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Research article

Bitcoin arbitrage: The role of an exchange

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Abstract: This paper examines how persistent BTC/USD price differences across major centralized exchanges are impacted by exchange-specific frictions, particularly fiat-to-crypto gateway frictions. Using tick-level trade data from Bitfinex, Bitstamp, Coinbase, and Kraken over January 2017 to June 2021, we construct a conservative hourly cross-exchange mispricing index from within-interval transaction price extrema, complemented by a 1-minute lifetime analysis and event study tests. The results show that approximately 80% of hours with a measured price dispersion include Bitfinex. When Bitfinex is excluded, the upper tail of the distribution contracts sharply, the correlation between mispricing and volatility falls from 0.86 to 0.59, and the restricted mean duration of positive episodes declines from 11.1 to 3.6 minutes. Event study evidence around banking stress and regulatory action supports these findings, with abnormal mispricing concentrated in the full sample and largely absent once Bitfinex is removed. We interpret the Bitfinex premium as a form of fiat redemption risk: When on-exchange USD balances cannot be redeemed with the same certainty as off-exchange dollars, BTC/USD quotes across venues no longer represent identical claims. The findings extend limits-of-arbitrage reasoning to the exchange-institutional level, showing that price convergence in digital asset markets is shaped by fiat-route stability and institutional trust.

Keywords: Bitcoin; cryptocurrency markets; econometrics; limits of arbitrage; market efficiency; market microstructure; survival analysis

JEL Codes: G14, G12, G18

Abbreviations: BTC: Bitcoin; USD: United States dollar; USDT: Tether; CEX: centralized exchange; VWAP: volume-weighted average price; OLS: ordinary least squares; CFTC: Commodity Futures Trading Commission; NYAG: New York attorney-general; ICO: initial coin offering; KYC: know your customer; AML: anti-money laundering; AMLD5: Fifth Anti-Money Laundering Directive; HSBC: Hongkong and Shanghai Banking Corporation; EUR: Euro; JPY: Japanese yen; GBP: British pound; OTC: over-the-counter; P2P: peer-to-peer; CME: Chicago Mercantile Exchange

1. Introduction

Arbitrage links prices of economically equivalent claims across trading venues and underpins the law of one price for an efficient market (Fama, 1970). In frictionless settings, cross-market price differences are quickly driven to zero by arbitrageurs buying cheap and selling high. In liquid traditional markets, competition among traders, rapid information transmission, and efficient settlement systems make persistent cross-market price differentials unusual (Budish et al., 2015; Aquilina et al., 2022).

In practice, cryptocurrency markets complicate this familiar story. Bitcoin trades continuously across a fragmented set of centralized exchanges that differ in their liquidity, banking access, legal oversight, reserve transparency, and settlement design. These differences result in Bitcoin prices not necessarily aligning across venues. Furthermore, a dollar balance credited on one exchange may not be economically equivalent to the same dollar balance credited on another if redemption into the banking system differs in speed, certainty, or legal clarity. Cross-exchange price differences may therefore reflect variation in the quality of the quote asset rather than pure price discrepancies.

Herein, Bitfinex provides a useful setting in which to examine this problem. The paper asks whether the largest persistent BTC/USD price gaps observed across major exchanges from 2017-01-01 to 2021-06-01 were mainly broad-market phenomena or if they were instead disproportionately linked to frictions specific to one venue. One important class of such frictions arises from fiat channels. These refer to the bundle of banking, deposit, withdrawal, and settlement constraints that connect an exchange's on-platform USD balances to the conventional dollar system. In this sense, exchange-level fiat frictions can be understood as a venue-specific extension of standard limits to arbitrage, shaping where cross-exchange price gaps arise, as well as their magnitude and persistence.

The Bitfinex premium can be described in two ways. First, a straightforward approach suggests that Bitcoin on Bitfinex traded at a premium relative to other venues, creating cross-exchange price gaps. A second interpretation is that what looked like expensive Bitcoin partly reflected a discount on Bitfinex USD balances. If a dollar on Bitfinex could not be withdrawn with the same speed, certainty, or legal clarity as a dollar credited elsewhere, then a BTC/USD quote on Bitfinex embedded an implicit discount on the fiat side of the pair. The two views are not mutually exclusive but they imply different interpretations of the spread. The first looks like a familiar law-of-one-price violation; the second looks more like a segmented-claims problem in which the same nominal quote asset is not the same economic object across venues.

Prior work has already shown that cryptocurrency markets display cross-exchange price gaps and that capital controls, transfer frictions, and exchange segmentation matter for arbitrage (Makarov and Schoar, 2020; Krückeberg and Scholz, 2020; Crépellière et al., 2023). This paper asks whether one venue's fiat channel problems can dominate the extreme right tail of measured BTC/USD mispricing in a multiyear sample. To do so, it combines three pieces of evidence: A conservative hourly cross-exchange mispricing index, a 1-minute lifetime analysis that measures how long positive episodes survive, and event window comparisons around dated banking and regulatory shocks that directly affected Bitfinex's fiat gateway.

The empirical design uses BTC/USD trade data from Bitfinex, Bitstamp, Coinbase, and Kraken. These exchanges were major BTC/USD venues in the sample period, offered direct dollar-denominated trading relevant to fiat on- and off-ramp conditions, and appear with continuous data coverage. The main hourly spread measure is built from transaction price extrema within each exchange hour and records a positive episode only when the highest hourly minimum across exchanges exceeds the lowest hourly maximum across exchanges, making it a conservative estimate of mispricing. This filters out fleeting or noisy crossings and focuses instead on persistent within-interval separation. It does not use contemporaneous bid–ask quotes, order book depth, venue-specific fees, or transfer delays, so it is better read as a persistent mispricing index than as a direct estimate of tradable arbitrage opportunities.

The results suggest that roughly 80% of hours with positive measured mispricing included Bitfinex. When Bitfinex is excluded from the system, the right tail of the mispricing distribution contracts markedly. The simple correlation between mispricing and volatility declines from 0.862 in the full system to 0.592 when Bitfinex is excluded, suggesting that the volatility-mispricing relationship was especially strong in episodes involving Bitfinex. The duration evidence is supportive of these results. The restricted mean duration of positive episodes falls from 11.11 minutes in the full sample to 3.64 minutes when Bitfinex is removed. Event-window comparisons around the Wells Fargo wire interruption, the October 2018 banking stress cluster, and the New York attorney general action tell a similar story, with abnormal positive mispricing concentrated in the full sample and often disappearing once Bitfinex is excluded.

The results show that the largest persistent BTC/USD dislocations were concentrated on Bitfinex and aligned with disruptions to its fiat channel, including banking and settlement frictions. The paper contributes by showing that exchange-level fiat channel frictions can constrain price convergence, linking these frictions not only to the size of cross-exchange gaps but also to their persistence. Although the Bitfinex episode is a specific case, it provides an empirical setting that illustrates why researchers and market participants should account for venue-specific institutional frictions and risk when interpreting prices and apparent arbitrage opportunities arising from cross-exchange price dispersion. More broadly, this episode connects to market microstructure evidence that apparently similar claims can trade at different prices when the venue, settlement, funding, or counterparty risks differ. The case study shows that settlement reliability, redemption certainty, and banking access can leave a measurable imprint on cross-venue pricing and operate as limits-of-arbitrage frictions at the exchange level. Unlike prior work that focuses on manipulation, such as Gandal et al. (2018) and Chen et al. (2019), the analysis examines how institutional constraints at a single exchange can drive persistent mispricing.

The paper proceeds as follows: Section 2 reviews the relevant literature, Section 3 provides a summary of Bitfinex's specific troubles, Section 4 presents the data and the empirical methodology, Section 5 presents the results, and Section 6 concludes this work.

2. Previous research

2.1. Limits of arbitrage and market microstructure

The theoretical starting point for this paper is the law of one price and the role of arbitrage in enforcing it. In frictionless models, if two markets trade the same claim, arbitrage should equalize prices once the transaction costs are taken into account (Harrison and Kreps, 1979; Varian, 1987). A large body of finance literature, however, shows that real-world arbitrage is limited. Shleifer and Vishny

(1997) stated that capital constraints and agency problems that can prevent arbitrageurs from correcting mispricing even when they recognize it. Gromb and Vayanos (2010) synthesized this literature and showed how funding constraints, margin requirements, and slow-moving capital can allow deviations from fundamental parity to persist.

Recent work on stablecoins points in a similar direction. Ma et al. (2025) showed that arbitrage in fiat-linked tokens is highly concentrated among a small set of institutional agents. Hence, redemption frictions and access constraints appear to be built into parts of the fiat-crypto interface rather than arising only as temporary disruptions. That evidence speaks directly to the interpretation discussed here: When the redemption capacity is concentrated, the ability to close cross-venue gaps is limited even when trading remains active.

Market microstructure adds a related but distinct set of factors. Stoll (1978) showed that dealer services are priced partly to compensate for inventory risk. Ho and Stoll (1980, 1981) formalized how transaction uncertainty and inventory management shape dealer pricing. Glosten and Milgrom (1985) showed that asymmetric information widens the gap between transaction prices and latent values, while Kyle (1985) linked price impact to informed trading and market depth. Chan and Chung (1993) also connected intraday volume, volatility, and arbitrage relationships across spot and futures markets. These models matter here because they imply that high volatility, thin depth, low liquidity, and information asymmetry can all generate wider spreads and slower price convergence, even without institutional failure.

The Bitfinex case complements standard microstructure explanations by introducing exchange-specific fiat and settlement frictions. In this sense, the setting is consistent with broader market microstructure evidence that apparently similar claims can trade at different prices when the venue, settlement, funding, or counterparty risks differ. Under conventional microstructure forces, BTC/USD gaps are expected to reflect volatility and liquidity conditions across venues. When exchange-specific fiat frictions are present, gaps may instead concentrate on a single venue and display weaker relationships with market-wide controls when that venue is excluded.

2.2. *Cryptocurrency arbitrage and market efficiency*

Makarov and Schoar (2020) showed that arbitrage spreads can be large and persistent, especially when capital mobility across jurisdictions is constrained. Their evidence is particularly important because it links Bitcoin price differentials to frictions in moving fiat capital, not merely crypto tokens, across borders and exchanges. Kroeger and Sarkar (2017) argued that the law of one Bitcoin price often fails across exchanges, especially when exchange-specific conditions differ. Krückeberg and Scholz (2020) examined arbitrage in Bitcoin markets and emphasized the role of market fragmentation and transaction frictions. Hattori and Ishida (2021) studied the relationship between spot-futures arbitrage and Bitcoin price movements, showing how pricing dislocations interact with broader market dynamics. Kabašinskas and Šutienė (2021) highlighted the central role of exchange design in generating arbitrage opportunities by showing how these opportunities are unevenly distributed across exchanges, while Shynkevich (2021) documented persistent Bitcoin arbitrage across exchanges. Crépellière et al. (2023) added a cautionary note by showing that observed crypto arbitrage must be interpreted carefully once the trading costs and execution constraints are taken seriously. Guo et al. (2025) used minute-level data from 16 exchanges to show that arbitrage episodes last longer when higher-risk exchanges post higher prices. Furthermore, greater liquidity accelerates convergence, and congestion or fees impede it. This finding is highly relevant here because it suggests that exchange-level risk is not a side issue but a first-order determinant of arbitrage's duration. Joshi (2025) showed that cryptocurrency market interdependencies are regime-dependent, with stronger cross-market transmission during periods of heightened stress.

A related but broader strand of the literature examines crypto market efficiency itself. Ko and Chen (2025) found that crypto asset co-movements with Bitcoin vary across time and frequency, further highlighting the heterogeneous and time-varying nature of cryptocurrency market integration. Nimalendran et al. (2025) showed that cryptocurrencies traded on Financial Crimes Enforcement Network (FinCEN)-regulated exchanges are more informationally efficient than those traded on less tightly supervised venues. Flowerday (2026) found increasing cryptocurrency market integration and a growing role for common market-wide information. This provides additional context for interpreting persistent cross-exchange deviations as reflecting venue-specific frictions. Bouteska et al. (2025) found that market efficiency improves with liquidity and weakens with volatility and uncertainty, showing these factors to be important determinants of crypto market efficiency at both the macro- and micro-levels. These findings indicate that persistent price gaps should not be understood solely as a technical artifact of a young asset class; they are also plausibly linked to institutional quality, oversight, liquidity provision, and the broader credibility of the trading venue.

2.3. Exchange-specific distress and institutional trust

A different strand of the literature examines how failures or distortions at a single crypto venue can affect broader price formation. The Mt. Gox episode is a canonical example. Before its 2014 collapse, Mt. Gox was a dominant Bitcoin exchange that experienced withdrawal problems, security failures, and above-market BTC/USD prices. Gandal et al. (2018) documented price manipulation as a driving factor of price in the Bitcoin ecosystem during the Mt. Gox period. Chen et al. (2019) analyzed the Mt. Gox transaction network and found evidence consistent with exchange-driven distortion. These papers establish the broader point that exchange-specific institutional weakness can spill over into wider market outcomes and contaminate cross-venue price formation.

Recent work on centralized exchange trust points in the same direction. The collapse of FTX in November 2022 provides a later example of venue-specific credibility risk at a major centralized exchange. FTX illustrates how exchange-level credibility problems involving solvency, custody, and user redemption can rapidly become market-wide stress events. Galati et al. (2024) showed that distress at a major exchange can transmit contagiously across crypto venues. Vidal-Tomás (2025) emphasized that proof of solvency and trust mechanisms are central to centralized exchange functioning. Cumming et al. (2025) showed that enforcement quality shapes crypto market reactions to regulation. Together, these studies support the paper's treatment of venue-specific settlement, solvency, and credibility problems as pricing-relevant. This later episode reinforces the relevance of exchange-level trust for interpreting price formation in centralized crypto markets, while the present paper focuses empirically on the earlier Bitfinex case.

2.4. Stablecoins and fiat funding infrastructure

Another stream of literature concerns the pipeline that links crypto trading venues to the broader monetary system. Stablecoins are relevant because they are part of the institutional environment in which fiat-restricted exchanges continued to operate. They can substitute for fiat rails when bank access is impaired, but they can also add another layer of reserve, redemption, and credibility risk.

Morin et al. (2022) and Gadzinski et al. (2024) studied stablecoin instability and showed how shocks can reverberate across crypto markets. Lee et al. (2025) examined stablecoin depegging risk, while Pérez Riaza and Gnabo (2025) showed that stablecoin-related instabilities can trigger jumps and co-jumps in BTC/USD and other crypto assets. In the Bitfinex setting, USDT is relevant because it provided an alternative dollar-like trading and settlement path when conventional fiat access was constrained. Because Tether was affiliated with Bitfinex through common ownership and management, USDT was not merely an unrelated stablecoin but part of the institutional background to Bitfinex's fiat channel problems. Reuter (2025) complemented this literature by showing that centralized exchanges sit at the core of international stablecoin flows and that the March 2023 banking crisis sharply disrupted flows originating from North America.

Recent evidence also shows that Bitcoin trading against fiat currencies is shaped the by local currency conditions, not merely global crypto sentiment. Di Casola et al. (2025) demonstrated that Bitcoin-fiat trading reflects both global and local drivers. That result is useful for interpreting the China-related events later in the paper: Even when a shock is not specific to Bitfinex, it can alter cross-exchange Bitcoin pricing by shifting fiat demand and capital-flow patterns. More broadly, Barthélemy et al. (2026) showed that stablecoin issuers' balance sheets connect crypto markets to conventional short-term funding markets. This supports the view that digital-asset market integration depends on the off-chain dollar infrastructure as much as on the on-chain transferability.

3. The role of Bitfinex

3.1. Bitfinex as the focal venue

The investigation of exchange pairs revealed that selling Bitcoin on Bitfinex accounted for the majority of measured arbitrage opportunities (Figure 1). In the exchange pair flow diagram, Bitfinex appears disproportionately on the sell side, indicating that the relevant price gap usually involved buying BTC on another exchange and selling it at a higher BTC/USD price on Bitfinex. This pattern is consistent with a persistent Bitfinex premium rather than a symmetric pattern of cross-exchange dispersion across all venues. The next three highest pairs have Bitfinex on the buy side, reinforcing the exchange's dominant role in measured price dispersion. Exchange pairs without Bitfinex account for only a small number of mispricing episodes, indicating relatively efficient pricing among the remaining exchanges. This is confirmed by the result that excluding Bitfinex from the analysis produces a dramatic 80% reduction in measured hourly mispricing episodes [*].

Figure 2 shows that the concentration of price dispersion was not evenly distributed over time. Arbitrage occurrences involving Bitfinex increased sharply after the onset of Bitfinex-related banking and regulatory disruptions, while the Bitfinex-excluded series remains more muted. The vertical event markers indicate several important episodes affecting Bitfinex's fiat infrastructure, including the Wells Fargo wire interruption, the October 2018 banking stress cluster, and the NYAG action. The visual pattern suggests that Bitfinex-related events coincide with periods in which measured cross-exchange mispricing was elevated primarily when Bitfinex was included in the

[*]Analogous leave-one-exchange-out checks produced much smaller reductions in positive dispersion observations. When Coinbase, Kraken, or Bitstamp were excluded, there was a 5.80%, 10.41%, and 7.07% decrease, respectively, compared with an 80.53% reduction when Bitfinex was excluded from the full cohort dataset.

exchange system. From 2018 onward, Bitfinex's elevated BTC/USD price appears to account for most measured arbitrage occurrences.

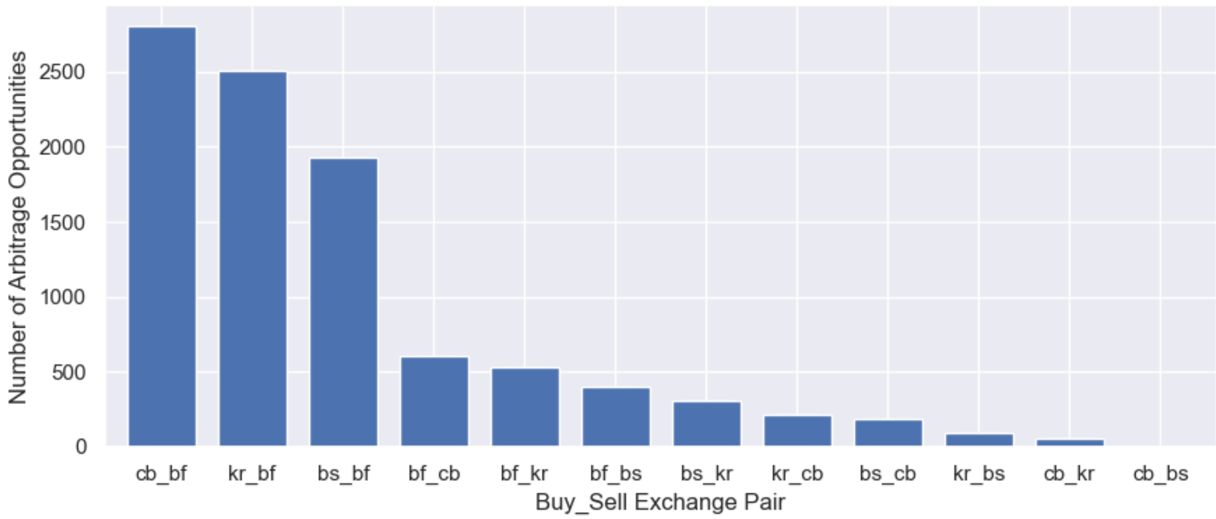

Figure 1. Optimal exchange pair flows for measured arbitrage opportunities. The x-axis denotes the buy exchange (left) and sell exchange (right). The y-axis is the number of mispricing observations within a bar. cb = Coinbase, bf = Bitfinex, kr = Kraken, bs = Bitstamp.

Prior literature predicts that pronounced cross-exchange arbitrage should arise on venues that combine high volatility with a thin trading volume. Contrary to this expectation, Bitfinex maintained the second lowest volatility among the four exchanges studied, closely behind Coinbase. Moreover, as shown in Figure 3, Bitfinex commanded the highest trading volume from early 2017 through to late 2018. Furthermore, Bitfinex's margin constraints, leverage options, and fee structures were comparable with the other exchanges. The coexistence of deep liquidity and persistent price premia suggests that Bitfinex's pricing patterns were not driven solely by thin trading activity.

3.2. Banking instability

Bitfinex suffered a major security breach in August 2016, during which approximately 120,000 BTC was stolen from the exchange, causing a decrease in capital reserves. A more decisive constraint affecting fiat liquidity was a sequence of banking-related disruptions which began in 2017. In April 2017, Wells Fargo ceased processing USD wire transactions connected to Bitfinex, disrupting the exchange's fiat gateway. This disruption pushed Bitfinex and traders to increase reliance on the USD-denominated stablecoin Tether (USDT).

With this disruption, a dollar credited on Bitfinex could no longer be assumed to flow into the conventional banking system with the same reliability as before. Without banking partners to process fiat transactions, Bitfinex struggled to maintain adequate fiat liquidity, a common challenge as traditional financial institutions increasingly avoided cryptocurrency exchanges amid growing regulatory concerns (Castor, 2018).

Bitfinex restored USD clearing in mid-2017 by opening accounts at the Puerto Rico-based Noble Bank, only to end that relationship in October 2018. During the same month, Bitfinex began routing fiat deposits through HSBC via a shell entity (Global Trading Solutions). However, shortly after the

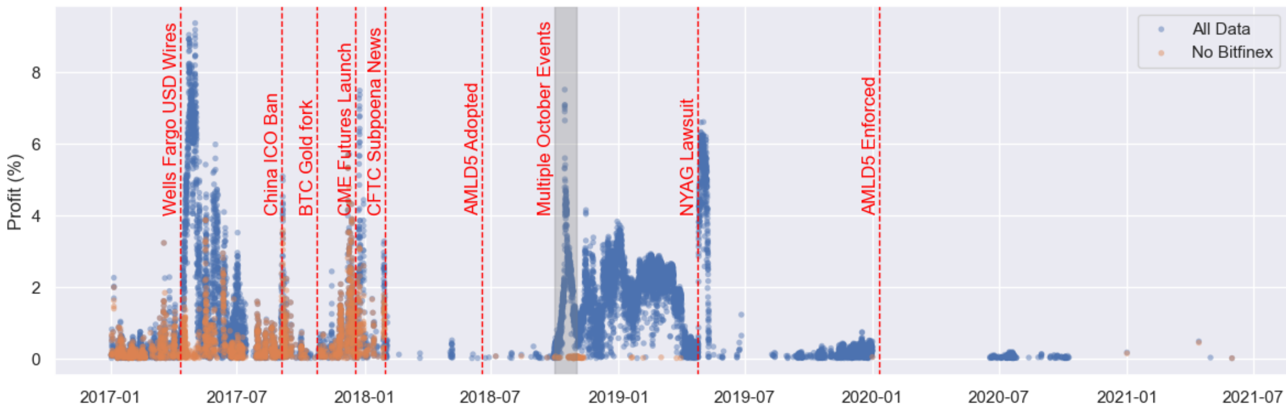

Figure 2. Comparison of measured arbitrage occurrences over time with and without Bitfinex in the dataset. Dates of events impacting Bitfinex have been included as red vertical lines. October 2018 events include the following: The end of the Noble Bank relationship, the HSBC account freeze, USDT depegging, and the Deltec Partnership announcement.

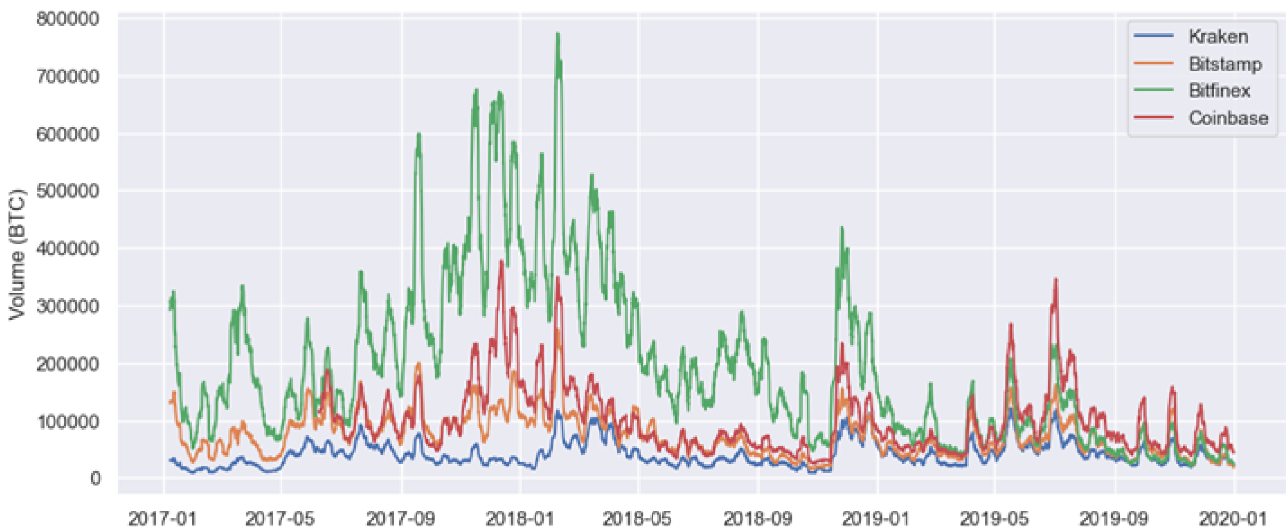

Figure 3. Weekly rolling average of hourly BTC exchange volumes over time per exchange.

partnership, HSBC closed the account, prompting a week-long Bitfinex fiat freeze affecting USD, EUR, JPY, and GBP. Unable to secure a conventional banking partner, the exchange channeled substantial balances to the payment processor Crypto Capital Corp. Authorities quietly seized Crypto Capital accounts during 2018, a fact that became public in April 2019, making $850 million of Bitfinex funds inaccessible. Furthermore, during October 2018, USDT struggled to consistently hold its dollar-pegged value, reaching as low as $0.88. Fiat access stabilized only after 1 November 2018, when Bitfinex announced a new banking partnership with Deltec Bank & Trust in the Bahamas, restoring USD deposit and withdrawal capability. By early 2020, these Deltec rails had matured into a reliable, though slower, fiat channel. These events all pointed in the same direction: Market participants repeatedly received signals that the exchange's fiat infrastructure was fragile, improvised, or vulnerable to interruption.

Bitfinex's extensive use of USDT introduced additional complexity to its price dynamics. USDT enabled traders to conduct transactions using USD equivalents without relying on traditional banking channels, effectively circumventing the exchange's fiat withdrawal constraints (Castor, 2018). However, this reliance on USDT created its own price discrepancies, particularly due to the early stability issues that caused Tether to occasionally deviate from its intended $1 peg (Morin et al., 2022; Browne, 2018; Tan et al., 2018). Traders also developed alternative methods to navigate fiat restrictions, including peer-to-peer (P2P) and over-the-counter (OTC) cryptocurrency transactions. These workarounds allowed trading to continue without adding or removing fiat currency from the system. Importantly, the difficulty of transferring capital back to the traditional banking system created a trapped liquidity effect, incentivizing traders to keep their funds active within the exchange ecosystem.

This interpretation also implies that fiat channel stress could reduce new fiat inflows to Bitfinex and encourage some users seeking to exit the exchange to purchase Bitcoin at elevated on-platform prices before withdrawing their crypto assets. Such behavior is consistent with a Bitfinex BTC/USD premium reflecting a discount on exchange-credited fiat balances. However, the transaction price data used in this study do not observe customer-level fiat deposits, fiat withdrawals, or linked crypto withdrawal activity, so this channel cannot be tested directly.

3.3. Regulatory attention

In August 2017, Bitfinex announced that it would phase out services to individual customers in the US, with trading, deposit, and withdrawal functionality scheduled to end by 9 November 2017. This restriction limits the class of traders who could directly act on measured Bitfinex-related price gaps, particularly for arbitrage involving US-based exchanges. However, it does not affect the measurement of the price gaps themselves or remove the relevance of Bitfinex's fiat channel frictions, thus affecting the exchange's broader fiat-processing infrastructure and not only US customers' access.

The broader macro environment also mattered. During 2017, Chinese authorities tightened restrictions on ICOs, domestic exchange activity, and capital outflows (Qi, 2017; Douglas and Feng, 2024). In response, Chinese investors increasingly utilized platforms like Bitfinex that operated beyond the reach of domestic regulations and provided a mechanism to access Bitcoin while circumventing the country's capital controls (Yu et al., 2024; Spegele and Feng, 2025). These developments likely affected the geography of crypto demand and the attractiveness of offshore venues. Bitfinex was one of the exchanges positioned to absorb part of that displaced or redirected demand. The point is not that Chinese policy created the Bitfinex premium on its own. Rather, China-related shocks may have amplified demand for offshore access precisely when Bitfinex's fiat channel was already fragile.

Between 2018 and 2019, Bitfinex and Tether faced mounting regulatory scrutiny, particularly in the United States. Regulatory attention sharpened on 30 January 2018, when it became public that the US Commodity Futures Trading Commission (CFTC) had subpoenaed both Bitfinex and Tether (subpoenas issued 6 December 2017) to obtain documentation on USDT's dollar reserves and on potential price manipulation links between the two entities. A watershed moment occurred when the NYAG filed a lawsuit in 2019, alleging that Bitfinex had misappropriated Tether's reserves to cover a shortfall linked to asset seizures held at Crypto Capital Corp, a shadow banking partner. This legal action triggered additional regulatory investigations and heightened concerns about the platform's operational transparency (New York Attorney General's Office, 2019). Trust issues were further exacerbated when over a billion USDT were minted in early 2018, raising serious questions about the stablecoin's backing.

These developments precipitated an erosion of institutional confidence in Bitfinex. Simultaneously, evolving global regulations (such as the EU's 5th Anti-Money Laundering Directive AMLD5) alongside the emergence of more compliant exchanges like Coinbase and Binance redirected traders toward platforms offering greater transparency and regulatory certainty (European Parliament and Council of the European Union, 2018). These developments made regulatory compliance, exchange transparency, and counterparty risk more salient features of exchange choice. By early 2020, Bitfinex had experienced a noticeable decline in market dominance. Institutional investors and major traders favored exchanges like Coinbase that offered superior regulatory clarity and more robust know your customer (KYC) and anti-money laundering (AML) protocols.

The next section turns from this institutional background to the measurement framework used in the paper, including the mispricing index, the volatility controls, the duration design, and the event analysis.

4. Data and empirical methodology

4.1. Data and variables

The collected data consists of the BTC/USD trading pair data from four major cryptocurrency exchanges: Bitfinex, Bitstamp, Coinbase, and Kraken. These exchanges were chosen due to their prominence during the period of investigation and their differing location-based regulatory regimes. Kraken and Coinbase are hosted in the United States, Bitstamp was founded in Luxembourg and is EU-regulated, and Bitfinex historically focused on servicing the Asian market, with a significant historical operating presence in Hong Kong and Singapore. However, Bitfinex is registered in the British Virgin Islands, where the regulatory regime remains less imposing.

Furthermore, these exchanges were four of the six exchanges included in the calculation of the CME Bitcoin Reference Rate (BRR) at its 2016 inception, supporting their use as reliable and representative price sources (CME Group, 2017). However, in April 2017, Bitfinex was removed from the BRR constituent exchanges, with transfer restrictions cited as the reason for removal (CME CF Oversight Committee, 2017). Since our arbitrage measure is only influenced by the largest cross-exchange spread within each interval, adding further exchanges would affect the results only if their prices widened the observed spread.

The raw data consist of executed transactions from the order book (including timestamp, trade price, BTC volume, and exchange) and cover the period from 2017-01-01 to 2021-06-01. From these data, the variables used for analysis were calculated for hourly discrete time intervals. $Volume_t$ is the total USD value of BTC transacted during period t. This USD volume was chosen over the volume of

BTC traded due to the exponential valuation of the asset during the data period. That is, the same USD value of trade would be approximately 40× more BTC's volume in the early periods of the data than at the end of the data.

The measure of arbitrage is defined as the highest minimum price among the four exchanges during the same discrete time interval, divided by the lowest maximum price among the exchanges during that interval, as described in Equations (1)–(3). Although shorter intervals were investigated, we report hourly interval results here to focus the analysis on the most persistent mispricing episodes. These episodes stand in contrast to the short-lived deviations typically expected in efficient markets.

$$\text{MaxMin}_t = \max\left(\min_{1\leq j\leq 4} p_t(j)\right) \tag{1}$$

$$\text{MinMax}_t = \min\left(\max_{1\leq j\leq 4} p_t(j)\right) \tag{2}$$

$$A_t = \frac{\text{MaxMin}_t}{\text{MinMax}_t} \tag{3}$$

Here, p_t represents the transaction prices during the hourly interval time $t \in [1, \ldots, N]$, with N being the number of observations, $j \in [1, 2, 3, 4]$ indicates the exchange, and A_t is the cross-exchange mispricing spread at time t. Within each hour, we identify, for each exchange j, the minimum and maximum transaction prices observed. MaxMin_t is the highest of the four hourly minima, and MinMax_t is the lowest of the four hourly maxima. A positive mispricing observation is recorded for hour t only when the hourly transaction price ranges across exchanges do not overlap; that is, when $\text{MaxMin}_t > \text{MinMax}_t$. Thus, A_t provides a conservative measure of the persistent price gap between the two exchanges exhibiting the largest spread. Accordingly, values of $A_t > 1$ indicate potentially profitable arbitrage opportunities, not accounting for fees and other frictions, with higher values of A_t indicating more attractive opportunities. Note that even if $A_t < 1$, there may still be arbitrage opportunities within the complete ecosystem of exchanges.

Since order book bid-ask data were not available, this method is used as a proxy measure for the bid-ask spread, providing a conservative estimate of cross-exchange price dispersion. Furthermore, because exchange trading fees are calculated as a percentage of the USD volume transacted, which is the largest contributor to costs for all but small transactions, this method makes it easy to set a threshold for profitable arbitrage, compared with a USD spread value. That is, $(A_t - 1) \times 100$ returns a conservative estimate for the percentage of profit achieved from an arbitrage trade during period t, excluding fees. Thus, setting a threshold greater than the percentage of exchange fees ensures a profitable trade. For the sake of simplicity, fees were not considered during this study, as the goal is to examine the persistence of cross-exchange mispricing rather than to estimate arbitrage's profitability.

Prior to definition of the volatility measures, the volume-weighted average price (vwap_t) and returns (r_t) were calculated as per Equations (4) and (5), respectively.

$$\text{vwap}_t = \frac{\sum_{i=1}^{n} (p_i \cdot v_i)}{\sum_{i=1}^{n} v_i} \tag{4}$$

$$r_t = \frac{\text{vwap}_t - \text{vwap}_{t-1}}{\text{vwap}_{t-1}} \tag{5}$$

where p_i is the average execution price of a trade, v_i is the volume of BTC transacted, and n is the number of transactions during period t.

Using the returns, five volatility measures were calculated for comparison, including the absolute hourly returns, squared hourly returns, standard deviation of tick-by-tick returns during an hour, standard deviation of 5-minute returns within an hour, and hourly realized volatility of 5-minute returns. Each of these measures has previously been used in the literature and captured volatility effects from fine granularity (transaction-by-transaction level), medium granularity (5-minute intervals), and larger trends (hourly). The standard deviation of 5-minute returns was seen to hold the highest correlation magnitude with A_t, closely followed by realized 5-minute returns; hence, this was the volatility measure chosen for any further analysis. It is noteworthy that the standard deviation of returns and realized volatility are very highly correlated when calculated from 5-minute returns, with a Pearson correlation coefficient of 0.999. These findings are consistent with Liu et al. (2015), who determined that 5-minute realized volatility was generally the best performing measure of market volatility.

Transaction-based measures of relative pricing and illiquidity were included to assess whether conventional market microstructure conditions help explain the observed mispricing. The VWAP premium captures an exchange's transaction price deviation from the market-wide VWAP, while Amihud illiquidity captures returns' sensitivity to traded volume (Amihud, 2002). The VWAP premium and Amihud illiquidity were calculated as per Equations (6) and (7), respectively. The premium was first calculated per exchange and then volume-weighted to determine the market-wide measure.

$$\text{Premium}_{j,t} = \frac{\text{vwap}_{j,t} - \text{vwap}_{market,t}}{\text{vwap}_{market,t}} \tag{6}$$

$$\text{Amihud illiquidity} = |r_t|/v_t \tag{7}$$

4.2. Data exploration

The distribution of A_t is illustrated in Table 1 and Figure 4. When observing the whole dataset (with Bitfinex included), the observations cluster tightly below 1 with a mean of 0.997 and a standard deviation of 0.016. A kurtosis value of 11.062 indicates a heavy leptokurtic distribution, as seen by the sharp peak and fat tails. Furthermore, the distribution is positively skewed, as seen by the significant cluster of points greater than 1, indicating a prevalence of mispricing episodes in the data. It is noteworthy that 25% of the observations present mispricing, with 5% of the observations holding an arbitrage profit of greater than 2.5%. Even if we assume that trading frictions (exchange fees, gas, slippage, etc.) amount to 1%, the 90th percentile of the full-sample distribution remains positive at 0.8%. In comparison, the Bitfinex-excluded percentile still is not positive under this constraint, even at the 95th percentile. This illustrates that the economically meaningful upper tail is concentrated in the Bitfinex-inclusive sample.

When Bitfinex is excluded from the data, there is a clear change in the distribution of A_t, particularly when looking at $A_t > 1$. The mean and standard deviation both decrease, indicating a lower likelihood of observing cross-exchange gaps within the data. This is further enforced by the skewness changing from positive to greatly negative. Now only 5% of observations present positive arbitrage opportunities, with the maximum profit decreasing from 9.4% to 5.7%. Thus, not only is there a decrease in the number of observed mispricing episodes, but the magnitude of opportunities is also seen to dampen. This implies that Bitfinex introduces dynamics not observed in the broader market.

Table 1. Summary statistics for the hourly cross-exchange mispricing index, A_t. "All Data" includes Bitfinex in the dataset, while "No Bitfinex" excludes Bitfinex. Values above one indicate positive measured price dispersion.

Statistic	Count	Skewness	Kurtosis	Mean	Std Dev	Min	5%
All Data	38504	0.383	11.062	0.997	0.016	0.721	0.976
No Bitfinex	38504	−3.806	42.012	0.991	0.011	0.721	0.974

Statistic	10%	25%	50%	75%	90%	95%	Max
All Data	0.983	0.990	0.996	1.000	1.018	1.025	1.094
No Bitfinex	0.980	0.988	0.994	0.997	0.999	1.000	1.057

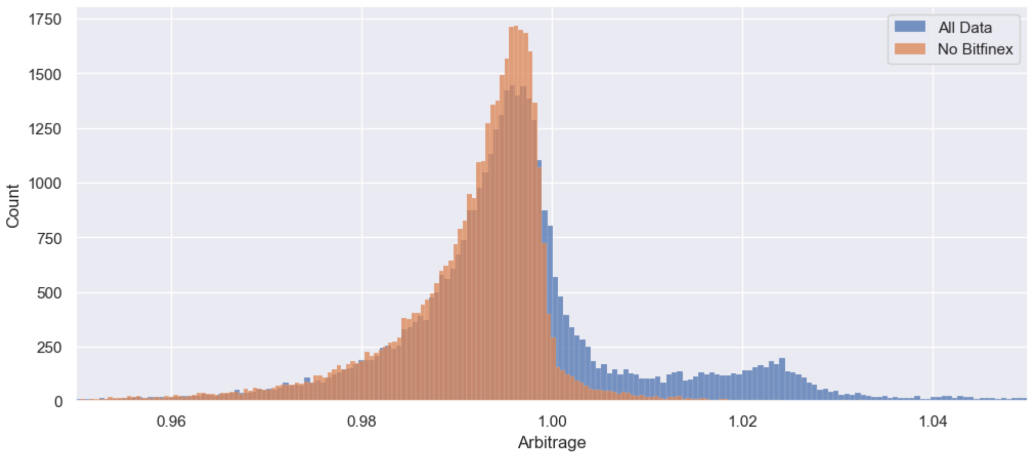

Figure 4. Distribution of hourly cross-exchange mispricing, A_t. Values above one indicate positive measured price dispersion, where the highest hourly minimum price across exchanges exceeds the lowest hourly maximum price.

The next question is whether the concentration of positive gaps on Bitfinex can be explained by ordinary market-wide conditions. Figure 5 shows a scatter plot illustrating the relationship between volatility and pricing spreads (A_t). When we consider the full dataset, there is a clear positive linear trend. Hence, the greater the arbitrage opportunity, the higher the expected volatility and vice versa. However, when Bitfinex is excluded from the data, the gradient is flattened. This suggests that volatility alone is not the whole story.

Table 2 shows that when $A_t > 1$, the correlation between arbitrage spreads and volatility is positive. Interestingly, the magnitude of the relationship is much weaker when Bitfinex is excluded from the data, decreasing from 0.862 for the full dataset to 0.592, confirming what was seen in Figure 5. This indicates that some unique characteristics of Bitfinex strongly influence the relationship between arbitrage and volatility. Volume's correlation with arbitrage and volatility increases once Bitfinex is excluded, suggesting that the exchange may experience some idiosyncratic behavior affecting these relationships. It is noted that the VWAP premium and Amihud illiquidity variables hold very low correlation values.

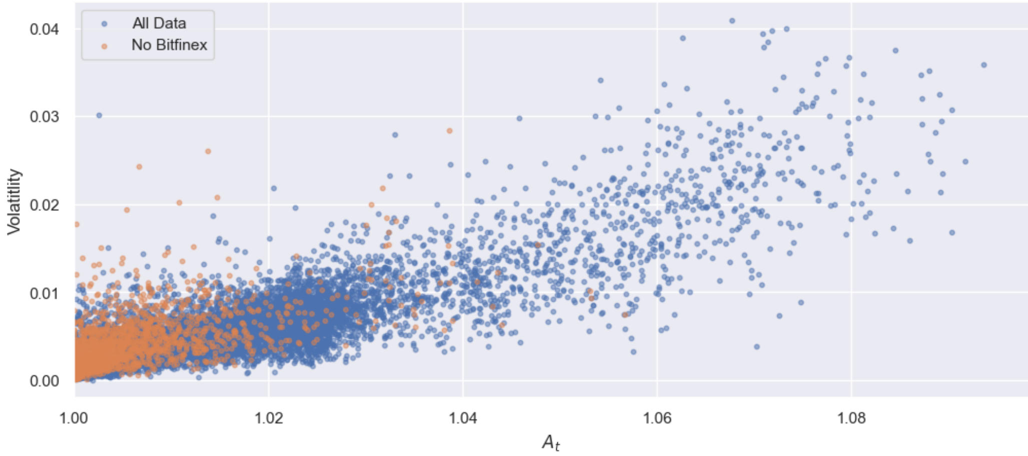

Figure 5. Scatter plot describing the relationship between price dispersion (A_t) and volatility.

Table 2. Correlation matrix for $A_t > 1$ observations. "All" includes Bitfinex in the exchange set, while "No BF" excludes Bitfinex.

Variable	**Arbitrage**		**Volume**		**Volatility**		**VWAP Prem.**	
	All	**No BF**	**All**	**No BF**	**All**	**No BF**	**All**	**No BF**
Volume	−0.023	0.385						
Volatility	0.862	0.592	0.094	0.338				
VWAP prem.	−0.009	0.008	0.012	−0.015	−0.009	−0.003		
Amihud illiq.	0.275	−0.041	−0.155	−0.210	0.271	0.079	0.005	−0.003

4.3. Limitations and interpretation

The descriptive evidence shows that mispricing concentrates on Bitfinex and that the volatility-arbitrage relationship weakens when Bitfinex is excluded. The remaining analysis investigates this further in three steps: OLS regressions to examine how the market conditions relate to mispricing in the full and reduced samples, a survival analysis to test whether Bitfinex's presence affects how long mispricing episodes last, and event studies to assess whether dated shocks to Bitfinex's fiat channel coincide with changes in the observed spreads. If Bitfinex-related fiat channel frictions contribute to the results, the relationship between mispricing and market conditions should weaken when the exchange is excluded, mispricing episodes should be shorter, and Bitfinex-specific shocks should affect the spreads only when Bitfinex is present in the sample.

The empirical strategy assesses whether the data are consistent with fiat channel frictions driving the observed patterns; however, some limitations apply. First, reverse causality is possible in that a persistent Bitfinex premium could itself increase withdrawal demand, worsening banking strain, leading to the event discussed in Section 3. The results are therefore treated as consistent with fiat channel frictions rather than proof of a one-way causal chain. Second, because the mispricing index is based on the system's largest cross-exchange spread, leave-one-exchange-out comparisons should be interpreted as a descriptive decomposition of the measured price dispersion. The exclusion results therefore show how the distribution of measured spreads changes when a given venue is removed, with the duration and event evidence providing complementary support. Third, the hourly mispricing index does not measure executable arbitrage profit, as it omits fees, order book depth, transfer speed, and collateral constraints. The paper therefore focuses on persistent price separation rather than net profitability, which may change on shorter time frames.

5. Results

5.1. Regression analysis

Regression analysis was performed for $A_t > 1$ on the two data groups, including and excluding Bitfinex (Table 3). This threshold identifies observations with cross-exchange pricing gaps [†]. Regressions were run with A_t and volatility as the dependent variable.[‡] Heteroskedasticity-consistent robust standard errors were implemented.

Table 3. OLS regression estimates for observations with a positive price dispersion ($A_t > 1$).

Dependent variable	Independent variables	Coefficient	SE
A_t (AD)	Volatility	2.73***	0.03
Obs. = 9 632	Volume	−0.99 * **	0.08
$R^2 = 0.75$	VWAP premium	4.65***	1.16
	Amihud illiquidity	45.79***	11.39
A_t (NB)	Volatility	1.26***	0.09
Obs. = 1 875	Volume	1.62***	0.33
$R^2 = 0.39$	VWAP premium	0.54***	0.19
	Amihud illiquidity	−14.34 * **	4.98
Volatility (AD)	A_t	0.27***	0.01
Obs. = 9 632	Volume	0.38***	0.03
$R^2 = 0.76$	VWAP premium	2.82	2.20
	Amihud illiquidity	30.48	23.77
Volatility (NB)	A_t	0.23***	0.02
Obs. = 1 875	Volume	0.55***	0.11
$R^2 = 0.38$	VWAP premium	−0.75 * **	0.17
	Amihud illiquidity	19.69***	4.52

Volume is reported in USD millions. VWAP premium coefficients and standard errors are multiplied by 10^{12} *for readability. All other variables are reported in their original units. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. AD = All Data; NB = No Bitfinex.*

The results, displayed in Table 3, present substantial differences between the variables' relationships when the two datasets are compared. Regardless of the dependent variable, the R^2 decreases significantly from the "All Data" model to the "No Bitfinex" model, with magnitudes falling from 0.75 to below 0.4. When A_t is the dependent variable, the coefficient of volatility falls from 2.73 to 1.26. Though their coefficients are significant, excluding volume, VWAP premium, and Amihud illiquidity from the

[†]As a robustness check, the regressions were repeated using the stricter threshold ($A_t > 1.01$), corresponding to a 100-basis-point gross price dispersion threshold, allowing for trading costs. The results remained robust for both datasets.

[‡]These regressions are not viewed as implying causal relationships between arbitrage spreads and volatility. The key point of the paper is that once Bitfinex is removed, there is a much weaker relationship between spreads and volatility.

models decreases the R^2 of arbitrage from 0.75 to 0.74 for "All Data" and from 0.39 to 0.35 for "No Bitfinex" when A_t is the dependent variable. This shows that the included transaction-based measures of relative pricing, illiquidity, and volume add little explanatory power beyond volatility. It is worth noting that recent research has indicated the presence of wash-trading at major Bitcoin venues, which may impact these volume results (Aloosh and Li, 2024; Cong et al., 2023).

5.2. *Survival analysis*

To construct the dataset for the survival analysis, the variables were sampled at 1-minute intervals. An arbitrage episode was said to begin at an instance when the value of A_t moved from a value of less than one to have a value greater than one. This event continued until the arbitrage value moved back below one. This provides a duration measure of the event in minutes, and each contiguous measure is counted as a single event. Thus, the dependent variable for this section of modeling is the duration of mispricing, measured in the length of time. The covariates were averaged for each event, except for volatility, which was calculated as per Equation (8), where σ is volatility and n is the number of 1-minute observations in an event. No censoring was present, and the events did not overlap.

$$\sigma_{event} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\sigma_i^2} \tag{8}$$

Kaplan–Meier survival curves were calculated from the "All Data" and "No Bitfinex" event data, as displayed in Figure 6. A log-rank test was used to determine if the two survival curves were significantly different. With a p-value of < 0.001, the null hypothesis can be rejected; thus, the two groups are not from the same survival distribution. The median survival time for both models is 2 minutes; however, when Bitfinex is included in the data, we see an increase in survival probability from a restricted mean survival time of 3.64 to 11.11 minutes. This indicates that the inclusion of the Bitfinex exchange plays a role in lengthening arbitrage events.

Cox proportional hazards models were estimated to evaluate the determinants of the duration of mispricing, as seen in Table 4. For the baseline hazard estimation, the Breslow method was used, and the Efron method was applied to handle tied event times. Data were scaled using the standard scaler prior to model fitting. Thus, the results suggest that a change of one standard deviation in the variable results in a coefficient percentage change to the baseline proportional hazard.

The "All Data" model has a concordance of 0.656, compared with 0.587 for "No Bitfinex". Although the full sample contains more mispricing overall, it produces fewer observations because episodes last longer on average. A 20-minute episode contributes one observation in the full sample, whereas the same 20-minute period may contain several shorter episodes once Bitfinex is excluded.

Volatility is significant in both models and carries a negative coefficient, indicating that higher volatility is associated with lower hazard and therefore longer mispricing episodes. Furthermore, volatility is the greatest contributor to changes in baseline event duration. An increase of one standard deviation in volatility decreases the proportional hazard by approximately 20%, which is an approximate duration increase of 25%.

Volume and Amihud illiquidity are significant in both models and hold positive coefficients, indicating an increase in the proportional hazard. This indicates that increases in these variables are consistent with decreases in the duration of arbitrage; however, their effects are very small, as shown by

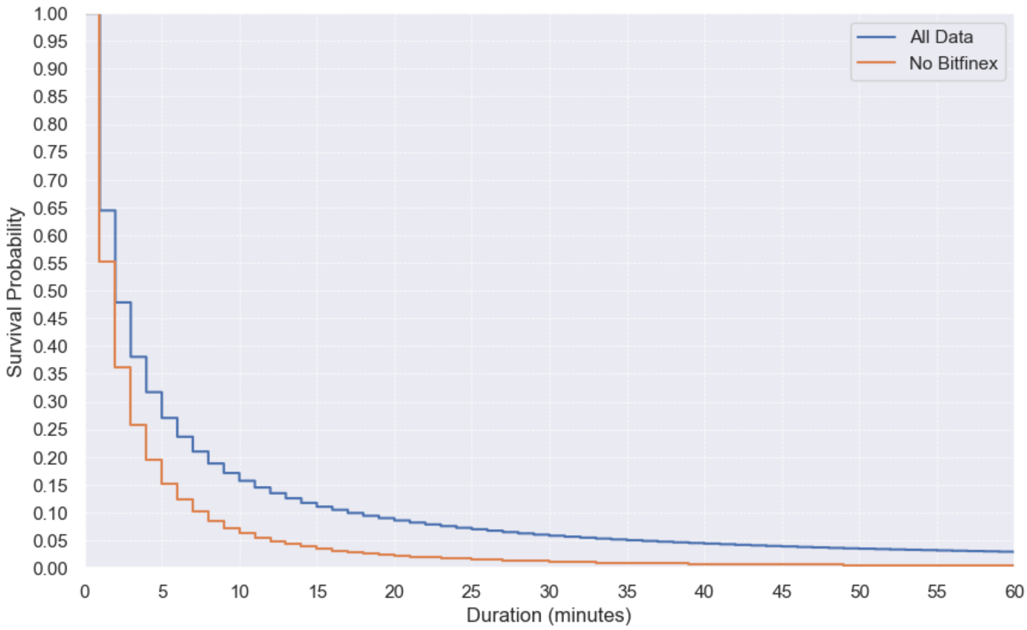

Figure 6. Kaplan–Meier survival estimates for the duration of mispricing. Duration is measured in minutes from the start of a positive mispricing episode, $A_t > 1$, until the episode ends, $A_t < 1$. The full-sample curve includes Bitfinex, while the No-Bitfinex curve recalculates episodes after excluding Bitfinex.

the exp(coef) values being close to one. VWAP premium is not significant in either model. Overall, the survival results are consistent with the earlier descriptive evidence.

5.3. Event studies

To investigate the impact of previously mentioned friction-related events on price dispersion, event studies were conducted. Again, the analysis was run on the two hourly datasets, namely, the full dataset with Bitfinex included and the dataset with Bitfinex excluded from the system. A list of the events investigated can be viewed in the first column of Table 5. The events fall into three broad groups: Bitfinex-related events, China-related events, and Bitcoin-related events.

To conduct the event study analysis, the values of A_t were transformed using the function $\max(0, A_t - 1)$. This allows the study to determine significant changes to actionable post-event arbitrage in percentage terms. The day (UTC) of the event was excluded from the data and a pre-event window comprising the 24 hours of the previous calendar day was used to determine "normal" arbitrage prior to the event taking place. This was done by taking the mean of the observations during this pre-event period. This arbitrage baseline value was subtracted from the post-event window observations, 24 hours of the calendar day following the event, and a two-sided t-test was used to determine if the result was statistically significant from zero. Thus, small p-values indicate significant changes to arbitrage due to the event's occurrence. The resulting t-test p-values are displayed in Table 5. Empty values indicate that no arbitrage was observed during the observation period. [§]

[§]The results were robust to different window sizes and configurations.

Table 4. Cox proportional hazard model estimates for the duration of mispricing. The dependent variable is the duration of positive mispricing episodes, measured in minutes. Coefficients are estimated after standardizing the covariates. "All Data" includes Bitfinex, while "No Bitfinex" excludes Bitfinex.

Model	Variable	coef	exp(coef)	se(coef)	p-value
All Data	Volatility	−0.236	0.790	0.004	<0.001
Obs = 159,847	Volume	0.018	1.018	0.003	<0.001
Conc = 0.656	Amihud illiquidity	0.026	1.026	0.001	<0.001
	VWAP premium	0.004	1.004	0.004	0.369
No Bitfinex	Volatility	−0.208	0.812	0.003	<0.001
Obs = 298,358	Volume	0.016	1.017	0.002	<0.001
Conc = 0.587	Amihud illiquidity	0.014	1.014	0.001	<0.001
	VWAP premium	0.001	1.001	0.003	0.574

Table 5. Event study p-values and mean deltas for post-event price dispersion.

Event	Date	p-values		Magnitude ($\Delta\%$)	
		All Data	No BF	All Data	No BF
Bitfinex-linked events					
Wells Fargo cuts USD wires	2017-04-11	<0.001***	0.473	0.243	0.010
CFTC Bitfinex subpoena news	2018-01-30	<0.001***	No Arb.	−1.021	–
Noble Bank ends relationship	2018-10-01	0.002***	0.519	0.140	0.002
HSBC deposit freeze	2018-10-11	<0.001***	No Arb.	0.476	–
Tether depegging	2018-10-15	<0.001***	No Arb.	2.254	–
Deltec partnership announced	2018-11-01	0.054*	No Arb.	0.071	–
NYAG lawsuit	2019-04-25	<0.001***	No Arb.	3.454	–
China-specific events					
China ICO ban	2017-09-04	<0.001***	0.002***	1.536	0.966
China CEX shutdown notice	2017-09-15	0.003***	0.005***	0.301	0.263
China CEX closure deadline	2017-09-30	<0.001***	<0.001***	0.206	0.131
Bitcoin-related events					
Bitcoin Gold hard fork	2017-10-24	0.086*	No Arb.	0.007	–
Bitcoin Diamond hard fork	2017-11-24	<0.001***	<0.001***	0.367	0.367
CME futures launch	2017-12-18	<0.001***	<0.001***	−0.673	−0.670

The dependent variable is positive price dispersion, $\max(0, A_t - 1)$, expressed in percentage terms. Magnitude ($\Delta\%$) reports the post-event mean minus the pre-event baseline mean. "All Data" includes Bitfinex in the dataset, while "No BF" excludes Bitfinex from the analysis. "No Arb." indicates that no positive price dispersion observations occurred in the event window. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The event study isolates 13 dated shocks and compares their impact on actionable cross-exchange arbitrage in the full sample and in a counterfactual dataset that excludes Bitfinex. Seven of those shocks are tied to Bitfinex's own banking or regulatory frictions; namely the Wells Fargo wire freeze, the CFTC subpoena news announcement, Noble Bank's exit, HSBC deposit freeze, the depegging of USDT, the Deltec banking partnership announcement, and the NYAG lawsuit being filed. Each of the seven produces a significant change in post-event arbitrage when Bitfinex is present yet becomes statistically insignificant once Bitfinex is removed. This pattern is consistent with the core hypothesis that Bitfinex-specific frictions are the source of the observed price spreads.

Policy shocks originating in China affect the whole market, as shown by the significant p-values in both datasets, yet their economic impact is clearly larger when Bitfinex is included. After the ICO ban, mean abnormal arbitrage widens by 1.54% in the full sample but by only 0.97% once Bitfinex is excluded. For the exchange shutdown notice, the spread increase falls from 0.30% to 0.26%, and for the closure deadline, it falls from 0.21% to 0.13%. These smaller magnitudes in the exclusionary sample indicate that Bitfinex may amplify, rather than generate, the shock transmitted by Chinese regulations.

Bitcoin market-wide events were included as placebos, notably the CME futures launch and Bitcoin forks. These events show near identical p-values and magnitudes in both datasets, as expected.[¶]

This event study complements the earlier regression analysis, survival results, and narrative developed in Section 3. Exchange-specific shocks related to Bitfinex's fiat-rail or regulatory status consistently widen post-event spreads in the full dataset yet vanish once Bitfinex is removed, mirroring the sharp fall in the regression's R^2 and drop in mean arbitrage duration earlier reported. Market-wide policy shocks, such as China's September 2017 measures, remain detectable without Bitfinex but with a muted economic impact. Placebo dates show little material difference between the two samples, reinforcing the conclusion that Bitfinex-linked frictions are the central source of the observed price discrepancies. Together, these patterns support the paper's central interpretation that fiat frictions on a single CEX venue can both create and amplify cross-exchange mispricing.

6. Conclusions

This paper asks whether the largest persistent BTC/USD gaps across major centralized exchanges during 2017-01-01 to 2021-06-01 were mostly broad-market phenomena or whether they were disproportionately tied to exchange-specific fiat channel frictions. Using tick-level trade data from Bitfinex, Bitstamp, Coinbase, and Kraken, it shows that the answer is strongly venue-specific. Roughly 80% of hours with positive measured mispricing place Bitfinex in the mispricing pair. When Bitfinex is excluded, the right tail of the mispricing distribution contracts sharply, the correlation between mispricing and volatility declines materially, and the restricted mean duration of 1-minute positive episodes falls sharply. Event window evidence around Bitfinex-linked banking, stablecoin, and regulatory disruptions points in the same direction. Beyond the specific findings, the Bitfinex episode constitutes an empirical case study in which exchange-level institutional frictions are directly observable and measurable, providing evidence for both the limits-of-arbitrage theory and market microstructure research on the conditions under which price convergence fails.

The interpretation remains conservative. The hourly statistic is built from transaction price extrema and does not use bid-ask quotes, order book depth, transfer delays, or venue-specific fees. It is therefore best understood as a measure of persistent cross-venue mispricing rather than realized arbitrage profit. Nor

[¶]Other events were explored, such as the EU AMLD5 milestones, the Bitcoin Cash hard fork, or ETF announcements, but showed no abnormal arbitrage surrounding the event dates, and thus were omitted.

does the paper claim to have structurally decomposed the Bitfinex premium into a pure Bitcoin overpricing component versus a discounted USD component. Instead, it argues that the observed premium is consistent with a fiat redemption problem: When dollars on one exchange are less readily redeemable than dollars elsewhere, BTC/USD prices across venues cease to represent identical economic claims.

That framing matters for how efficiency should be understood in digital asset markets. A market may look technologically integrated because the asset trades continuously, transfers are possible, and information is globally visible. Yet price convergence can remain incomplete when the settlement quality differs across venues. Faster matching engines, lower latency, and tighter displayed spreads do not by themselves guarantee integration if one venue's banking access is fragile or one platform's dollar balances are discounted. In that sense, the paper extends limits-of-arbitrage reasoning to the exchange-institutional level. The arbitrage constraint is not only the trader's capital or risk tolerance; it is also the venue's ability to transform on-platform balances into reliable external fiat claims.

The policy implication is that price convergence in digital asset markets depends on the fiat route's stability as much as trading speed. Market integrity therefore depends not only on exchange uptime or matching engine quality, but also on banking access, redemption certainty, reserve transparency, legal clarity, and a stable settlement architecture. This interpretation is consistent with recent evidence that regulatory quality improves informational efficiency, that illiquidity and volatility sustain crypto market inefficiency, and that stablecoin balance sheets connect crypto markets to conventional short-term funding markets (Nimalendran et al., 2025; Bouteska et al., 2025; Barthélemy et al., 2026). Operational resilience and settlement credibility are therefore part of the infrastructure of market efficiency, not merely ancillary compliance issues. Reuter (2025) reached a related conclusion in the stablecoin setting, showing that the March 2023 banking crisis sharply reduced stablecoin flows originating from North America, underscoring how disruptions at the banking layer can impair fiat-crypto channels beyond any single exchange.

The dynamics surrounding Bitfinex's sustained BTC/USD price premium share notable parallels with the collapse of Mt. Gox. Following serious security breaches in which both exchanges lost significant amounts of Bitcoin, each maintained above-market BTC/USD prices. Both exchanges subsequently suffered from critical liquidity constraints. Mt. Gox's 2014 collapse stemmed in part from its inability to meet withdrawal demands. Bitfinex's fiat withdrawal restrictions prevented an immediate bank run but created a trapped capital dynamic in which traders could not easily exit to the banking system, sustaining the on-platform price distortion and encouraging users to trade rather than leave their money dormant. In both cases, resolution came through a combination of regulatory intervention and market reallocation toward more transparent competitors, underlining the fragility of exchanges that hold dominant market positions without adequate transparency, and the capacity of regulatory pressure to correct artificial price inefficiencies over time.

This study provides a foundation for understanding how exchange-level institutional frictions shape price formation in digital asset markets. The joint pattern of concentration, duration, and event sensitivity documented here is difficult to explain without fiat-channel frictions playing a central role, and the evidence is robust across three complementary empirical designs. Future work extending this framework could incorporate quote-level data to sharpen the distinction between gross mispricing and net executable arbitrage, apply pairwise exchange panel designs with fixed effects to further isolate the Bitfinex-specific mechanism, and broaden the analysis to BTC/USDT pairs and later crisis episodes to assess how general the fiat-channel mechanism is beyond this setting. Even in its present form, the evidence points in one direction: The largest persistent BTC/USD dislocations in this sample were not simply a generic feature of crypto volatility; they were the measurable imprint of one exchange's impaired fiat gateway on the broader market.

Author contributions

E.F.: Conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, software, validation, visualization, writing – original draft, writing – review and editing. N.G.: conceptualization, formal analysis, funding acquisition, investigation, methodology, project administration, resources, supervision, writing – review and editing. H.H.: conceptualization, investigation, writing – review and editing. E.O.: conceptualization, formal analysis, investigation, methodology, writing – review and editing. G.A.: Data curation.

Use of Generative AI tools declaration

Generative Artificial intelligence (AI) tools were not used in this investigation or for the creation of this article.

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Conflict of interest

The authors declare no conflict of interest in this paper.

Data Statement

Data are available from Coin Metrics (`https://www.coinmetrics.io`).

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