"Spot to The Future" Attacks on Cryptocurrency Derivative Markets

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Abstract. Cryptocurrency derivative markets have continued to gain popularity, allowing some lucky speculators to realize large profits. The most popular derivative, perpetual futures, provide speculators with high liquidity, up to 125x leverage, and virtually no regulatory oversight. In this paper, we describe how this environment is uniquely-suited for a specific type of market manipulation: "spot to the future" attacks. Using a lead-lag analysis of the spot and futures markets, we identify immediate price volatility transfer from the spot market to the futures market. We then use an event study to analyze the price changes surround significant volatility periods, revealing large price deviations between futures prices and the mark price used for the liquidation process. This combination, in addition to the high leverage limits, creates the potential for attackers to suffer a minor loss while manipulating the spot market, while simultaneously realizing large profits from leveraged futures positions.

Keywords: Cryptocurrency · Blockchain · Derivatives · Event Study.

1 Introduction

Following the November 2022 collapse of FTX [22], the third largest cryptocurrency exchange by volume, U.S. regulators have directed more attention to reining in cryptocurrency markets. In June 2023, the Securities and Exchange Commission (S.E.C.) sued two other large cryptocurrency exchanges for mishandling user funds [14] and for failing to register as a broker [15]. While actions by the S.E.C. represent an attempt to exert regulatory oversight by treating these markets similarly to traditional financial markets, the exchanges themselves have implicitly embraced this definition through the services offered. Derivative markets, leveraged trading, and lending services are all widely available in cryptocurrency markets, yet with virtually none of the protections placed on their traditional financial market counterparts.

One cryptocurrency derivative in particular, the perpetual futures contract, was first proposed in 1993 by Nobel Prize-winning economist Robert Shiller [26]. While failing to gain traction in traditional markets, the perpetual future has become the single most traded asset in cryptocurrency derivative markets. At the time of writing, the Bitcoin/Tether contract on Binance is single-handedly responsible for more than $15 billion in trading over the past 24 hours. These cryptocurrency derivative markets exhibit all the features found in traditional

financial markets, including margin calls, leverage options, and guides to hedge risk, without any of the regulatory oversight.

In this paper we investigate the potential for abuse when these unregulated and volatile cryptocurrency derivatives interact with more conventional spot trading. We propose "spot to the future" attacks in which traders create short-lived spot price fluctuations that induce perpetual futures price deviations from the mark price, which guarantee substantial profits. Obtaining incontrovertible evidence that these tactics have been employed is impossible using publicly available data. Nonetheless, we can (and do) gather evidence to support the feasibility of such attacks that demonstrates a predictable relationship between volatile spot prices and fluctuations in futures prices. Combined with the leveraged trading afforded by perpetual futures, unethical traders can expect to reliably profit from such attacks.

First, the attacker opens a long or short position (ideally when the market impact of their trades in the spot market is relatively high) in the futures market. This position can use leverage to increase the potential profit from the attack. Second, the attacker then fills a significant portion of orders in the spot market underlying the futures contract they recently entered at a price aligned with their futures position. If the price manipulation by the attacker is large enough, the counterparty to the attacker will become liquidated and the attacker will have their futures position filled for a profit.

This manipulation strategy is not new, it was first explained for traditional cash settled futures by Kumar and Seppi [21] in 1992. However, in their analysis they identified four inhibiting factors for this manipulation:(1) transaction costs, (2) position limits, (3) strict margin requirements, and (4) manipulator risk aversion, where the latter three are combined with price discreteness. In contrast, cryptocurrency markets offer low transaction costs, extremely high position limits, and relaxed margin requirements. What's more, traditional markets often rely on organizations such as the Commoditiy Futures Trading Commission to monitor markets and raise the alarm when manipulation is identified. The nearly complete lack of regulatory oversight within the decentralized markets means no such organization exists for perpetual cryptocurrency futures. Therefore, we believe the current implementation of perpetual futures contracts is largely immune to the inhibiting factors identified by Kumar and Seppi. Additionally, perpetual futures offer recurring opportunities for attackers to take advantage of this manipulation strategy to obtain a profit given the absence of any expiration date.

To determine how susceptible cryptocurrency perpetual futures markets are to spot to the future attacks, we investigate each step of the manipulation using publicly available data. Certain steps of the attack are simple and indistinguishable from noise traders. Specifically, opening a leveraged position in a futures contract and filling orders in the spot market are normal behaviors which we cannot identify as being attributed to a malicious actor. Instead, we seek to answer three questions related to the rest of the attack process: Do fluctuations in cryptocurrency spot prices affect the value of cryptocurrency perpetual futures?

Are the cryptocurrency perpetual futures contracts sufficiently insulated from the volatile nature of spot markets? Can a manipulation of the spot market produce favorable conditions for reliable profit in the perpetual futures market?

The rest of the paper will proceed as follows: In Section 2 we will discuss related work. In Section 3 we explain the spot to the future attack in detail, as well as the data we use to perform our analysis. In Section 4 we seek an answer to our first research question by using five-minute price data to measure the relationship between the markets. Namely, do fluctuations in the spot market result in noticeable and predictable price responses in the futures market? In Section 5 we answer our second question by determining if futures markets are adequately protected from any price fluctuations identified in the preceding section. Following this, we answer our third question in Section 6 by measuring the impact of price fluctuations in the spot market. In Section 7 we discuss how spot to the future attacks may be conducted in the current perpetual environment. We conclude in Section 8.

2 Related Work

The relationship between spot markets and derivative markets in the traditional financial sector is a heavily researched topic. In 1987, Herbst et al. [18] found evidence supporting an index futures price lead over spot prices, and a 2002 study by Asche and Guttormsen [6] came to a similar conclusion regarding gas oil futures and spot prices. A recent study by Shao et al. [25] found that neither the future or the spot market is the primary price leader when looking at the crude oil market. However, these findings contradict those found by Quan [23], which observed a strong spot market lead over future prices. This inconsistency in findings is common in the existing literature, and is likely due to the selection of markets being evaluated, the granularity of the data, methods employed to evaluate the relationships, and the time period reviewed.

As the derivative markets have grown in popularity within the cryptocurrency ecosystem, they have attracted the same attention from researchers [2], [24], [28]. Much of this research on cryptocurrency derivative markets is focused on the Chicago Mercantile Exchange (CME) and Chichago Board Options Exchange (CBOE) bitcoin futures, which exist on traditional exchanges, and with traditional expiration dates. Corbet et al. [9] analyzed both the CME and CBOE bitcoin futures, and found that bitcoin spit prices played a leading role in price discovery, and that the introduction of these derivatives resulted in an increase of spot volatility. Baur and Dimpfl [8] also look at the CME and CBOE futures as compared to the bitcoin spot prices, and come to the same spot lead conclusion. However, they note that a possible reason for this could be due to the constant trading of the spot market worldwide, while the futures they investigate are only available to trade during daytime hours in the United States. Much like the traditional markets, these findings are also challenged by researchers finding evidence of the contrary [19],[4], [10]. Alexander and Heck [4], who find that futures prices have lead spot prices in the past, make a point that even though

their results differ from some of the preceding research, it is possible that this could be due to different data and timelines investigated. A common thread across all of the previous bitcoin derivative research, is the use of traditional future contracts offered by CME and CBOE. Today, the most popular markets are perpetual futures, which often dwarf all other trading activity. Although these markets have been researched as well, they are often investigated in regard to the co-movement of prices across multiple exchanges [5], [3], or cryptocurrencies [17]. A notable exception to this is a 2021 paper by Soska et al. [27], which investigates perpetual futures contracts at a single exchange, BitMEX. Among their findings, Soska et al. find that large, professional traders control large amounts of bitcoin and account for only a small portion of the liquidations, which are mostly attributed to smaller, noise-based traders.

Criminal activity within the cryptocurrency ecosystem has also been a primary focus of researchers since its inception. From early research [11], [13] investigating the shady business practices of Mt. Gox, to the Griffin and Shams [16] paper uncovering the manipulation of bitcoin prices using tokens tied to the popular exchange Bitfinex. While the pseudonymous nature of cryptocurrencies makes it difficult to attribute manipulations to individual actors, the evidence of such manipulation can be observed using publicly available blockchain and API data. By using this data, we follow the steps taken by prior researchers in identifying the lead-lag relationship of bitcoin spot and futures prices on the popular exchange Binance, and use this to understand anomalous patterns in trade and price activity.

3 Spot to the Future Attack

In this section we explain the current implementation of perpetual futures markets at Binance, the largest centralized exchange by trade volume. We then explain each step of the spot to the future attack, as well as the data we collected to perform our analysis.

3.1 Perpetual Futures Contracts

To understand how perpetual futures contracts work, it is important to understand how traditional futures work. A traditional cash-settled futures contract allows speculators to lock in the price of an underlying asset. If the speculator believes the price of an asset will rise over time they will enter into a long position by agreeing to purchase the asset in the future at the current price. If the price does increase, the speculator will be paid by a short position holder for the difference between the price at expiration and the price they paid. In contrast, if the price decreases, they will owe the short position holder the difference since their original purchase price is higher than the expiration price. As the remaining time until the contract expires grows shorter, the difference between the futures price and the underlying asset spot price converges, since the value of the futures contract at expiry is worth exactly the same as the underlying asset.

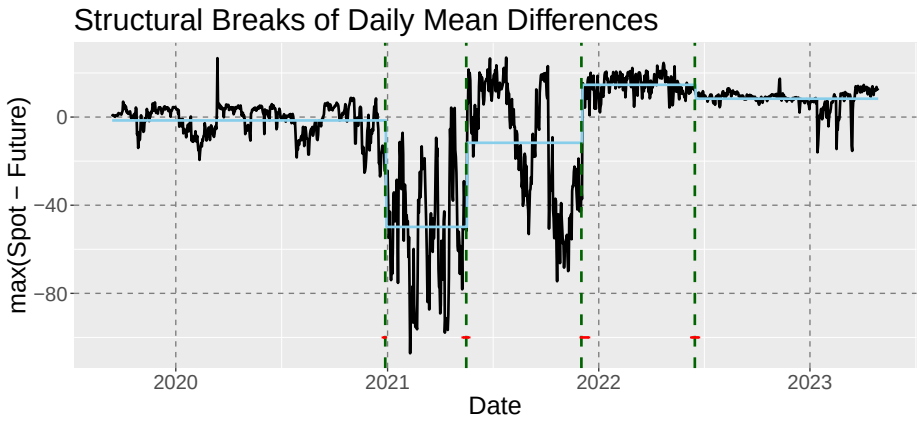

Fig. 1. Approximate breakpoints (green dashed) for the spot and future price differences (black), as well as 2.5%-97.5% confidence intervals (red) for each break at the bottom. The mean difference within each regime is shown in blue.

Perpetual futures also provide speculators with the ability to bet on the future price of an underlying asset, however there is no expiration date. As a result, there is no inherent mechanism to ensure price convergence. Without a solution to this problem, perpetual futures contract holders would simply refuse to settle until prices become favorable again. To prevent this, a regular payment is enforced between each side of the perpetual futures contract. If the perpetual futures price is above the underlying asset price, long positions will pay short positions a fee based on a small percentage of their position called the funding rate. This funding rate makes it costly to indefinitely hold a losing position, and drives the prices towards equilibrium. However, from Figure 1, we can see that this is not a flawless mechanic, and price differences still occur regularly.

Another issue with cryptocurrency perpetual futures is the inherent volatility of the underlying assets. This volatility makes it difficult to determine a "true" value of the underlying cryptocurrency asset. Exchanges are aware of this, with Binance explaining the use of a mark price to limit this exposure [1]:

> *To avoid unnecessary liquidations during periods of market volatility and prevent price manipulation, Binance Futures uses the mark price as a liquidation benchmark. [...] [T]he Mark Price of a contract is determined by various factors, including the contract's Last Price, the bid and ask series from the order book, the funding rate, and a composite average of the asset's spot price on major crypto exchanges.*

Despite this, exchanges frequently deal with futures positions that they are unable to manage. The extremely high leverage offered by many of them means positions can quickly become illiquid before the position can be closed without a loss. Binance has implemented an insurance fund (funded by transaction fees) to cover the losses from bad positions which were unable to be closed in time.

3.2 Performing a Spot to the Future Attack

The general strategy behind this attack is simple. The attacker will enter into a futures contract just as any benign trader would, and subsequently force the market into a profitable arrangement through spot market trade manipulation. This can be done in one of two ways: either the attacker will create the spot market required to sell off the futures position at a profit, or they will cause volatility within the futures market which forces the counterparty to liquidate. The former tactic is much more costly, as it requires the spot market to maintain a profitable price for the duration of the liquidation process. The latter tactic is simpler, however it relies on automatic exchange processes to become profitable. The rest of this section will explain each step of the spot to the future attack, as well as the data used to perform our analysis.

Establish a Futures Position The first step in the attack is to enter a perpetual futures contract in either a long or short position. The manipulator will likely enter into this position with leverage, which will amplify their buying power and allow for a greater profit with less capital. The side chosen by the attacker is important, as they would want to choose the side in the futures market which is easier to manipulate within the spot market. The market depth in the direction they need to fill spot orders, and the current deviation between the futures price and the mark price are both important factors.

Manipulate the Spot Market The second step in the attack is to fill orders in the spot market which compliment the futures position. For example, if the attacker entered into a long position in the Bitcoin/Tether perpetual futures contract, they will only make a profit if the price of Bitcoin rises. As such, the manipulation in this example will require the attacker to fill buy orders above the market price. This step will incur a loss for the attacker, however the use of sufficient leverage in the futures market position would ideally make up for this loss. As Kumar & Seppi describe, "since the futures position is larger than the expected short position, the profit on the futures allows the manipulator to recoup on average his loss from overpaying (being underpaid) on the spot market." Because perpetual futures have no expiration, this attack only needs to manipulate the spot market long enough to trigger the liquidation of counterparty positions on the futures market. Therefore, the actual change in spot price required is relatively small. The magnitude of these necessary price changes are quantified in Section 6.

Force the Future Price to Favorably Shift For an efficient market, the price discovery in the spot market would be quickly reflected in the futures market. Coincidentally, the same behavior is necessary for this attack to be successful. As such, in Section 4, we use cointegration and causality tests to determine the lead-lag relationship between the markets. The results of these test will reveal how price discovery manifests in these markets. The cointegration test we use is the

Johansen test [20], which uses two metrics to test for the cointegration: the *trace statistic* and the *maximum eigenvalue statistic*. A Vector Error Correction Model (VECM) can then be used to determine the significance of the Error Correction Term (ECT) driving the prices towards equilibrium. Using the Wald test we can then identify short term causality between the time series'. The null hypothesis states that there is no short run causality from the opposite time series to the one being tested, while the alternative hypothesis states that there is a short term causal relationship from the other time series to the one being tested. If such a short-term causal relationship exists, it will inform which market leads to price changes in the other. We then perform an event study of the spot and futures price returns surrounding these events to determine how they respond to volatility. For this attack to be reliable, the spot market would need to lead the futures market, or both markets must move together. If the futures market leads the spot market, or if volatility in the spot market is not transferred to the futures market, then this attack is infeasible.

Trigger the Liquidation of Counterparty Positions Should the spot market be found to lead the futures market, this is not enough to reliably manipulate the futures market. A successful attack is dependent on the mark price responding to the volatility in a predictable manner as well, forcing opposing futures market positions into liquidation territory. In Section 5 we investigate whether this pattern of spot market price chasing is seen. We do this by conducting another event study of the price difference between the futures contract and the mark price surround significant price volatility events. If there is a large price difference between the futures price and the mark price, liquidations will begin for losing positions. This liquidation process, where positions are automatically closed at the current price and paid out to the winning side, would benefit the attacker if the deviation compliments the attackers futures positions. If the attacker was using leverage, the winnings could be significantly larger than the capital used to manipulate the spot market.

3.3 Data

For each of our tests we use data collected directly from the popular centralized cryptocurrency exchange Binance, which, at the time of writing, facilitates roughly $12Bn in cryptocurrency spot trades every day. Through their API, candlestick data at five-minute granularity is collected for Bitcoin/Tether (BTC/USDT) spot and perpetual future pairs. Candlestick data includes six metrics for every five-minute period: open price, high price, low price, close price, total trades, and total volume. The first Bitcoin perpetual future contract on Binance was released on September 13, 2019, and the data collected for this analysis ranges from this initial release to April 30, 2023. For any daily analysis, the daily price is calculated as the average opening price across the entire day. We also collect five-minute candlestick data for the BTC/USDT mark price from Binance, which is the value Binance calculates internally for use with determining when to liquidate derivative positions.

4 Forcing the Future Price to Favorably Shift

For a spot to the future attack to be successful, a lead-lag relationship must exist from the spot market to the futures market. Additionally, significant volatility in the spot market must reliably transfer to the futures market. In this section we will first determine which lead-lag relationships, if any, exist in the spot and futures markets at Binance. Then we will perform an event study to quantify the magnitude of price change following volatility events.

Open Price		**Dickey-Fuller**	**P-Value**
Spot	Level	-1.4619	0.8061
	First Difference	-10.072	$<$ **0.01**
Future	Level	-1.4647	0.8049
	First Difference	-10.072	$<$ **0.01**

Table 1. Augmented Dickey-Fuller stationarity test results for spot and future daily opening prices at level and first difference.

4.1 Lead-Lag Relationship of Markets

To identify any cointegrating and causal relationships between the spot and perpetual futures markets, we must first confirm the data is stationary using an ADF test. The results of this test, which can be seen in Table 1, reveal a non-stationary time series. As such, we take the first difference of each time series which results in a stationary time series for both markets.

Cointegrating Vectors (r)		**Test Statistic**	**10%**	**5%**	**1%**
Eigen	$r \leq 1$	2.25	6.50	8.18	11.65
	$r = 0$	891.35	12.91	14.90	19.19
Trace	$r \leq 1$	2.25	6.50	8.18	11.65
	$r = 0$	893.61	15.66	17.95	23.52

Table 2. Trace and eigenvalue Johansen test results for the BTC/USDT spot and future prices.

While the individual prices are both stationary at the first differences, the spread between these prices can also vary, as shown by the black line in Figure 1. Unaccounted for variation in the spread can lead to unreliable results for the causal relationship tests in the following steps. Therefore, we proceed with a structural break test to determine if the price spread between the markets is stable over time. The structural break test based on work by Bai & Perron [7] will approximate how many breaks exist in the time series, and where they occur. Our test reveals four breakpoints, which can be seen as dashed green lines

in Figure 1. These breakpoints will be assigned dummy variables to distinguish between them during the causal relationship tests.

Response Variable	χ^2		**F-Statistic**	
	Statistic	P-Value	Statistic	P-Value
Spot	57.86	5.5×10^{-8}	4.82	8.5×10^{-8}
Future	58.24	4.7×10^{-8}	4.85	7.3×10^{-8}

Table 3. Wald test results for each null hypothesis.

We proceed to the Johansen test to evaluate the cointegration between the two prices. The results of the test can be seen in Table 2. Both test statistics are used, and are labelled in the first column by "Eigen" or "Trace". The Johansen test is a series of null hypothesis tests ranging from the existence of zero cointegration vectors, r, up to the existence of as many cointegration vectors as those included in the model. For this analysis, the cointegrating relationships are tested for only two time series: the spot prices and the futures prices. The first null hypothesis tested is that $r = 0$, or that there are no cointegrating vectors. This would imply the absence of any cointegration between the time series. This can be seen in the second and fourth rows of Table 2, and the test statistic is larger than the critical values of 10%, 5%, and 1%, allowing us to reject this null hypothesis at the 1% critical level. The next null hypothesis states that there are one or less cointegrating vectors, and the test statistic for both metrics is lower than required to reject it at the 10% level. Therefore, the Johansen test results indicate the existence of a single cointegrating vector for the spot and future prices.

Next, the short term causal relationship between the prices is investigated using the Wald test, as seen in Table 3. From this table, we observe statistically significant causal relationships in both directions. That is, the perpetual futures and spot prices quickly react to price deviations, with neither price clearly leading over the other. While this behavior reflects an efficient market in general, it also implies volatility within either market could quickly spread to the other market. This is the premise of our second research question, and will be investigated in the next section.

On a daily scale, the perpetual future contracts and spot prices appear to have no singular, permanent lead-lag configuration. The continuous trading allowed on cryptocurrency exchanges, paired with the endless nature of perpetual futures contracts allows these prices to react quickly to price deviations. What's more, when these markets exist within the same exchange network, there is no delay when moving cryptocurrency between markets.

Although these mechanisms are used to counter price deviations between the spot and future prices, it can be seen from Figure 1 that deviations do occur. In this section we perform a series of event studies around periods of significant volatility to observe the behavior in each market. Specifically, we measure the price return of the spot market, the futures market, and the mark price within four hours before and after the volatility event.

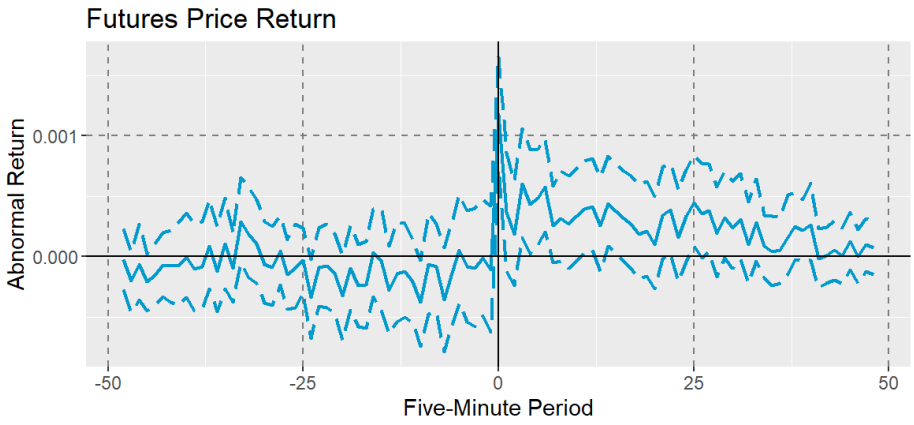

Fig. 2. Event study of futures price return surrounding spot high price volatility.

4.2 Identifying Volatility Spikes

We measure volatility by the five-minute high and low prices for each five-minute window. The high and low price represent the highest and lowest prices the asset was traded at, and deviations for these measurements between the markets represent a conservative minimum volatility reached during that window. For example, if the futures price had a high price of $100 and the spot price had a high price of $ 150, this means that for *at least one* trade, the underlying asset was valued 50% higher than the future.

Significant deviations occur when the difference between the spot high (low) price and the future high (low) price is higher (lower) than three standard deviations of the rolling four hour average. This process provides two distinct types of price deviation between the markets. In total, there are 2,063 high price deviations, and 3,370 low price deviations.

4.3 Deviation Event Studies

The first event study we perform is on the future returns around spot high price deviation events. These events represent the spot price increasing in value and deviating significantly from the future price. The results of this event study can be seen in Figure 2. The figure shows the abnormal return at each five-minute period within four hours surrounding the event, which is calculated as the return minus the rolling weekly average return. At the time of the event we see the futures returns spike in the abnormal returns, showing an immediate transfer of volatility from the spot market to the futures market. Although the magnitude of these abnormal returns is relatively small at 0.1%, this is a sudden change within a five-minute window compared to the four hour rolling average.

Next, we perform an event study of the futures returns around the spot low price deviation events, which can be seen in Figure 3. Again we see an immediate

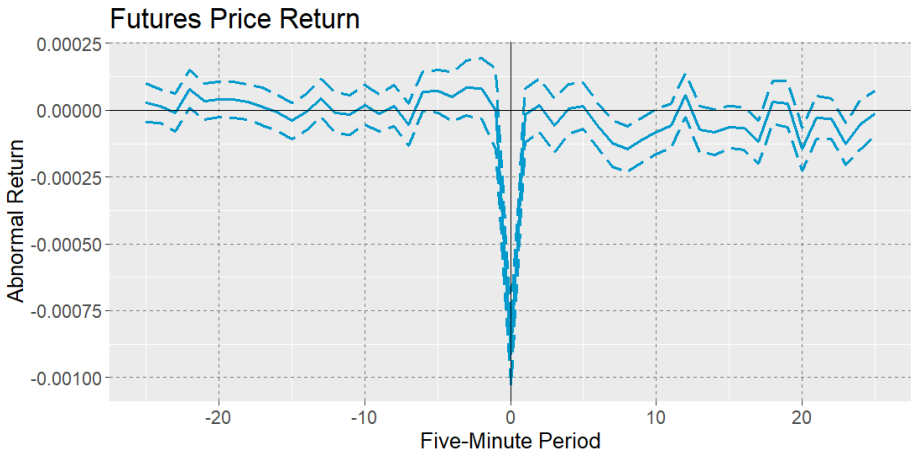

Fig. 3. Event study of futures price return surrounding spot low price volatility.

change in the futures price returns following a spot low price deviation. This time, the direction is negative, and the magnitude is slightly less at -0.08%.

These immediate abnormal returns, when combined with the short-term causal relationship identified earlier in this section, indicate a strong connection between the spot and futures prices. As mentioned in Section 3, this behavior is not enough to represent a potential spot to the future attack scenario. In the next section, we will investigate the final condition: the deviation between the mark price and the future price.

5 Trigger the Liquidation of Counterpart Positions

The previous section identified the short-term causal relationship between the spot and futures markets, and the event study revealed the reliable nature of volatility spread from spot markets to futures markets. In this section, we discuss how a spot to the future attacker could trigger liquidations in the futures market, provided the markets are not adequately protected from this volatility spread.

To begin, we perform a third event study, this time focusing on the mark price reaction to volatility events. We perform the event studies for significant low spot price events and significant high spot price events. The results were similar for both events, although in opposite directions. For consistency, we again show the significant low spot price events in Figure 4. Due to the causal relationship between the spot and futures markets, we expect the futures price to drop during these low spot price periods. Surprisingly, the mark price returns show a volatile reaction to the spot market price drop at a level nearly identical to the futures price returns.

In the time periods immediately following the event, the mark price returns revert to a stable behavior. This return to equilibrium could be the result of

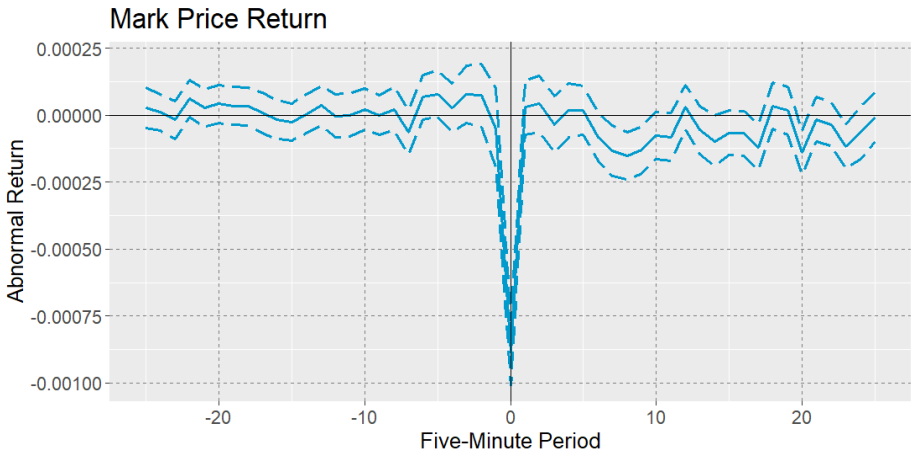

Fig. 4. Event study of the mark price returns surrounding significant low spot price events.

the liquidation process closing risky positions, although it is not possible to determine without access to liquidation data. We can, however, investigate the relationship between the mark price and the futures price surrounding these events. Liquidations are a function of the price difference between the mark price and the futures price, and a large enough deviation would make such liquidations more likely. To do this, we we run a fourth event study on the difference between the mark price and the futures price as seen in Figure 5. For roughly an hour leading up to a significant low spot price volatility event we see the futures prices climb away from the mark price, reaching a peak in the five minutes before a sudden low spot price event. During the event, and in the 10 minutes following, the difference quickly reverts to a near-zero level.

It is noteworthy that the peak in the difference between the futures and mark prices occurs immediately before the significant low spot price event. Should a manipulator be the cause of the event, this peak offers a remarkable incentive for their actions. The positive spike represents a futures price which is substantially higher than the mark price, imposing higher risk on the long positions in the futures market and increasingly the likelihood of a liquidation if the mark price were to drop. Furthermore, the liquidation of these long positions, if it were to occur, would result in the forced closing of long positions to pay out short positions. Such a series of events would benefit a short position holder in the futures market, and would lead to a return to equilibrium between the futures and mark prices, the latter of which is observed in Figure 5.

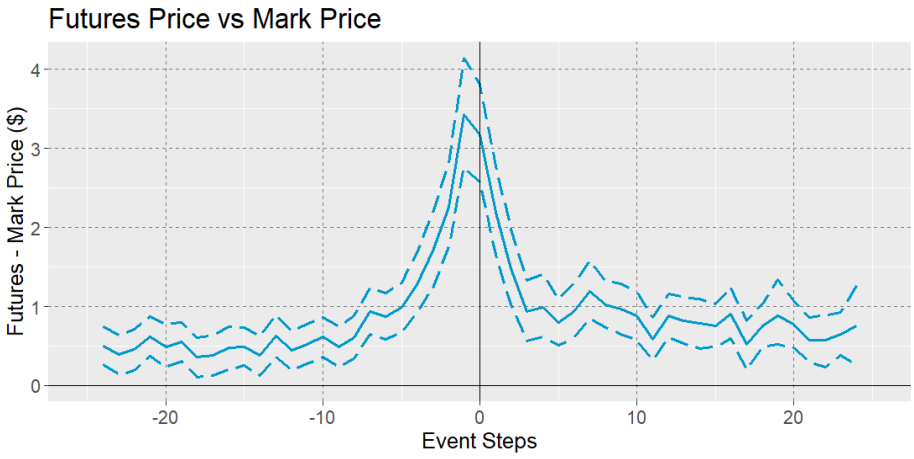

Fig. 5. Event study of the futures price minus the mark price surrounding significant low spot price events.

6 Requirements for a Successful Spot to the Future Attack

The existence of a cointegrated and causal relationship between the spot and futures markets, as well as the reliable transfer of volatility between the markets has proven the ability to inflict a volatile price change in the futures market using spot market manipulation. Furthermore, the deviation between the mark price and futures price surrounding these events provides a profitable window for futures position holders. What is not yet clear is how much capital a spot to the future attacker would need to perform such an attack, or what the likelihood is of a victim being liquidated. To the capital requirement of an attacker, the amount necessary to invoke the required spot market manipulation is unclear. The volume per trade ratio during these events rose slightly, from an average of .05 Bitcoin per trade during normal trading, to .067 Bitcoin per trade during significant volatility events. That is, larger traders were active during these events, however the individual trades conducted is not available in the aggregated data provided by Binance. This influx of larger traders is visualized in Figure 6, which shows an event study of the spot volume ratio (volume per trade) returns around spot high price deviations. The moment of the deviation there is a 10% increase in the spot volume and the next five-minute window completely cancels it out.

Regardless of the capital required by a potential attacker, the impact on victims was clear. Using the liquidation formula used by Binance we created hypothetical positions in the futures market and determined if we would be liquidated or not. A simplified version of the formula used by Binance to calculate the liquidation price of an open futures contract is:

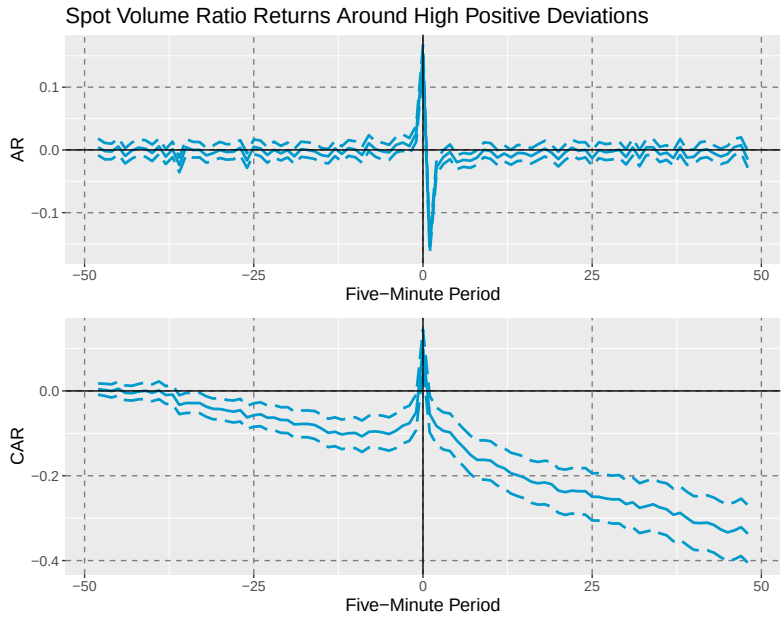

Fig. 6. Spot volume ratio return surround high positive (spot high price deviations) events.

$$LP = \frac{WB + MA + Pos \times EP}{Pos \times MR} \tag{1}$$

where the liquidation price, LP, depends on the wallet balance, WB, of the speculator, the margin amount, MA, and margin rate, MR, and the position size, Pos, multiplied by the entry price, EP. The margin amount and margin rate are both determined by the size of the position held.

We used this liquidation calculation to create a hypothetical trader who had only $500 in their account, and was trading two Bitcoin. We then had the hypothetical trader enter into the position thirty minutes before a significant event, and used the liquidation equation to determine if they would be liquidated or not. For long positions, a significant deviation in the high price led to our trader being liquidated 24% of the time. For short positions, the rate increased to 26%. As we increase the position value, which would easily happen if a speculator was using leverage, these rates only became worse given the increase margin requirements.

7 Discussion

Without individual trade data, identifying information about traders in each market, or specific liquidation amounts surrounding these events, it is impossible to confirm whether a spot to the future attack has occurred. However, it is

clear that the perpetual futures market is susceptible to such an attack given an attacker with enough capital. Circling back to the four inhibiting factors of this attack within traditional futures markets detailed by Kumar & Seppi, we also see that none of these inhibiting factors are present in cryptocurrency markets. The first factor was transaction costs between markets, of which none exist within Binance. It is free to move money between the spot market and futures market. Position limits are also not an issue in Binance futures markets, as the only limitation is what an individual can afford. While there are margin requirements, they are significantly more relaxed than traditional markets. Finally, risk aversion is not a commonly associated trait to speculators of cryptocurrency markets.

Despite the results presented here, two important questions are yet to be answered. First, it seems reasonable that non-malicious traders would quickly identify the manipulation and the spot price would revert back to the "true" value. While this may be true, it is simply irrelevant to the attack. Due to the rapid settlement – as well as liquidation in extreme cases – of perpetual futures contracts, the manipulation need only exist for a short period of time. If the price reverts within minutes, this is sufficient time for the auto-liquidation of opposing positions. In fact, these perpetual markets which cater to short-term speculators are an ideal environment for "speculator herding" as described by [12]. This type of herding is defined by short-term traders who must take immediate action to avoid a loss, and are therefore more willing to accept false or misleading information leading to short-term market inefficiencies. Second, given the relative simplicity of this attack, it begs the question why such attacks are not widespread in traditional markets. The answer to this one is quite simple: there are several factors unique to cryptocurrency perpetual futures which make this attack significantly harder, if not impossible. Chief among them is the lack of any regulator with authority over cryptocurrency markets. The risk of prosecution is itself a major deterrence for would-be market manipulators. In addition, traditional markets are far less fragmented than cryptocurrency markets, margin requirements are strictly enforced, and perpetual futures do not exist in traditional markets.

Moving forward, liquidation data would offer valuable insights for an extension to this work. Liquidation data at the exchange level is available through private companies, and could be used to further determine how often this attack has occurred in the past. By observing the long or short liquidations which occur at the same time as the high or low spot price volatility, potential profit from these attacks could be quantified. Additionally, individual order book trades could be used to determine the size of trades required to induce these price changes. This data also exists, however it too is available only through paid APIs or private data brokers. Access to either of these datasets would improve the assessment of spot to the future attacks greatly, and serve as promising future research tracks. Furthermore, an analysis of how mark prices behave under extreme conditions begs to be answered. Preliminary analysis performed by the authors of this paper while conducting the analysis within showed signs of mark

prices which are heavily influenced by the origin exchange, despite claims that it is a weighted aggregate.

8 Conclusion

Cryptocurrency markets operate largely in a regulatory void, offering many of the traditional financial market innovations with little protection. These markets thrive by promoting a high risk, high reward environment for their users. One of the most popular assets is the perpetual future derivative, which offers speculators the ability to take out large loans to make short-term bets on the price movement of cryptocurrencies. We find that these futures positions are susceptible to a well understood market manipulation tactic, spot to the future attacks. These attacks take advantage of the perpetual nature of these derivatives, causing slight price deviations in the spot market which become profitable positions in the futures market.

We describe how this attack may occur, and use a series of tests including the Johansen cointegration test, as well as VECM and Wald causality tests to confirm the market mechanics necessary for a successful spot to the future attack. We then investigate the circumstances surrounding these large price deviations using intraday price, volume, and trade data within an event study process. We find that the futures markets often lose parity with the mark price mechanic used for battling manipulation at the same time as these spot market deviations occur. The combination of these two events provides the ideal environment for a spot to the future attack to take place. We discuss the manipulation opportunity presented by this unique relationship, as well as future research potential.

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