Price Discovery and Microstructure in Ether Spot and Derivative Markets

Carol Alexander[a,b,*], Jaehyuk Choi[c], Hamish R. A. Massie[a,d], Sungbin Sohn[c]

[a] *University of Sussex Business School, Falmer, Brighton, United Kingdom*
[b] *Peking University HSBC Business School, Boars Hill, Oxford, United Kingdom*
[c] *Peking University HSBC Business School, Nanshan, Shenzhen, China*
[d] *Bank of Ireland, Bread Street, London, United Kingdom*

Abstract

Ethereum is an important blockchain, being the first and most popular public platform for the smart contracts underpinning financial transactions, time-stamping of supply chains, decentralized applications and initial coin offerings. Ethereum's cryptocurrency, ether, is actively traded on centralized exchanges, second only to bitcoin. It has attracted investor's interest primarily because of its intrinsic value – small units of ether called 'gas' are used, essentially, as the fuel driving smart contract transactions on the Ethereum blockchain. We ask whether off-chain trading on ether derivatives plays a dominant role in ether spot price discovery, thereby driving ether's utility value for on-chain activity. Using minute-by-minute data we find that the ether perpetual swap on BitMEX, an unregulated cryptocurrency derivative exchange, has dominant trading volume and price discovery over the major spot exchanges. Furthermore, we identify interesting hour-of-day and day-of-week effects in trading volume on the spot exchanges, and these indicate that more informed institutional players are trading ether spot and derivatives.

Keywords: BitMEX, Cryptocurrency, Ethereum, Futures, Perpetual Swaps
JEL: G13, G14

1. Introduction

Ethereum is a blockchain-based computing platform intended as *an alternative protocol for building decentralized applications* (Buterin, 2013), which the bitcoin blockchain cannot facilitate without a second-layer protocol. Since its inception in July 2015, numerous smart contract applications have been developed on Ethereum using its programming language, Solidity. Ether is Ethereum's cryptocurrency and, unlike bitcoin, it has a utility, i.e. to compensate miners for executing smart contract instructions on Ethereum.[1] Thanks to Ethereum's functionality (and the increasing attention to crypto assets overall) the price of ether rose from 0.31 US Dollar (USD) at the pre-sale in 2014 to 1,400 USD at its peak in January 2018. As of October 2019, ether remains the second-largest

*Corresponding author *Tel:* +44-1273-673950, *Address:* University of Sussex, Falmer, Sussex, BN1 6SL, UK
Email: c.alexander@sussex.ac.uk

[1] We know from the public information given by the ether block explorer (etherscan.io) that just a few large conglomerates such as Ethermine and Sparkpool mine most of the smart contract transactions for ether.

cryptocurrency by market capitalization, next to bitcoin.[2] Currently ether is traded on numerous spot exchanges both centralized (off-chain) and decentralized (on-chain), similar to bitcoin. Several centralised exchanges also offer derivatives products on ether but none of these transactions is recorded on the Ethereum chain. Ether's high price and easy trading has also contributed to the rise of initial coin offerings (ICO) as a popular (and less-regulated) method of funding for blockchain-related startups, triggering several strands of finance research (Fisch, 2019; Deng et al., 2018; Lee et al., 2019).

Despite ether's important position among cryptocurrencies and its role being quite distinguished from bitcoin, it has still been overshadowed. The literature on cryptocurrency markets has been surging in recent years, yet the vast majority of previous studies focus only on bitcoin – or treat ether as *just another* cryptocurrency. This study, therefore, fills the gap by investigating the microstructure of ether markets. We believe that the investigation on ether is meaningful in either direction. If ether markets exhibit patterns consistent with bitcoin markets we may generalize the findings about bitcoin, which we review shortly. If they do not, this is also of academic interest because we should investigate the ether characteristics which contribute to this difference. For this purpose we restrict the scope of study to centralized exchanges (CEX). In decentralized exchanges (DEX) the limit order books are run based on smart contracts without central authority. Although DEXs may be an intriguing research subject (see Daian et al. (2019) for example) the majority of ether trades are on CEXs and the vast majority of the finance literature on bitcoin, not to mention traditional asset classes, is also based on CEXs.

Given that cryptocurrencies are traded in multiple markets all over the world, price discovery is a key microstructure question. In bitcoin, the introduction of futures on the Chicago Mercantile Exchange (CME) and the Chicago Board Options Exchange (CBOE) in December 2017 triggered academic discussion on the role of futures in bitcoin price discovery (Baur and Dimpfl, 2019; Corbet et al., 2018; Alexander et al., 2020). Hale et al. (2018) argue that the bitcoin price collapse is related to the launch of these futures as similar patterns have been observed in other asset classes. This argument implies that the price discovery is stronger in those futures markets than in spot markets. Using the time series data from both futures exchanges, however, Corbet et al. (2018) and Baur and Dimpfl (2019) independently report that the futures markets neither exercise a price leadership nor serve as an effective hedge against the spot market. This is possibly due to low trading volume in futures contracts compared with the spot. Yet, this is contrary to general findings that mature futures markets play a dominant role in price discovery in other asset classes: currency futures (Tse et al., 2006), freight futures (Kavussanos and Nomikos, 2003), and VIX futures (Chen and Tsai, 2017). Alexander et al. (2020) reconciles the inconsistency between bitcoin and traditional asset classes with regard to the price discovery role of the derivatives. Instead of CME and CBOE futures, which have relatively small trading volume, they use the derivative contracts in an unregulated CEX, BitMEX in which trading volume is an order of magnitude above CME, CBOE and major spot exchanges. Using minute-by-minute price and volume data from July 2016 to December 2018, Alexander et al. (2020) confirm the dominant price leadership role of BitMEX over the major spot exchanges, Bitstamp, Coinbase (previously known as GDAX), and Kraken.

This study employs similar data to investigate the overall microstructure of the ether markets, focusing on the role of BitMEX's ETHUSD perpetual contract in the ether USD spot markets. We

[2] https://coinmarketcap.com

first describe the ether exchanges and their contracts, focusing on BitMEX and its ETHUSD perpetual swap contract. Then, we utilize the cointegration relationship among the log prices in several major ether exchanges to estimate the vector error correction model (VECM) and thereby derive various measures of price discovery. We also make a comparison of market characteristics such as return, volatility and trading volume before and after the launch of the ETHUSD perpetual swap. We find that this swap dominates centralised ether spot exchanges in all price discovery shares we scrutinize. These findings are robust to the model specification. In particular, a two-dimensional approach with perpetual swap and the underlying ether spot index (.BETH) and a four-dimensional approach with the perpetual swap and .BETH-constituent spot exchanges produce consistent results. We also examine the price discovery between BitMEX's two perpetual swaps, ETHUSD and XBTUSD but the spillover effects are low, suggesting little informational interdependence between the two major cryptocurrencies. Finally, we find evidence that the introduction of the ether perpetual swap attracts more informed traders, rather than uninformed speculators, leading to increased trading volume, reduced volatility and improved market efficiency in the spot markets.

The remainder of this paper is organized as follows. Section 2 describes the exchanges and contracts. Section 3 explains the methodology used in the investigation. Section 4 describes the data and the reasoning behind our choice of the data. Section 5 details the findings of this study. Finally, Section 6 concludes.

2. BitMEX and ETHUSD Perpetual Swap

Here we describe BitMEX and its derivative products as they are less known compared to CME and CBOE and their standard futures products. BitMEX was founded in 2014 by Arthur Hayes, Ben Delo and Samuel Reed and the name comes from the Bitcoin Mercantile Exchange. BitMEX states that it is *"the Next Generation of bitcoin Trading Products"* and trades solely in derivatives.[3] BitMEX offers a variety of products focusing on quarterly, semi-annual and perpetual futures; these contracts allow up to one hundred times leveraging, thereby requiring much lower margin. In addition, contract size is smaller 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 bitcoin 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 virtual private networks (VPN), and BitMEX will 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 BitMEX 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, totaling 500 million USD for July 2019 (Partz, 2019).

[3] https://www.bitmex.com

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

Exchange	Max Leverage	Initial Margin	Maintenance Margin	Minimum contract size (bitcoin)
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. Source: https://www.bitmex.com/app/whatsDifferent

In May 2016, BitMEX introduced the first bitcoin perpetual swap (XBTUSD). This contract is settled every 8 hours and is based on BitMEX's bitcoin spot index (.BXBT). The swap rapidly became BitMEX's most popular product with a daily average volume of 339,520 bitcoins in 2019 (Alexander et al., 2020), over 20 times the volume of BitMEX's traditional fixed-maturity futures. Following the success of the XBTUSD swap, BitMEX introduced the ETHUSD perpetual swap based on the .BETH index, an equally weighted average of Coinbase, Bitstamp and Kraken's ether spot prices. Because BitMEX uses bitcoin as its base currency, the ETHUSD swap contract is designed not to handle ether at all; although quoted in USD, the contract is valued and settled in bitcoin (10^{-6} bitcoin per 1 USD). In effect, it is a quanto swap denominated in bitcoin. This allows speculators to make a naked short position on the ether value [4].

There have been debates surrounding whether the creation of this instrument led to a collapse in the ether price. The value of ether fell by 59% from 4th August 2018 to 12th September 2018. BambouClub (2019), in a Hackernoon article, claims that the perpetual swap has made *"a highly unstable market entirely composed of speculators"*. Tom Lee, a leading crypto analyst, claims that the introduction of the ETHUSD swap may have a link to the fall in the ether 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"*.[5] 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.

3. Methodology

Let p_t be the $N \times 1$ vector of log prices of the N cointegrated instruments trading at time t. To represent the time series of p_t, we use the VECM:

[4] On the BitMEX chat, a BitMEX cofounder, 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 $\cdots$ you never need to touch that shitcoin called Ether"*, at the time of the ETHUSD swap launch.

[5] http://www.medium.com/squared-capital/imminent-firesale-of-eth-held-by-icos-278a6cf914

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

introduced by Engle and Granger (1987). Here α is the $N \times N-1$ error-correction coefficient matrix, $\beta' p_t$ is the cointegration error, Q is the lag length (optimised using the Bayesian information criteria), A_q is the $N \times N$ autoregressive coefficient matrix, and ϵ_t is the zero-mean $N \times 1$ vector of serially uncorrelated disturbances having covariance matrix of Ω. The effects of the short-term fluctuations are displayed by A_q and α reflects the response to the deviation of log prices from the long-run equilibrium relationship.

Using the standard vector moving average (VMA) representation of this VECM, Hasbrouck (1995) derives the information share (IS) of the ith asset or instrument in the system as:

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

where M is the Cholesky factorisation of the covariance Ω, ψ is a $1 \times N$ common row of the total sum of moving average coefficients in the VMA (denoted by $\Psi(1)$), and $[\psi M]_i$ is the ith element of the row matrix ψM. This IS measures the ith's asset/instrument's contribution to price discovery in comparison to other assets/instruments. Since the IS depends on the order of state variables in the VECM, we use the average of values obtained from all possible permutations.

Lien and Shrestha (2009) modify Hasbrouck (1995)'s IS and propose the modified information share (MIS), which does not vary with the order of state variables.

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

where $F = [G\Lambda^{-1/2}G'V^{-1}]^{-1}$, Λ is the diagonal matrix whose elements are eigenvalues of ϵ_t's correlation matrix, G is a matrix whose columns are eigenvectors corresponding to eigenvalues in Λ, and V is a diagonal matrix of standard deviations of ϵ_t. The MIS measures price discovery in the same way as IS, i.e. it gives the percentage contribution that an instrument has to the price discovery of the market in comparison to the other instruments, at time t, but it performs better according to simulations. Another alternative generalisation of IS is given by Lien and Shrestha (2014). Their generalized information share (GIS) allows analysis of price discovery across broader interrelated markets, removing any restrictions on the cointegrating vector. Also, the IS and MIS estimates from high-frequency samples are more susceptible to distortions from transitory frictions, especially illiquidity. So, for reasons of robustness, we also employ the GIS:

$$GIS_i = \frac{([\psi_1^r F]_i)^2}{\psi_1^r \Omega \psi_1^{r'}}, i = 1, \ldots, N \tag{4}$$

where ψ_1^r is the 1st row of $\Psi(1)$ estimated without restrictions on the cointegrating vector.

By splitting the log price into two components – a common factor c_t and a stationary component – Gonzalo and Granger (1995) derive an alternative measure which is commonly used in addition to an information share, i.e. the component share (CS):

$$CS_i = \frac{\alpha_{\perp,i}}{\sum_{n=1}^{N} \alpha_{\perp,n}}, i = 1, \ldots, N \tag{5}$$

where $\alpha_\perp$ is the orthogonal component of the error correction coefficient; the permanent coefficient vector is orthogonal to this. The CS indicates which instruments lead reversion to the long-run equilibrium following a market shock.

We also analyse the error variance decomposition and the gross and net spillover effects, following Pesaran and Shin (1998) and Diebold and Yilmaz (2012). These summarise how each instrument reacts to shocks in the other instruments based on the generalised impulse response. The generalised forecast error variance decomposition is normalised, to obtain the gross spillover from j to i, as:

$$\tilde{\theta}_{ij}(h) = \frac{\theta_{ij}(h)}{\sum_{n=1}^{N} \theta_{in}(h)} \tag{6}$$

where $\theta_{ij}(h)$ is the h-step ahead forecast error variance of variable i due to the innovations in variable j. The net spillover from j to i is $\tilde{\theta}_{ij}(h) - \tilde{\theta}_{ji}(h)$. In this paper, we examine the 1-hour ahead effects ($h = 60$).

Throughout the paper, we obtain the above measures on a daily basis using the minute-level intraday data, and report their time series average.

4. Data

We employ minute-by-minute data collected from BitMEX and CoinAPI starting from 3rd August 2018, i.e. one week before the inception of trading on the ether perpetual swap. We collect an additional week's worth of data on spot prices and the the settlement price for the ether perpetual swap – the .BETH index – to provide an insight to the spot market information flows before the introduction of the perpetual swap. The .BETH index is an equally weighted average of the ether spot prices from three exchanges, Bitstamp, Coinbase, and Kraken. These are three of the five most liquid exchanges of the ten exchanges that Bitwise Asset Management (Hougan et al., 2019) dictate to be 'real' in that their fee structure does not encourage in wash trading to boost volume data artificially. These three exchanges, in addition to the BitMEX perpetual swap, make up the constituents of the four-dimensional analysis. We also use the .BETH index in the two-dimensional price discovery model.

We use BitMEX's RestAPI to obtain the minute-by-minute data for BitMEX's ETHUSD perpetual swap and .BETH. To investigate the price discovery between the bitcoin and ether perpetual swaps we also collect minute-level data for the XBTUSD perpetual swap. Our HTML requests provide full minute-level open, high, low, close, and volume (OHLCV) data from which we extract the UNIX time-stamp, the close price of that minute and the volume traded during that minute. The volume data provided by BitMEX for the ETHUSD perpetual swap is the number of contracts traded during time interval t, N_t. But the contract size for the perpetual swap is denominated in bitcoin (it is 0.001 mXBT per 1 USD) so we translate the volume data into ether by setting $V_t^E = 10^{-6} B_t N_t$, where B_t is the bitcoin reference rate (.BXBT) at time t. The sample ends on 17th July 2019.

Table 2 displays the summary statistics for the perpetual swap and the data from the three spot exchanges, both minute-by-minute and daily with the close at 23:59 Coordinated Universal Time (UTC) for each day. The daily volume for the perpetual swap is so much greater than on the spot markets that we use a log scale in Figure 3 below. None of the returns are normally distributed. Returns are quite low on average but have large minima and maxima so kurtosis is very high. The greatest loss over 1 min was 19.28%, observed on Bitstamp on 14th July and the highest gain was 18.96% one a minute later. But all the spot exchanges exhibit some extreme price fluctuations at different times. Indeed, the correlation of minute returns between the perpetual swap and the three spot exchanges, shown in Table 3, is remarkably low. There is a slightly stronger correlation between the returns of the .BETH index and the perpetual swap, but it may not be as high as one could expect between a futures contract and its settlement price.

Table 2: Descriptive Statistics for Minute-by-Minute Ether Exchange Data Used

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
Number of Samples	502014	514021	514021	514021
Daily Volume (in ether)	1,693,194	149,914	105,404	52,374
Minute Statistics				
Mean	-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
Standard Deviation	0.15%	0.15%	0.34%	0.38%
Annualised Volatility	105.66%	108.58%	249.10%	273.23%
Daily Statistics				
Mean	-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
Standard Deviation	5.37%	5.18%	5.24%	5.15%
Annualised Volatility	102.59%	98.96%	100.11%	98.39%

Table 2 displays the descriptive statistics for the 1-minute and daily returns of BitMEX's ETHUSD perpetual swap and the ether spot markets of Coinbase, Kraken, and Bitstamp.

Table 3: Correlation Between the Ether returns Among Four Exchanges

	BitMEX	Coinbase	Kraken	Bitstamp
BitMEX	100.00%	31.35%	15.14%	14.81%
Coinbase	31.35%	100.00%	27.89%	26.07%
Kraken	15.14%	27.89%	100.00%	15.49%
Bitstamp	14.81%	26.07%	15.49%	100.00%
	ETHUSD	.BETH		
ETHUSD	100.00%	77.12%		
.BETH	77.12%	100.00%		

Table 3 displays the correlation between the minute returns of the ETHUSD perpetual swap and the ether spot markets of Coinbase, Kraken, and Bitstamp, and the perpetual swap and the .BETH index.

Returning to Table 2, we notice that for Kraken and Bitstamp there is a remarkable difference in volatility derived from minute-level data compared with daily data. The figures are annualised and so they should be comparable – as, indeed, they are for BitMEX's swap and the Coinbase spot. However, the Kraken spot price volatility is almost 250% in minute-level data but only about 100% on daily data. Similarly, the Bitstamp spot price volatility is almost 275% in minute-level data but a bit less 100% on daily data. What could explain these findings?

There is no error in the calculations, so we took a closer look at the minute level data and found evidence of a considerable amount of 'wash trading' (or 'washing') on these exchanges.[6] The effect of washing is an oscillation of prices at a very high frequency, which is not detectable in daily data, only in minute data. There is no flash crash or other feature that explains this exceedingly high volatility. Indeed, a flash crash would show up in an extreme value for kurtosis on minute-level data, which is not apparent here. Of course the kurtosis is higher in minute-level data because of any law of large numbers, such as the central limit theorem, but the kurtosis on Kraken (and Bitstamp) is less than half the kurtosis on the other exchanges. For instance, Coinbase returns have a kurtosis of 282.8 and Kraken returns have a kurtosis of 129.9 – the difference here being entirely attributable to the fact that the volatility for Kraken is about 2.5 times the volatility on Coinbase.

Figure 1 displays the minute returns for each of the five instruments. Particularly idiosyncratic periods are evident, particularly within the first section of the time series up to mid-October 2018, but starting again from 2nd April 2019. Returns are more volatile towards the end of the sample. Figure 2 depicts the percentage basis for each spot price relative to the price of the perpetual swap. More considerable variations occur during the more volatile periods at the beginning and end of the sample. The greatest deviation occurs on 17th May 2019, around 29% for each exchange. Figure 3

[6]Washing is common practice on many of these unregulated cryptocurrency exchanges because their fee structure rewards market makers – only market takers are charged. This provides an incentive for market makers to set up two accounts to trade against each other, buying and then selling at very high frequency just either side of market price. This way, they extract value from the exchange, often in the form of the exchange's own tokens. The exchange is then able to report high trading volumes (albeit based on artificial trades) which in turn helps them to become visible on coin-ranking sites such as CryptoCompare. In fact, CryptoCompare is fully aware of this practice – it has wash-detection methods, as outlined in its Monthly Exchange Review.

shows the daily trading volumes on a logarithmic scale for the ETHUSD perpetual swap on BitMEX and the ether spot trades on Bitstamp, Coinbase, and Kraken. The volume on BitMEX is far greater than on the three spot exchanges. Throughout our sample the average daily trading volume for the perpetual swap is 1,693,194 ether, over five times the cumulative average daily volume for the three exchanges. By 11th August 2018, nine days after the introduction of the contract, the daily volume of the perpetual swap reached 233,462 ether, higher than the summation of the three spot exchanges on the same day whose cumulative volume was 231,356 ether. Figure 4 displays the proportional volume between the three spot exchanges. We see that Coinbase has the most substantial volume of the three exchanges, and the relative volumes do not change by significant amounts throughout the sample.

5. Empirical Results

5.1. ETHUSD Swap and Spot Index

Following Corbet et al. (2018), Baur and Dimpfl (2019), Kapar and Olmo (2019) and Karkkainen (2018) we analyse the price discovery between the futures and its settlement index, i.e. BitMEX's ETHUSD perpetual swap and .BETH index. Our analysis uses the GIS (Lien and Shrestha, 2014), the CS (Gonzalo and Granger, 1995) and the spillover effect (Pesaran and Shin, 1998; Diebold and Yilmaz, 2012). All three measures shown in Table 4 demonstrate that, on average, the perpetual swap has dominance over the spot index, with a GIS of 62% and a CS of 64%. A time-series graph (not shown for brevity) confirm that this share is relatively constant over the entire sample, except during the first few weeks of trading on the perpetual swap.

Table 4: Daily Average Price Discovery Measures for BitMEX Perpetual Swap and .BETH Index

Price Discovery Measure	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 4 tabulates the results of the two-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and .BETH index. Price discovery is evaluated by four measures: information share, modified information share, generalised information share and component share.

The net spillovers in Table 5 confirm that the perpetual swap is the dominant instrument in price discovery, leading .BETH with a net spillover of 1.29%.

Table 5: 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 5 tabulates the results of the gross and net spillover analysis for the two-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and .BETH index.

5.2. ETHUSD Swap and Three Spot Exchanges

We use a four-dimensional approach into the price discovery analysis, similar to Alexander et al. (2020), comparing the BitMEX perpetual swap and the three ether spot exchanges. Figure 5 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. Table 6 displays the average CS and GIS shares throughout the sample. The perpetual swap dominates the price discovery, and Coinbase also plays the price discovery role to some extent.

Table 6: Daily Average Price Discovery Measures for BitMEX Perpetual Swap and Spot Exchanges

Price Discovery Measure	BitMEX	Bitstamp	Coinbase	Kraken
Information Share	40.05%	17.05%	26.62%	16.28%
Modified Information Share	45.73%	14.48%	26.44%	13.36%
Generalised Information Share	45.85%	14.45%	26.44%	13.26%
Component Share	52.85%	10.00%	27.37%	9.78%

Table 6 tabulates the result of the four-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and the ether spot markets of Coinbase, Kraken and Bitstamp. Price discovery is evaluated by four measures: information share, modified information share, generalised information share and component share.

The price discovery role of BitMEX in ether markets is qualitatively similar to that in bitcoin markets reported in Alexander et al. (2020) – BitMEX leads the price discovery, not only for bitcoin but also for ether. BitMEX's ether perpetual swap, though introduced much later than its bitcoin swap, is already having a very dominant price discovery role. However, BitMEX's shares found in this paper are slightly lower in comparison to those in Alexander et al. (2020). Table 7 shows that the spillover analysis provides a consistent result – BitMEX and Coinbase are the two exchanges that have positive net spillover effects to the other exchanges. As in the case of price discovery shares, the magnitude of the net spillover from BitMEX is lower than that in bitcoin, probably due to substantially lower trading volumes across all exchanges.

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

To \ From	BitMEX	Bitstamp	Coinbase	Kraken	The Others
BitMEX	42.24%	17.49%	23.05%	17.22%	57.76%
Bitstamp	18.80%	45.79%	20.05%	15.37%	54.22%
Coinbase	22.73%	18.32%	40.59%	18.37%	59.42%
Kraken	19.34%	15.79%	20.75%	44.12%	55.88%
The Others	60.87%	51.60%	63.85%	50.96%	56.82%
Net Spillover	3.11%	-2.62%	4.43%	-4.92%	

Table 7 tabulates the results of the gross and net spillover analysis for the four-dimensional investigation into price discovery between BitMEX's ETHUSD perpetual swap and the ether spot markets of Coinbase, Kraken and Bitstamp.

5.3. Ether and Bitcoin Perpetual Swaps

So far, we confirm the strong price discovery role of the ETHUSD swap in the ether market. As the XBTUSD swap plays the same role in the bitcoin market (Alexander et al., 2020), it is natural to question whether there is possible information flow between the two perpetual swaps on BitMEX. Given the dominant market capital of bitcoin among the cryptocurrencies, past studies have reported that bitcoin usually transmits shocks to other cryptocurrencies including ether; see Ji et al. (2019); Katsiampa et al. (2019); Yi et al. (2018). However, they only focus on spot exchanges with sample period predating the ETHUSD swap launch. Therefore, it is worthwhile to explore the price discovery and spillover between the ETHUSD and XBTUSD swaps on BitMEX.

Figure 6 displays the patterns of price discovery between the two perpetual swaps in the sample period, and Table 8 summarises these result. We find that the GIS shows a clearly different pattern from the other price discovery shares. Given that the GIS is obtained from the VECM estimated without any restriction on the cointegration vector, this contrast between GIS and other measures indicates that the cointegration relationship between the two cryptocurrencies is qualitatively different. Indeed, we find that the cointegration vector between ETHUSD and XBTUSD is $(1, -0.6)'$ on average, while those among different exchanges within the same cryptocurrency are almost $(1, -1)'$. To the extent that the GIS is superior to the other measures in capturing various types of cointegration relationships, the ETHUSD swap appears to have a greater contribution to price discovery than the XBTUSD swap. Yet, this result should be interpreted with caveat. Despite the larger price discovery, the net spillovers from ETHUSD is almost zero as shown in Table 9. In fact, the total spillover effect between the ether and bitcoin swaps is much smaller than that among ether swap and spots.

Table 8: Daily Average Price Discovery Measures for Both BitMEX Perpetual Swaps

Price Discovery Measure	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 8 tabulates the results of the two-dimensional investigation into price discovery between BitMEX's ETHUSD and XBTUSD perpetual swaps. Price discovery is evaluated by four measures: information share, modified information share, generalised information share and component share.

Table 9: Gross and Net Spillovers for the Both BitMEX Perpetual Swaps

To \ From	ETHUSD	XBTUSD
ETHUSD	73.36%	26.64%
XBTUSD	26.48%	73.52%
Net Spillover	-0.16%	0.16%

Table 9 tabulates the results of the gross and net spillover analysis for the two-dimensional investigation into price discovery between BitMEX's two perpetual swap: ETHUSD and XBTUSD.

5.4. Market Efficiency and Microstructure Effects

Since BitMEX is an ideal trading venue for informed crypto traders (e.g., miners, blockchain-related start-ups and hedge funds trading cryptocurrencies), we conjecture that the launch of BitMEX's ETHUSD perpetual swap might precipitate more arbitrage trading and hence improve market efficiency. To test this presumption, this subsection makes a comparison between the trading activities in the spot exchanges before and after the launch of the ETHUSD perpetual swap. The introduction of derivatives could stabilize or destabilize an underlying spot price, depending on the main role of the derivatives (Pericli and Koutmos, 1997). Therefore, addressing the issue empirically is an important task.

Table 10 reports how trading volumes, returns, return volatilities, return autocorrelations, and market efficiency coefficients (MECs) in the three ether spot exchanges have changed since the launch of the ETHUSD perpetual swap. The return autocorrelation is the average of daily autocorrelations of 1-minute returns. Motivated by Hasbrouck and Schwartz (1988), we define the MEC as the average of daily ratios of 5-minute return variance to 1-minute return variance divided by 5. Both return autocorrelation and MEC are commonly used as the measure of market efficiency (Alexander et al., 2020; Comerton-Forde and Putniņš, 2015). Specifically, a smaller absolute autocorrelation (an MEC closer to one) implies higher efficiency.

Trading volume increased significantly on Bitstamp and Kraken but not on Coinbase; and volatility decreased markedly on all three spot exchanges. Both autocorrelations and MECs indicate that after the launch of the ETHUSD perpetual swap, the market efficiency significantly improves in Bitstamp and Kraken. These findings are consistent with the notion that the ETHUSD perpetual swap attracts more informed traders, who stabilize the market, rather than uninformed speculators.

We delve further into the microstructure of the ether spot markets by examining the hour-of-day and the day-of-week effects. In BitMEX, trading continues on a 24/7 basis, so if trades are independent of geographic location there would be no trading pattern within a 24-hour day. Given a normal daily life cycle (sleep at night, have a lunch break around noon, etc), the existence of a particular trading pattern within a day implies that there are some particular regions where most trades concentrate. The local time zone for BitMEX is China Standard Time (CST) which is UTC + 8.

Table 10: Comparison of Trading Activities Before and After the ETHUSD Perpetual Swap Launch

	Full sample	Pre-Swap	Post-Swap	p-value (%)
Trading volume (thousands)				
Bitstamp	45.156	35.366	51.200	0.000
Coinbase	149.897	150.863	145.143	60.783
Kraken	81.992	49.908	106.663	0.000
Daily return (%)				
Bitstamp	-0.121	-0.024	-0.190	72.248
Coinbase	-0.121	-0.023	-0.190	72.049
Kraken	-0.123	-0.027	-0.190	72.731
Daily volatility (%)				
Bitstamp	7.058	8.446	5.706	0.000
Coinbase	5.961	7.055	5.031	0.003
Kraken	6.725	8.296	5.353	0.000
Return autocorrelation				
Bitstamp	0.1224	0.1523	0.1016	0.000
Coinbase	0.0670	0.0681	0.0662	66.010
Kraken	0.0965	0.1350	0.0697	0.000
Market efficiency coefficient				
Bitstamp	1.2543	1.2819	1.2351	0.014
Coinbase	1.1588	1.1543	1.1619	48.944
Kraken	1.1956	1.2413	1.1637	0.000

Table 10 reports how the trading volume, returns, return volatilities, return autocorrelations, and market efficiency coefficients in the three ether spot exchanges have changed since the launch of the ETHUSD perpetual swap. Trading volume and return are measured from the average of daily values for a given sample period. Return volatility is the standard deviation of the daily returns for a given period. Return autocorrelation is the average of daily autocorrelations of 1-minute returns. Market efficiency coefficient is the average of daily ratios of 5-minute return variance to 1-minute return variance divided by 5. p-value is the probability of rejecting the null hypothesis of the equal means before and after the launch of the ETHUSD perpetual swap.

Figure 7 shows that there is a clear trading pattern within a day. Specifically, we find the same pattern on the three spot exchanges as we do on BitMEX, indicating that traders on all four exchanges may share similar time zones. Notably, the greatest trading volumes occurs between 16:00-17:00 UTC, i.e. 00:00 - 01:00 CST and 11:00-12:00 Eastern Standard Time (EST) and, even though the hour displaying the lowest volume varies across the exchanges, it is somewhere between 05:00-12:00 UTC i.e. 14:00 - 21:00 CST and 00:00-07:00 EST. Two-sample t-tests confirm that these differences in trading volume are significantly different from that observed during the rest of the day. Comparing the graphs on the left side of Figure 7, these time-of-day effects seem to have become more pronounced since the introduction of the ether perpetual spot on BitMEX. Trading on all three spot exchanges now has a very clear peak at 16:00-17:00 UTC.

Our findings hint at substantial trades by US or European traders, even on the unregulated BitMEX exchange. Although US residents are banned from trading in BitMEX, this may still be acheived by disguising their connecting locations using VPNs and/or via the lightning network on the Omni layer – where only the initial and final settlement of the channel is recorded on-chain.

This may be the first study that provides some evidence of trading on BitMEX by US traders.

The day-of-week effects may be explained by noting the behavioral differences between retail and institutional traders. A lower trading volume on Mondays coincides with more retail activities (Baur et al., 2019). If most ether trades are hedges by retail investors or start-ups holding ether from an initial coin offering, these players would have a normal weekly life cycle – especially with a relatively heavier workload on Mondays. Thus, the dominance of retail traders implies significantly less trading activities on Mondays but, if most ether trading is executed by large institutions, there would be no clear Monday effect.

Figure 8 indicates that there used to be a clear Monday effect in the spot exchanges, but this effect has weakened since the ETHUSD perpetual swap launch. Formal two-sample t-tests show that, before the swap launch, the trading volume on Mondays was significantly less than that on other week days; but after the launch there is no significant difference. This finding is consistent with the story that the launch of the ETHUSD swap has attracted substantially more informed trading by large institutions. Two other findings also support this story: (i) trading volume on all spot exchanges increased substantially after the swap launch; and (ii) the time-of-day effects – which point towards most trading coming from the US or Europe – have also become more pronounced since BtMEX introduced the ETHUSD swap.

6. Conclusions

Using minute level price and volume data we analyse the microstructure of ether trading on the derivative exchange (BitMEX) and the spot exchanges (Bitstamp, Coinbase, and Kraken). BitMEX is an influential, but unregulated, crypto-only derivative exchange which started gaining attention in May 2016 because it was the first to introduce a perpetual swap derivative contract on bitcoin. At the time of writing trading on the bitcoin spot markets is dwarfed by trading on BitMEX's perpetual swap and similar products recently introduced by other unregulated centralised crypto exchanges such as OKex and Huobi.

BitMEX introduced the ETHUSD perpetual swap in August 2018 and – at the time of writing – it is the only exchange to offer this type of instrument. Our empirical results find little evidence of information spillovers between the XBTUSD and ETHUSD swaps. However, there is clear evidence of an increasing leadership role from the ETHUSD swap to the USD prices of ether on the three major spot markets. Furthermore, the volume traded on BitMEX's ether swap is already more than five times greater than the combined trading on these spot exchanges. We measure various information and component shares between these markets, and analyse the total, gross and net spillover effects to investigate the price discovery of ether. The ETHUSD perpetual swap on BitMEX clearly plays a dominant price discovery role in all measures. This is consistent with the finding in traditional asset classes as well as bitcoin (Alexander et al., 2020). In addition, we show that ether markets exhibit hour-of-day and day-of week differences in trading volumes and both effects changed significantly after the introduction of the ether perpetual swap on BitMEX. Specifically, the hour-of-the day effect strengthened while the day-of-week effect weakened. Moreover, since the BitMEX swap was introduced, the spot trading volume have increased, the price volatility has decreased, and the measures of market efficiency have improved. All of these signs indicate increased participation from more informed institutional traders in ether markets.

The ether markets we study are located on centralised exchanges so transactions are not on the Ethereum blockchain. However, the utility of ether – as the 'gas' used to fuel smart contract transactions – has value for miners on the Ethereum blockchain. Thus, the income for on-chain activity is driven by off-chain trading on centralised exchanges. The BitMEX swap is already playing the dominant role in ether price discovery, and trading volumes on all centralised exchanges has increased considerably since the introduction of this derivative instrument.

References

Alexander, C., Choi, J., Park, H., Sohn, S., 2020. BitMEX Bitcoin Derivatives: Price Discovery, Informational Efficiency and Hedging Effectiveness. Journal of Futures Markets 40, 23–43. doi:10.1002/fut.22050.

BambouClub, 2019. Has Arthur Hayes Destroyed the Ethereum Market and Bankrupted ICO Treasuries? Hackernoon.com URL: https://hackernoon.com/notes-about-the-new-ethusd-perpetual-swap-at-bitmex-1b58bac7cb8b.

Baur, D.G., Cahill, D., Godfrey, K., Liu, Z.F., 2019. Bitcoin time-of-day, day-of-week and month-of-year effects in returns and trading volume. Finance Research Letters 31, 78–92. doi:10.1016/j.frl.2019.04.023.

Baur, D.G., Dimpfl, T., 2019. Price discovery in bitcoin spot or futures? Journal of Futures Markets 39, 803–817. doi:10.1002/fut.22004.

Buterin, V., 2013. Ethereum White Paper: A next-Generation Smart Contract and Decentralized Application Platform. Technical Report. URL: https://github.com/ethereum/wiki/wiki/White-Paper.

Chen, Y.L., Tsai, W.C., 2017. Determinants of price discovery in the VIX futures market. Journal of Empirical Finance 43, 59–73. doi:10.1016/j.jempfin.2017.05.002.

Comerton-Forde, C., Putniņš, T.J., 2015. Dark trading and price discovery. Journal of Financial Economics 118, 70–92. doi:10.1016/j.jfineco.2015.06.013.

Corbet, S., Lucey, B., Peat, M., Vigne, S., 2018. Bitcoin Futures – What use are they? Economics Letters 172, 23–27. doi:10.1016/j.econlet.2018.07.031.

Daian, P., Goldfeder, S., Kell, T., Li, Y., Zhao, X., Bentov, I., Breidenbach, L., Juels, A., 2019. Flash Boys 2.0: Frontrunning, Transaction Reordering, and Consensus Instability in Decentralized Exchanges. arXiv:1904.05234 [cs] URL: http://arxiv.org/abs/1904.05234, arXiv:1904.05234.

Deng, X., Lee, Y.T., Zhong, Z., 2018. Decrypting Coin Winners: Disclosure Quality, Governance Mechanism and Team Networks. SSRN Electronic Journal doi:10.2139/ssrn.3247741.

Diebold, F.X., Yilmaz, K., 2012. Better to give than to receive: Predictive directional measurement of volatility spillovers. International Journal of Forecasting 28, 57–66. doi:10.1016/j.ijforecast.2011.02.006.

Engle, R.F., Granger, C.W.J., 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. Econometrica 55, 251–276. doi:10.2307/1913236.

Fisch, C., 2019. Initial coin offerings (ICOs) to finance new ventures. Journal of Business Venturing 34, 1–22. doi:10.1016/j.jbusvent.2018.09.007.

Gonzalo, J., Granger, C., 1995. Estimation of Common Long-Memory Components in Cointegrated Systems. Journal of Business & Economic Statistics 13, 27–35. doi:10.1080/07350015.1995.10524576.

Hale, G., Krishnamurthy, A., Kudlyak, M., Shultz, P., 2018. How Futures Trading Changed Bitcoin Prices. FRBSF Economic Letter 2018-12. Federal Reserve Bank of San Francisco. URL: https://www.frbsf.org/economic-research/publications/economic-letter/2018/may/how-futures-trading-changed-bitcoin-prices/.

Hasbrouck, J., 1995. One Security, Many Markets: Determining the Contributions to Price Discovery. The Journal of Finance 50, 1175–1199. doi:10.1111/j.1540-6261.1995.tb04054.x.

Hasbrouck, J., Schwartz, R.A., 1988. Liquidity and execution costs in equity markets. The Journal of Portfolio Management 14, 10–16. doi:10.3905/jpm.1988.409160.

Hougan, M., Kim, H., Lerner, M., 2019. Economic and Non-Economic Trading In Bitcoin: Exploring the Real Spot Market For The World's First Digital Commodity. Available at SEC Website. Bitwise Asset Management. URL: https://www.sec.gov/comments/sr-nysearca-2019-01/srnysearca201901-5574233-185408.pdf.

Ji, Q., Bouri, E., Lau, C.K.M., Roubaud, D., 2019. Dynamic connectedness and integration in cryptocurrency markets. International Review of Financial Analysis 63, 257–272. doi:10.1016/j.irfa.2018.12.002.

Kapar, B., Olmo, J., 2019. An analysis of price discovery between Bitcoin futures and spot markets. Economics Letters 174, 62–64. doi:10.1016/j.econlet.2018.10.031.

Karkkainen, T., 2018. Price Discovery in the Bitcoin Futures and Cash Markets. SSRN Electronic Journal doi:10.2139/ssrn.3243969.

Katsiampa, P., Corbet, S., Lucey, B., 2019. Volatility spillover effects in leading cryptocurrencies: A BEKK-MGARCH analysis. Finance Research Letters 29, 68–74. doi:10.1016/j.frl.2019.03.009.

Kavussanos, M.G., Nomikos, N.K., 2003. Price Discovery, Causality and Forecasting in the Freight Futures Market. Review of Derivatives Research 6, 203–230. doi:10.1023/B:REDR.0000004824.99648.73.

Lee, J., Li, T., Shin, D., 2019. The Wisdom of Crowds in FinTech: Evidence from Initial Coin Offerings. SSRN Electronic Journal doi:10.2139/ssrn.3195877.

Lien, D., Shrestha, K., 2009. A new information share measure. Journal of Futures Markets 29, 377–395. doi:10.1002/fut.20356.

Lien, D., Shrestha, K., 2014. Price Discovery in Interrelated Markets. Journal of Futures Markets 34, 203–219. doi:10.1002/fut.21593.

Partz, H., 2019. Bitmex Outflows Hit Record in July Exceeding $500M Amid CFTC Probe. Cointelegraph.com URL: https://cointelegraph.com/news/bitmex-outflows-hit-record-in-july-exceeding-500m-amid-cftc-probe.

Pericli, A., Koutmos, G., 1997. Index futures and options and stock market volatility. Journal of Futures Markets 17, 957–974. doi:10.1002/(SICI)1096-9934(199712)17:8<957::AID-FUT6>3.0.CO;2-K.

Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. Economics Letters 58, 17–29. doi:10.1016/S0165-1765(97)00214-0.

Robertson, B., Hunter, G.S., 2019. U.S. Regulator Probing Crypto Exchange BitMEX Over Client Trades. Bloomberg.com URL: https://www.bloomberg.com/news/articles/2019-07-19/u-s-regulator-probing-crypto-exchange-bitmex-over-client-trades.

Tse, Y., Xiang, J., Fung, J.K.W., 2006. Price discovery in the foreign exchange futures market. Journal of Futures Markets 26, 1131–1143. doi:10.1002/fut.20229.

Yi, S., Xu, Z., Wang, G.J., 2018. Volatility connectedness in the cryptocurrency market: Is Bitcoin a dominant cryptocurrency? International Review of Financial Analysis 60, 98–114. doi:10.1016/j.irfa.2018.08.012.

Figure 1: Minute Returns for Each Instrument and Exchange

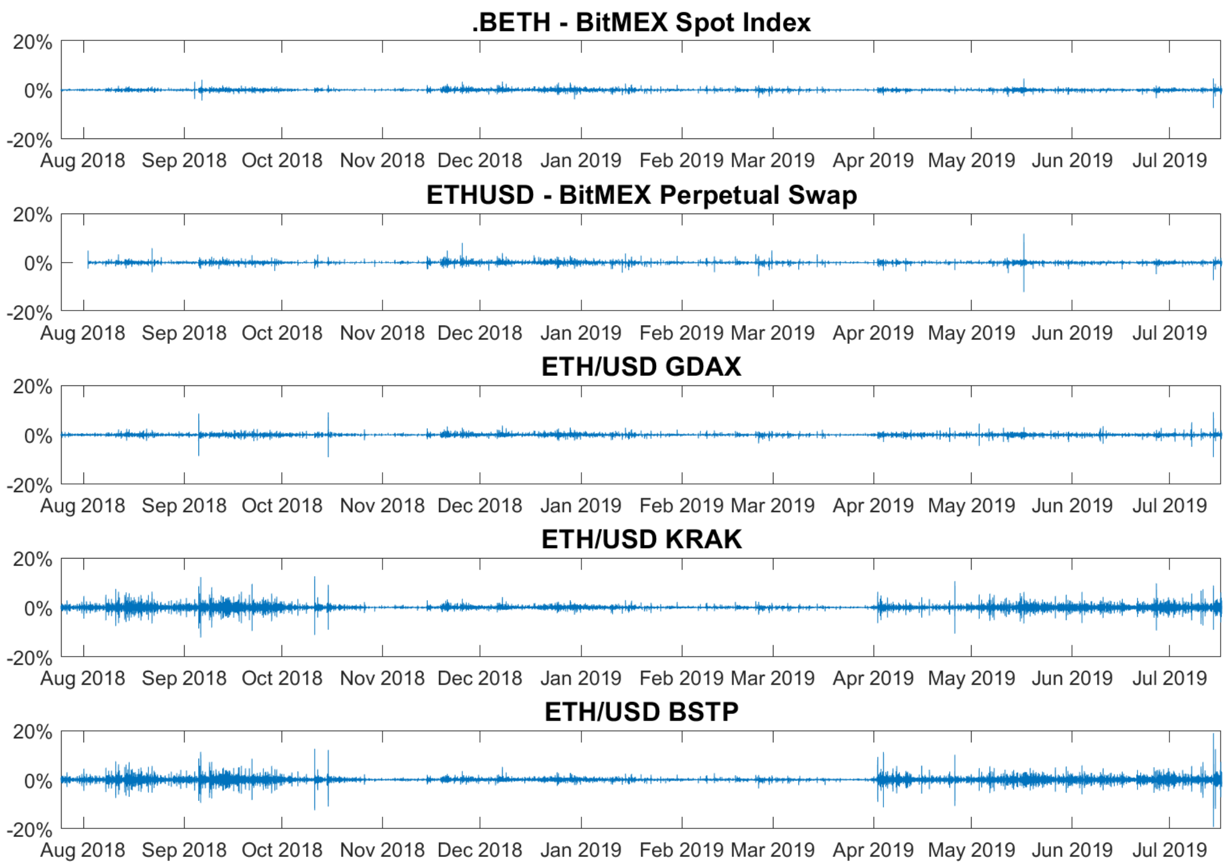

Figure 1 displays the 1-minute log-returns of BitMEX's .BETH index and ETHUSD perpetual swap, in addition to those from Bitstamp (BSTP), Coinbase (GDAX), and Kraken's (KRAK) ether spot exchanges. We can see that the .BETH index and the perpetual swap are much less noisy than the spot exchanges. Kraken and Bitstamp are much louder than the Coinbase 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 2: Basis of Close Price for the Spot Exchanges to the ETHUSD Perpetual Swap

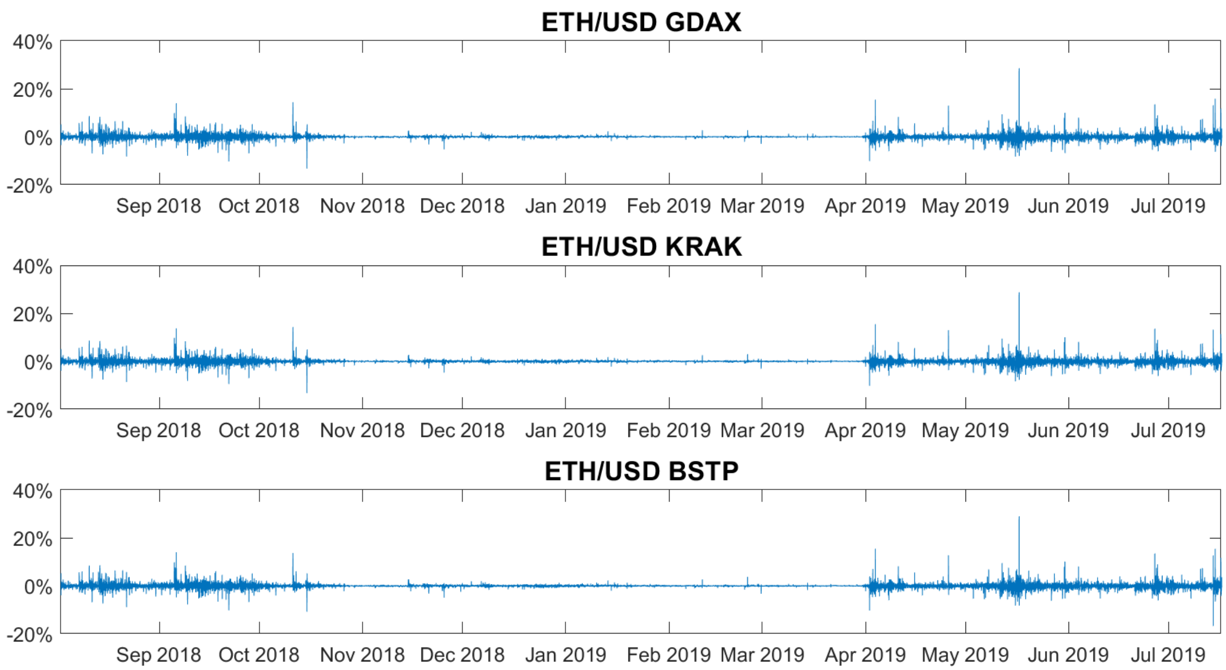

Figure 2 displays the 1-minute log basis of Bitstamp (BSTP), Coinbase (GDAX), and Kraken's (KRAK) ether close prices of the ETHUSD perpetual swaps close price. The basis shows the percentage deviation of the close price of the spot exchanges to the close price of the perpetual swap. Between mid-October 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 3: Daily Trading Volume of the Three Exchanges and the ETHUSD Perpetual Swap on a Logarithmic Scale

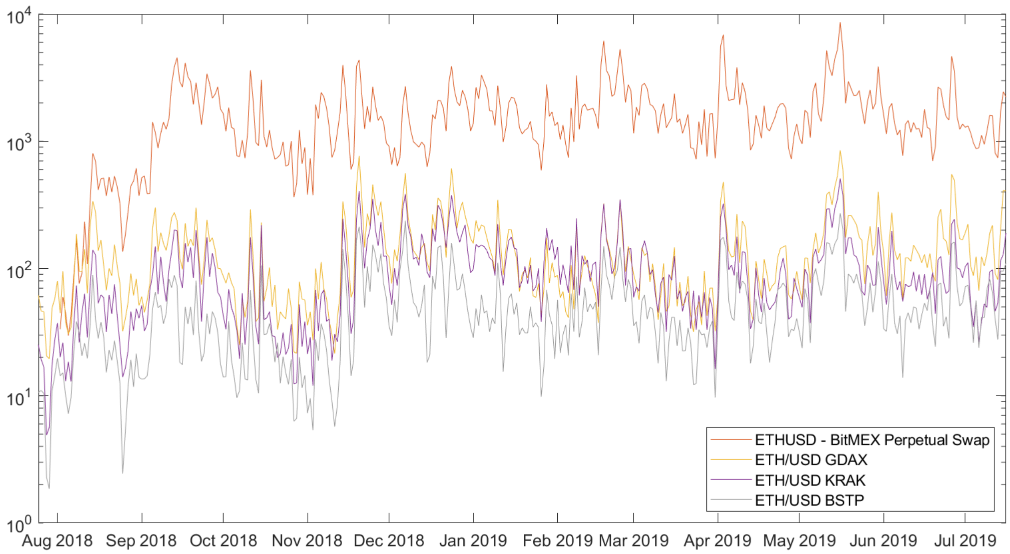

Figure 3 displays the daily trading volume of the ETHUSD perpetual swap, in addition to the volume of Bitstamp (BSTP), Coinbase (GDAX), and Kraken's (KRAK) ether spot exchanges, on a logarithmic scale. We can see that within two weeks of the perpetual swap's introduction, its volume rose to that higher 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 4: Relative Percentage Volume Between the Three Spot Exchanges

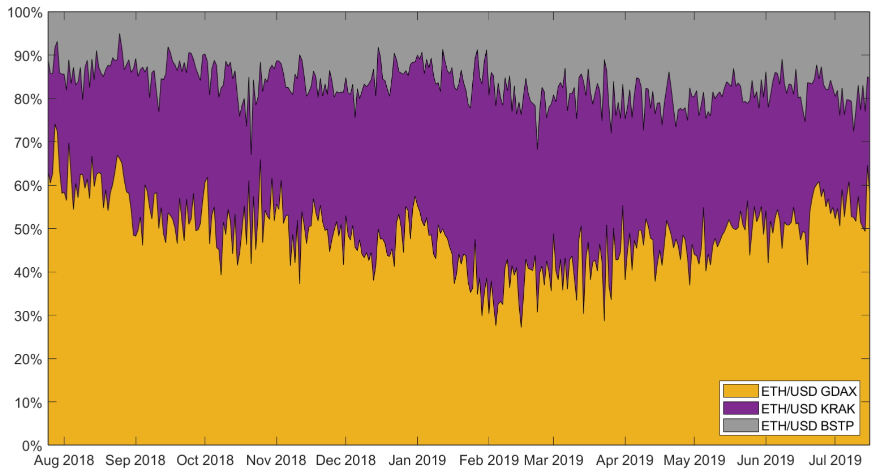

Figure 4 shows the relative percentage trading volume between the three spot exchanges. Throughout our entire period, we can see that Coinbase (GDAX) has the most substantial relative volume, with Kraken (KRAK) and Bitstamp (BTSP) following behind. The relative volumes are reasonably consistent throughout our entire time-period.

Figure 5: Price Discovery Measures for the Four-Dimensional Approach

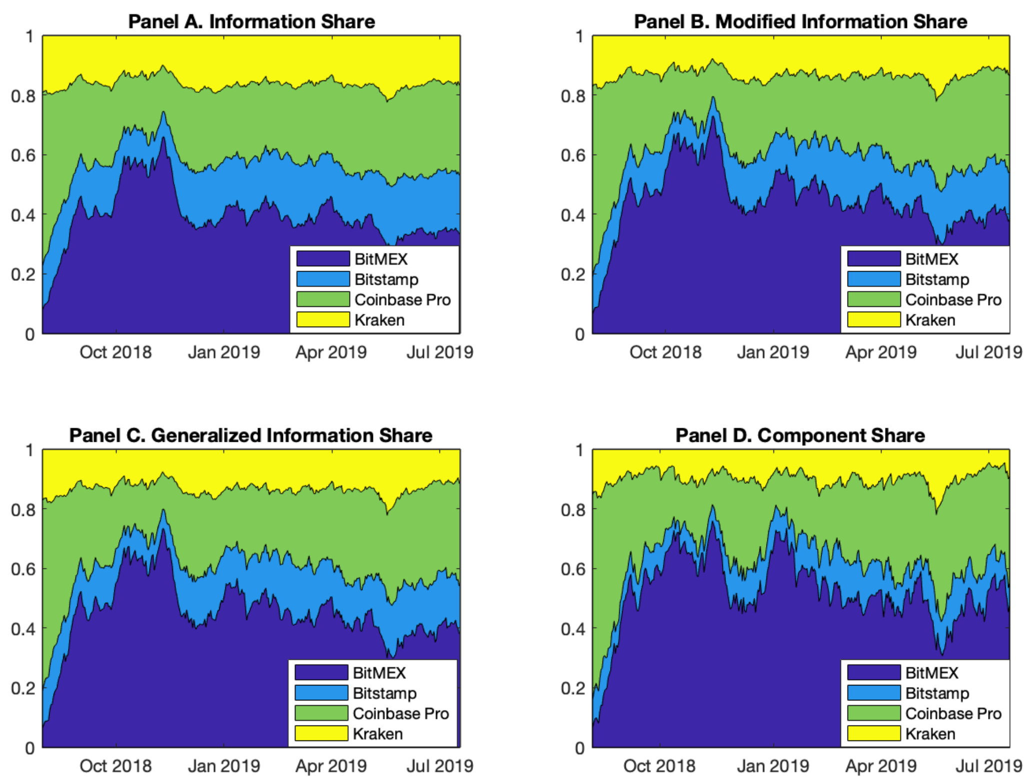

Figure 5 displays the information share (IS - Equation (2)) (Hasbrouck, 1995), modified information share (MIS - Equation (3)) (Lien and Shrestha, 2009), generalized information share (GIS - Equation (4)) (Lien and Shrestha, 2014) and component share (CS - Equation (5)) (Gonzalo and Granger, 1995) used to analyse the price discovery between BitMEX's ETHUSD perpetual swap and the ether spot markets of Bitstamp, Coinbase and Kraken. All measures show that the perpetual swap dominates the three spot exchanges in terms of price discovery.

Figure 6: Price Discovery Measures for the Two-Dimensional Approach Between Both Perpetual Swaps

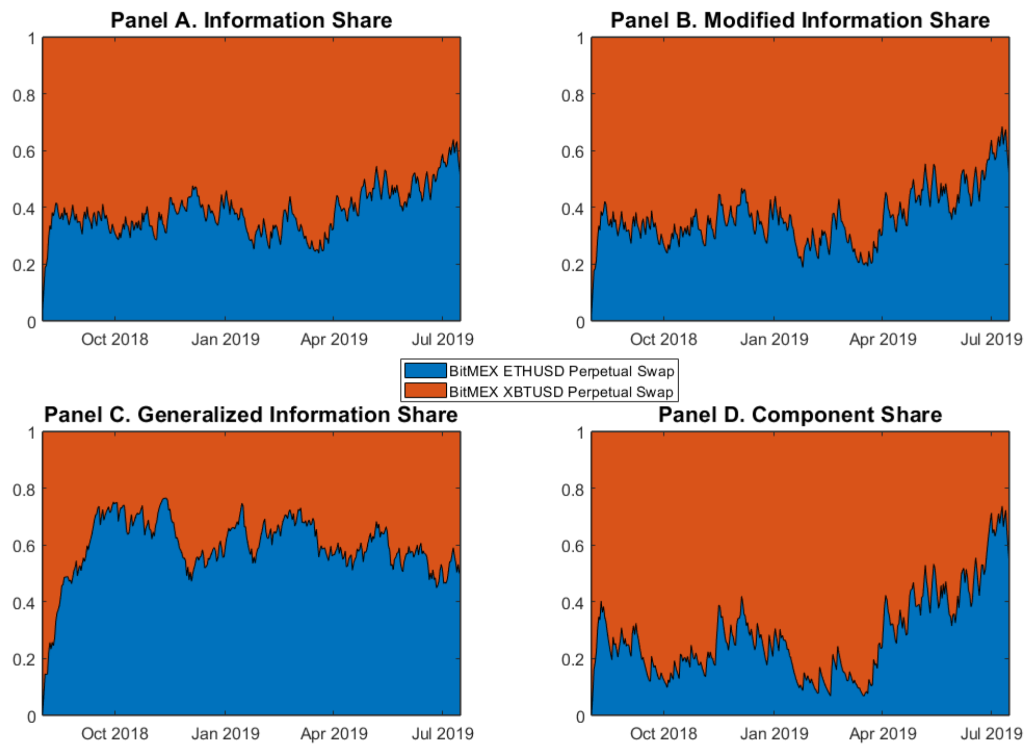

Figure 6 displays the information share (IS - Equation (2)) (Hasbrouck, 1995), modified information share (MIS - Equation (3)) (Lien and Shrestha, 2009), generalized information share (GIS - Equation (4)) (Lien and Shrestha, 2014) and component share (CS - Equation (5)) (Gonzalo and Granger, 1995) used 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.

Figure 7: The hour-of-day effect in ether markets

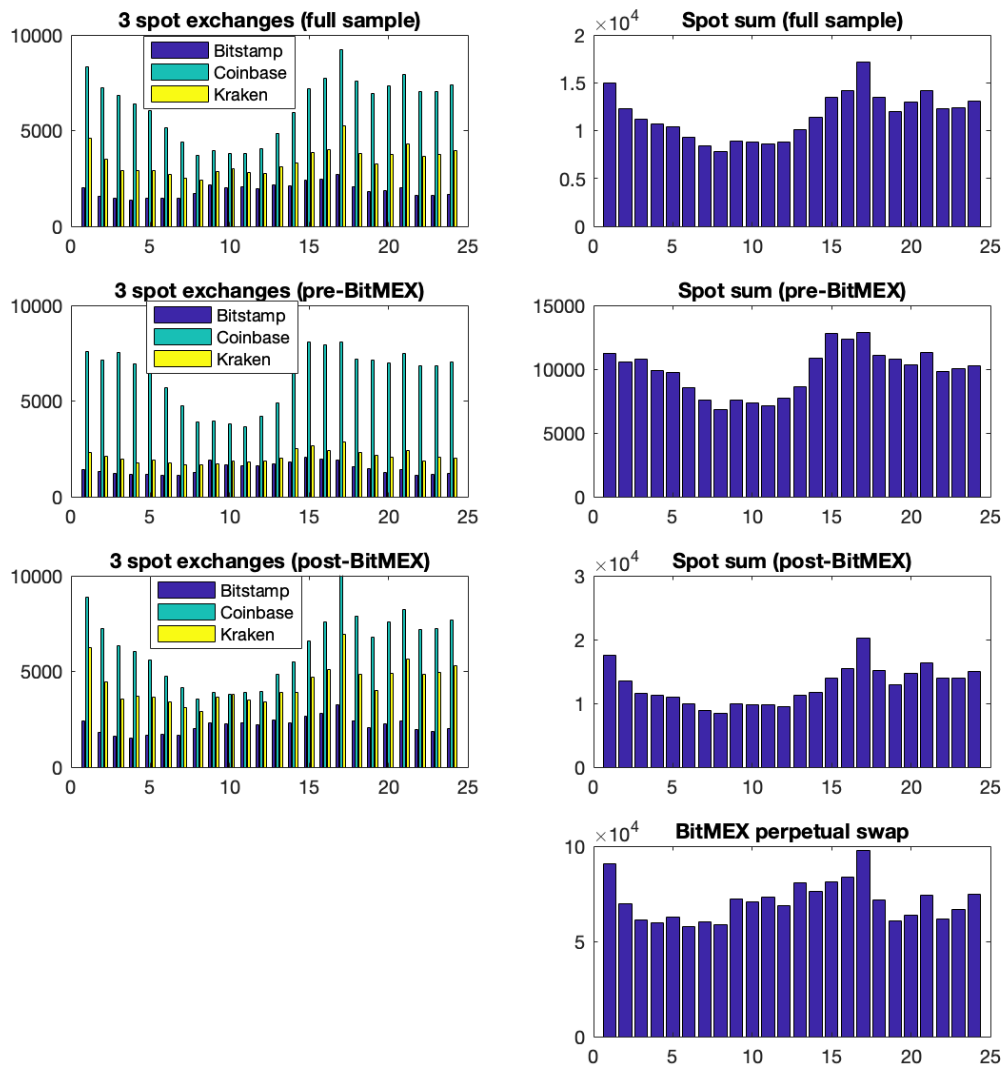

Figure 7 displays the individual (left panel) and aggregated (right panel) hourly trading volume in a day of the three spot exchanges. In each panel, we display the result for the full sample (top), pre-BitMEX (middle), and post-BitMEX period (bottom). The hourly trading volume of the ETHUSD perpetual swap in BitMEX is separately displayed in the bottom right corner. The horizontal axis is the hour in UTC time.

Figure 8: The day-of-week effect in ether markets

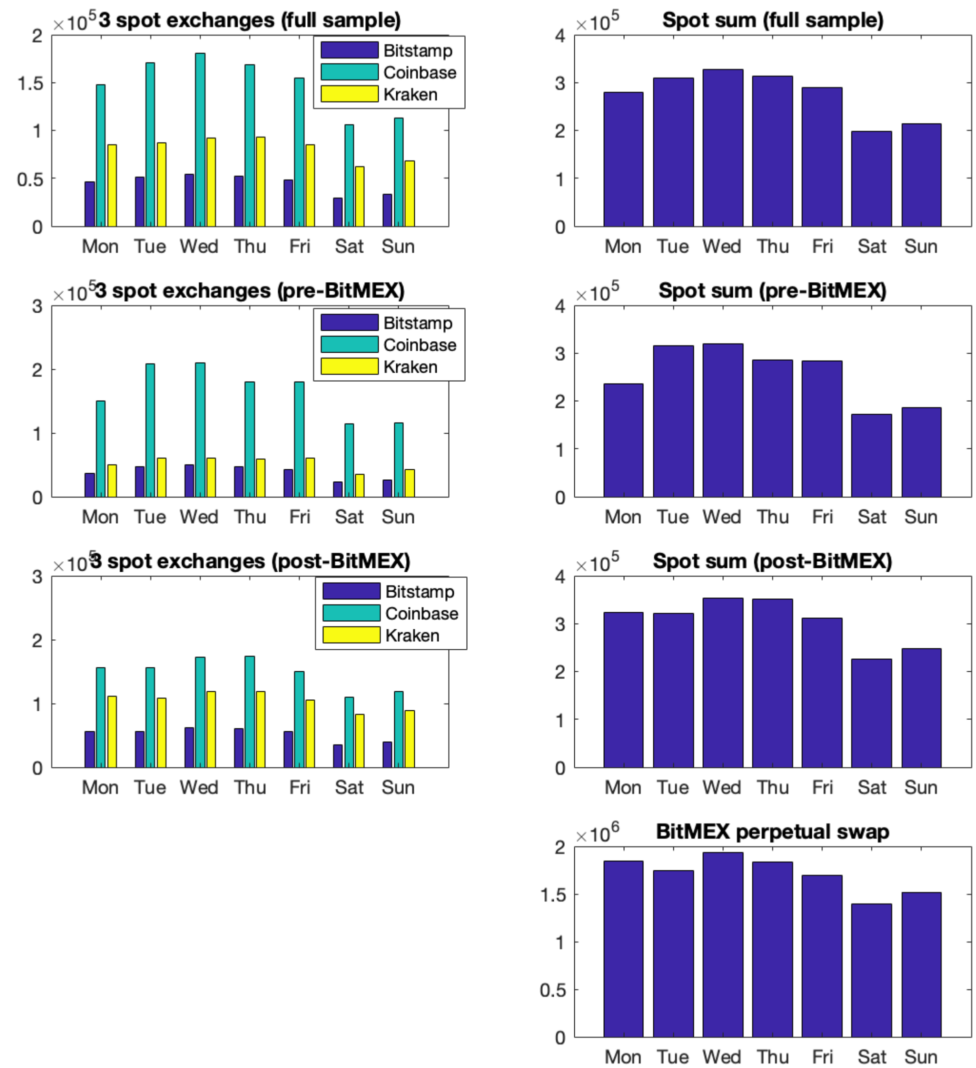

Figure 8 displays the individual (left panel) and aggregated (right panel) daily trading volume in a week in the three spot exchanges. In each panel, we display the result for the full sample (top), pre-BitMEX (middle), and post-BitMEX period (bottom). The daily trading volume of the ETHUSD perpetual swap in BitMEX is separately display in the bottom right corner.