bit surprising for the study. They suggest that the unregulated derivatives market leads in price discovery, for the majority of the part. There are a few things to

note. Namely, we expected to see Binance, Huobi and BeQuant much higher on the list of exchanges which lead in price discovery. As a follow-up to our analysis, we would like to consult with Kaiko on getting even more tick-by-tick data from Binance. We also want to highlight that this scoring method was based on a medium blog post, titled "An Analysis of Price Discovery in Bitcoin Spot Markets" written in the digital asset research section of Medium (https://medium.com/digitalassetresearch/an-analysis-of-price-discovery-in-bitcoin-spot-markets-7563fbf1c890). While we think this scoring method is really robust, it does not control for exchanges that have fake volume. The authors of the article had a vetting methodology that points out exchanges that likely have fake volume, but we would like to develop a methodology that integrates more into the process of scoring the exchanges.

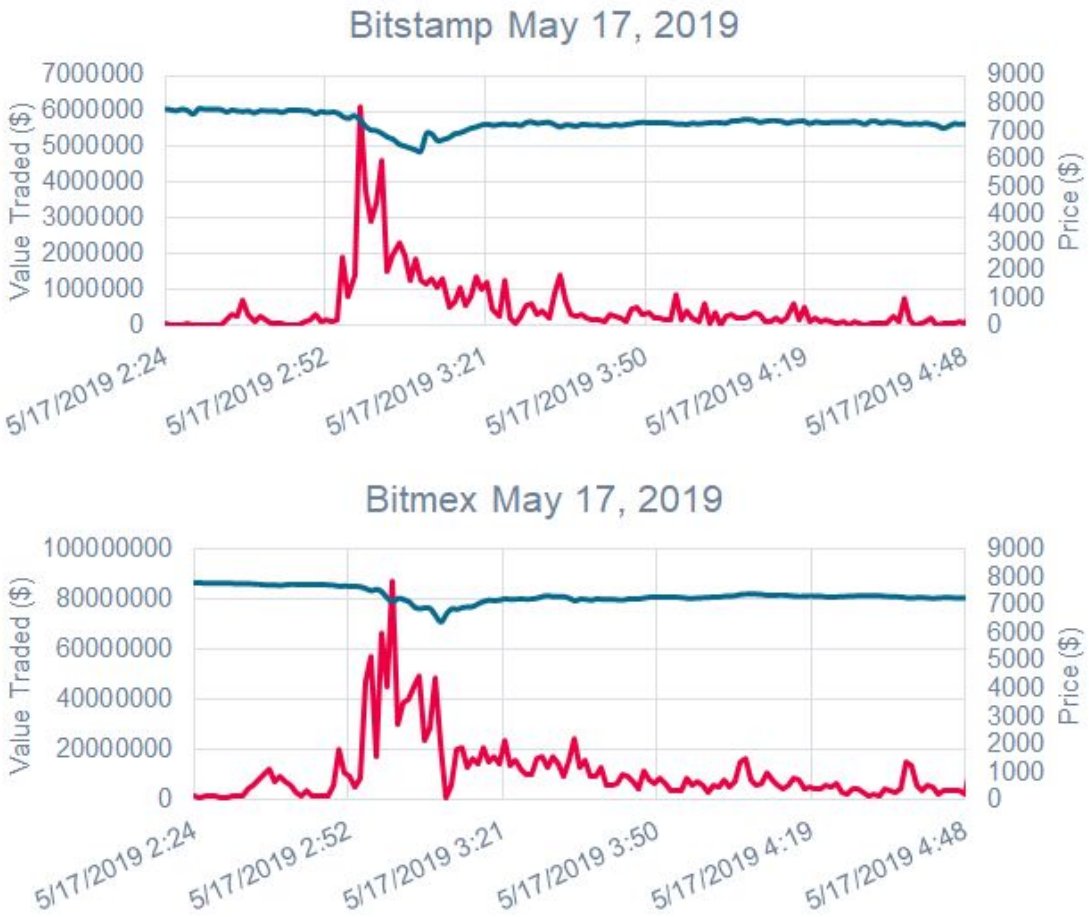
Data Analysis: Deep Dive on May 17, 2019

We decided to do a deep dive into May 17th, 2019 and study the Bitcoin flash crash that dropped almost $2000 in the matter of minutes, from $8000 down to $6100 and back to $7800. We chose this date because traders and researchers in the cryptocurrency derivatives space heavily cited and referenced this as clear evidence of manipulation. The resounding opinion we heard is that there were a series of large sell orders at low prices on Bitstamp, which caused BitMEX to crash and liquidate over $250 million in positions. It is important to note that Bitstamp comprises 25% of the price composition of the BitMEX price index:

Exchanges:	**Bitstamp**	**Bittrex**	**Coinbase**	**Gemini**	**Itbit**	**Kraken**
BitMEX BTC/USD Price	24.86%	2.53%	44.98%	4.61%	2.80%	20.22%

Source: https://www.bitmex.com/app/indices

In order to study this, we took a general look at the BitMEX and Bitstamp prices across May 16th to May 18th to see the trends in price and then isolate the time frame we would look into. After doing this, we realized that the majority of the activity occurred between 2:59 AM to 3:10 AM on May 17th.



We looked at every trade that occurred, across BitMEX, Bitstamp, and the general spot market (composed mostly of the Coinbase price). When analyzing the Bitstamp price, it was important for us to get a sense of how big the trades were, and how they compared to the average trade size of Bitstamp in the trade data of $1,722 **(see table below)**. We saw very interesting results. We see a series of large block trades, from a sell order of over 30 Bitcoin priced at around $6,300 (more than 100x the average trade size) to sell orders of over 100 Bitcoin priced at around $6,200 (more than 350x the average trade size), that push the BitMEX price down.

More specifically, we saw the BitMEX-Bitstamp price difference increase to 8.6% as the block trades occur at 3:08.52 AM. Not even a second afterwards, the price of BitMEX quickly follows to reduce the difference in price to 6.7%. As we trace the Bitstamp price, on its decline from $6,365 to $6,211, we see the price of BitMEX fall incredibly fast (in the span of 1 minute)

to $6,426 at a price difference of 3.5%. This is clearly evidence that Bitstamp significantly impacted the price of BitMEX. Furthermore, we can see that the price of the general Bitcoin to USD price pairing did not follow Bitstamp directly. In fact, the price of the general spot market followed BitMEX instead. Once BitMEX begins its cascade down, we see the difference in price, from BitMEX to the general spot market, increase as wide as 3%. Then, within just a few milliseconds, the price decreased from $6715 to $6495 and the difference in price decreased to 1.1%. See the table below for the detailed, millisecond-by-millisecond activity that highlights the price movement across BitMEX, Bitstamp and the general market.

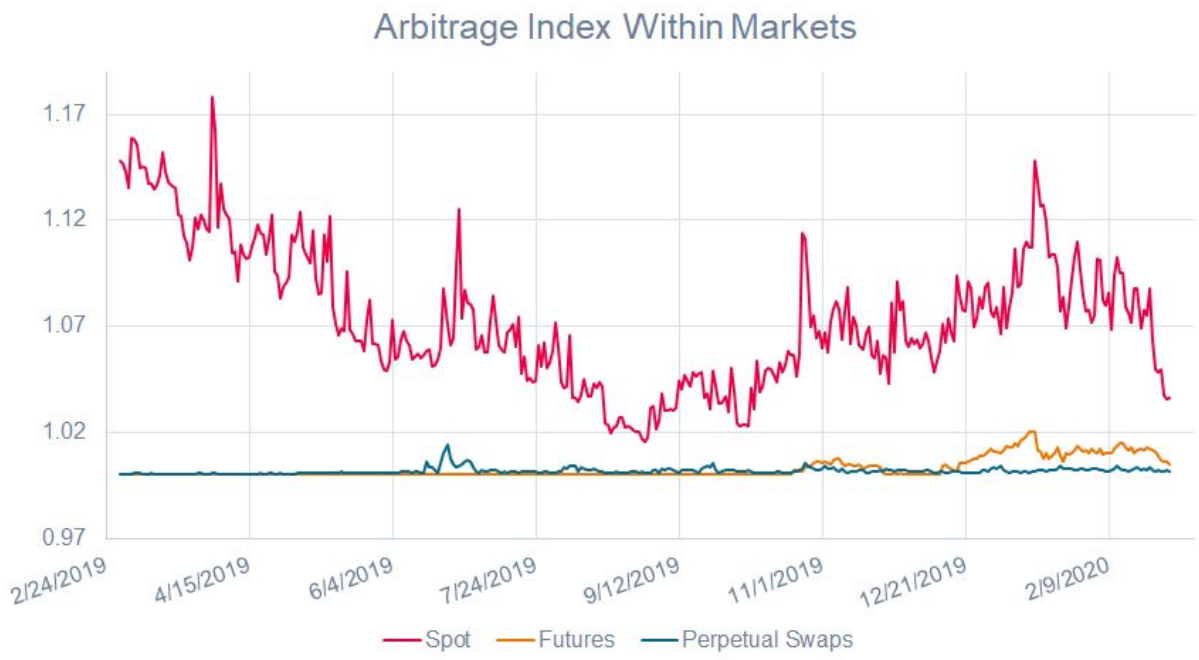
Huge Block Trades in Bitstamp impacting BitMEX and cascading into General Market

TimeStamp	BitMEX BTC_USD Px	Bitstamp BTC_USD Price	Bitstamp BTC_USD Vol	BitMEX-Bitstamp Price Difference %	Market BTC_USD Price	BitMEX - Market Price Difference %
3:08:52 AM	6,861.96	6,365.18	10.22 BTC	7.80%	6,880.84	0.28%
3:08:53 AM	6,890.56	6,356.60	1.79 BTC		6,910.50	
3:08:55 AM	6,837.60	6,376.31	1.67 BTC		6,899.50	
3:08:56 AM	6,904.34	6,355.80	6.04 BTC	8.63%	6,935.24	0.45%
3:09:01 AM	6,772.09	6,349.47	13.54 BTC	6.66%	6,863.13	1.34%
3:09:03 AM	6,770.20	6,338.00	1.75 BTC		6,690.19	
3:09:04 AM	6,820.51	6,338.00	4.66 BTC		6,687.36	
3:09:11 AM	6,798.34	6,326.00	2.03 BTC		6,787.48	
3:09:13 AM	6,855.25	6,320.00	1.77 BTC		6,668.94	
3:09:17 AM	6,756.63	6,682.72	1.06 BTC		6,817.22	
3:09:24 AM	6,688.21	6,302.40	2.02 BTC		6,745.38	
3:09:30 AM	6,688.21	6,287.05	58.83 BTC	6.38%	6,736.66	0.72%
3:09:32 AM	6,688.21	6,286.63	5.92 BTC	6.39%	6,824.66	2.04%
3:09:33 AM	6,577.91	6,284.00	8.54 BTC	4.68%	6,746.02	2.56%
3:09:38 AM	6,519.01	6,307.85	10.45 BTC	3.35%	6,715.60	3.02%
3:10:00 AM	6,519.01	6,249.00	15.01 BTC	4.32%	6,709.71	2.93%
3:10:07 AM	6,519.01	6,233.33	4.08 BTC	4.58%	6,704.53	2.85%
3:10:21 AM	6,426.58	6,211.63	6.82 BTC	3.46%	6,495.07	1.07%

Data Analysis: Arbitrage Index Within Markets

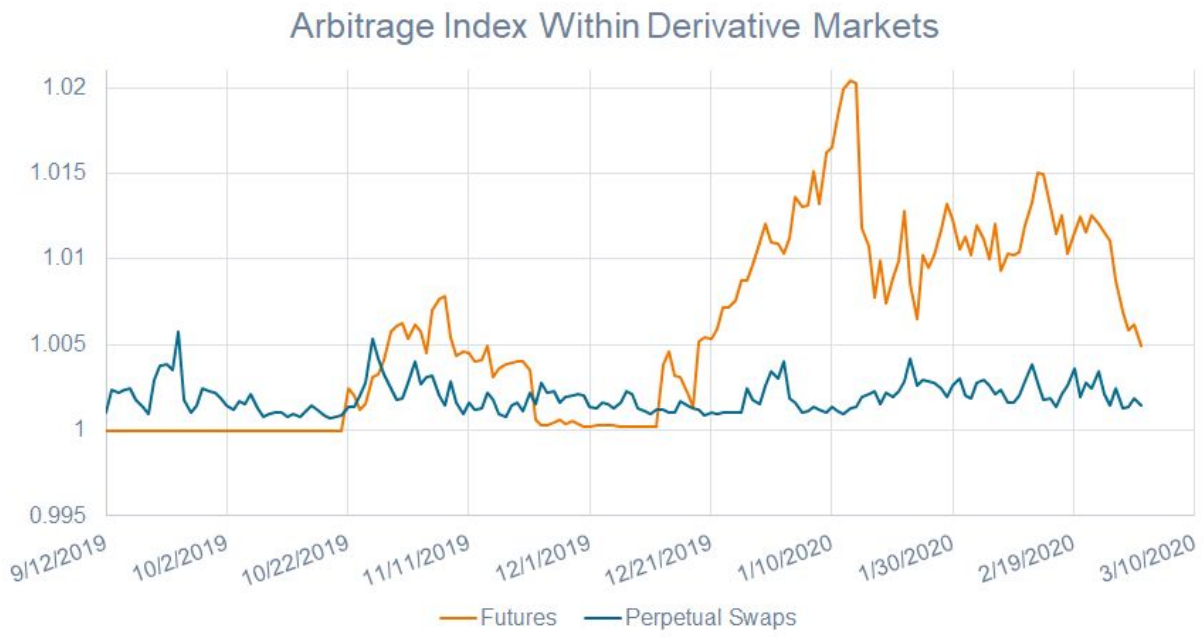
In order to calculate an arbitrage index within markets, we first calculated the volume weighted average price for each exchange at the minute level. Then, we divided the maximum price by the minimum price to get an arbitrage index for each minute. Finally, we aggregated the arbitrage index up to the daily level in order to reduce intra-day volatility (Source: Trading and Arbitrage in Cryptocurrency Markets).

Starting by looking at the arbitrage index across all three markets, we see that most arbitrage opportunities exist in the spot market, with the largest spike occurring in early April of 2019.



This would suggest that the spread of prices within markets is much larger in the spot market versus the derivative markets.

Next we looked at the arbitrage index for only the derivatives markets. We only looked at late October 2019 to March 2020 because prior to October 2019, we only had data for one futures exchange, so the arbitrage index is 1. Within this time period, we can see that the futures market has more arbitrage opportunities with a spike around mid-January 2020. Across the entire time period, arbitrage opportunities in the perpetual swaps market are quite low, which suggests that there is a small price spread within that market.



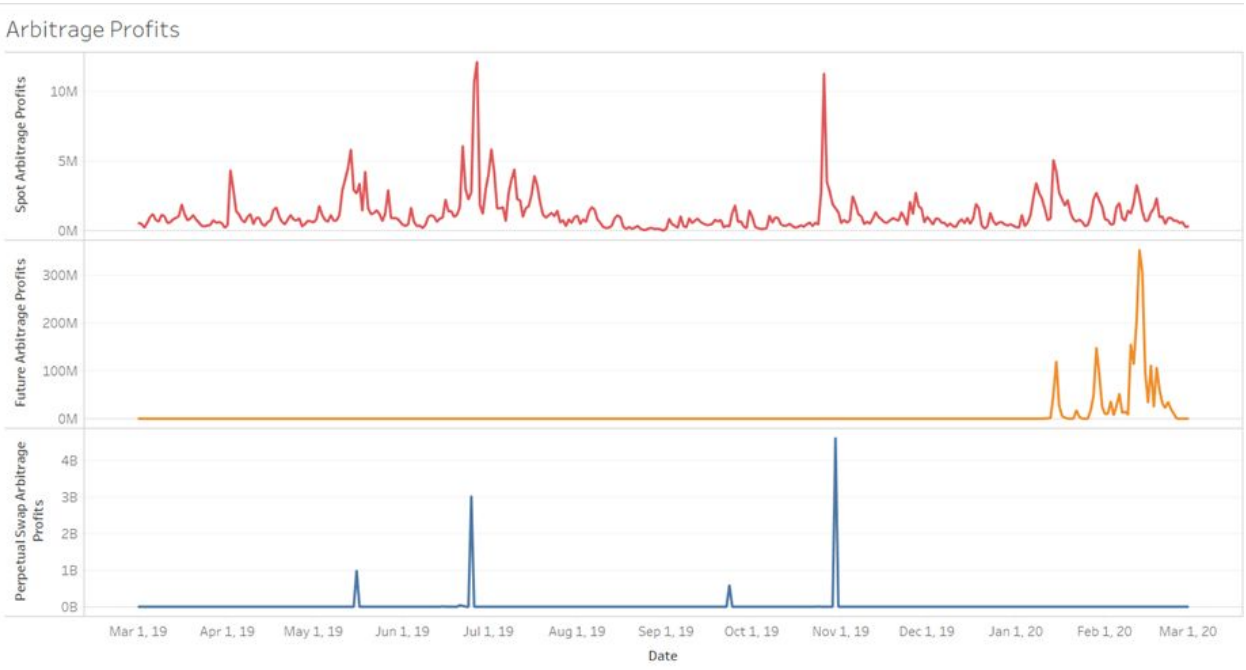
Data Analysis: Arbitrage Profits Within Markets

Now that we know arbitrage opportunities exist within markets, we wanted to quantify the magnitude of the opportunity by calculating arbitrage profits. In order to calculate arbitrage profits, we first calculated the volume weighted average price for each exchange at the minute level. Next, we determined the maximum and minimum price within each minute along with their corresponding volumes. From here, we calculated arbitrage profits for each minute using the formula below:

Arbitrage profits = (Max Price - Min Price) * MIN(Max Volume, Min Volume)

We used the minimum volume in order to ensure that there was adequate demand for the trade to occur. We also only looked at minutes where the difference between the minimum and maximum price was larger than 2%. Finally, we aggregated the arbitrage profits up to the daily level by summing profits over each minute (Source: Trading and Arbitrage in Cryptocurrency Markets).

Looking at all three markets, we see that arbitrage profit opportunities are most frequent in the spot market, which makes sense based on the arbitrage index calculated in the previous section.



However, we also see that while arbitrage profits are infrequent across the derivative markets, they do allow for much larger profits when they occur, particularly in the perpetual swaps market.

Data Analysis: Arbitrage Profits Across Markets

After looking at arbitrage profits within markets, we wanted to see what sort of potential arbitrage profits exist across spot and derivative markets. In order to calculate this, we first calculated the volume weighted average price for each exchange at the minute level. Then we determined the maximum and minimum price within each minute along with their corresponding volumes for both the spot and derivatives markets. From here, we calculated arbitrage profits for each minute using the formula below:

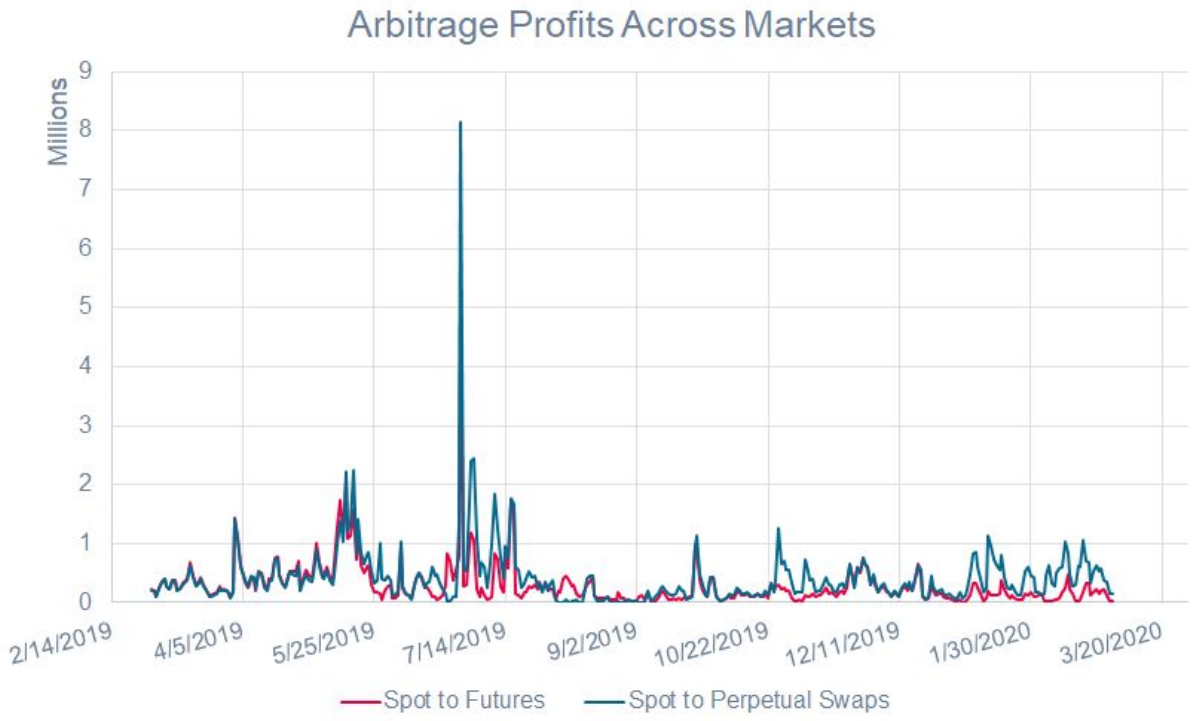
Arbitrage profits =

MAX(Spot Max Price, Der Max Price) - Min Price) * MIN(Max Volume, Min Volume)

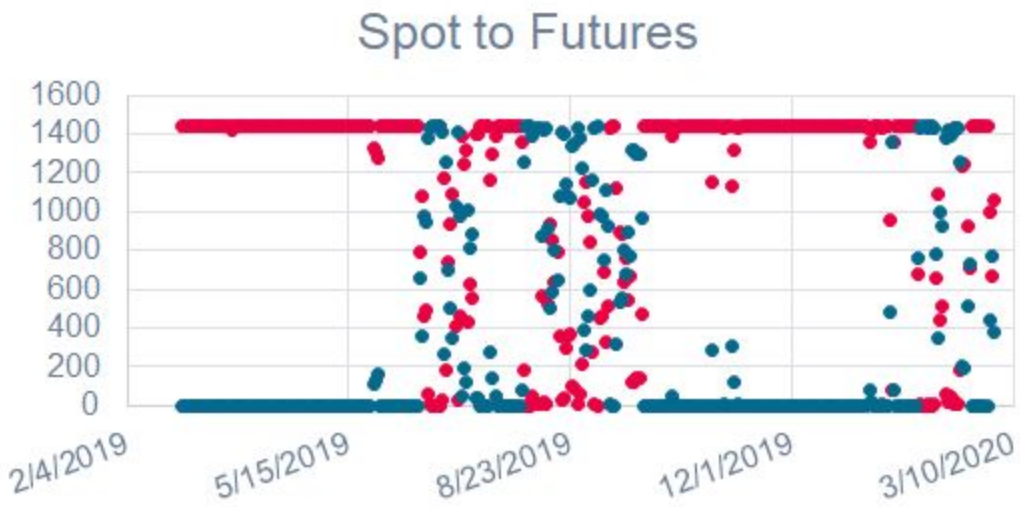
Note, the minimum price used is the price of the market not chosen for the maximum price. For example, if the spot market has the maximum price, then the minimum price is the minimum price in the derivatives market. Again, we used the minimum volume in order to ensure the trade

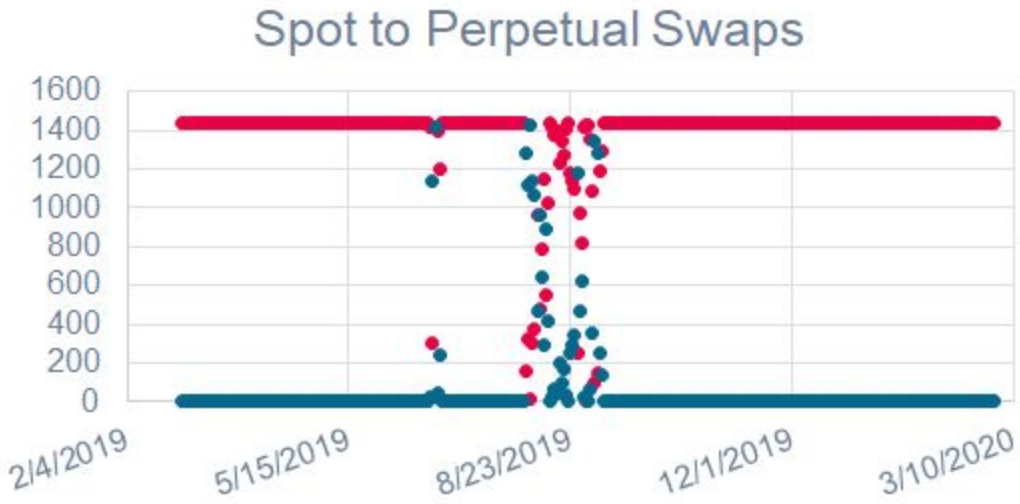
would be feasible. Finally, we aggregated the arbitrage profits up to the daily level by summing profits over each minute.

From the results, we can see there are arbitrage opportunities across both markets. Recently however, more profits are recognized from the spot market to the perpetual futures market. In both cases, the spike of profits occured in late June of 2019.



Apart from profits, we looked at how the arbitrage opportunity was most often implemented. In the graphs below, the red dots represent the minutes per day where the spot price was the maximum price, and the blue dots represent the minutes per day where the derivative price was the maximum price. As you can see, across both markets, it is more common to short the spot and long the derivative in order to recognize the arbitrage opportunity.


Spot to Futures
1600
1400
1200
1000
800
600
400
200
0
2/4/2019
5/15/2019
8/23/2019
12/1/2019
3/10/2020


Spot to Perpetual Swaps
1600
1400
1200
1000
800
600
400
200
0
2/4/2019
5/15/2019
8/23/2019
12/1/2019
3/10/2020

Limitations of the Study:

While this is a comprehensive study of tick-by-tick data for twelve months it just begins to scratch the surface of what goes on in crypto markets and hence might not necessarily be fully representative of the market or the players within the market. The asset class is extremely new and volatile, with bitcoin derivatives first coming into existence in 2017. Additionally, this asset class has become more popular during a period of unprecedented distortion in markets given fiscal stimulus and black swan events (ie COVID19). As such, we must be clear in vocalizing the limitations of the study given the time and computational constraints.

The first limitation is regarding the scope - in order to take the study one step further, we would have liked to extend the time period of the study to include data from 2017 to today. This would have included trades since the inception of the derivative space, and might have either confirmed our findings or proved that the lead lag relationship between spot and derivative markets oscillates (this concern was in fact vocalized by some of the traders we interviewed, please refer to the *Trader Insights* section). Additional data would perhaps help clarify our intuitions on the lead-lag analysis, and to better understand why the results are what they are. One exchange where we lacked data was Binance - a key market player, but unfortunately one that we did not have full access to. Furthermore, we have decided to group stablecoins, such as Tether and USDC, as fiat for the purposes of this analysis. This does not, clearly, take into consideration the credit risk that stablecoins pose. Furthermore, a concern we have with the data is volume manipulation; while this is extremely hard to point out in the data set, we examined over 30 unregulated exchanges that could have significantly altered our results given fake volumes. The next step would be to work with Kaiko and traders to perhaps create a sample set of exchanges with more trustworthy figures, and to re-run the study.

A second limitation of the study are the thresholds and the dates evaluated. While we stuck to thresholds and dates that were suggested in our conversation with traders, there were other thresholds and dates that we could have evaluated to substantiate our results. For example, there was a specific date in July when volatility and arbitrage profits from spot to perpetual futures spiked dramatically. Online research pointed to increased concerns over regulation of Facebook's Libra, however a deeper analysis of the data could have perhaps pointed to a

different cause. Doing deep dives on dates other than May 17th would perhaps also have helped clarify the consistency of the relationship between spot and derivatives; it would have been interesting and enlightening to find a period of a rapid increase (rather than decline) in the price of bitcoin to analyze what happened in the spot and derivatives market. This would have helped ascertain whether what was mentioned in *Trader Insights* holds true - that derivatives lead in bullish markets, and that spot markets lead in downturns.

Lastly, our study did not take into account trading fees or any structural barriers across markets when calculating arbitrage profits. The calculations are contingent on one market player capturing all the profits by making use of the whole minimum volume; while this is a useful calculation to understand the opportunities within the market, it is not a practical calculation. In addition, the trade opportunities discussed did not consider the real collateral that traders would need to put up, along with further mechanisms such as the funding rate for opportunities in the derivatives market, for those orders to be executable. This is an interesting follow-up to our study, which is done to highlight theoretical opportunities, and we would love to delve into this further as next steps.

Appendix:

Rank	Exchange	3/1/2019	4/1/2019	5/1/2019	6/1/2019	7/1/2019	8/1/2019	9/1/2019	10/1/2019	11/1/2019	12/1/2019	1/1/2020	2/1/2020	Total
1	**OkEX**	0.0	1.2	11.0	60.4	29.6	40.3	0.0	0.3	3.5	0.0	0.5	2.6	149.3
2	**Coinbase**	0.3	1.8	13.8	13.3	53.8	12.9	0.0	0.0	1.3	0.5	4.5	3.2	105.3
3	**Bitstamp**	1.5	2.5	16.1	4.4	52.8	12.3	0.0	0.0	3.1	4.2	2.8	3.8	103.3
4	**Quoine**	0.0	1.6	9.9	33.3	43.2	6.5	0.0	0.0	2.1	1.8	0.5	3.7	102.4
5	**Bitfinex**	1.5	3.1	10.3	15.6	39.6	12.5	0.0	0.0	6.5	0.6	4.1	2.9	96.6
6	**Kraken**	0.0	1.5	10.5	7.1	22.5	9.5	0.0	0.0	3.3	0.0	2.1	4.7	61.2
7	**BitMEX**	1.5	1.9	4.7	8.3	17.6	3.5	0.0	0.5	1.0	3.3	2.2	0.8	45.3
8	**bitFlyer**	0.0	1.3	5.0	10.0	13.1	1.8	0.0	0.0	0.6	0.3	0.0	0.3	32.3
9	**Zaif**	0.0	0.0	1.9	8.8	13.4	3.3	0.0	0.0	2.2	0.0	0.0	0.0	29.6
10	**Poloniex**	0.0	1.0	3.2	12.3	6.9	2.3	0.0	0.0	1.0	0.3	1.8	0.8	29.3
11	**KuCoin**	0.0	0.0	6.1	3.8	12.8	2.7	0.0	0.5	0.3	0.0	0.8	0.8	27.8
12	**BTC-Alpha**	0.0	0.0	9.4	6.6	5.4	3.0	0.0	0.0	1.0	0.0	0.0	0.5	25.9
13	**BeQuant**	0.0	0.0	1.8	12.2	6.7	1.6	0.0	0.5	0.6	0.5	0.5	1.3	25.6
14	**Huobi**	0.0	0.3	0.8	11.8	8.6	2.7	0.0	0.0	0.6	0.0	0.5	0.0	25.3
15	**Deribit**	0.0	0.6	3.1	4.2	9.8	5.0	0.0	0.3	0.8	0.3	0.0	0.6	24.6
16	**Bithumb**	0.0	0.0	0.5	16.3	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.6
17	**Gemini**	0.3	0.3	2.3	0.8	8.2	4.2	0.0	0.5	0.8	0.6	0.8	0.6	19.2
18	**CryptoFacilities**	0.0	0.3	1.6	1.2	4.8	3.6	0.0	0.0	0.0	0.3	1.4	1.3	14.4
19	**Huobi Derivative Market**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	3.0	0.8	3.6	3.3	12.2
20	**Bittrex**	0.0	0.5	1.1	0.0	3.3	0.6	0.0	0.0	0.8	0.0	0.0	1.8	8.2
21	**CEX.IO**	0.0	0.0	1.3	0.6	0.5	1.3	0.0	0.0	1.3	0.6	0.0	2.0	7.6
22	**OkCoin**	0.0	0.0	0.8	0.3	2.1	0.8	0.0	0.3	0.8	0.6	0.3	0.3	6.2
23	**TideBit**	0.0	0.0	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.6	4.6
24	**Itbit**	0.0	0.0	0.7	0.3	1.3	0.5	0.0	0.0	0.9	0.3	0.0	0.5	4.4
25	**FTX**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.3	2.6
26	**Binance Futures**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.6	1.3	2.2
27	**BinanceUS**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.3	0.5	1.5
28	**Bybit**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.3	1.3
29	**BitBay**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0
30	**Bitlish**	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
30	**LGOMarkets**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3

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