Price Discovery in Ether Futures Utilising BitMEX

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Abstract

The two major cryptocurrencies are Bitcoin and Ether. The Bitcoin Mercantile Exchange (BitMEX) is an unregulated cryptocurrency exchange which has contributed to their financialisation by trading perpetual swaps. We focus on the Ether/USD swap, which settles on Bitcoin. We investigate BitMEX's effect on Ether spot prices using minute-by-minute data of BitMEX's ETHUSD perpetual swap, its underlying index and the index constituent prices from Coinbase Pro, Kraken and Bitstamp. We investigate these instruments using the *Generalised Information Share*, *Component Share* and *Spillover Effects* for our analysis, in both two-dimensional and four-dimensional frameworks. We find evidence that BitMEX's Ether perpetual swap leads price discovery in this system.

Keywords: Price Discovery, Futures, BitMEX, Ether, Perpetual Swaps, Cryptocurrency

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1 Introduction

In 2013, Vitalik Buterin produced his White Paper on the Ethereum blockchain. He looked to produce a blockchain which created *"an alternative protocol for building decentralized applications"* (Buterin et al., 2014), something which the Bitcoin blockchain does not facilitate. On 30th July 2015, the blockchain went live and quickly rose to become the platform to hold the second-largest cryptocurrency by market capitalisation.[1] This came seven months after release, even though Ethereum was not founded as a means of payment.

Ether (ETH Ξ) is the utility token used on the Ethereum blockchain to facilitate the applications and compensate miners at nodes. The pay rate for transactions, known as Gas, is measured in Gwei (ETH = 10^9 Gwei). ETH has no cap in its supply, unlike the Bitcoin currency (XBT) which has a hard cap of 21,000,000 XBT. The gain in popularity of the Ethereum blockchain has increased the attention given to Ether, thus leading to greater speculative and trading interest. Ether's primary type of trading is spot markets, but as of late, derivative products have become increasingly popular. BitMEX offers one of the most significant derivative instruments for Ether.

The Bitcoin Mercantile Exchange (BitMEX) was founded in 2014 by Arthur Hayes, Ben Delo and Samuel Reed. BitMEX states that it is *"The Next Generation of Bitcoin Trading Products"* and trades solely in derivatives.[2] BitMEX offers a variety of products focusing on quarterly, semi-annually and perpetual futures; these contracts allow up to one hundred times leveraging. In addition to the high leverage, BitMEX offers much lower margin requirements and smaller contract sizes than its competitors. Table 1 displays the difference in leverage, margins and contract size between BitMEX and its competitors. BitMEX does not accept FIAT currencies, which increases its attractiveness to investors, in addition to the points mentioned above. As BitMEX only accepts XBT deposits, they do not run any "Know Your Client" or "Anti-money Laundering" checks, thus are not subject to government regulation, meaning increased ease of access for investors. Due to the lack of checks, citizens of the United States (US) are banned from trading on BitMEX, in line with local laws. Despite the ban, US citizens can still use BitMEX through VPNs, and BitMEX will

[1] coinmarketcap.com/historical/20160214/
[2] bitmex.com

not detect this as they do not perform any identification checks. In July 2019, The United States Commodity Futures Trading Commission (CFTC) announced that they are investigating BitMEX, despite being based in the Seychelles. The probe is due to BitMEX allowing US citizens to trade on the site; this is illegal as BitMEX does not hold registration with the regulator (Robertson and Hunter, 2019). This news caused large outflows from BitMEX, totalling 500M USD for July 2019 (Partz, 2019).

Table 1: Leverage, Margins and Minimum Contract Sizes of BitMEX and Their Competitors [3]

Exchange	Max Leverage	Initial Margin	Maintenance Margin	Minimum contract size (XBT)
BitMEX	100x	1%	0.5%	0.0007
Bitfinex	3.33x	30%	15%	0.01
OKCoin	20x	5%	1%	0.07
BTCC Pro	20x	5%	1%	1
BitVC	20x	5%	1%	0.012
CryptoFacilities	50x	2%	0.75%	1

Table 1 displays the details for derivatives contracts from BitMEX and their competitors. Note how BitMEX has the highest leverage and the lowest margins and minimum contract size.

In May 2016, BitMEX introduced its first perpetual swap, XBTUSD. This contract is settled every eight hours and is priced on BitMEX's .BXBT index. The swap rapidly became BitMEX's most popular product with a daily average volume of 339,520 XBT in 2019 (Alexander et al., 2019), over 20 times the volume of BitMEX's XBT futures. Following the success of the XBT dollar-denominated swap, BitMEX introduced the ETHUSD perpetual swap priced on BitMEX's .BETH index. The .BETH index is comprised of an equally weighted measure of Coinbase Pro, Bitstamp and Kraken's ETH/USD spot prices. The contract itself is quoted in USD but settles in XBT as BitMEX only handles Bitcoin. Therefore, the swap does not handle ETH at all, and the contracts are valued in micro-bitcoin, 0.001mXBT per 1 USD, meaning the swap is also influenced by the price of XBT. This allows speculators to make a naked short on the ETH market. On the BitMEX chat, Arthur Hayes was quoted as saying *"If you are a Bitcoin based speculator this is the perfect way to punt on the ETH/USD price [. . .] you never need to touch that shitcoin called Ether"*, at the time of the perpetual swap's release. There have been debates surrounding whether the creation of this instrument led to a collapse in the price of ETH. The value of ETH/USD fell by 59% from 4th August 2018 to 12th September 2018. BambouClub, in a Hackernoon article, claims that the

[3] bitmex.com/app/whatsDifferent

perpetual swap has made *"a highly unstable market entirely composed of speculators"* (BambouClub, 2019). Tom Lee, a leading crypto analyst, claims that the introduction of the ETHUSD swap may have a link to the fall in the ETH/USD price. He said that the reduction in Ethers value *"is more due to the Bitmex futures/swap launch, and the impact of fundamentals on price is substantially less than perceived"*.[4] The claim is supported by the fact that the last five futures and swaps launched by BitMEX have seen a fall in their spot prices in the month following.

Within this report, we aim to investigate if BitMEX's ETHUSD perpetual contract influences the Ether USD spot market. We lay out the report as follows: the Literature Review shall investigate the current literature on cryptocurrency price discovery between futures/ swaps and the spot market. The Methodology will explain the process used to carry out our investigation. The Data section shall describe the data used and the reasoning behind our choice of the data. Finally, Empirical Results and Discussion will detail the findings of our work.

2 Literature Review

There are several papers that investigate the price discovery elements of the Bitcoin currency (XBT), like those by Baur and Dimpfl (2019), Kapar and Olmo (2019), Karkkainen (2018), Alexander and Heck (2019), Alexander et al. (2019) and Corbet et al. (2018), but very little discussion into the price discovery of Ether (ETH). Table 2 tabulates the findings from the Bitcoin papers we discuss in our report. Standard financial literature indicates that futures markets lead the price discovery across different assets. The literature includes papers for currency futures (Tse et al., 2006), freight futures (Kavussanos and Nomikos, 2003) and VIX futures (Chen and Tsai, 2017). Financial literature indicates that futures tend to lead price discovery due to lower transaction costs, absence of short-sale restrictions, built-in leverage as well as more transparency, which is more attractive to investors. Particular work finds that the spot market leads price discovery in some assets, including agricultural markets (Dimpfl et al., 2017) and Islamic stock markets (Karabiyik et al., 2018). Additionally, a few investigations find that spots and futures hold a joint discovery in price discovery like that of the EU Carbon Market (Milunovich and Joyeux, 2010). Hale et al. (2018) probe the late 2018 crash of

[4] medium.com/squared-capital/imminent-firesale-of-eth-held-by-icos-278a6cf914

the XBT market, which they discuss coincides with the introduction of CME (Chicago Mercantile Exchange) XBT futures. They find that the issuance of the futures has an impact on the spot price of Bitcoin, in line with other trading theory. They state that the spot price is pushed upwards by optimists within the market before there is an instrument available to short the market. Once the futures market becomes sufficiently large, pessimists drive the value of XBT downwards.

Table 2: Bitcoin Price Discovery Papers

Paper	Spot	Future	Time Interval	Information Share	Component Share	Common Factor Component	Spillover Effect	Overall Result
Corbet et al. (2018)	Coinmarketcap weighted average	CBOE and CME	1-minute	✓	✓			Spot Dominance
Baur and Dimpfl (2019)	Bitstamp	CBOE and CME	15-minute	✓	✓			Spot Dominance
Kapar and Olmo (2019)	Coindesk's XBT/USD Index	CME	Daily Data	✓		✓		Future Dominance
Karkkainen (2018)	Coindesk's XBT/USD Index	CBOE	1,5,15,30,60 minute and Daily	✓	✓			Future Dominance
Alexander and Heck (2019)	Bitcoin Reference Rate [5]	CBOE and CME	1, 30 minute	✓(GIS)	✓			Future Dominance
Alexander et al. (2019)	Bitstamp, Coinbase and Kraken	BitMEX - Perpetual Swap	1-minute	✓(GIS)	✓		✓	Future Dominance

Table 2 summarises the findings of the papers focused on within our Literature Review.

Corbet et al. (2018) explore the impact of the introduction of Bitcoin futures on the pricing of the Bitcoin spot price. They utilise minute-by-minute data from the CBOE (Chicago Board Options Exchange) and CME futures contracts. Unlike Bitcoin spot exchanges, these futures contracts are not traded on a 24/7 basis. They make use of the Hasbrouck (1995) Information Share (IS), and the Gonzalo and Granger (1995) Component Share (CS). From their investigation, they identify that 85% of the price discovery between the futures and spots comes from the spot when looking at IS. In addition, when investigating with regards to CS, 82% of price discovery comes from the spot market. Corbet et al. (2018) claim that "*the price discovery analysis indicated that price discovery is focused on the spot market, which is in keeping with the argument that the traders in the futures market are uninformed noise traders*" (p.6).

Baur and Dimpfl (2019) similarly report comparable findings to Corbet et al. (2018), using 5-minute data from CBOE and CME for their future prices. They further manipulate this data to obtain a dataset at 15-minute intervals, using XBT spot price data from Bitstamp. Using CS

[5] Bitstamp, Coinbase, Kraken and itBit

(Gonzalo and Granger, 1995), they find that the spot price contributes 80% to the price discovery when compared to the CME futures. The CBOE futures are found to have more of a presence in the price discovery, varying between 7 and 38%, contract dependent, but still, do not dominate when compared to the spot. The IS (Hasbrouck, 1995) delivers similar results with a "*clear dominance of the spot market over the futures market in the price discovery process*" (Baur and Dimpfl 2019, p.810). During their sample period, they find that the amount traded on Bitstamp was over 80 times the volume of the futures contracts, thus, surprisingly, the futures contract can contribute a significant amount to the price discovery. The more substantial volume is one of the elements that they explain as a contributing factor for the dominance of the spot market. They discuss the 24/7 market for the spot exchange and the fact that *"investors expected a correction driven by the futures contracts"*(p.816) as a reason for the dominance of the spot market. The fact that the instrument with the higher volume dominates follows the work of Brandvold et al. (2015). Within their paper, they investigate price discovery for Bitcoin spots between different exchanges; they discover that exchanges with the highest volume traded are those which contribute most to price discovery. Care must be taken when using exchanges with the most volume as many exchanges engage in wash trading to bolster their presence. Bitwise Asset Management (Hougan et al., 2019) find that 95% of volume on unregulated exchanges are not real – either being noneconomic or fake. They find that the "*prevalence of fake data sows distrust and obscures the true nature of the bitcoin markets,*"(p.12) but they argue that this does not "*influence price discovery in the real bitcoin spot market*"(p.2).

In contrast to Baur and Dimpfl's findings, Kapar and Olmo (2019) also investigate price discovery between the futures and spots of XBT. They use the CME futures, due to greater data availability, from 12th December 2017 to 16th May 2018, in addition to Coindesk's XBT/USD index. Unlike the papers we previously discussed, the authors choose not to use high-frequency intraday data and instead opt to use daily data. Kapar and Olmo attribute the difference in data frequency as one of the reasons their results differ to those of Baur and Dimpfl (2019). Kapar and Olmo use the Common Factor Component Model (Gonzalo and Granger, 1995) and the IS (Hasbrouck, 1995). They find that the IS for the CME futures is 88.7%, indicating clear dominance for the futures in price discovery. The results from the CFC show the same dominance in price discovery for the futures.

Karkkainen (2018) explores price discovery between CBOE futures and Coindesk's XBT index. Unlike many similar papers, they choose to analyse the price discovery using a higher number of intervals; 1, 5, 15, 30 and 60-minute intervals, in addition to daily data. They use both IS (Hasbrouck, 1995) and CS (Gonzalo and Granger, 1995) to investigate the relationship in price discovery. At the 1-minute interval, they find that the futures market is the leader for price discovery with an IS of 66.6% and a CS of 82.3%. Throughout all of the time samples they use in their analysis, the futures market dominates with an IS ranging from 56-73% and a CS between 82-95%.

Alexander and Heck (2019) also investigate price discovery between Bitcoin futures and spots. They scrutinise the two-dimensional relationship between CME or CBOE and the spot, from 17th December 2017 to 19th June 2019 for CBOE and 30th June 2019 for CME. They implement higher frequency data than Kapar and Olmo (2019) at 30-minute intervals. In fact, for the later contracts, Alexander and Heck increase the frequency to 1-minute data for select areas of interest, a much higher frequency than Baur and Dimpfl (2019). Within the initial 30-minute interval analysis, where rolling over is accounted for, they find that CS (Gonzalo and Granger, 1995) is equal for the CME with respect to the spot market. The CME results contrast the results for the CBOE, which plays a dominant role in the price discovery compared to the spot market, with a CS of 77%. However when they investigate with regards to the Generalised Information Share (GIS) (Lien and Shrestha, 2014), both futures contracts show dominance in price discovery compared to the spot market, CME (56%) and CBOE (58%). Alexander and Heck extend the sample period by an additional three months. They find that the CME plays a more significant role in price discovery when comparing to spots with a CS of 73% and a GIS of 66%. Within this extension, the CBOE still dominates the spot market, but to a lesser extent with a CS of 68% and a GIS of 56%. When drilling into particular areas of interest, around expiry dates and during large swings in price, at the higher frequency intervals, they find particular areas of spot market dominance around the dates of contract issuance. Within this, they discover that the average GIS for CME and CBOE are 75% and 71% respectively, with an average CS of 82% and 78%. The authors identify a potential cause of this as the small initial volumes for these contract distorting results.

Alexander et al. (2019) produce an additional paper that investigates the price discovery between the Bitcoin futures and spot markets. This paper differs from the papers previously mentioned as it does not seek to investigate the relationship between spots and either the CBOE or CME futures. Instead, this paper focuses on the BitMEX perpetual swap. Utilising BitMEX provides new insight into the price discovery as the future instrument does not have a maturity date and is traded 24/7 as BitMEX does not close. The authors discover that the trading volume for the BitMEX perpetual swap is much larger than the futures on the regulated CBOE and CME exchanges. BitMEX has higher trading volume than the chosen spot exchanges; Bitstamp, Coinbase Pro and Kraken; 162,000 XBT per day on BitMEX compared to a combined 27,000 XBT per day for spot trading. The authors cover the most extensive sample period of the papers in this section from 1st July 2016 to 3rd January 2019. Within this sample period, their chosen exchanges cover a cumulative 55.9% of the market, when excluding Bitfinex. They highlight a few features of the contracts that lead to an increase in market participation; smaller contract size, no regulation, Bitcoin-based design, small margins and low trading costs. The authors link these points to Admati and Pfleiderer (1988), which specifies that these lead to higher participation from informed traders. To investigate price discovery, Alexander et al. (2019) introduce an updated version of Hasbrouck's IS, the GIS (Lien and Shrestha, 2014) in addition to the regularly used CS (Gonzalo and Granger, 1995). The authors also use the gross and net spillover effects of Pesaran and Shin (1998) and Diebold and Yilmaz (2012). In another change to previous papers on Bitcoin price discovery, the authors utilise a four-dimensional price discovery approach as opposed to the regularly used one-to-one method. Within the full sample period, the average of the daily GIS of the BitMEX perpetual swap is 51.53% with the component share being 57.5%, showing the BitMEX swap to be the leader in price discovery. When analysing price discovery in terms of net spillover, BitMEX has a sizeable positive net spillover of 8.25%, thus showing its dominance over the spot exchanges.

3 Methodology

Within our analysis and investigation into the price discovery of Ether Futures and Spot prices, we shall follow the methodology set out in the paper by Alexander et al. (2019). We discuss the models and formulae we use below, and the derivations are found within the referenced literature. To perform analysis on the time series of data where the future and spot prices are cointegrated and have an underlying stochastic trend, we use the Vector Error Correction Model (VECM) (Engle and Granger, 1987) as our basis to represent the cointegration of p_t, the $N \times 1$ vector of the log prices of the N instruments at time t. Equation 1 is the VECM model where α is the $N \times N-1$ error-correction coefficient matrix, $\beta' p_t$ is the cointegration error, Q is the lag length for this model (found by using the Bayesian information criteria), A_q is the $N \times N$ autoregressive coefficient matrix, and ϵ_t is the $N \times 1$ zero mean vector of serially uncorrelated disturbances with a covariance matrix of Ω. The effects of the short-term fluctuations are displayed by A_q and α reflects the deviation of the prices to the long-run equilibrium relationship.

$$\Delta p_t = \alpha \beta' p_{t-1} + \sum_{q=1}^{Q} A_q \Delta p_{t-q} + \epsilon_t \tag{1}$$

Hasbrouck (1995) represents the VECM formula as the Vector Moving Average (VMA). We use Equation 2 to display the VMA where e_t is ϵ_t from the VECM and Ψ is a polynomial in the lag operator.

$$\Delta p_t = \Psi(L) e_t \tag{2}$$

Hasbrouck makes further derivations to the VMA formula to find the Information Share (IS)(3):

$$IS_i = \frac{([\psi F]_i)^2}{\psi \Omega \psi'}, i = 1, ..., N \tag{3}$$

where F is the Cholesky factorisation of Ω, thus meaning that $[\psi F]_i$ is the ith element of the row matrix ψF. We use the IS to measure an instrument's contribution to the price discovery of a market in comparison to the other instruments used.

Lien and Shrestha (2009) modify Hasbrouck's IS to create a model that outperforms it. They eliminate the bounds applied to the IS to create the Modified Information Share (MIS)(4):

$$S_j^* = \frac{\psi_j^{*2}}{\psi \Omega \psi^T} \tag{4}$$

where $\psi* = \psi F*$, $F* = [G \Lambda^{-1/2} G^T V^{-1}]^{-1}$ where Λ is the diagonal elements of the correlation matrix Φ, G is the corresponding eigenvalues and V is a diagonal matrix containing the standard deviations of Ω.

This measure provides us with a unique analysis of price discovery that performs well under Monte Carlo simulation, a point that Lien and Shrestha (2009) argue makes the MIS a better candidate to measure price discovery than the IS. The MIS measures price discovery in the same way, showing the percentage contribution that an instrument has to the price discovery of the market in comparison to the other instruments we analyse.

Lien and Shrestha (2014) generalise the IS to create the Generalised Information Share (GIS). The GIS allows us to analyse the price discovery process across interrelated markets rather than identical markets, which IS and MIS measure. We create the GIS by removing any restriction on the cointegrating vector and by removing the dependence on the order of the state variables. Equation 5 represents the GIS formula where $F = [G\Lambda^{-1/2}G^T V^{-1}]^{-1}$.

$$GIS_i = \frac{([\psi_1^r F]_i)^2}{\psi_1^r \Omega \psi_1^{r'}}, i = 1, ..., N \tag{5}$$

Gonzalo and Granger (1995) derive the Component Share (CS) from the VECM. Similar to the IS, the CS splits the price innovation of an instrument into permanent and temporary components. The CS measures the levels of noise in the market to infer the price discovery. Like the other measures, it records the contribution of each instrument analysed to the price. To obtain the CS from the VECM model, they split the price into two components; the common factor c_t and a stationary component. Equation 6 is the formula we use to find the CS, where $\alpha_\perp$ is the adjustment coefficient; the permanent coefficient vector is orthogonal to this.

$$CS_i = \frac{\alpha_{\perp,i}}{\sum_{n=1}^{N} \alpha_{\perp,q}}, i = 1, ..., N \tag{6}$$

Yan and Zivot (2010) investigate the IS and CS to determine their effectiveness. These measures are similar as they both indicate how each instrument deviates from the long-run trend price. Yan and Zivot find that both IS and CS account for the relative avoidance of noise trading and liquidity shocks. They discover that the IS provides details of the informativeness of individual markets, whereas the CS does not. The IS estimates from high-frequency samples can face distortions from transitory frictions; thus, our analysis shall employ the GIS rather than the IS or MIS.

We also use the spillover effect to investigate the price discovery elements; we derive this from the VECM. Pesaran and Shin (1998) introduced this principle; Diebold and Yilmaz (2012) latterly modify this. The error variance decomposition provides the gross and net spillover effects from instruments. The spillover effect provides an insight into how each instrument reacts to shocks within the other instruments, a difference to what is measured using GIS and CS.

Pesaran and Shin (1998) compute the generalised impulse response to an h-period ahead response with respect to a unit innovation. Following this, we obtain the generalised forecast error variance decomposition. This measure is normalised to obtain the gross spillover from j to i:

$$\tilde{\theta}_{ij}(h) = \frac{\theta_{ij}h}{\sum_{n=1}^{N}\theta_{ik}(h)} \tag{7}$$

where $\theta_{ij}(h)$ is the generalised h-step ahead forecast error variance of variable i due to the innovations in variable j. Therefore the net-spillover (Diebold and Yilmaz, 2012) from j to i is:

$$\tilde{\theta}_{ij}(h) - \tilde{\theta}_{ji}(h). \tag{8}$$

As in Alexander et al. (2019), we run a four-dimensional analysis to investigate the share of information flows between the future contract and multiple exchanges. However, Alexander and Heck (2019) do not employ a four-dimensional framework, as the price discovery role of a spot exchange may become underestimated. The underestimation occurs since the information and component shares become split between multiple exchanges. Due to this factor, we employ a two-dimensional framework in this report in parallel with the four-dimensional framework.

4 Data

To facilitate our study, we obtain the highest frequency of data available to ensure we do not miss any price movements within the data. We collect minute-by-minute data from BitMEX and CoinAPI. BitMEX's RestAPI is used to obtain the minute-by-minute data for BitMEX's ETHUSD Perpetual Swap and the .BETH Index, of which the perpetual contract is priced. The .BETH Index is an equally weighted index based on the ETH/USD spot prices from three exchanges; Bitstamp, Coinbase Pro and Kraken. We also collect 1-minute data for the XBTUSD perpetual swap from BitMEX to investigate the price discovery between the two perpetual swaps. Out HTML requests, run using code made on Visual Basic, provide full 1-minute OHLCV data. From this data, we take the UNIX timestamp, close price and the volume. The volume data provided by BitMEX for the ETHUSD contract is not denominated in either USD or ETH. BitMEX provides the number of contracts for the perpetual swap to denote its volume. The contract size for the perpetual swap is denominated in XBT; it is 0.001 mXBT per 1 USD. Therefore, Equation 9 is the counter-intuitive formula we use to calculate the volume of contracts traded at time, t, in ETH (V_t^E) where B_t is the .BXBT XBT/USD reference rate at time, t, and N_t is the number of contracts traded at time, t.

$$V_t^E = 10^{-6} B_t N_t \tag{9}$$

We sample the period from 2nd August 2018 to 17th July 2019. The start date reflects the introduction date of the perpetual swap to BitMEX's market place. We collect an additional week's worth of data for the spots and the .BETH index to provide an insight into the spot market before the introduction of the perpetual swap. We obtain the .BETH index to allow for the facilitating of a two-dimensional framework.

From CoinAPI, we obtain the ETH/USD spot rate from three exchanges; Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken (KRAK). We choose these exchanges as they are the constituents of the .BETH index and are three of the five most liquid exchanges of the ten exchanges that Bitwise Asset Management (Hougan et al., 2019) dictate to be 'real'. Real indicates that these exchanges do not engage in wash trading to boost their volume data artificially. CoinAPI does not provide complete data free of charge, limiting requests to 100,000 lines of data per key per day. Since we are using minute-by-minute data, a large amount of data is required, over 500,000 lines per exchange, thus requiring 18 separate downloads. To avoid taking 18 days to obtain the data, we create 18 separate keys by creating 18 new Google email accounts. We require the use of VPNs to avoid the University being IP banned by the CoinAPI servers. The requests provide full OLHCV data, including the volume data denominated in ETH. The data we gather from CoinAPI is not as full as the data we obtain from BitMEX due to lower trading volume in these exchanges. To ensure that there is a full dataset, we fill any spaces in the pricing data set with the price taken from .BETH index as this is the best alternative due to the exchange being a constituent. The three exchanges, in addition to the BitMEX perpetual swap, make up the constituents of the four-dimension analysis framework.

Table 3 displays the summary statistics for the perpetual swap and the three spot exchanges data. This data is both minute-by-minute and daily data, which takes the close at 23:59 for each day. Within the summary statistics, we observe that the markets are highly volatile, where the Bitstamp annualised volatility for the minute-by-minute data is 273.23%, and the lowest annualised volatility is 105.66% for the perpetual swap. In addition, we see that the annualised volatility is lower when observing daily data across all of the exchanges, more so for Kraken and Bitstamp. The minute-by-minute returns are not normally distributed as they are highly leptokurtic and have either a negative or positive skew. The daily returns are less leptokurtic and have less of a skew than the minute-by-minute returns. We see signs of substantial minute-by-minute returns with a high of 19.28% minute-by-minute loss on Bitstamp on 14th July and then the highest gain a minute later of 18.96%.

Table 4 shows the correlation of minute returns between the perpetual swap and the three spot exchanges, in addition to the correlation of returns between the perpetual swap and the .BETH index. We observe very little correlation between the returns with the spot exchanges and the perpetual swap. There is a stronger correlation between the returns of the .BETH index and the perpetual swap, but it may not be as high as we would expect between a future and its pricing index.

Table 3: Descriptive Statistics for Minute-by-Minute Exchange Data Used

	ETHUSD BTMX	ETH/USD GDAX	ETH/USD KRAK	ETH/USD BSTP
Exchange	Bitmex	Coinbase	Kraken	Bitstamp
Contract Type	Perpetual Swap	Spot	Spot	Spot
Start Date	02/08/2018	25/07/2018	25/07/2018	25/07/2018
End Date	17/07/2019	17/07/2019	17/07/2019	17/07/2019
N	502014	514021	514021	514021
Daily Volume (ETH)	1,693,194	149,914	105,404	52,374
μ	-0.0001%	-0.0002%	-0.0002%	-0.0002%
Median	0.00%	0.00%	0.00%	0.00%
Min	-12.00%	-9.02%	-12.14%	-19.28%
Max	11.75%	9.14%	12.58%	18.96%
Skewness	16.67	-4.09	6.47	-3.18
Kurtosis	283.8	282.8	129.9	155.2
σ	0.15%	0.15%	0.34%	0.38%
Annualised Volatility	105.66%	108.58%	249.10%	273.23%
Daily Data				
μ	-0.21%	-0.24%	-0.24%	-0.24%
Median	-0.08%	-0.15%	-0.11%	-0.11%
Min	-21.97%	-19.16%	-18.91%	-19.09%
Max	17.72%	17.70%	18.15%	17.81%
Skewness	-0.373%	-0.214%	-0.262%	-0.183%
Kurtosis	5.40	4.93	4.97	5.03
σ	5.37%	5.18%	5.24%	5.15%
Annualised Volatility	102.59%	98.96%	100.11%	98.39%

Table 3 displays the descriptive statistics for the 1-minute and daily returns of BitMEX's ETHUSD perpetual swap and the ETH/USD spot markets of Coinbase (GDAX), Kraken (KRAK) and Bitstamp (BSTP). We find that the daily volume for the perpetual swap is higher than those for the spot markets. We see low returns on average, but large minimum and maximum returns are present with high levels of volatility. Our statistics show that the returns for the instruments are not normally distributed.

Table 4: Correlation Between ETHUSD Perpetual Swap and Spots Exchanges Returns

	ETHUSD	GDAX	KRAK	BSTP
ETHUSD	100.00%	31.35%	15.14%	14.81%
GDAX	31.35%	100.00%	27.89%	26.07%
KRAK	15.14%	27.89%	100.00%	15.49%
BSTP	14.81%	26.07%	15.49%	100.00%

	ETHUSD	.BETH
ETHUSD	100.00%	77.12%
.BETH	77.12%	100.00%

Table 4 displays the correlation between the minute returns of the ETHUSD perpetual swap and the ETH/USD spot markets of Coinbase (GDAX), Kraken (KRAK) and Bitstamp (BSTP), and the perpetual swap and the .BETH index. We find that there is little correlation between the spot exchanges and the perpetual swap. Our results show a higher correlation between the perpetual swap and the .BETH index, but this is not as strong of a correlation as we would expect between a swap and its pricing index.

Figure 1 displays the close prices for the entire time period. Following the introduction of the perpetual swap, seven days into the time series, we see that the price falls downwards. The fall in price shows a correlation between the presence of the swap and downward pressure on the price, as discussed in the Introduction. The minimum price across the time-series occurs on 15th December 2018 for Coinbase Pro and 14th December 2018 for the remaining exchanges at 82.82-83.00 USD.

Figure 2 displays the minute returns for each of the five instruments and markets. We observe that particular areas of abnormal volatility are evident, particularly within the first section of the time series encompassing up to mid-October 2018 and starting again from 2nd April 2019. Kraken and Bitstamp are louder during the more volatile period. We see that returns are more volatile towards the end of the sample. In Figure 3, it is evident that during quieter periods, the minute-by-minute standard deviations of the returns are similar across all the instruments and markets. Table 5 displays the correlations between our minute volatilities from our instruments. Our results show that the correlation between the standard deviations are higher during the periods when conditional standard deviation is lower, i.e. the calmer period.

Equation 10 is the exponentially weighted moving average (EWMA) formula that we use to calculate the conditional standard deviations, where λ is the smoothing factor, r_{t-1}^2 is the previous return squared and σ_{t-1}^2 is the previous variance. We observe the highest minute standard deviation for Coinbase Pro and Bitstamp occur on 14th July 2019 at 3.4% and 8.4% respectively, where Kraken reaches 6.0% but the highest standard deviation for Kraken is 6.9% on 11th October 2018.

$$\sigma_t^2 = (1 - \lambda) r_{t-1}^2 + \lambda \sigma_{t-1}^2 \tag{10}$$

Table 5: Correlation Between ETHUSD Perpetual Swap and Spots Exchanges Standard Deviation

Panel A: **Volatile Period 1**	.BETH	ETHUSD	GDAX	KRAK	BSTP
.BETH	100.00%	86.08%	45.30%	64.45%	63.45%
ETHUSD	86.08%	100.00%	44.09%	63.17%	64.03%
GDAX	45.30%	44.09%	100.00%	38.03%	41.10%
KRAK	64.45%	63.17%	38.03%	100.00%	84.44%
BSTP	63.45%	64.03%	41.10%	84.44%	100.00%
Panel B: **Calm Period**	.BETH	ETHUSD	GDAX	KRAK	BSTP
.BETH	100.00%	96.04%	97.56%	92.26%	92.76%
ETHUSD	96.04%	100.00%	94.84%	90.08%	89.23%
GDAX	97.56%	94.84%	100.00%	93.21%	92.94%
KRAK	92.26%	90.08%	93.21%	100.00%	93.86%
BSTP	92.76%	89.23%	92.94%	93.86%	100.00%
Panel C: **Volatile Period 2**	.BETH	ETHUSD	GDAX	KRAK	BSTP
.BETH	100.00%	93.44%	49.94%	45.25%	54.91%
ETHUSD	93.44%	100.00%	43.76%	42.73%	49.39%
GDAX	49.94%	43.76%	100.00%	41.23%	42.72%
KRAK	45.25%	42.73%	41.23%	100.00%	71.08%
BSTP	54.91%	49.39%	42.72%	71.08%	100.00%

Table 5 displays the correlation between the minute conditional standard deviations of the ETHUSD perpetual swap, .BETH index and the ETH/USD spot markets of Coinbase (GDAX), Kraken (KRAK) and Bitstamp (BSTP). Our results within the table show that the correlation between the volatilities is higher when the volatility is lower. Our first period, Volatile Period 1, encompasses the data between 2nd August 2018 and 21st October 2018. Our calm period follows from 21st October 2018 to 2nd April 2019. Our final period follows this up to the end of our sample period, 16th July 2019.

Figure 4 displays the basis for the spot exchanges to the perpetual swap; displaying the percentage difference between each exchange's spot price and the price of the BitMEX perpetual contract. We see the more considerable variations in price occur during the more volatile periods. There is much less variance away from the price of the perpetual swap in the periods with a lower conditional standard deviation, rarely exceeding 3%. The highest deviation from the price of the swap occurs on 17th May 2019, where the deviations are around 29% for each exchange. The highest variance for each exchange in the first volatile period is around 14% for all three exchanges, occurring on 11th October 2018.

Figure 5 shows the daily trading volumes for the ETHUSD perpetual swap on BitMEX and the ETH/USD spot market on Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken (KRAK) in ETH, on a logarithmic scale. We observe that there is much more volume on BitMEX than the three spot exchanges. By 11th August 2018, nine days after the introduction of the contract, the daily volume of the perpetual swap reached 233,462 ETH, higher than the summation of the three spot exchanges on the same day whose cumulative volume was 231,356 ETH. Throughout our chosen time period, the average daily trading volume for the perpetual swap is 1,693,194 ETH, over five times the cumulative average daily volume for the three exchanges. Figure 6 displays the proportional volume between the three spot exchanges. We see that Coinbase Pro has the most substantial proportional volume of the three exchanges, and the relative volumes do not change by significant amounts through the sample period.

5 Empirical Results and Discussion

The following section details the results from this investigation into the contribution of price discovery to Ether.

5.1 Two-dimensional framework analysis - ETH Swap and Spot Index

The purpose of this subsection is to detail the results of our first two-dimensional approach used, as is consistent with the work of Corbet et al. (2018), Baur and Dimpfl (2019), Kapar and Olmo (2019), Karkkainen (2018), and Alexander and Heck (2019). The two constituents of the framework are BitMEX's ETHUSD perpetual swap and .BETH index. As we explore within the Methodology, there are various models which allow the measurement of price discovery. Our analysis makes use of generalised information share (Lien and Shrestha, 2014), component share (Gonzalo and Granger, 1995) and spillover effect (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012), like that of Alexander et al. (2019).

Figure 7 shows the Generalised Information Share (GIS) (Panel C) and Component Share (CS) (Panel D) for the price discovery of ETH between the perpetual swap and spot index, in addition to the information share (Hasbrouck, 1995) and the modified information share (Lien and Shrestha, 2009). We see that the perpetual swap dominates the price discovery throughout the time sample. There are signs of low contribution from the perpetual swap over the first three of weeks of its issue. However, after 24 days of issuance, we observe that the contract dominates the price discovery consistently in both the GIS and CS measures. Table 6 displays the average shares displayed in Figure 7. All of the measures show that, on average, the perpetual swap has dominance over the index within price discovery. The perpetual swap has a GIS of 62% and a CS of 64%. Our findings are in agreement with that of Kapar and Olmo (2019), and Karkkainen (2018), as well as that of common financial literature outside of the cryptocurrency space. However, our findings contradict the work of Corbet et al. (2018), and Baur and Dimpfl (2019). Our results from the two-dimensional share analysis appear to imitate those of Alexander et al. (2019); the only paper that investigates price discovery utilising BitMEX perpetual swaps. Alexander et al. (2019) also find that the perpetual swap, in this case XBTUSD, dominates spot exchanges. Albeit, they conducted their research utilising a four-dimensional framework.

Table 6: Daily Average Information and Component Shares for BitMEX Perpetual Swap and .BETH Index

	ETHUSD	.BETH
Information Share	57.90%	42.10%
Modified Information Share	61.67%	38.33%
Generalised Information Share	61.85%	38.15%
Component Share	64.06%	35.94%

Table 6 tabulates the results of the Information Share, Modified Information Share, Generalised Information Share and Component Share analysis for our two-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and .BETH index. We find that the ETHUSD perpetual swap leads price discovery on all four of the shares we investigate.

Figure 8 displays the total spillover from the markets. The spillover increases over time with a long term trend with the highest spillover occurring on the last measurement and the lowest spillover occurring on the first measurement. We see clear peaks and troughs throughout this time period which appear to be as volatile as those found by Alexander et al. (2019) over the same time period, albeit Alexander et al. find more total spillover than our two-dimensional analysis. Figure 9 shows us the gross spillovers from and to each market. We observe a correlation between the spillovers of the two instruments throughout the time period. Figure 10 displays the net spillovers for the two markets. Our graphical representation shows clearly that the perpetual swap has a more significant effect than that of the index. The net spillovers allow us to infer that the perpetual swap is the dominant instrument in price discovery. There are two periods where we see that the index is leading the price discovery, the first being at the inception of the perpetual swap contract where there is meagre trading volume. The second period occurs around 25th January 2019, which is where the ETH/USD price struggled around 120USD, as can be seen in Figure 1. Table 7 tabulates our results from Figures 9 and 10. The table shows us that the perpetual swap leads the price discovery with a net spillover of 1.29%. When we compare our net spillovers to Alexander et al. (2019), our net spillover from the perpetual swap is much lower, meaning there is less dominance over the spot than found in their four-dimensional analysis.

Table 7: Gross and Net Spillovers for the Two-Dimensional Analysis

To \ From	ETHUSD	.BETH
ETHUSD	63.46%	36.54%
.BETH	37.83%	62.17%
Net Spillover	1.29%	-1.29%

Table 7 tabulates the results of the Gross and Net Spillover analysis for our two-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and .BETH index. We find that the ETHUSD perpetual swap leads price discovery over the .BETH index due to its positive net spillover.

From the two dimensional analysis, we can see that the perpetual swap contract from BitMEX does lead the price discovery for the price of ETH over the spot market, represented by the .BETH index. Our findings contrast the XBT findings of Corbet et al. (2018) and Baur and Dimpfl (2019) who found the XBT spot market to have the price discovery dominance over the futures. The results of this subsection are similar to the XBT findings of Kapar and Olmo (2019), Karkkainen (2018), and Alexander and Heck (2019).

5.2 Four-dimensional framework analysis - ETH Swap and Three Spot Exchanges

Within this subsection, we use a four-dimensional approach into the price discovery analysis, like that of Alexander et al. (2019). The components of our four-dimensional framework are the BitMEX perpetual swap and three ETH spot exchanges; Bitstamp, Coinbase Pro and Kraken. As with the previous subsection, we use GIS, CS and spillover effects to investigate the leaders for the price discovery of ETH.

Figure 11 shows all of the share measures for the perpetual swap and the three exchanges. Throughout the sample period, our results show clear evidence of the dominance of the perpetual swap in the price discovery. Looking at Panel C, we can split the GIS into three sections with relation to the share of the perpetual swap. The first section includes the introduction of the perpetual swap to the market. We observe that the swap gains a larger share than measured in our initial two-dimensional model, measuring a maximum GIS of 95% in the first section. The second noticeable section of the GIS occurs when the GIS of the BitMEX rapidly falls an average of less than 50% over four months, even though the swap is still the clear leader in price discovery. The third section occurs once the swap regains the majority of the GIS. Within this period, the GIS reaches a maximum of 95%.

Figures 2 and 3 show there is a correlation between noisy time periods and growth in the GIS of the spot exchanges. This trend seems to continue in Panel D, of Figure 11, where the CS of the swap falls during this noisy period. On the other hand, this does not seem to occur when looking at Figure 7. Throughout the sample we see that the perpetual swap dominates the price discovery, even though it appears that the swap takes longer to dominate the CS in comparison to the GIS. During the noisy period, the CS does not fall as low as the GIS for the swap. Within our total sample, Coinbase Pro is the leader of price discovery out of the spot exchanges. Table 8 displays the average CS and GIS shares throughout the time period, as can be seen in Figure 7. The perpetual swap dominates the price discovery, and Coinbase Pro leads the price discovery for the spot exchanges.

Table 8: Daily Average Information and Component Shares for BitMEX Perpetual Swap and Spot Exchanges

	BitMEX	Coinbase Pro	Kraken	Bitstamp
Information Share	69.05%	13.24%	8.22%	9.49%
Modified Information Share	72.21%	12.61%	6.88%	8.30%
Generalised Information Share	72.63%	12.26%	8.28%	6.84%
Component Share	72.22%	15.50%	5.59%	6.69%

Table 8 tabulates the results of the Information Share, Modified Information Share, Generalised Information Share and Component Share analysis for our four-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and the ETH/USD spot markets of Coinbase, Kraken and Bitstamp. We find that the ETHUSD perpetual swap leads price discovery over the spot exchanges on all four of the shares we investigate. Coinbase Pro is the second largest contributor to the price discovery.

Our results are similar to that of Alexander et al. (2019) who also find that BitMEX leads the price discovery, but over XBT. However, the shares found by Alexander et al. are lower in comparison to those we have found; they found a generalised information share of 52% and a component share of 58%. Alexander et al. also find that Coinbase Pro is the lead for the spot exchanges in price discovery but for the XBT market. They discover that Bitstamp has a substantially larger

GIS and CS than Kraken, which we do not find for the ETH market. Throughout the time sample, the average GIS and CS for the perpetual swap is higher in the four-dimensional framework than that of the two-dimensional approach.

Figure 12 displays the total spillover from all of the markets together. We see that the spillover is low during periods of high volatility, whereas during the middle section of low volatility, the total spillover spikes for approximately five months. We observe that the spillover falls again when the volatility increases in April 2019. Compared to the total spillover in the two-dimensional approach in Figure 8, the peak of total spillover is much higher than the two-dimensional framework, but the troughs at either side of the peak are much lower than any point in the two-dimensional total spillover. Figure 15 shows the net spillovers from BitMEX and the spot exchanges. We see evidence that Coinbase Pro and Kraken have a negative relationship with their net spillovers. During the volatile period, Kraken leads Coinbase Pro in price discovery and during the less volatile period, Coinbase Pro leads Kraken. Throughout our sample, BitMEX has a positive net spillover apart from in the period around 25th January 2019 where BitMEX has a negative net spillover, very similar to that in the two-dimensional framework as seen in Figure 10.

Table 9 tabulates our results from Figures 13, 14 and 15. Throughout the entire period, we observe that Bitstamp has the highest net spillover of all the instruments, 0.84%. BitMEX also has a positive net spillover, 0.63%, but is not the leader in price discovery, contrary to results of Alexander et al. (2019) who find that BitMEX is the dominant leader in price discovery for the XBT market. We find that Coinbase Pro and Kraken have negative net spillovers, which Alexander et al. also find. The spillovers we obtain in the ETH markets are much lower than those found by Alexander et al. in their research for the XBT markets.

Table 9: Gross and Net Spillovers for the Four-Dimensional Analysis

To \ From	BitMEX	Bitstamp	Coinbase Pro	Kraken	The Others
BitMEX	73.08%	9.03%	9.99%	7.89%	26.92%
Bitstamp	9.02%	68.99%	12.26%	9.73%	31.01%
Coinbase Pro	10.01%	12.62%	65.05%	12.33%	34.95%
Kraken	8.52%	10.20%	12.42%	68.86%	31.14%
The Others	27.55%	31.85%	34.67%	29.95%	31.00%
Net Spillover	0.63%	0.84%	-0.28%	-1.18%	

Table 9 tabulates the results of the Gross and Net Spillover analysis for our four-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and the ETH/USD spot markets of Coinbase, Kraken and Bitstamp. We find that Bitstamp's ETH/USD spot market leads price discovery within our four-dimensional analysis. The perpetual swap is also a net contributor to the price discovery for Ether; meanwhile, Coinbase Pro and Kraken have negative net spillovers, showing that they have little contribution to price discovery.

The results from our four-factor framework provide strong evidence that the BitMEX ETHUSD perpetual swap is the leader in price discovery for the markets. The CS and GIS found for the perpetual swap show a significant dominance in the price discovery. Meanwhile, regarding the net spillovers, we find that Bitstamp leads the price discovery while the perpetual swap is the second-highest contributor. This research offers support to that conducted by Alexander et al. (2019), Alexander and Heck (2019), Kapar and Olmo (2019), and Karkkainen (2018), in contrast to the work by Corbet et al. (2018) and Baur and Dimpfl (2019).

5.3 Two-dimensional framework analysis - ETH and XBT Swap

Within this subsection, we explore the price discovery between BitMEX's two perpetual swaps; ETHUSD and XBTUSD. We use the same methodology used in the previous two-dimensional approach. Due to the nature of the ETHUSD swap, being a Quanto swap, we must investigate the price discovery relationship between the two perpetual swaps. We first perform an Engle-Granger test to test for cointegration between the returns of the two swaps, and we find that they are cointegrated. Figures 16 and 17 display the total and received/ sent spillovers for the sample period, respectively. We can see cyclical waves in nature throughout this time period. Our results show us particularly low spillover through the first week of the issuance of the ETHUSD swap. Within November, we can see a low point in the spillover levels; within this period, we see very little volatility in the ETHUSD swap, as seen in Figure 3. Figure 18 shows the net spillovers throughout our chosen time-period. The XBTUSD dominates the perpetual swap during the first two months of the issuance of the ETHUSD perpetual swap. Post-October, the ETHUSD swap dominates the net spillover between the two swaps until May. From May 2019 onwards, the XBTUSD swap dominates the ETHUSD swap. Table 10 tabulates our spillover results. Our findings show very little net spillovers between the two swaps, even lower than those found between the ETHUSD swap and .BETH index.

Table 10: Gross and Net Spillovers for the Two-Dimensional Analysis of Both Swaps

To \ From	ETHUSD	XBTUSD
ETHUSD	73.44%	26.56%
XBTUSD	26.39%	73.61%
Net Spillover	-0.17%	0.17%

Table 10 tabulates the results of the Gross and Net Spillover analysis for our two-dimensional investigation into price discovery between BitMEX's ETHUSD and XBTUSD perpetual swaps. We find that the XBTUSD perpetual swap dominates the ETHUSD swap in price discovery. We see that the net spillovers between the two swaps are small, less than those found in the other two analyses.

Figure 19 displays the Generalised Information Share (GIS) (Panel C) and Component Share (CS) (Panel D) for the price discovery between the two perpetual swaps. As with the net spillover (Figure 18), we see that the ETHUSD swap has a low contribution to the GIS and CS within its first week of issuance. From mid-September, the ETHUSD swap dominates the GIS consistently, rarely falling below 50%. The XBTUSD swap dominates the CS throughout until late-May / early-June. From here our results show that the ETHUSD perpetual swap dominates the price discovery with regards to component share, over the XBTUSD swap. Table 11 displays our results from Figure 19. We can see that, throughout our sample period, the XBTUSD swap dominates the IS, MIS and CS. On the other hand, the ETHUSD swap dominates the GIS during our sample period. Our findings find little relation between BitMEX's two perpetual swaps as we see a very low spillover between the two swaps and conflicting results between the GIS and CS.

Table 11: Daily Average Information and Component Shares for Both BitMEX Perpetual Swaps

	ETHUSD	XBTUSD
Information Share	39.70%	60.30%
Modified Information Share	37.69%	62.31%
Generalised Information Share	60.63%	39.37%
Component Share	29.41%	70.59%

Table 11 tabulates the results of the Information Share, Modified Information Share, Generalised Information Share and Component Share analysis for our two-dimensional investigation into price discovery between BitMEX's ETHUSD and XBTUSD perpetual swaps. We find that the ETHUSD perpetual swap leads price discovery on the generalised information share. In contrast, the XBTUSD perpetual swap leads price discovery in the three other share measures we investigate.

6 Conclusion

The purpose of our report is to investigate the price discovery of BitMEX's Ether perpetual swap on the Ether market. We discuss the exchange and ETHUSD contract, detailing why the perpetual swap sees a substantially higher volume than those of the ETH/USD spot markets as shown within the Data section. We use three approaches to investigate price discovery within Ether, two two-dimensional frameworks and a four-dimensional framework. Within the first two-dimensional approach, we compare the perpetual swap to the .BETH spot index, the index which the swap is priced. We use Generalised Information Share (GIS) (Lien and Shrestha, 2014), Component Share (CS) (Gonzalo and Granger, 1995) and spillover effects (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) to investigate price discovery between the two assets.

Our investigation finds that the perpetual swap dominates the spot exchange in all of the shares we scrutinise. Our findings support the results of the two-dimensional investigations from Alexander and Heck (2019), Kapar and Olmo (2019), and Karkkainen (2018) and do not reinforce the results of Corbet et al. (2018) and Baur and Dimpfl (2019). Additionally, we show that the swap leads the spot index when investigating the spillover effects. Our second two-dimensional approach investigates price discovery between BitMEX's two perpetual swaps, ETHUSD and XBTUSD. We use the same methods as the previous approach. Our results find no significance for the price discovery between the two swaps as the spillover effects are low.

We use a four-dimensional approach that compares the perpetual swap to the constituents of the .BETH index; Coinbase Pro, Bitstamp and Kraken. Within the four-dimensional framework, we apply the same methodology as that use in the two-dimensional approaches. We find that within the shares that we investigated, the futures contract dominates the spot market. Our findings agree with those in the two-dimensional analysis, between .BETH and ETHUSD, but to an even greater extent where the GIS and CS in the two-dimensional are 61.85% and 64.06%, respectively, compared to 72.63% and 72.22% in our four-dimensional analysis. Our results agree with the findings of Alexander et al. (2019). Exploring the net spillover effects for the four-dimensional investigation, we find that BitMEX does not lead the price discovery; instead, Bitstamp is the dominant instrument in price discovery. This finding is in contrast to that of Alexander et al. (2019), but BitMEX does have a positive net spillover, unlike Coinbase Pro and Kraken which have negative net spillover, agreeing with the findings of Alexander et al. (2019). However, within our study, the net spillovers are much less than that which Alexander et al. finds.

Our study finds clear evidence that BitMEX's perpetual swap has great importance on the Ether market. The Ethereum blockchain was not established to be a transfer of value, unlike Bitcoin, yet still, its token has become a financialised asset. That makes our findings in this report significant to financial literature, especially within the cryptocurrency space, which tends to focus on Bitcoin. Ether is used increasingly by traders, speculators and hedgers and it is evident that BitMEX's contract has a significant influence on the market, which is surprising when neither ETH or USD are used in the transaction.

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Appendix

Figures

Figure 1: Close Prices for Each Instrument and Exchange

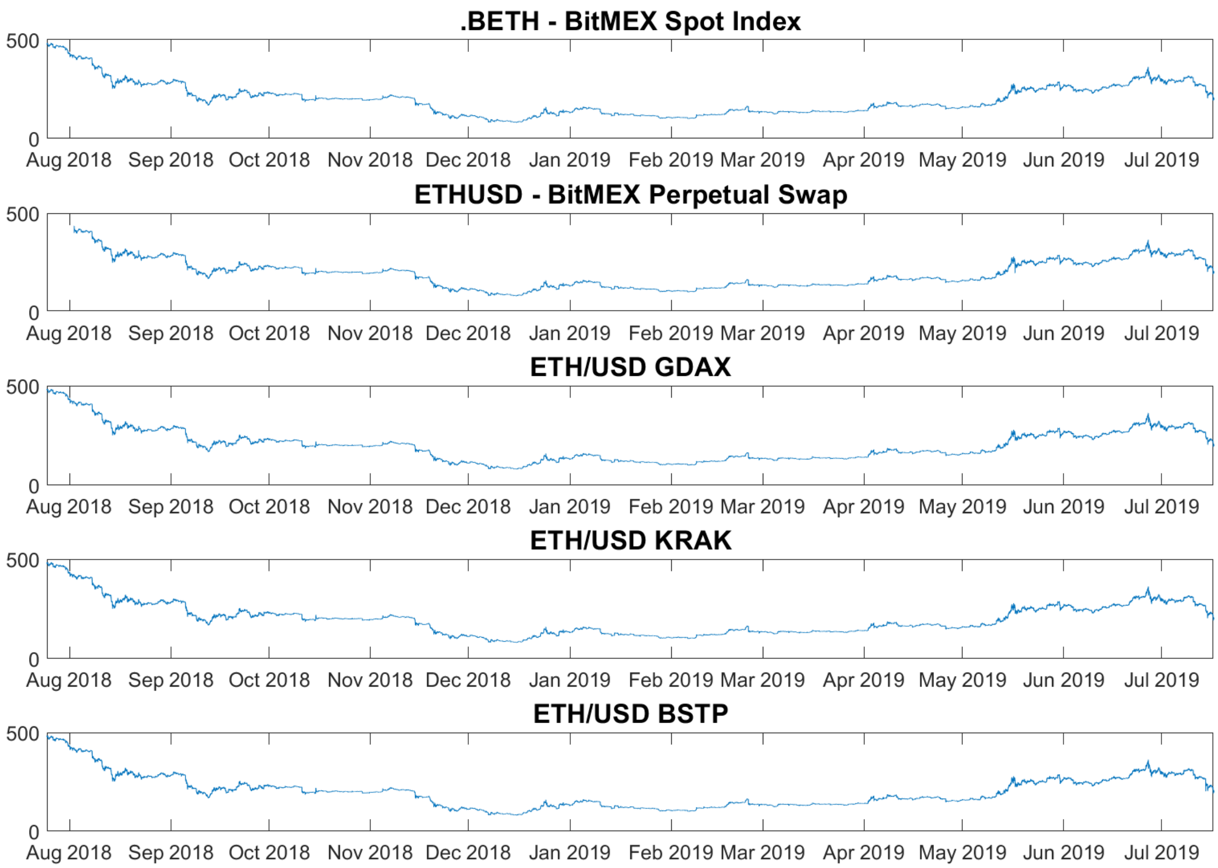

Figure 1 displays the close price of BitMEX's .BETH index and ETHUSD perpetual swap, in addition to those from Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken's (KRAK) ETH/USD spot exchanges. At the start of our time period, the prices of all exchanges are falling to their minimum in mid-December at around 83 USD. We see a long term rise in the price until the end of June 2019. From July 2019, we see a fall in the close prices.

Figure 2: Minute Returns for Each Instrument and Exchange

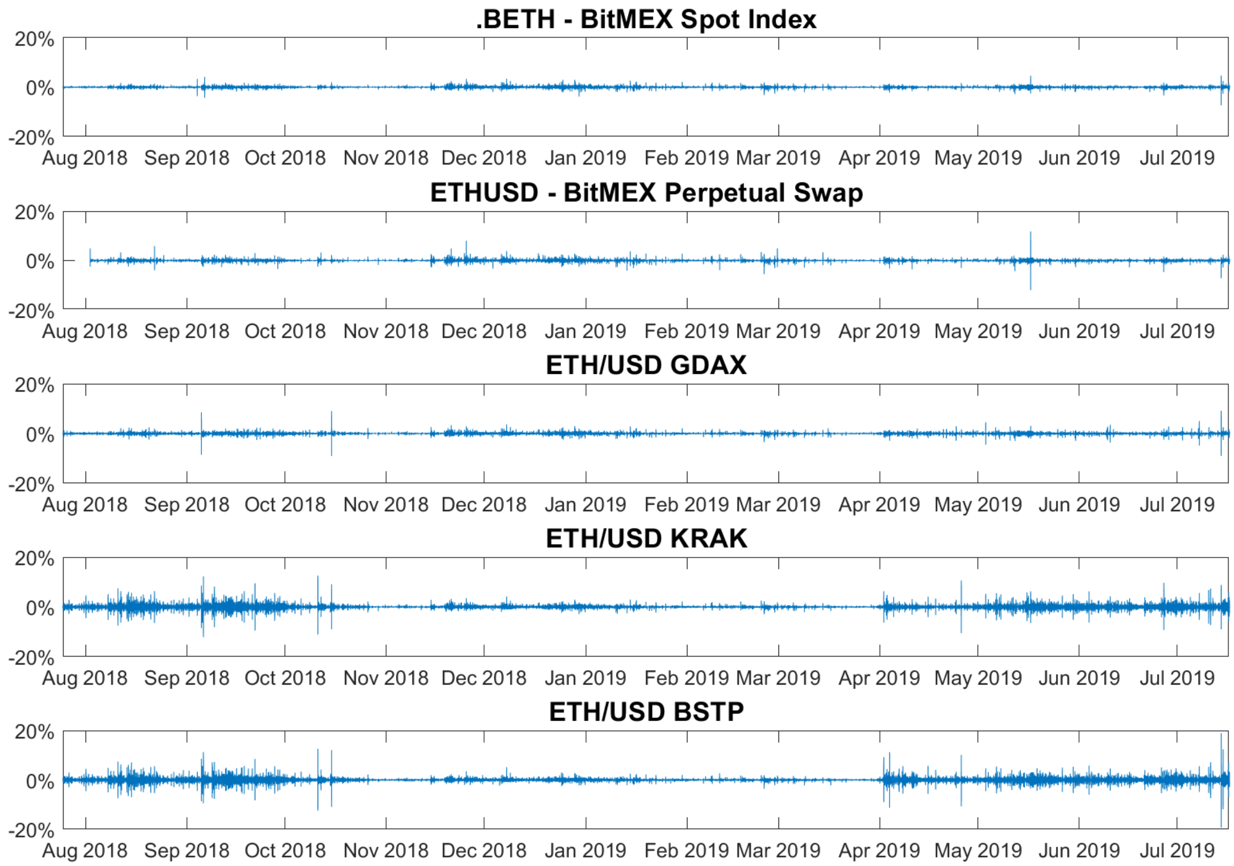

Figure 2 displays the 1-minute log-returns of BitMEX's .BETH index and ETHUSD perpetual swap, in addition to those from Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken's (KRAK) ETH/USD spot exchanges. We can see that the .BETH index and the perpetual swap are much less noisy than the spot exchanges. Kraken and Bitstamp are much louder than the Coinbase Pro exchange. We can separate the periods of return into three distinct periods. The first period runs till mid-October 2018 where we see Kraken and Bitstamp are louder than the other instruments/ exchanges. The second period runs until April 2019, and we can see that Kraken and Bitstamp are quieter throughout this period. Kraken and Bitstamp appear to have the same amount of volatility as the .BETH index, perpetual swap and Coinbase's spot price, in this period. The third period from April 2019 sees the abnormal volatility in the Kraken and Bitstamp exchanges increase again like that of the first period. We see the other instruments and exchanges have much lower absolute returns.

Figure 3: Conditional Standard Deviation of Minute Returns for Each Instrument and Exchange

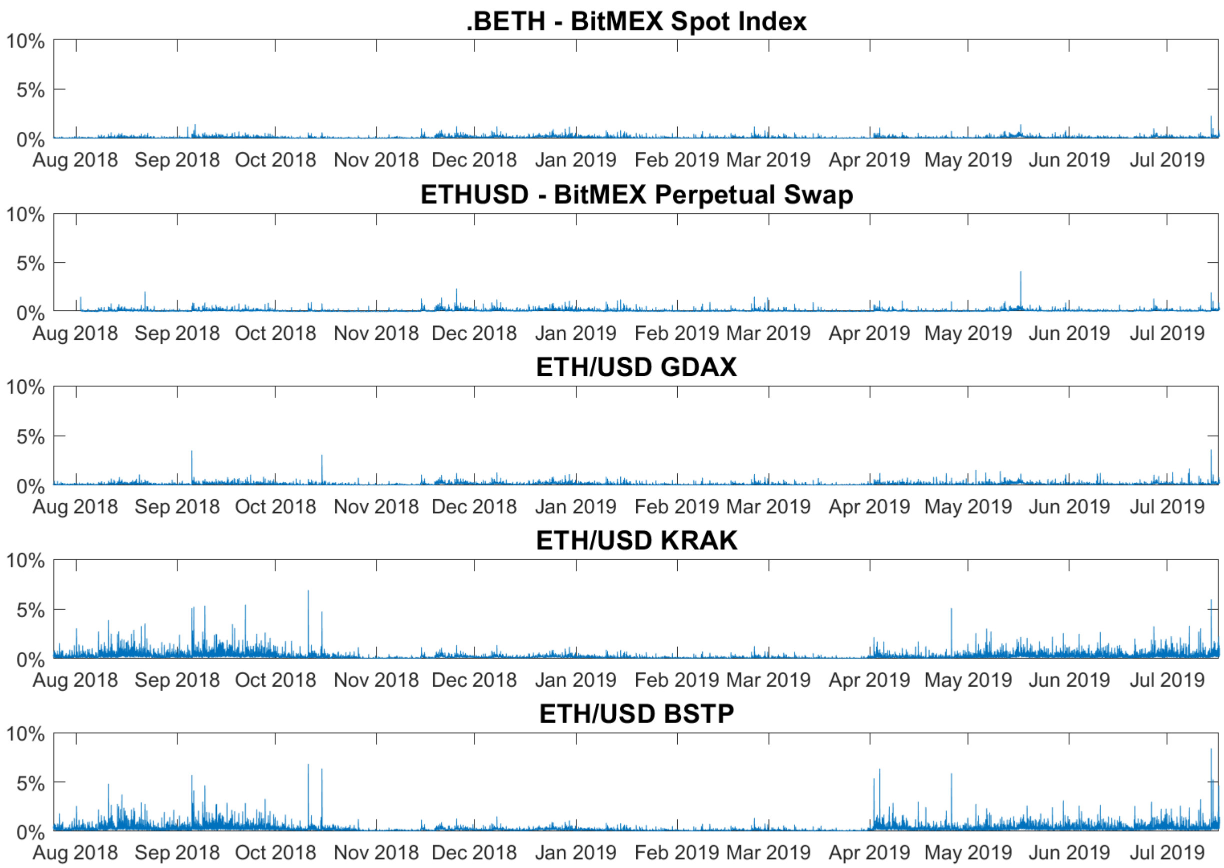

Figure 3 displays the conditional standard deviation of the 1-minute log-returns of BitMEX's .BETH index and ETHUSD perpetual swap, in addition to those from Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken's (KRAK) ETH/USD spot exchanges. We calculate the conditional standard deviation using the exponentially weighted moving average (See Equation 10). Throughout the entire time period, we can see that the spot prices from Kraken and Bitstamp are much louder than the other exchanges and instruments.We can split the 1-minute standard deviation into three periods. The first runs until mid-October 2018. Within this period, we see that the conditional standard deviations for the .BETH index and ETHUSD perpetual swap are consistently shallow. The standard deviations for Coinbase Pro are also very low with a couple of points of high standard deviation. The standard deviations for Kraken and Bitstamp are very high within the first period. From mid-October 2018 to April 2019, the standard deviation of returns of Bitstamp and Kraken are much lower, even less than those for the .BETH index, perpetual swap and Coinbase's spot price, even though they remain low.From April 2019, we see a significant increase in the conditional standard deviations for Kraken and Bitstamp. The standard deviation for the .BETH index, perpetual swap and Coinbase's spot price stay at the relative level of noise as seen in the second period.

Figure 4: Basis of Close Price for the Spot Exchanges to the ETHUSD Perpetual Swap

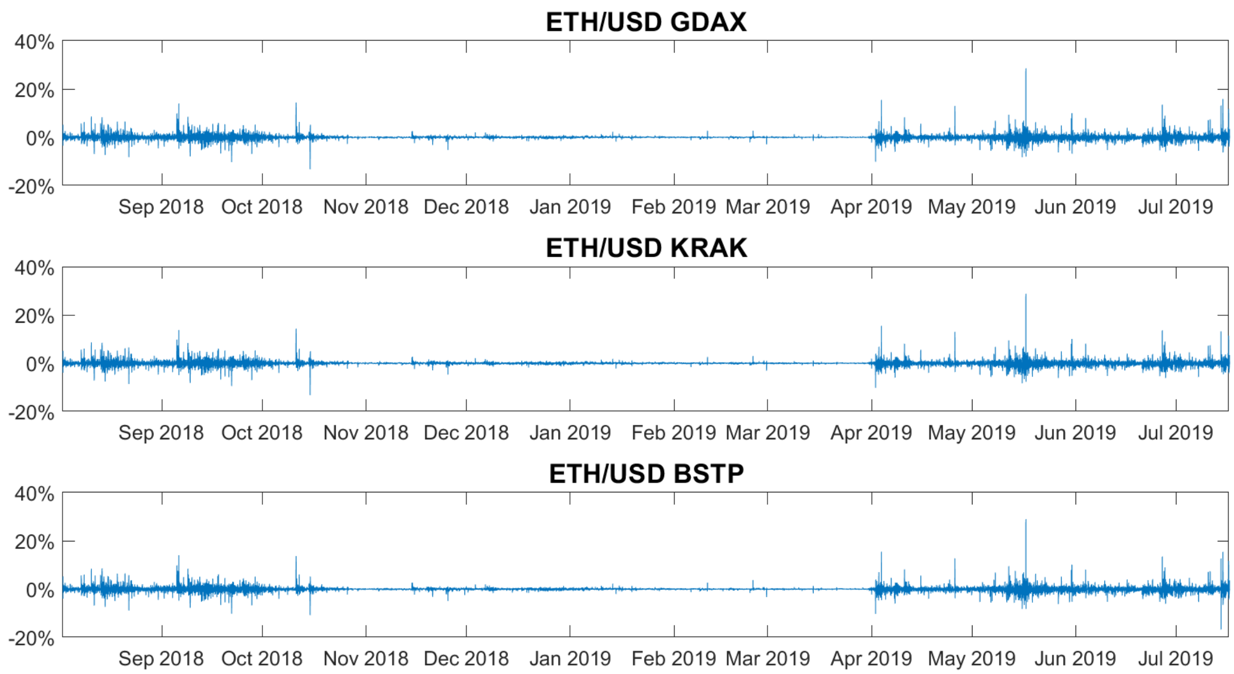

Figure 4 displays the 1-minute log basis of Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken's (KRAK) ETH/USD close prices of the ETHUSD perpetual swaps close price. The basis shows the percentage deviation of the close price of the spot exchanges to the close price of the perpetual swap. We can see a correlation between the noise in the basis to the noise in the conditional standard deviation, as seen in Figure 3. Between mid-October 2018 and April 2019, we see that there is minimal deviation for the spot exchanges from the close price of the perpetual swap. Outside this period, we see large deviations between the close prices of the spots and swap.

Figure 5: Daily Trading Volume of the Three Exchanges and the ETHUSD Perpetual Swap on a Logarithmic Scale

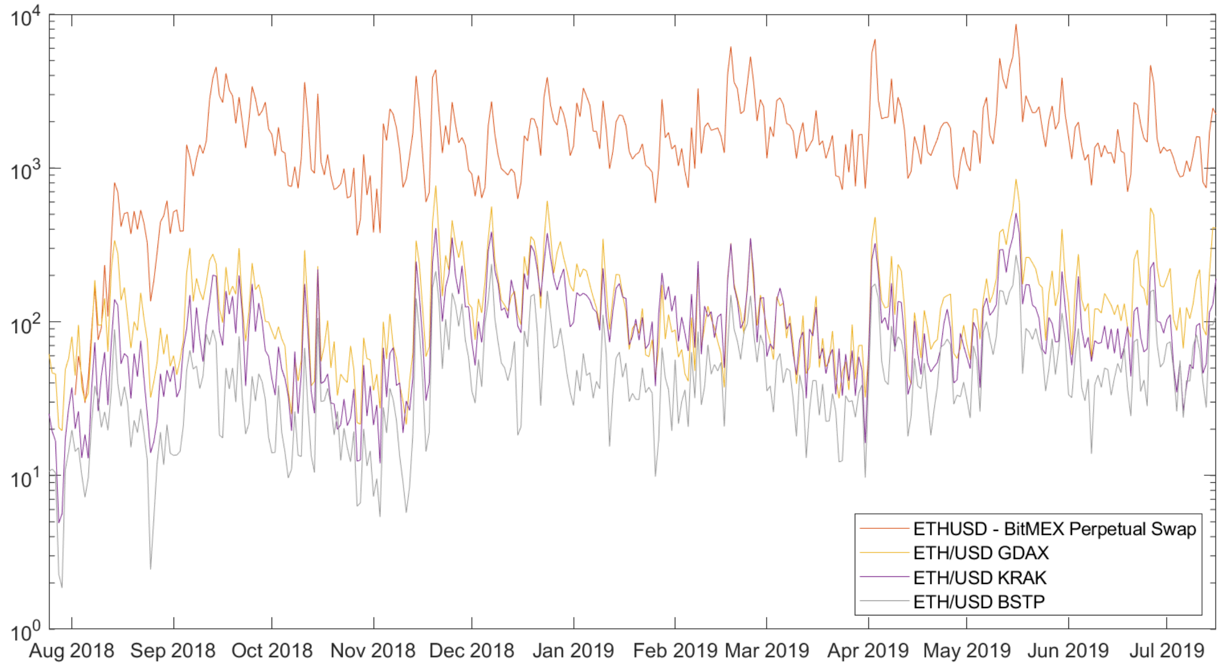

Figure 5 displays the daily trading volume of the ETHUSD perpetual swap, in addition to the volume of Bitstamp (BSTP), Coinbase Pro (GDAX) and Kraken's (KRAK) ETH/USD spot exchanges, on a logarithmic scale. We can see that within two weeks of the perpetual swap's introduction, its volume rose to that higher than that of each spot exchange. Throughout the remainder of the sample period, the perpetual swap always has a higher volume than each swap. For the entire period, the swap has an average daily trading volume of over five times that of the three spot exchanges combined.

Figure 6: Relative Percentage Volume Between the Three Spot Exchanges

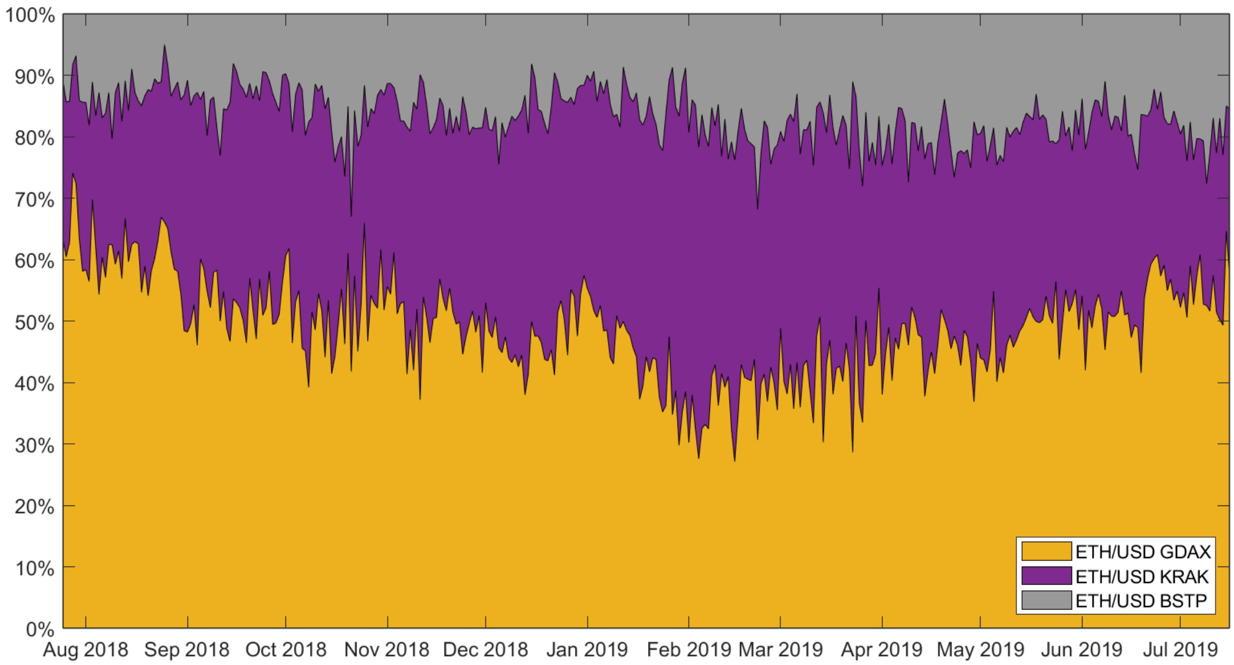

Figure 6 shows the relative percentage trading volume between the three spot exchanges. Throughout our entire period, we can see that Coinbase Pro (GDAX) has the most substantial relative volume, with Kraken (KRAK) and Bitstamp (BTSP) following behind. The relative volumes are reasonably consistent throughout our entire time-period.

Figure 7: Information and Component Shares for the Two-Dimensional Approach Between the .BETH Index and ETHUSD Perpetual Swap

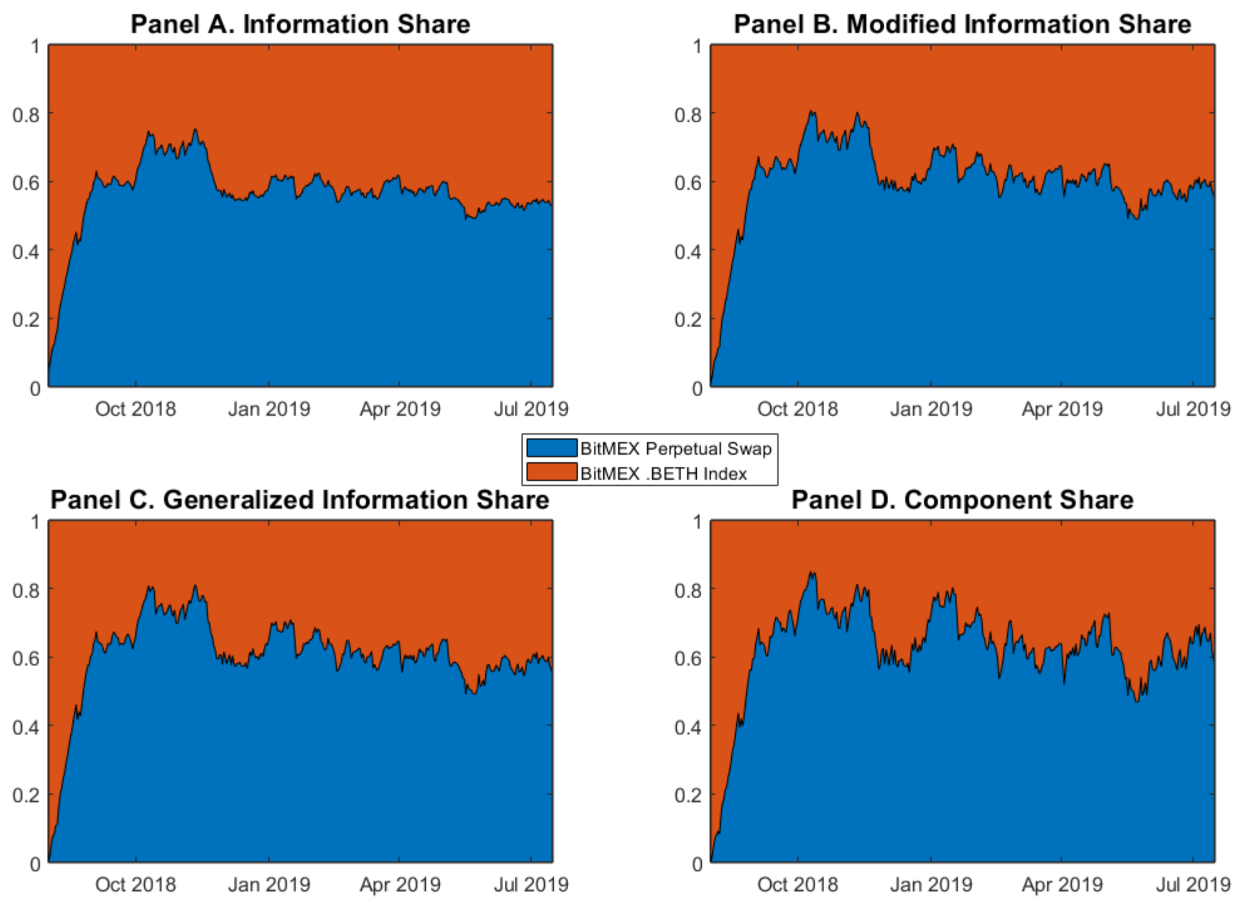

Figure 7 displays the Information Share (IS - Equation 3) (Hasbrouck, 1995), Modified Information Share (MIS - Equation 4) (Lien and Shrestha, 2009), Generalised Information Share (GIS - Equation 5) (Lien and Shrestha, 2014) and Component Share (CS - Equation 6) (Gonzalo and Granger, 1995) used to analyse the price discovery between BitMEX's ETHUSD perpetual swap and .BETH index. For our analysis, we focus on the GIS and CS. Panels C and D show that the perpetual swap dominates the price discovery throughout the time period. In the first 24 days of the contract's issuance, price discovery contribution for the swap is low, but it dominates after these 24 days.

Figure 8: Total Spillover for the Two-Dimensional Approach Between the .BETH Index and ETHUSD Perpetual Swap

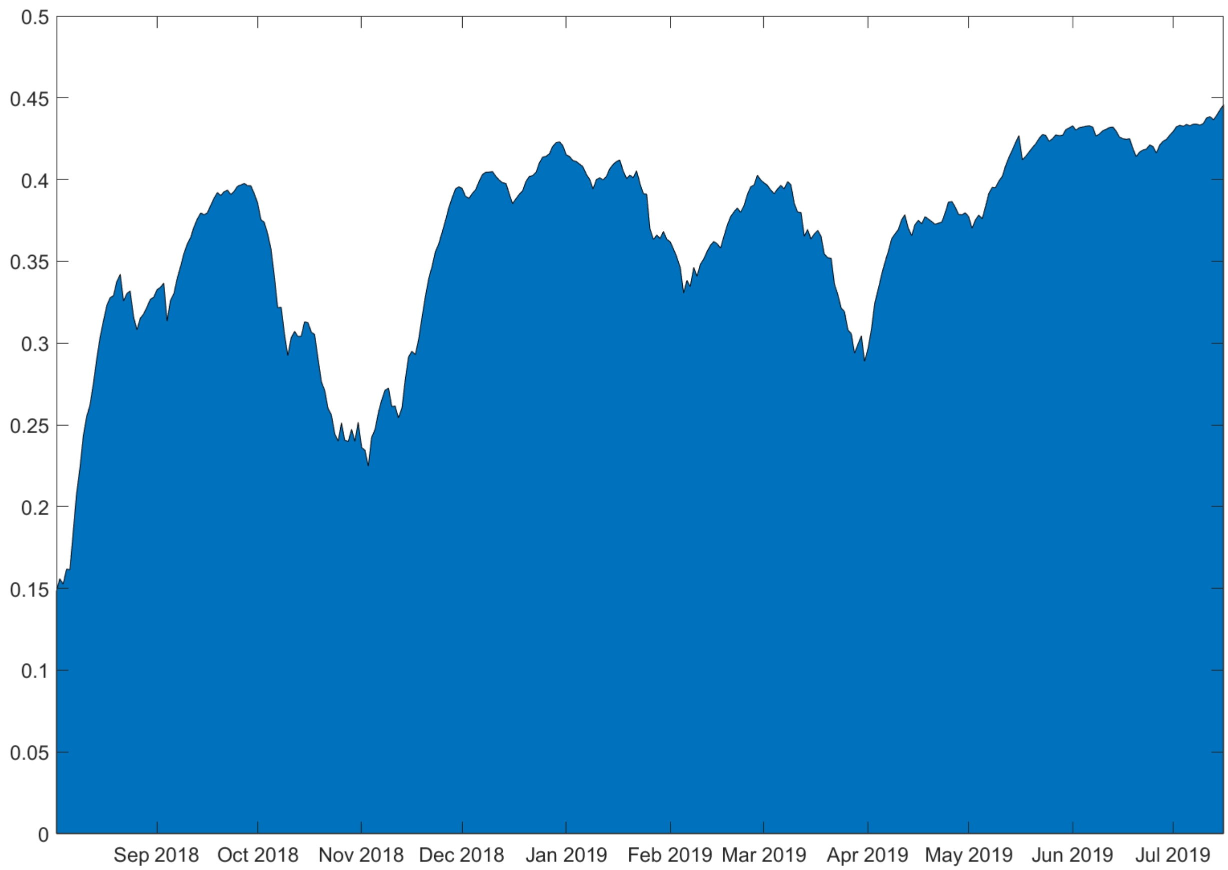

Figure 8 displays the total spillover (Pesaran and Shin, 1998) from BitMEX's ETHUSD perpetual swap and .BETH index within our two-dimensional analysis from the two instruments. We can see that the total spillover is low at the start of our sample period due to a low contribution from the perpetual swap. The low initial contribution is due to the contract being new to the market. The long term trend shows an increase in the total spillover with the occasional peak and trough within the time-series.

Figure 9: Given Spillover for the Two-Dimensional Approach Between the .BETH Index and ETHUSD Perpetual Swap

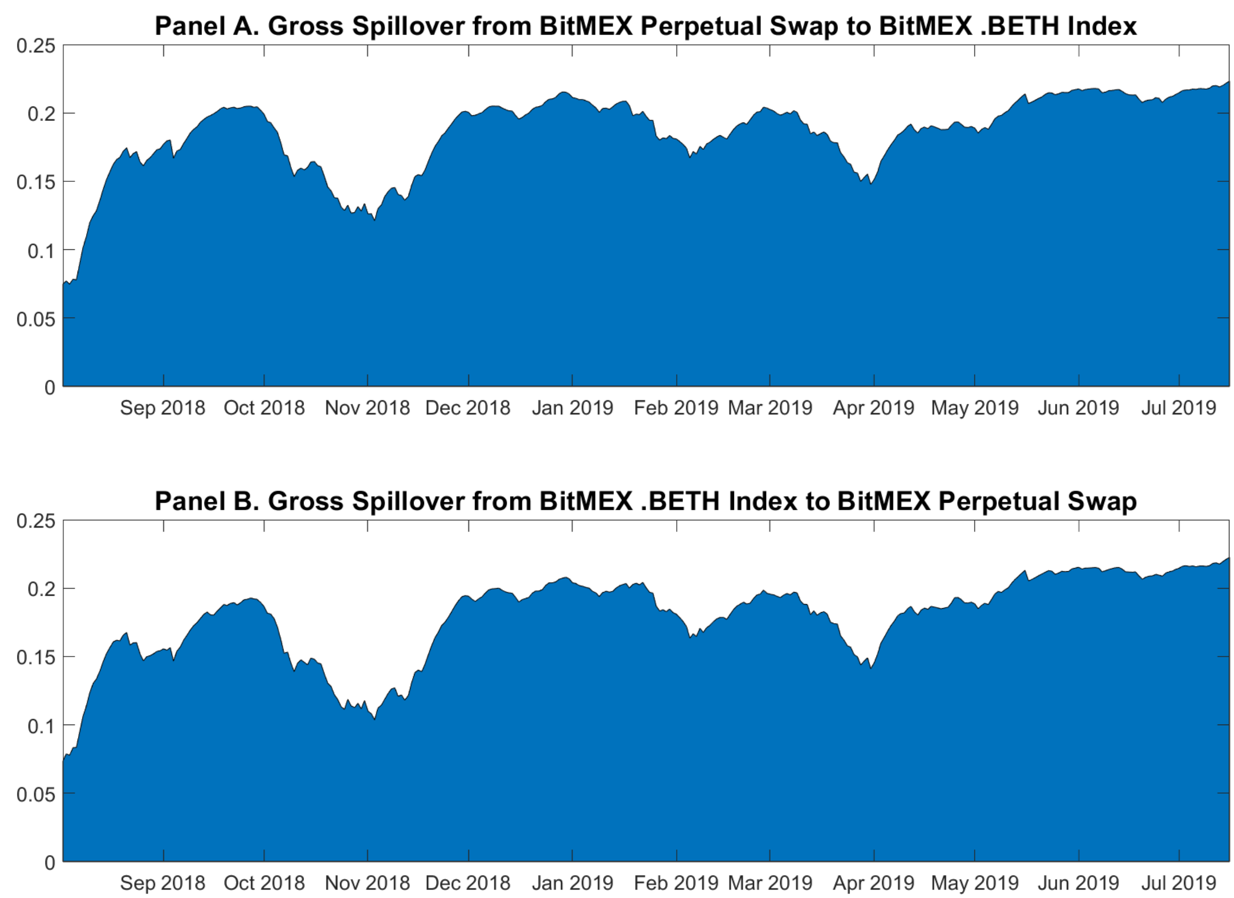

Figure 9 displays the directional spillovers (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) between BitMEX's ETHUSD perpetual swap and .BETH index within our two-dimensional analysis from the two instruments. The figure shows the volatility spillover sent from each instrument to the other in the analysis. Like in the total spillover (Figure 8), we can see that the directional spillovers are low at the start of our sample period. The long term trend shows an increase in the total spillover with the occasional peak and trough within the time-series. We see a high correlation between the two directional spillovers throughout the entire time period, with matching peaks and troughs.

Figure 10: Net Spillover for the Two-Dimensional Approach Between the .BETH Index and ETHUSD Perpetual Swap

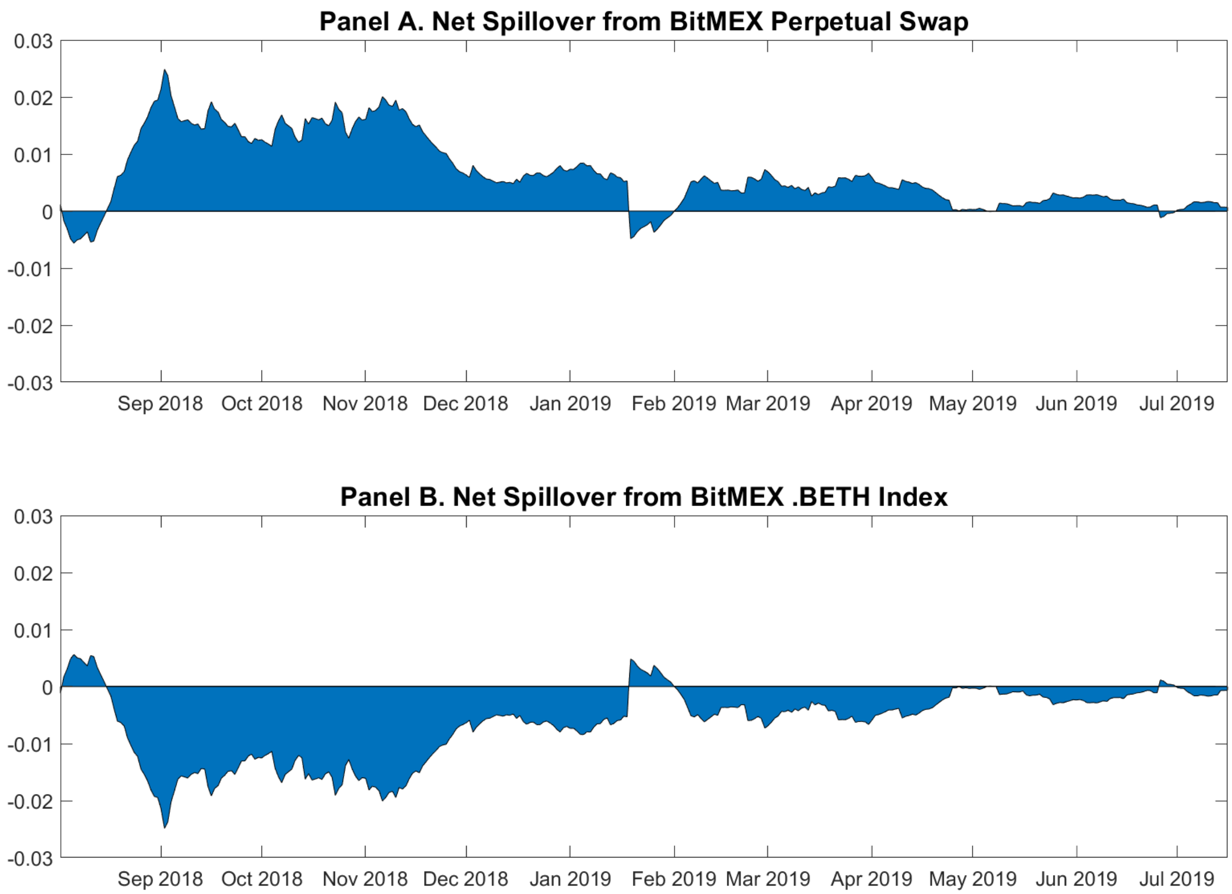

Figure 10 displays the net spillovers (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) between BitMEX's ETHUSD perpetual swap and .BETH index within our two-dimensional analysis from the two instruments. The figure shows the net spillovers for each instrument; this is the difference between the spillover sent and the spillover received. We see that across the whole period, the ETHUSD perpetual swap dominates the .BETH Index. Within the first half of August 2018, we see that the .BETH index dominates the perpetual swap during the first 14 days of the contract's issuance. Following this, the swap dominates the index, even if this is at a diminishing rate. These findings are consistent with those of Figure 7.

Figure 11: Information and Component Shares for the Four-Dimensional Approach

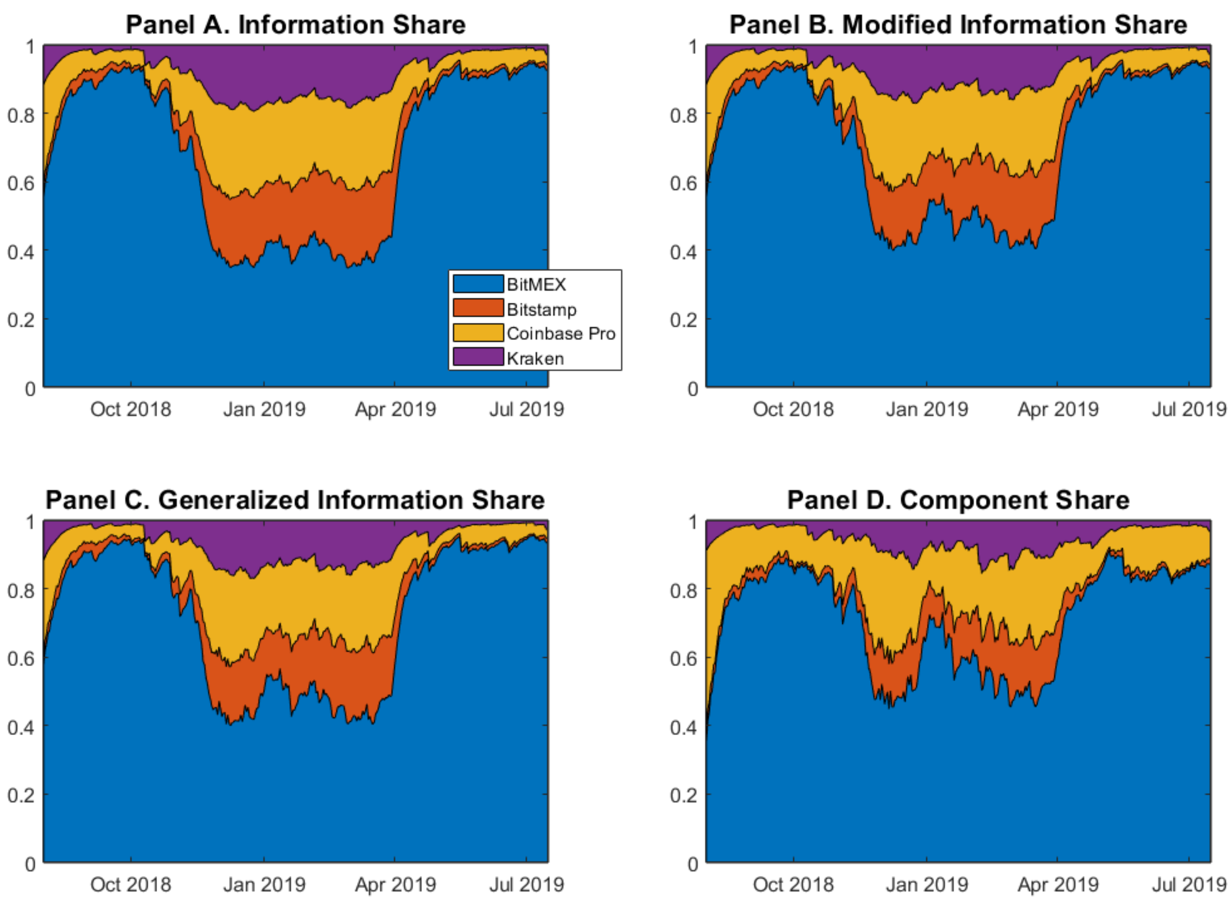

Figure 11 displays the Information Share (IS - Equation 3) (Hasbrouck, 1995), Modified Information Share (MIS - Equation 4) (Lien and Shrestha, 2009), Generalised Information Share (GIS - Equation 5) (Lien and Shrestha, 2014) and Component Share (CS - Equation 6) (Gonzalo and Granger, 1995) used to analyse the price discovery between BitMEX's ETHUSD perpetual swap and the ETH/USD spot markets of Bitstamp, Coinbase Pro and Kraken. For our analysis, we focus on the GIS and CS. Panels C and D show that the perpetual swap dominates the three spot exchanges in terms of price discovery. We see that between November 2018 and April 2019, the swap no longer holds the majority of the price discovery throughout, even though it does still dominate the price discovery. This period coincides with the period of lower conditional standard deviation we see in Figure 3 and the head in the total spillover in Figure 12.

Figure 12: Total Spillover for the Four-Dimensional Approach

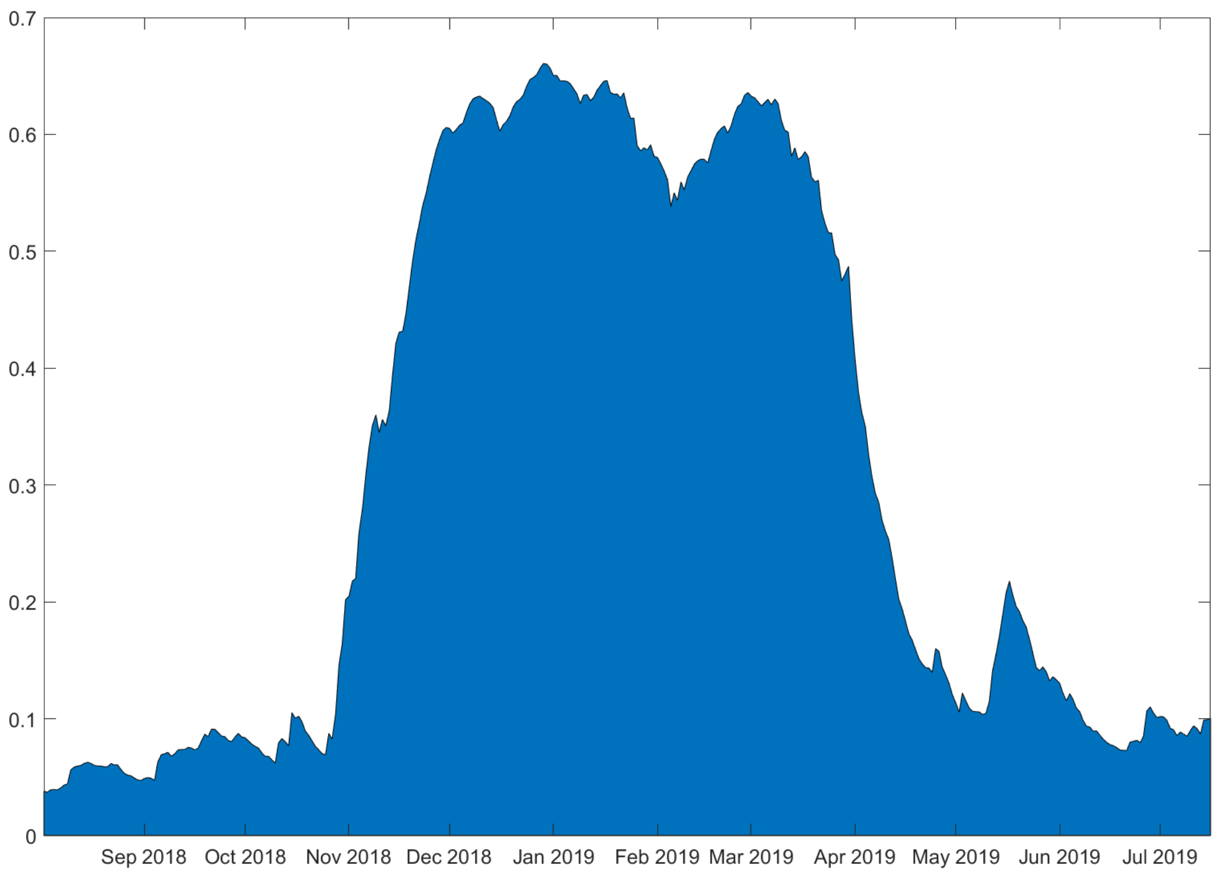

Figure 12 displays the total spillover (Pesaran and Shin, 1998) from BitMEX's ETHUSD perpetual swap and the ETH/USD spot exchanges of Bitstamp, Coinbase Pro and Kraken within our four-dimensional analysis. We see a general head shape which centres around a period from November 2018 to April 2019. The peak of the head occurs during the period of lower conditional standard deviation we see in Figure 3 and during the period of reduced contribution from the perpetual swap in Figure 11.

Figure 13: Given Spillover for the Four-Dimensional Approach

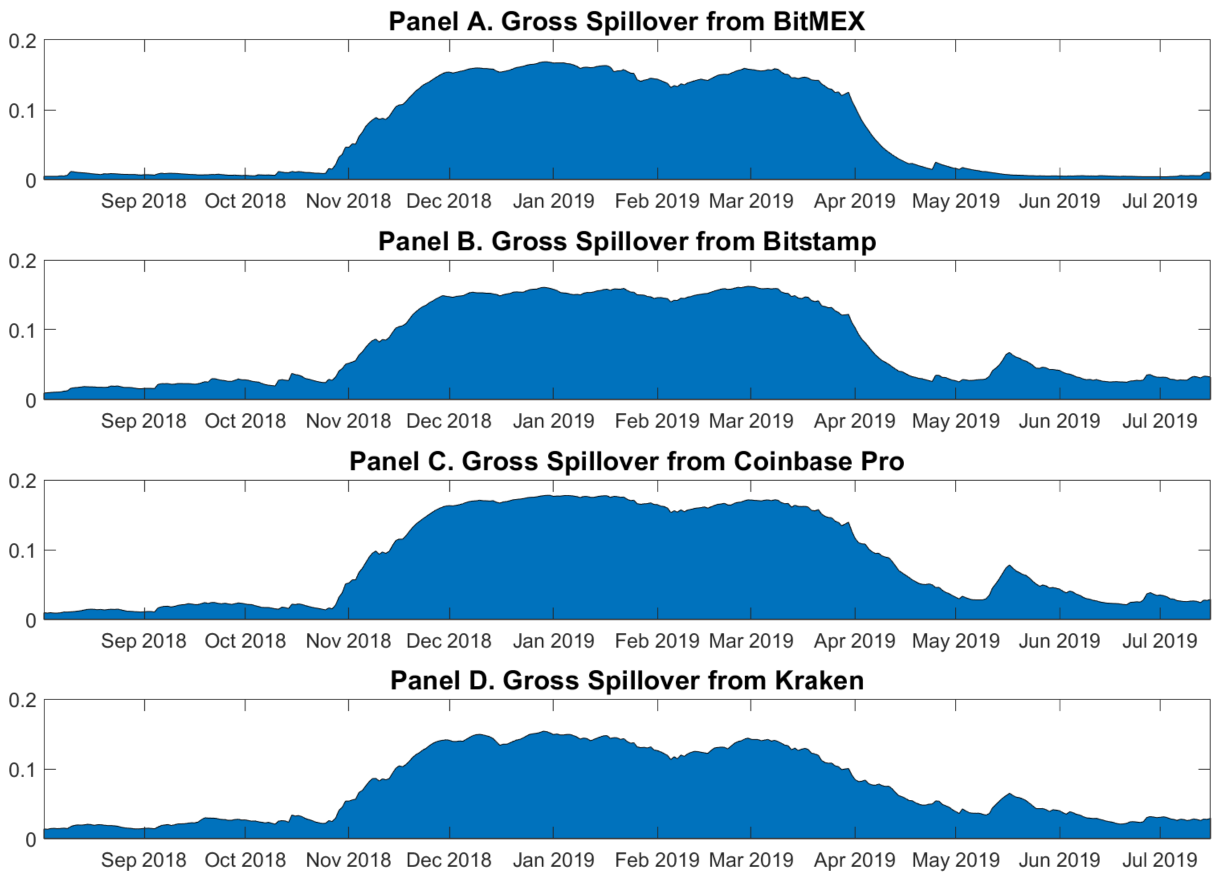

Figure 13 displays the given spillover (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) from BitMEX's ETHUSD perpetual swap and the ETH/USD spot exchanges of Bitstamp, Coinbase Pro and Kraken within our four-dimensional analysis. The figure shows the amount of spillover that each instrument/ market transmits to the other instruments. We see a general head shape which centres around a period from November 2018 to April 2019, as seen in Figures 12 Figure 13. The peak of the head occurs during the period of lower conditional standard deviation we see in Figure 3 and during the period of reduced contribution from the perpetual swap in Figure 11. The given spillovers all appear to be correlated, following a similar shape. We spot some areas of difference in the spillovers in mid-October 2018 and mid-May 2019 where the perpetual swap does not provide as much spillover as the spot exchanges.

Figure 14: Received Spillover for the Four-Dimensional Approach

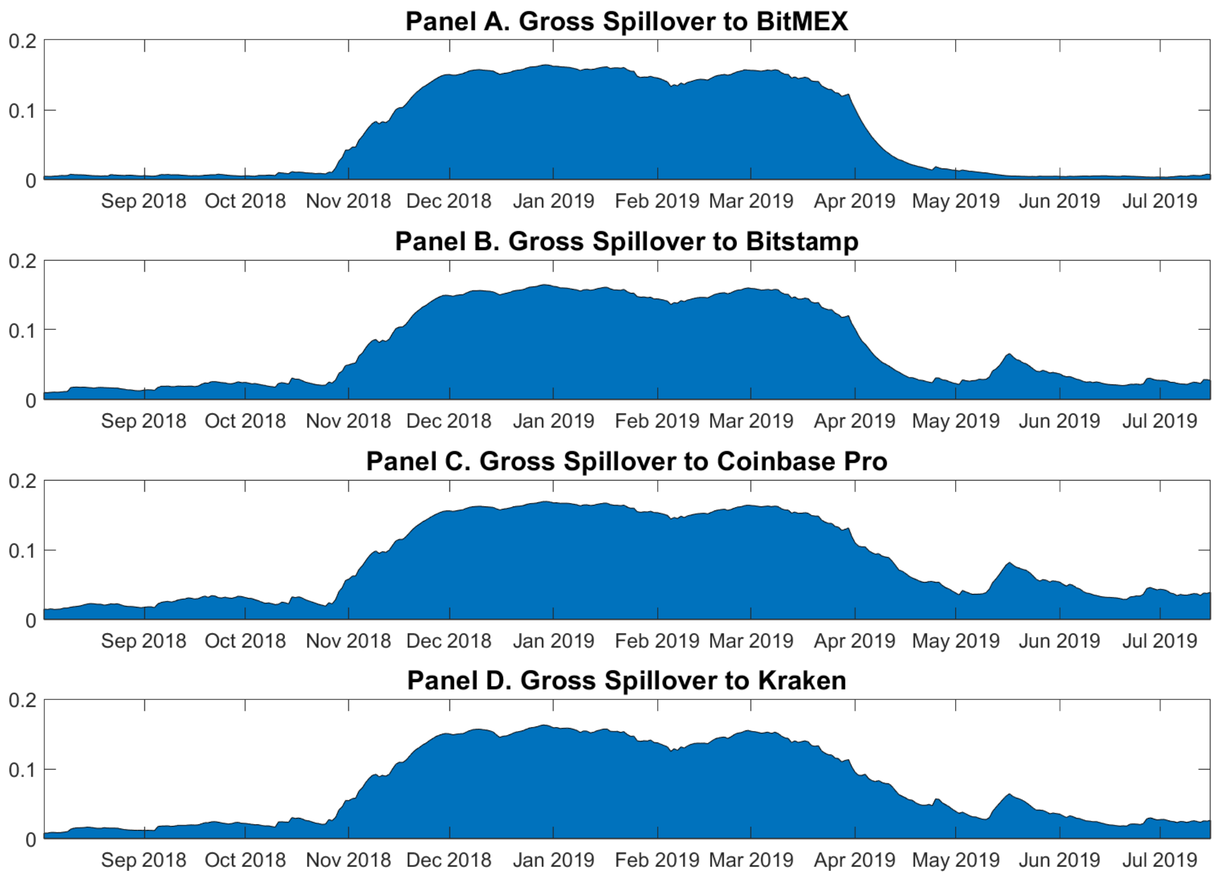

Figure 14 displays the received spillover (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) for BitMEX's ETHUSD perpetual swap and the ETH/USD spot exchanges of Bitstamp, Coinbase Pro and Kraken within our four-dimensional analysis. The figure shows the amount of spillover that each instrument/ market receives from the other instruments. We see a general head shape which centres around a period from November 2018 to April 2019, as seen in Figure 12 and Figure 13. The peak of the head occurs during the period of lower conditional standard deviation we see in Figure 3 and during the period of reduced contribution from the perpetual swap in Figure 11. The received spillovers all appear to be correlated, following a similar shape. We identify some areas of difference in the spillovers pre-November 2018 and post-April 2019, where the perpetual swap does not receive as much spillover as the spot exchanges.

Figure 15: Net Spillover for the Four-Dimensional Approach

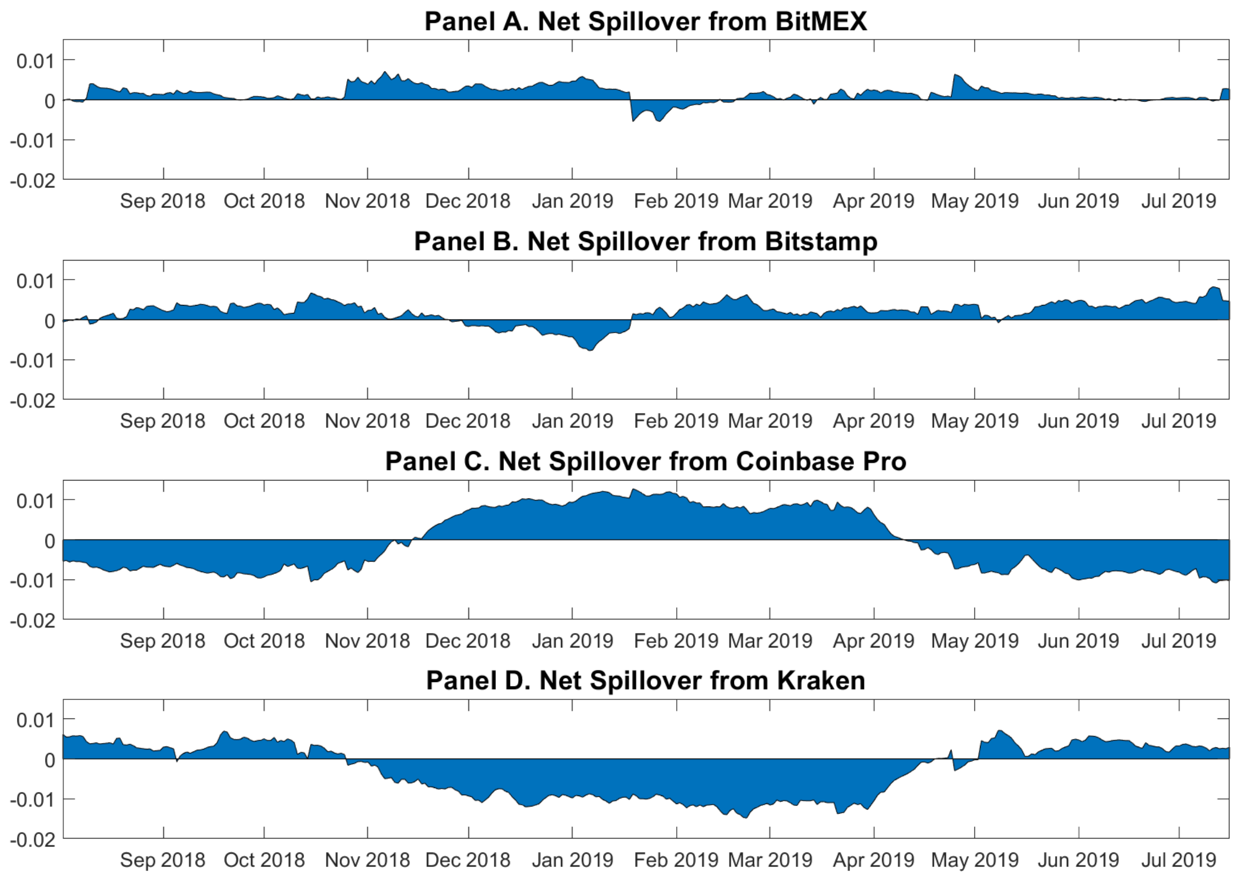

Figure 15 displays the net spillovers (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) of BitMEX's ETHUSD perpetual swap and the ETH/USD spot exchanges of Bitstamp, Coinbase Pro and Kraken within our four-dimensional analysis. The figure shows the net spillovers for each instrument. The net spillover is the difference between the spillover sent and the spillover received. We can see that Coinbase Pro and Kraken have negative relationships with each other, as they have similar shapes. During the volatile period we see in Figure 3, Kraken leads Coinbase Pro; in the less volatile period, Coinbase Pro leads Kraken. We see that the perpetual swap's net spillover is mostly positive throughout the sample period, as is that of Bitstamp. We see a negative net spillover for the swap around 25th January 2019, which is similar to that we see in Figure 10.

Figure 16: Total Spillover for the Two-Dimensional Approach Between Both Perpetual Swaps

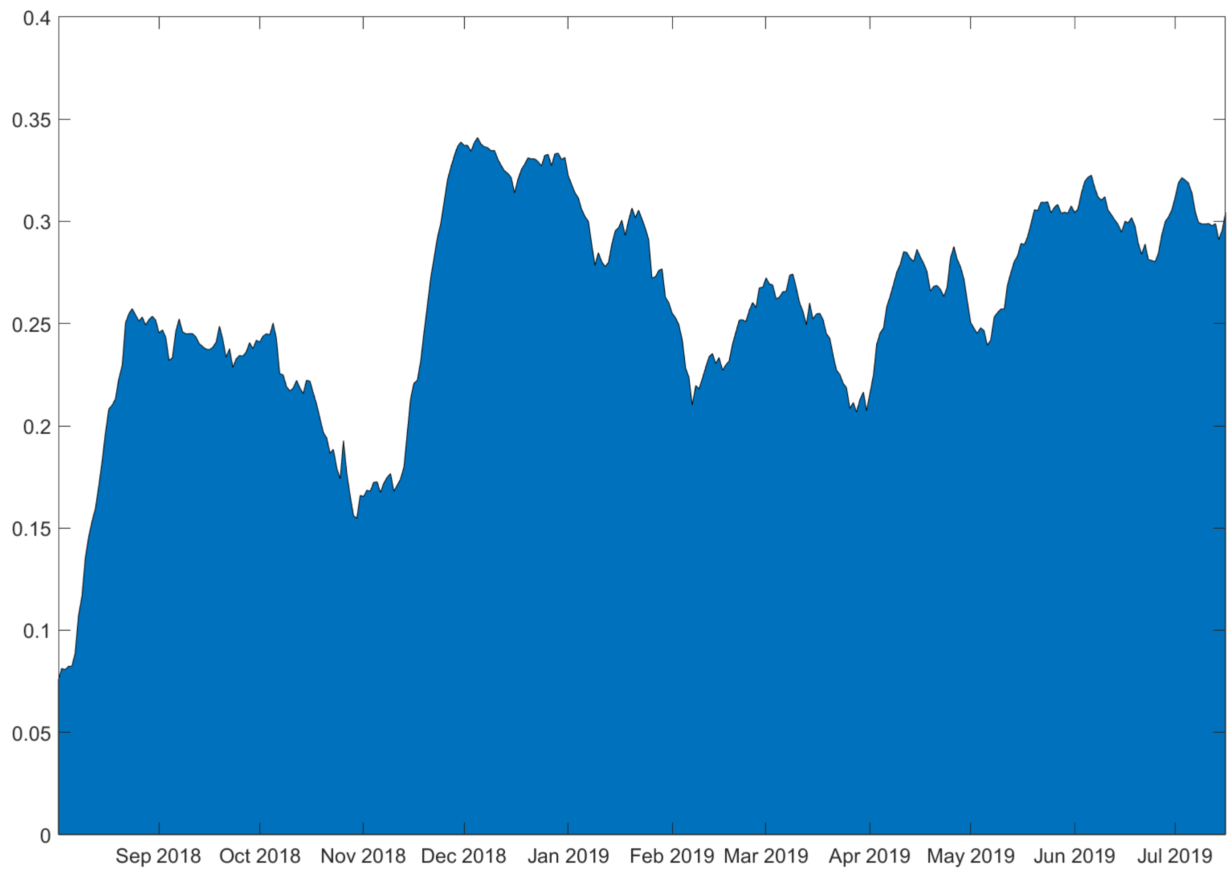

Figure 16 displays the total spillover (Pesaran and Shin, 1998) from BitMEX's ETHUSD and XBTUSD perpetual swaps within our second two-dimensional analysis of the two swaps. We can see a slight upwards moving trend within the sample period with cyclical peaks and troughs. Some of these movements in the total spillover are correlated to those in our other two-dimensional analysis, as seen in Figure 8, although these similarities are to be expected as the ETHUSD perpetual swap features in both. We also see how there appears to be less total spillover than that which we see in our other analyses shown in Figures 8 and 12.

Figure 17: Given Spillover for the Two-Dimensional Approach Between Both Perpetual Swaps

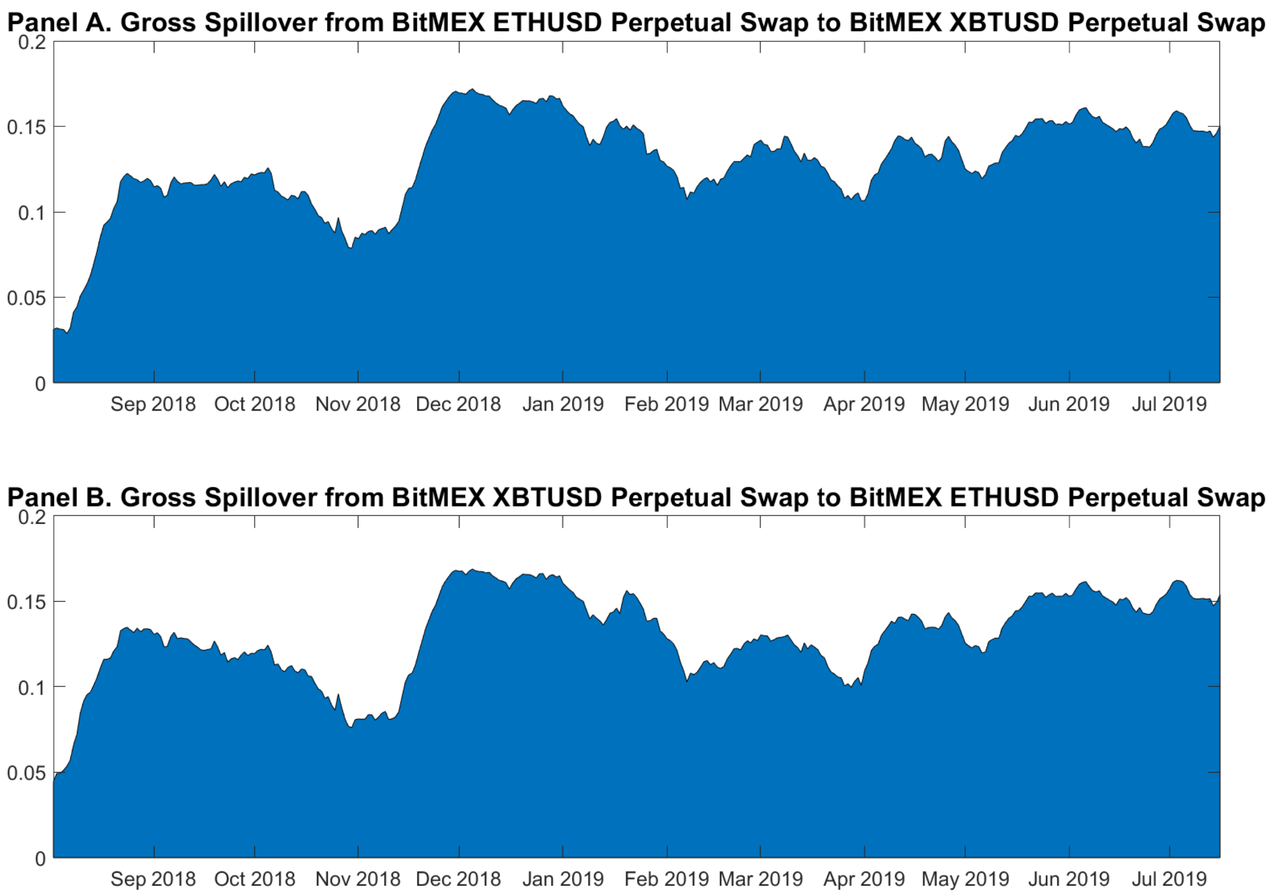

Figure 17 displays the directional spillovers (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) between BitMEX's ETHUSD and XBTUSD perpetual swaps within our two-dimensional analysis of the two swaps. The figure shows the volatility spillover sent from each instrument to the other in the analysis. Like in the total spillover (Figure 16), we can see that the directional spillovers are low at the start of our sample period. The ETHUSD swap has a visually lower transmitted spillover due to the contract having low volume as it is within two weeks of its issue. We see a high correlation between the two directional spillovers throughout the entire time period, with matching peaks and troughs. The figure also shows us that the gross spillover transmitted by each swap is less than those transmitted by the ETHUSD swap and .BETH index in Figure 9.

Figure 18: Net Spillover for the Two-Dimensional Approach Between Both Perpetual Swaps

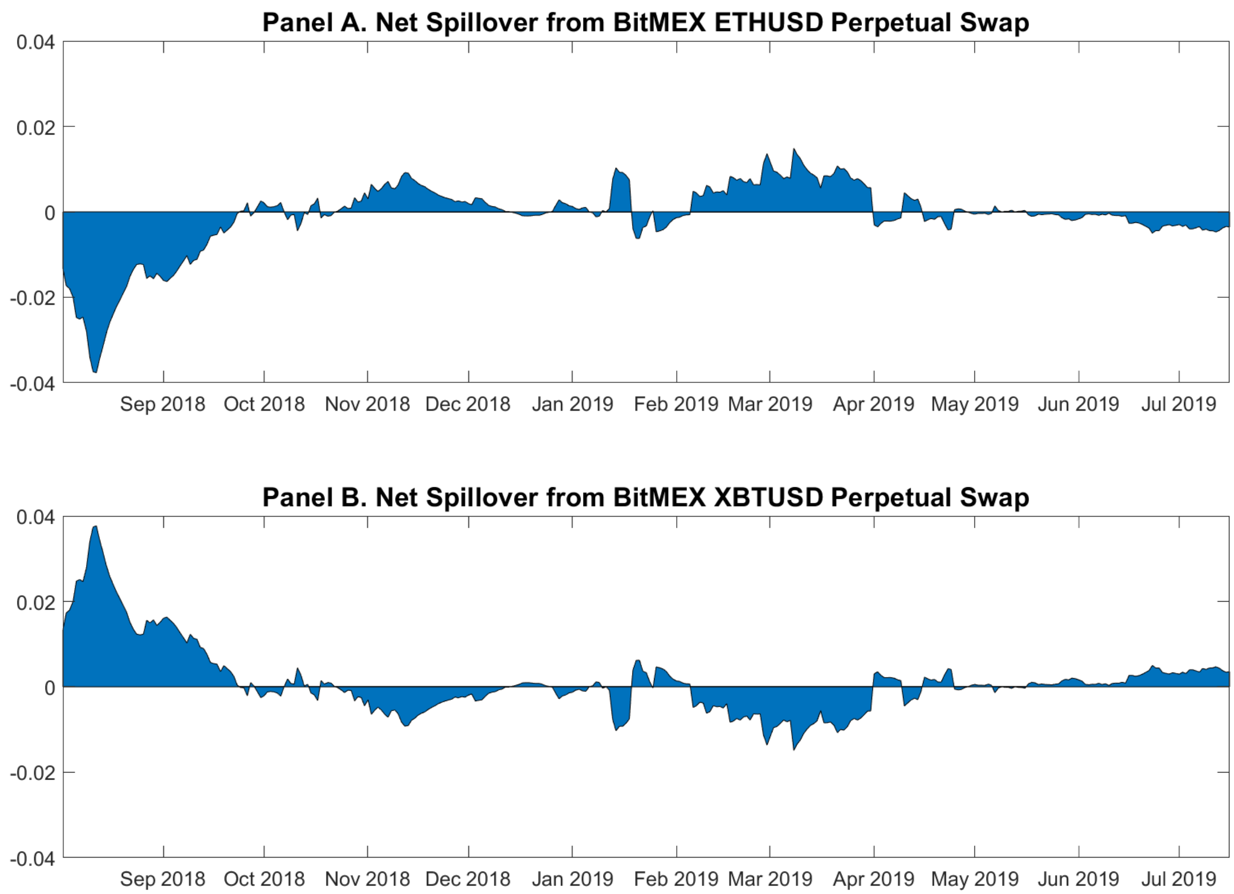

Figure 18 displays the net spillovers (Pesaran and Shin, 1998) (Diebold and Yilmaz, 2012) between BitMEX's ETHUSD and XBTUSD perpetual swaps within our two-dimensional analysis of the two swaps. The figure shows the net spillovers for both swaps; this is the difference between the spillover sent and the spillover received. We see that through the first seven weeks of our sample period, the ETHUSD perpetual swap is dominated by the XBTUSD swap, due to the ETHUSD swap being recently issued. Following October 2018, we see that the ETHUSD swap mostly dominates the XBTUSD swap. Following mid-May 2019, we see that the XBTUSD swap dominates the price discovery process again.

Figure 19: Information and Component Shares for the Two-Dimensional Approach Between Both Perpetual Swaps

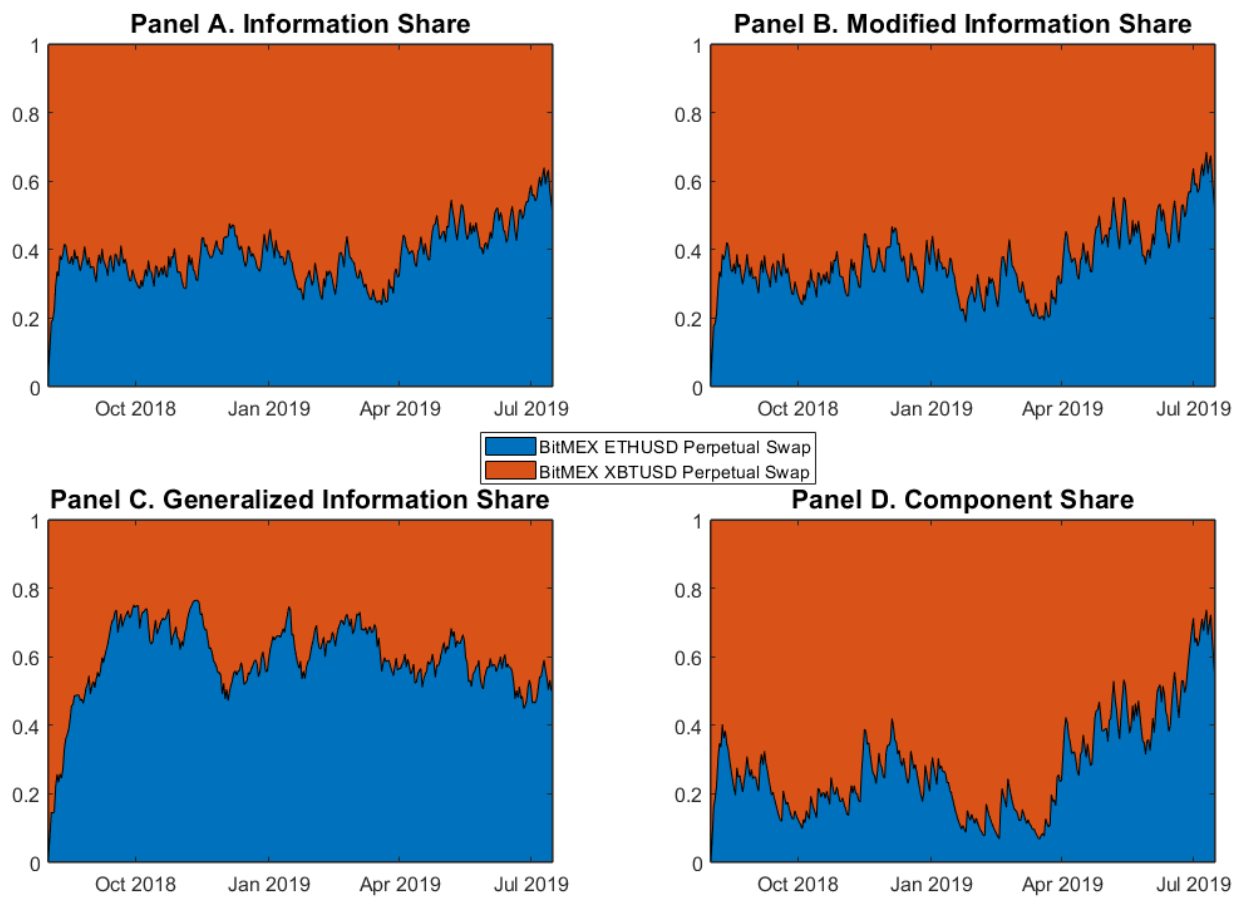

Figure 19 displays the Information Share (IS - Equation 3) (Hasbrouck, 1995), Modified Information Share (MIS - Equation 4) (Lien and Shrestha, 2009), Generalised Information Share (GIS - Equation 5) (Lien and Shrestha, 2014) and Component Share (CS - Equation 6) (Gonzalo and Granger, 1995) used to analyse the price discovery between BitMEX's ETHUSD and XBTUSD perpetual swaps. For our analysis, we focus on the GIS and CS. Panel C shows that the ETHUSD swap dominates the price discovery process on average across the time period. Within Panel C, we can see that the Bitcoin swap dominates the Ether swap in the first two months of our sample. This is due to the ETHUSD contract having been newly issued. Within Panel D, the XBTUSD swap dominates the ETHUSD swap throughout the entire time period, on average. In the later part of our sample period, we find that the ETHUSD swap starts to dominate. The results from Panel C and D make it hard for us to infer the price discovery between the two swaps.