Econometric Studies of Crypto Asset Markets

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1. Overview of Crypto Assets

Market Watch

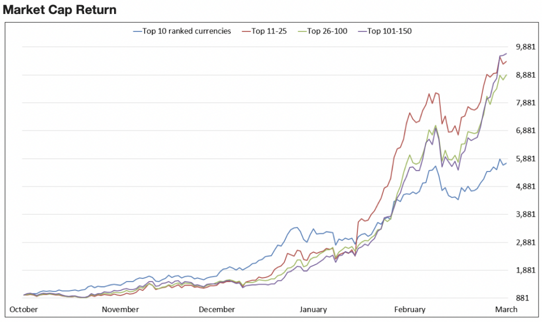
Name	Current Price	7d %	30d Vol	90d Vol	21d EMA	50d EMA
Bitcoin	$59,692.58	18.36%	81.81%	92.66%	$52,769.33	$46,876.84
Ethereum	$1,858.25	8.11%	98.01%	120.13%	$1,724.49	$1,584.30
Binance Coin	$263.420	11.47%	277.46%	191.23%	$242.18	$186.47
Polkadot	$37.71	8.62%	100.35%	167.23%	$34.69	$29.11
Cardano	$1.05	-8.04%	127.13%	159.59%	$1.09	$0.8999
XRP	$0.44	-4.89%	106.63%	207.97%	$0.4618	$0.4543
Uniswap	$30.99	-8.42%	172.45%	171.49%	$28.41	$23.15
Litecoin	$216.26	14.97%	116.54%	126.63%	$197.36	$181.22
Chainlink	$28.73	0.21%	130.43%	143.75%	$28.99	$26.92

*As of 3/15/2021 5:27 am UTC

Source: GSG Digital Asset Management

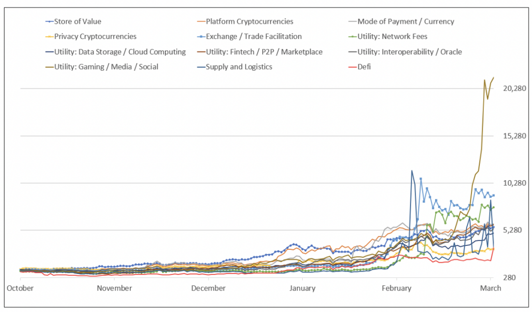
Returns by Market Cap – Last 6 Months

Market Cap Return



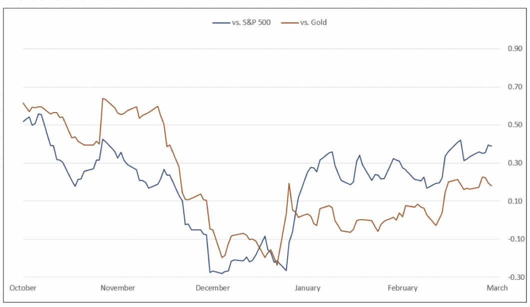
Returns by Sector – Last 6 Months

Sector Return



Correlation of BTC Returns with Gold and US Equities

BTC Correlation



Main Players in the Crypto Ecosystem

Issuers

Stable Coins

Ranking Sites

CryptoCompare

Exchanges

coinbase

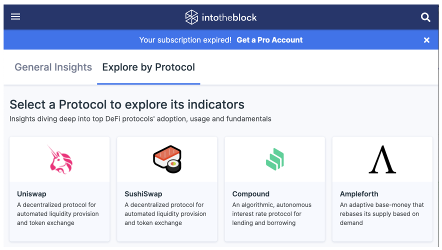
Increasingly also traditional asset managers, regulators, central banks and shadow banks....

Central Bank Digital Currencies

Digital money on private blockchains controlled by central banks

Decentralized Finance (DeFi)

Using crypto and other assets as collateral for P2P high-yield loans



IntoTheBlock

Ranking Sites

#	Coin	Price	Direct Vol	Total Vol	Top Tier Vol	Market Cap		Last 7 Days	24h
1	Bitcoin BTC	$ 54,085.65	$ 2.91 B	$ 15.55 B	$ 15.53 B	$ 1,008.65 B	B+		7.55%
2	Ethereum ETH	$ 1,821.92	$ 1.20 B	$ 8.27 B	$ 8.22 B	$ 209.48 B	A-		6.45%
3	Chiliz CHZ	$ 0.2807	$ 1.37 M	$ 2.70 B	$ 2.70 B	$ 2.50 B			72.63%
4	Binance Coin BNB	$ 273.87	$ 33.81 M	$ 2.29 B	$ 2.29 B	$ 46.70 B	C		18.01%
5	Cardano ADA	$ 1.179	$ 98.75 M	$ 1.72 B	$ 1.71 B	$ 37.68 B	B-		5.74%
6	Litecoin LTC	$ 198.81	$ 147.08 M	$ 1.27 B	$ 1.26 B	$ 13.35 B	B-		9.15%
7	XRP XRP	$ 0.4793	$ 42.60 M	$ 1.01 B	$ 1.01 B	$ 47.93 B	C+		1.96%
8	Polkadot DOT	$ 36.11	$ 37.26 M	$ 984.61 M	$ 984.61 M	$ 38.06 B	C+		7.12%
9	Dogecoin DOGE	$ 0.05721	$ 38.56 M	$ 921.96 M	$ 919.01 M	$ 7.35 B	C		4.30%
10	Chainlink LINK	$ 30.98	$ 133.93 M	$ 829.33 M	$ 829.33 M	$ 30.98 B			6.50%

CryptoCompare

De-Fi Token Rankings

Chainlink is a blockchain-base middleware that allows smart contracts to communicate with external resources by acting as a bridge between them and off-chain resources like data feeds, web APIs and traditional bank account payments

#	Coin	Price	Direct Vol	Total Vol	Top Tier Vol	Market Cap		Last 7 Days	% Chg
1	Chainlink LINK	$ 30.80	$ 112.84 M	$ 710.47 M	$ 710.47 M	$ 30.80 B			0.52%
2	Enjin Coin ENJ	$ 1.691	$ 39.84 M	$ 717.94 M	$ 706.61 M	$ 1.69 B			2.55%
3	Uniswap Protocol UNI	$ 32.92	$ 81.63 M	$ 649.22 M	$ 649.22 M	$ 32.92 B			-0.06%
4	Terra LUNA	$ 11.32	-	$ 562.85 M	$ 562.85 M	$ 10.70 B			22.56%
5	COTI COTI	$ 0.3740	-	$ 259.53 M	$ 259.53 M	$ 747.95 M			-8.88%
6	Swipe SXP	$ 2.970	$ 3.02 M	$ 248.45 M	$ 248.45 M	$ 849.89 M			3.41%
7	Aave AAVE	$ 426.29	$ 36.42 M	$ 222.57 M	$ 222.57 M	$ 6.82 B			4.96%
8	Bancor Network T BNT	$ 9.113	$ 38.62 M	$ 189.78 M	$ 189.78 M	$ 1.44 B			4.70%
9	Sushi SUSHI	$ 18.04	$ 5.39 M	$ 159.36 M	$ 157.35 M	$ 3.68 B			5.50%
10	JUST JST	$ 0.05900	$ 0	$ 143.17 M	$ 143.17 M	$ 584.09 M			3.36%
11	Curve DAO Token CRV	$ 2.345	$ 2.19 M	$ 140.75 M	$ 140.75 M	$ 3.40 B			3.49%
12	Reserve Rights RSR	$ 0.07381	-	$ 130.73 M	$ 130.73 M	$ 25.07 M			6.22%

Non-Fungible Tokens (NFT)

IP on blockchains: digital images, music, game cards, cryptokitties....

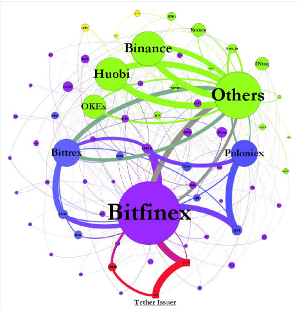
#	Name	Marketcap	Price	24h Volume	Blockchain	Change 24h	Change 7d
1	Enjin Coin ENJ	$1.52B	$1.82479	$1,382,308,101	Ethereum	+12.17%	+132.24%
2	Decentraland MANA	$916.49M	$0.58209	$813,793,393	Ethereum	+30.9%	+109.82%
3	Flow (Dapper Labs) FLOW	$882.36M	$37.8681	$112,501,102	Own Blockchain	+13.7%	+31.38%
4	WAX WAXP	$298.46M	$0.19490	$213,576,269	Ethereum	+43.39%	+156.05%
5	Ultra UOS	$127.36M	$0.45037	$5,466,918	Ethereum	+10.51%	+66.7%
6	The Sandbox SAND	$386.57M	$0.56826	$595,626,816	Ethereum	+38.67%	+125.69%
7	RedFOX Labs RFOX	$205.2M	$0.15640	$3,286,221	Own Blockchain	+6.9%	+6.8%
8	BakeryToken BAKE	$193.99M	$1.44774	$38,355,292	Binance Chain	+21.94%	+7.43%
9	WHALE WHALE	$182.75M	$34.8817	$2,148,379	Ethereum	+8.57%	+49.8%
10	Axie Infinity AXS	$152.78M	$3.54994	$59,526,363	Ethereum	+7.36%	+99.73%
11	SuperFarm SUPER	$114.72M	$1.14148	$4,442,287	Ethereum	-1.81%	-1.86%
12	NFTX NFTX	$114.39M	$258.851	$7,746,447	Ethereum	-8.68%	-15.95%

Stable Coins

#	Name	Marketcap	Price	24h Volume	Blockchain	Change 24h	Change 7d
1	Tether USDT	$36.82B	$1.00066	$94,729,465,435	Omni	+0.01%	-0.01%
2	USD Coin USDC	$8.94B	$1.00017	$1,658,089,001	Ethereum	+0.01%	+0.01%
3	Binance USD BUSD	$3.05B	$1.00020	$3,845,534,389	Ethereum	+0.01%	+0.02%
4	Dai DAI	$2.6B	$1.00105	$501,415,877	Ethereum	+0.05%	-0.08%
5	TerraUSD UST	$815.37M	$1.00061	$50,450,576	Ethereum	+0.03%	+0.08%
6	Paxos Standard PAX	$801.68M	$1.00008	$82,891,916	Ethereum	+0.38%	+0.31%
7	HUSD HUSD	$603.06M	$1.00079	$1,120,443,190	Ethereum	+0.11%	+0.09%
8	TrueUSD TUSD	$291.75M	$0.99926	$95,464,705	Ethereum	+0.01%	-0.07%
9	Vai VAI	$153.09M	$0.99550	$5,339,626	Binance Chain	+0.56%	-0.18%
10	JUST JST	$135.1M	$0.05977	$213,886,790	Tron	+9.04%	+26.61%
11	Gemini Dollar GUSD	$119.17M	$0.99696	$13,391,672	Ethereum	-0.27%	-0.42%
12	Neutrino USD USDN	$172M	$0.99935	$1,092,848	Waves	+0.63%	-0.31%

Tether market cap exceeds $36 Billion 10 × greater than in June 2019

Tether and BitFinex



Griffin and Shams (2020)


Tether and Bitfinex agree to pay $18.5m penalty after New York probe

State's attorney-general accused groups of covering up 'massive' financial losses

Adam Samson in London FEBRUARY 23 2021

 Carol Alexander

FT, June 2019

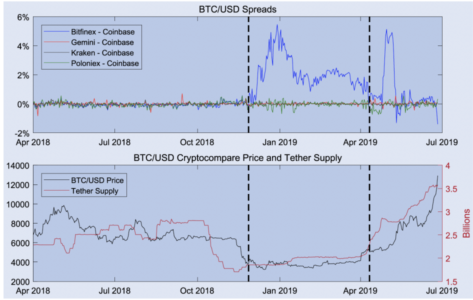


Figure 4. BTC tether-adjusted price spreads, BTC price level and USDT supply. **Upper graph:** Bitfinex–Coinbase, Gemini–Coinbase, Kraken–Coinbase and Poloniex–Coinbase BTC price spreads, all expressed relative to Coinbase's BTC price. Bitfinex and Poloniex prices are expressed in USD via the Kraken USDT/USD cross-rate. **Lower graph:** BTC price index from CC. The data frequency is daily, and the sample period is 1 April 2018–26 June 2019. Vertical dotted lines denote dates of interest.

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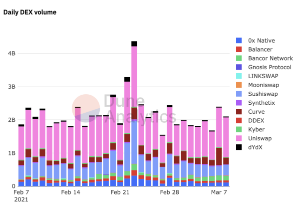
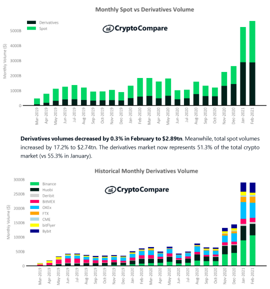
2. On-Chain and Off-Chain Exchanges

Decentralised Exchanges (DEX)
On Chain



Centralised Exchanges (CEX)
Off-Chain



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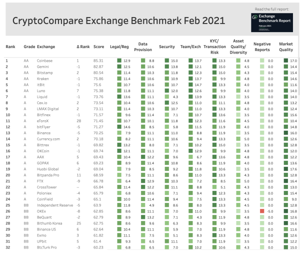
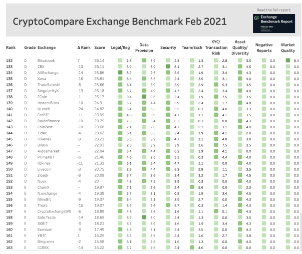
Centralised Exchanges





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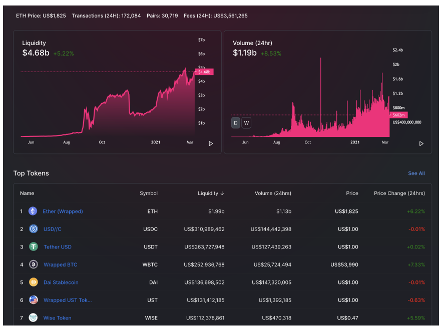
Decentralized Exchanges



How to swap ERC-20 tokens

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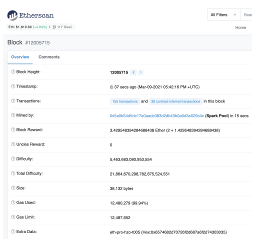
Block Explorer

Records all transactions on a blockchain including smart contract transactions for protocols like Ethereum, Polkadot, etc. Etherscan



Visualisation of bitcoin blocks

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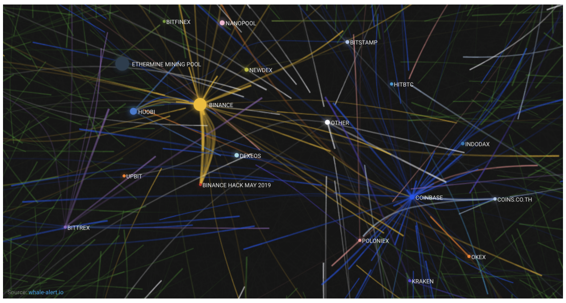
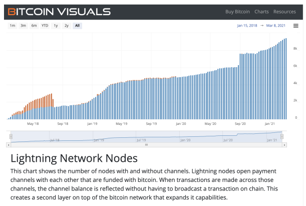
Recording On-Chain BTC Flows



Whale Alert

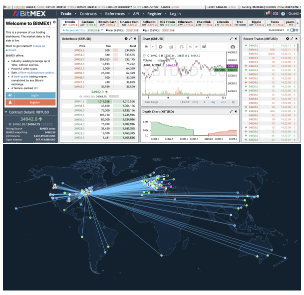
Bitcoin Lightning Network

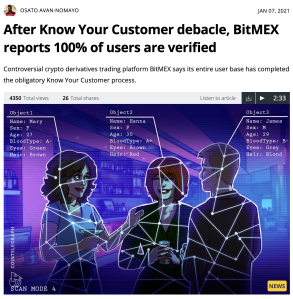


- Currently more than 9000 nodes and millions of channels
- USD value locked in channels exceeds $52 million (5 times more than a year ago)

Channel Explorer

BitMEX Research Node




OSATO AVAN-NOMAYO

JAN 07, 2021

After Know Your Customer debacle, BitMEX reports 100% of users are verified

Controversial crypto derivatives trading platform BitMEX says its entire user base has completed the obligatory Know Your Customer process.

BitMEX

3. Data Matters

Alexander C. and M. Dakos (2020) A Critical Investigation of Cryptocurrency Data and Analysis *Quantitative Finance*, 20(2), 173-188

- Compares traded prices of BTC and ETH on 3 CEXs with non-traded VWAP prices provided by ranking sites Coingecko (CG), Coinmarketcap (CM) and Cryptocompare (CC)
- Compares crypto market indices CCi30, CRIX and MVDA25
- Results presented include:
  - Sample statistics
  - Capital Asset Pricing Model (CAPM) estimations

$$r_{it} = \alpha_i + \beta_i R_t + \varepsilon_{it},$$

where r_{it} is the daily return on the i^{th} source of the coin price and R_t is the daily return on the market index
  - Volatility estimations using various statistical models

Crypto Price Indices

The daily price index p_t^i for each coin i is obtained using p_t^{ij}, the price of coin i from source j at time t, and v_t^{ij}, the corresponding 24-hour volume traded from $t-1$ to t, both expressed in USD, in the VWAP formula:

$$p_t^i = \left(\sum_{j=1}^{N} v_t^{ij}\right)^{-1} \sum_{j=1}^{N} p_t^{ij} v_t^{ij}, \qquad (1)$$

where N is the total number of price sources, e.g. in the BTC/USD price index, at the time N was approximately 300 for CG, 400 for CM, but only 40 for CC.

Crypto Market Indices

The CCi30, CRIX and MVDA25 are cap-weighted indices derived from 25–50 large cap coins, typically constructed as:

$$I_t = d_t^{-1} \sum_{i=0}^{k} p_t^i \, q_s^i \,, \qquad (2)$$

where: k is the number of coins included; p_t^i is the price index of coin i at time t, based on (1); q_s^i is the circulating supply of coin i at time $s \le t$, which is typically the point when the index was last rebalanced; and the normalizing divisor d_t resets when the index composition changes

The CRIX and MVDA25 indices are constructed as per (2), while the CCi30 index here employs a variant of (2) that weights coin prices by the square root of their market cap. In (2), k is 30 for the CCi30 and 25 for the MVDA25 (it varies for the CRIX). The p_t^i is constructed as per (1) but uses different data sources: CCi30 uses CoinAPI data; CRIX uses CG price indices; MVDA25 uses CC price indices.

Summary Statistics (BTC)

Table A1. Sample statistics on BTC non-traded price indices and traded prices.

	BTC Non-Traded			BTC Traded				
	CG	CM	CC	Bitfinex	Coinbase	Gemini	Kraken	Poloniex
1 Apr 2016–31 Mar 2017								
Mean (p.a.)	113.1%	110.8%	112.6%	111.3%	113.5%	113.1%	113.4%	113.9%
Volatility	58.9%	56.6%	58.0%	55.9%	58.5%	58.3%	60.0%	59.9%
Skewness	– 0.74	– 0.73	– 0.84	– 0.58	– 0.50	– 0.84	– 0.79	– 0.88
Ex. Kurtosis	6.24	6.01	6.62	5.79	6.03	6.11	6.51	7.09
1 Apr 2017–31 Mar 2018								
Mean (p.a.)	241.7%	241.2%	240.4%	243.0%	238.5%	239.7%	238.0%	242.0%
Volatility	105.2%	104.1%	104.3%	107.8%	103.9%	104.7%	102.5%	106.7%
Skewness	0.41	0.33	0.28	0.35	0.46	0.42	0.27	0.34
Ex. Kurtosis	4.57	2.57	2.20	2.06	2.68	2.68	1.97	2.01
1 Apr 2018–31 Mar 2019								
Mean (p.a.)	– 33.9%	– 33.9%	– 31.9%	– 29.2%	– 31.7%	– 31.4%	– 31.3%	– 31.6%
Volatility	61.8%	61.6%	63.8%	65.6%	64.4%	64.6%	64.6%	64.2%
Skewness	– 0.15	– 0.13	– 0.16	– 0.07	– 0.19	– 0.17	– 0.18	– 0.18
Ex. Kurtosis	2.96	3.02	2.90	3.12	3.20	3.13	3.14	3.20

Note: Sample statistics of the daily returns on BTC prices from CG, CM and CC, and from Bitfinex, Coinbase, Gemini, Kraken and Poloniex.

Summary Statistics (ETH)

Table A2. Sample statistics on ETH non-traded price indices and traded prices.

	ETH Non-Traded			ETH Traded				
	CG	CM	CC	Bitfinex	Coinbase	Gemini	Kraken	Poloniex
1 Jul 2016–31 Mar 2017								
Mean (p.a.)	238.8%	247.8%	249.8%	241.7%	252.1%	250.1%	247.9%	249.5%
Volatility	113.4%	114.1%	115.3%	110.0%	118.1%	117.9%	114.6%	115.9%
Skewness	0.97	1.32	1.17	1.49	1.32	0.84	1.15	1.08
Ex. Kurtosis	8.49	8.12	6.87	6.66	6.70	5.38	6.63	6.69
1 Apr 2017–31 Mar 2018								
Mean (p.a.)	290.8%	293.8%	292.7%	294.4%	291.6%	298.2%	289.6%	293.2%
Volatility	130.7%	133.6%	132.9%	133.3%	132.7%	136.2%	130.2%	132.4%
Skewness	0.54	0.76	0.66	0.41	0.81	0.79	0.60	0.43
Ex. Kurtosis	2.06	2.74	1.81	1.24	2.37	2.11	1.41	1.16
1 Apr 2018–31 Mar 2019								
Mean (p.a.)	– 56.9%	– 57.5%	– 52.2%	– 51.3%	– 52.7%	– 52.5%	– 51.9%	– 53.9%
Volatility	95.5%	95.0%	99.2%	99.0%	99.5%	99.6%	99.7%	97.9%
Skewness	0.05	– 0.04	– 0.02	0.02	– 0.07	– 0.03	– 0.04	– 0.01
Ex. Kurtosis	2.02	2.08	1.98	1.95	2.05	2.11	2.00	1.99

Note: Sample statistics of the daily returns on ETH/USD prices from CG, CM and CC, and from Bitfinex, Coinbase, Gemini, Kraken and Poloniex.

CAPM Estimations

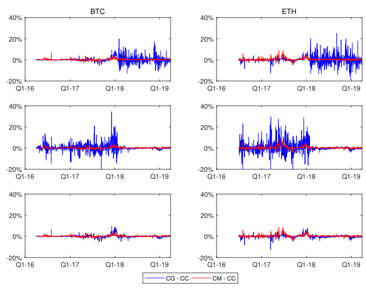
Table 1. Market betas of BTC and ETH w.r.t. CCi30, CRIX and MVDA25 indices.

	CG	CM	CC	Bitfinex	Coinbase	Gemini	Kraken	Poloniex
BTC								
CCi30	0.374	0.730	0.744	0.742	0.734	0.743	0.734	0.743
	(14.6)	(44.3)	(44.9)	(43.4)	(43.2)	(44.1)	(43.5)	(43.3)
CRIX	0.903	0.528	0.519	0.515	0.506	0.515	0.497	0.521
	(69.4)	(20.9)	(20.1)	(19.6)	(19.4)	(19.7)	(18.9)	(19.8)
MVDA25	0.359	0.495	0.509	0.501	0.504	0.508	0.504	0.504
	(15.4)	(24.1)	(24.6)	(23.7)	(24.2)	(24.4)	(24.3)	(23.8)
ETH								
CCi30	0.501	1.008	1.020	1.012	1.012	1.023	0.998	1.021
	(13.1)	(37.3)	(37.4)	(37.7)	(36.1)	(36.0)	(36.3)	(37.8)
CRIX	1.041	0.513	0.502	0.489	0.490	0.498	0.471	0.510
	(33.6)	(12.0)	(11.6)	(11.4)	(11.2)	(11.2)	(10.9)	(11.8)
MVDA25	0.568	0.763	0.778	0.757	0.778	0.777	0.760	0.772
	(16.8)	(25.3)	(25.6)	(25.0)	(25.4)	(24.8)	(25.0)	(25.5)

Notes: Market betas with corresponding t-statistics in parentheses of daily returns on BTC (upper panel) and ETH (lower panel) prices from CG, CM and CC, and from Bitfinex, Coinbase, Gemini, Kraken and Poloniex. The market factor is the return on either the CCi30, the CRIX or the MVDA25 crypto market index. The sample period is 1 April 2016–31 March 2019 for BTC and 1 July 2016–31 March 2019 for ETH. Parameters of interest are highlighted in blue and red.

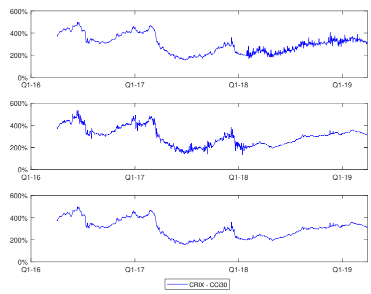
CoinGecko Problems

CG – CC and CM – CC price spreads relative to CC's daily price for BTC (left-hand graphs) and ETH (right-hand graphs), using CG price data as is (upper), lagged by one day (middle s), and as is until 29 January 2018 and lagged from 30 January 2018 (lower graphs).



Spillover to CRIX

CRIX – CCi30 spread relative to CCi30, using CRIX daily data as is (upper graph), lagged by one day (middle graph), and lagged starting from 30 January 2018 (lower graph).



GARCH Models

Generalised Autoregressive Conditional Heteroscedasticity

Bollerslev (1986)

- Crypto asset returns require two sources of asymmetry – i.e. volatility response and innovations and a regime-switching setting

Skew Student t Asymmetric Markov Switching GARCH:

$$\sigma_{it}^2 = \omega_i + \left(\alpha_i + \gamma_i I_{\{\varepsilon_{t-1}<0\}}\right)\varepsilon_{t-1}^2 + \beta_i \sigma_{i,t-1}^2 \text{ where } \varepsilon_t \sim t_{\eta_i,\xi_i} \text{ and } i = 1, 2.$$

Unconditional steady-state volatility of each regime:

$$UV_i = \sqrt{\frac{365\,\omega_i}{1-\alpha_i-0.5\gamma_i-\beta_i}}.$$

Unconditional state transition probability matrix:

$$\mathbf{\Pi} = \begin{pmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{pmatrix},$$

where $p_{ij} = P\left(s_t = j | s_{t-1} = i\right)$.

Skew Student t Asymmetric Markov Switching GARCH

Markov switching GJR-GARCH on BTC daily returns from CG, CM and CC and from the Bitstamp and Kraken CEXs. Estimation using MCMC. Sample period is 1 September 2013 – 31 March 2019.

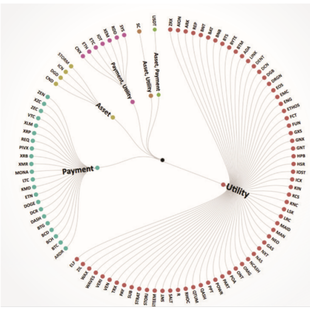
	CG	CM	CC	Bitstamp	Kraken
			Low Volatility State		
ω_1	0.145	0.007	0.197	0.036	0.011
α_1	0.147	0.052	0.156	0.070	0.100
γ_1	-0.067	-0.019	-0.097	-0.006	-0.074
β_1	0.865	0.953	0.858	0.922	0.917
η_1	2.948	2.396	2.873	2.832	3.057
ξ_1	1.013	1.046	0.998	1.028	1.100
p_{11}	0.94	0.96	0.98	0.98	0.86
UV_1	49.57	21.45	45.70	36.32	14.22

Skew Student t Asymmetric Markov Switching GARCH

Markov switching GJR-GARCH on BTC daily returns from CG, CM and CC and from the Bitstamp and Kraken CEXs. Sample period is 1 September 2013 – 31 March 2019.

	CG	CM	CC	Bitstamp	Kraken
			High Volatility State		
ω_2	30.442	2.377	4.599	24.312	1.828
α_2	0.003	0.240	0.067	0.231	0.022
γ_2	0.297	-0.055	0.204	0.311	0.168
β_2	0.009	0.767	0.682	0.308	0.880
η_2	51.933	4.172	4.165	3.131	65.485
ξ_2	0.710	0.865	0.937	0.854	0.906
p_{22}	0.77	0.95	0.97	0.95	0.60
UV_2	115.07	204.41	106.27	170.28	216.24

4. Initial Coin Offerings



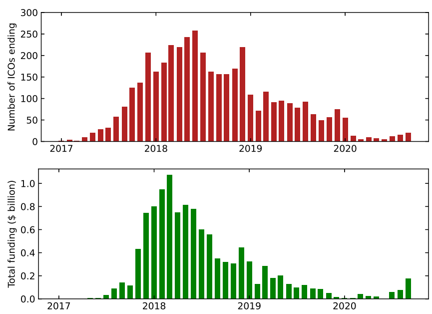
Evolution of ICOs

Data Sources

Alexander C. and M. Dakos (2021) The Changing Face of Initial Coin Offerings *In Prep.*

- Primary data source: ICObench
- Other ICO rating websites used: ICOdata, TokenData, ICOdrops, ICOrating and Neironix, ICOholder, Cryptocompare, Smith and Crown, ICOmarketdata, ICOstats, Coincodex, Cryptodiffer and Cryptorank.
- Initial sample of 4,152 ending before 31 Dec 2019
- Reduced to 1,215 with data on amount raised, price, supply, distribution, team, etc..
- Some large ICOs such as EOS, TON and LEO excluded
- Now extending to end 2020

Our Sample



Number of ICOs ending (red) and USD total amount raised (green)
Total amount raised ∼ $12 billion

Authors	Momtaz (2020a)	Momtaz (2020b)*	Roosenboom et al. (2020)**	Ante and Fiedler (2020)	Aggarwal et al. (2019)	Albrecht et al. (2020)	Boreiko and Vidusso (2019)	Chen (2019)	Fisch (2019)	Lyandres et al. (2019)	Amsden and Schweizer (2018)	Blaseg (2018)*	Bourveau et al. (2018)	Lee et al. (2018)*
Data start	8/15	8/15	8/15	4/17	1/15	1/17	1/13	1/15	3/16	1/13	1/15	1/14	4/14	1/16
Data end	7/18	4/18	12/17	10/18	9/18	3/18	9/17	3/18	3/18	11/18	3/18	12/17	2/18	5/18
N	495	132	630	151	853	522	178	479	423	980	214	670	200	727
Price			o			o						o		
Supply	+		+						+		+			
Github			+			+			o		o		o	
Whitepaper				o			o			o				
Presale		−	+						o	+	o			−
Rating		+			+		+						+	+
Team size			+	+	+			+		+	+	o	+	
# Advisors				o							o			
ETH			+				o				o	+		
Bonus			o								o	o		−
Distribution			o						o	−	−	o		−
Duration	−	−	o			−		−	−			o		
R^2	0.23	0.18	0.23	0.38	0.18	0.37	0.30	0.22	0.42	0.39	0.28	0.14	0.28	0.03

Binary Variables Considered – but not Significant

- **Pre-Sale**: 1 = Private sale prior to the main ICO start
- **Github**: 1 = Venture had active Github profile at start of ICO
- **Twitter**: 1 = Twitter account active at time of ICO start
- **Whitepaper**: 1 = Whitepaper on ICObench
- **Bonus**: 1 = scheme for rewarding early ICO investors

Determinants of Success

	ICO boom (Jan 2017 - Jun 2018)				Post-boom (Jul 2018 - Dec 2019)			
	(i) Basic		(ii) Full		(i) Basic		(ii) Full	
Constant	-0.959***	(-3.91)	-0.961***	(-3.45)	-0.219	(-0.96)	0.110	(0.38)
Log Target Cap	0.260***	(4.67)	0.269***	(5.14)	0.361***	(9.16)	0.347***	(8.40)
Rating	0.389***	(5.99)	0.350***	(5.33)	0.089	(1.39)	0.100	(1.51)
Team Size	0.022***	(4.14)	0.022***	(3.86)	0.016***	(2.94)	0.017***	(2.92)
ETH price	0.174***	(3.90)	0.172***	(3.82)	0.164***	(2.74)	0.164***	(2.67)
Tax Haven	0.162**	(2.22)	0.166**	(2.26)	0.202***	(2.82)	0.187**	(2.49)
% Distributed in ICO	-0.150***	(-3.75)	-0.152***	(-3.64)	-0.019	(-0.47)	-0.034	(-0.85)
Log Duration	-0.150***	(-4.65)	-0.166***	(-4.95)	-0.070**	(-2.57)	-0.082***	(-2.73)
Observations	589		589		626		626	
Adjusted R^2	0.282		0.290		0.198		0.200	

Dependent variable: log amount raised

Regression (ii) includes control variables and industry fixed effects (e.g. KYC, Accepts BTC, IEO, etc.)

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, t-statistics in parentheses

5. Price Discovery

Alexander, C. and D. Heck (2020) Price Discovery in Bitcoin: The Impact of Unregulated Markets. *Journal of Financial Stability* 50, 1-18.

Alexander, C., Choi, J., Massie, H. and S. Sohn (2020) Price Discovery and Microstructure in Ether Spot and Derivatives Markets. *International Review of Financial Analysis*, 71

Alexander C., Choi, J., Park, H., and S. Sohn (2019) BitMEX Bitcoin Derivatives: Price Discovery, Informational Efficiency and Hedging Effectiveness. *Journal of Futures Markets*, 40(1) 23-43

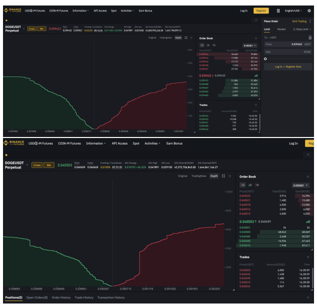
Alexander and Heck (2020)

Multidimensional price discovery analysis on bitcoin spot and futures
Minute-level data from 21 exchanges

Futures	Perpetuals	Spot
Bakkt^{Sep}	BitMEX	BinanceUS^{Oct}
CME	Deribit	Bitfinex
BitMEX	Kraken^{Oct}	Bitstamp
Deribit	OKEx^{July}	Bittrex
Huobi^{July}		Coinbase
Kraken^{Oct}		Exmo
OKEx		Gemini
		itBit
		Kraken
		OKCoin

We exclude Binance because almost all its trading is on tether perpetuals

Binance Exchange



Dogecoin Perpetual

Where are the most Speculative Trades?

$\downarrow$ average holding period $\Rightarrow$ $\uparrow$ in speculative activity

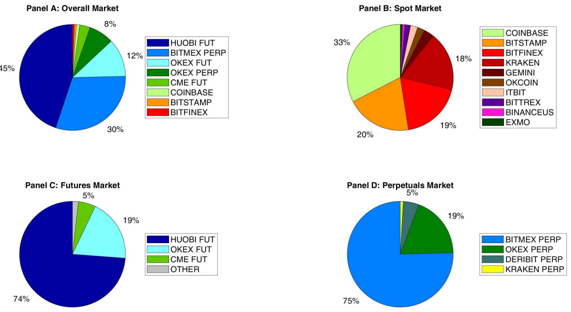
Average Holding Period (hours)

	Perpetuals			Futures			
	BitMEX	Deribit	OKEx	BitMEX	Deribit	Huobi	OKEx
September	20.25	25.65	25.44	423.49	315.01	32.13	107.59
October	18.80	25.08	19.53	277.96	225.44	7.28	36.85
November	19.33	24.95	17.78	366.50	241.71	6.29	28.74
December	21.64	41.36	13.95	628.12	385.26	20.83	56.55
January	17.61	35.35	17.06	402.81	345.69	7.61	37.66

$$\text{Average holding period} = \frac{\text{Open Interest}}{\frac{1}{2}\text{Volume}}$$

Relative Volumes

Data from 1 April 2019 to 31 January 2020



Futures Contract Specifications

Table 1 Futures Specifications

	Regulated Futures		Unregulated Futures				
Contracts	CME	Bakkt	BitMEX	Deribit	Huobi	Kraken	OKEx
Contract Size	5 XBT	1 XBT	1 USD	10 USD	100 USD	1 USD	100 USD
Frequency	Monthly	Daily, Monthly	Quarterly	Quarterly	Weekly, Quarterly	Monthly, Quarterly	Weekly, Quarterly
Margin Requirement	37%	37%	1%	1%	1%	2%-6%*	10%
Settlement	Cash in USD	Physical	Cash in XBT	Cash in XBT	Cash in XBT	Cash in XBT	Cash in XBT
Trading Days	Weekdays	Weekdays	24/7	24/7	24/7	24/7	24/7
Delivery Date	Last Friday	3rd Friday	Last Friday	Last Friday	Last Friday	Last Friday	Last Friday
Fees (maker/taker)	$1.25	$1.25	-2.5/7.5	-2/5	2/3**	-2/7.5	2/5**

Note: The table shows the main specifications of the quarterly futures contracts included in our analysis. Except for CME and Bakkt, fees are reported in basis points. *Kraken is the only exchange that distinguishes between margins for professional and retail clients. The former face margin requirements of 2-6%, while the latter have to deposit 50% as initial margin. **Huobi and OKEx do not offer maker rebates for ordinary users, but for VIP investors with a 30-day trading volume of at least $500m or 100,000 XBT, respectively.

Measures

Generalized Information Share (GIS) for Product X

- When new information arrives to the network, what proportion of the total price innovation originates on product X?

Impulse Response of Product X

- When a price jump occurs on a leading product, how long does a following product take to adjust to the new market price?
- What happens when a jump occurs on a following exchange?

Procedure

- Various n-dimensional vector error correction models (VECM)
- Five Systems of traded BTC prices:
  - Spot $(n = 10)$
  - Perpetuals $(n = 4)$
  - Futures (reg. $n = 2$, unreg. $n = 5$)
  - Main $(n = 8)$
- Day-by-day analysis of minute-level traded prices $\rightarrow$ daily time series of GIS for each exchange in the system
- Exponential smoothing of GIS aids visual displays
- Robustness checks: 5-min and 15-min frequencies and different information measures

Vector Autoregression Models

Let $\mathbf{p}_t$ be the $n \times 1$ vector of cointegrated log prices at time t and let $z_t = \boldsymbol{\beta}^T \mathbf{p}_t$ denote their deviations from long-run equilibrium. Then the VECM is:

$$\Delta \mathbf{p}_t = \boldsymbol{\alpha} + \sum_{i=1}^{q-1} \boldsymbol{\Gamma}_i \Delta \mathbf{p}_{t-i} + \boldsymbol{\delta} z_{t-1} + \mathbf{e}_t,$$

where $\mathbf{e}_t$ are serially uncorrelated innovations with zero mean and covariance matrix $\boldsymbol{\Omega}$ and $\boldsymbol{\delta}$ captures reactions to transitory equilibrium deviations. Inverting and integrating gives:

$$\mathbf{p}_t = \mathbf{p}_0 + \boldsymbol{\Psi}(1) \sum_{j=1}^{t} \mathbf{e}_j + \boldsymbol{\Psi}^{\star}(L) \mathbf{e}_t$$

where $\boldsymbol{\Psi}(1)$ i.e. the sum of the MA coefficients in the inversion of the AR, has identical rows which we denote $\boldsymbol{\psi}$. Then the scalar $\boldsymbol{\psi}\mathbf{e}_t$ is the common efficient price and it has variance $\boldsymbol{\psi}\boldsymbol{\Omega}\boldsymbol{\psi}^T$

Information Shares

The Hasbrouck (1995) information share of each market, i.e. its relative contribution to the variance of the common efficient price, is:

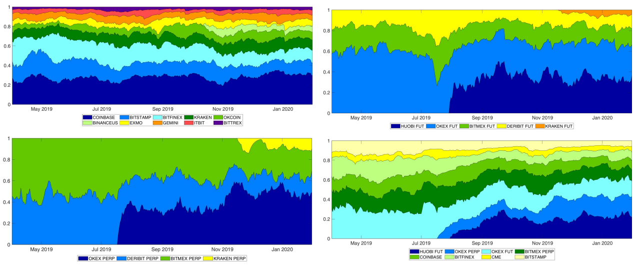
$$\mathrm{IS}_i = \frac{([\boldsymbol{\psi}\mathbf{M}]_i)^2}{\boldsymbol{\psi}\boldsymbol{\Omega}\boldsymbol{\psi}^T} \quad \text{for } i = 1, \ldots, N,$$

where $\mathbf{M}$ is the lower triangular matrix of the Cholesky decomposition of $\boldsymbol{\Omega}$ and $[\boldsymbol{\psi}\mathbf{M}]_i$ is the i-th entry of $\boldsymbol{\psi}\mathbf{M}$.

Various improvements of the IS have been proposed for different reasons – we use the generalised information share of Lien and Shrerestha (2015)

We also check robustness with the component share of Gonzalo and Granger (1995)

Results



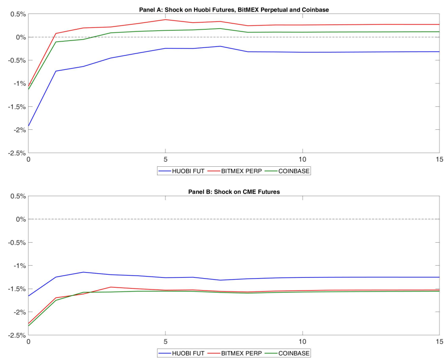
Impulse Responses to/from CME Futures

- How does CME react to price jumps on an unregulated exchange?
- How do the unregulated exchanges react to price jumps on CME?
- Two-dimensional VECMs on all transaction data for January 2020
- Spread measured relative to the CME price – i.e.

$$\frac{p_{\mathrm{cme}} - p_{\mathrm{unreg}}}{p_{\mathrm{cme}}}$$

- Next two graphs show the expected spread after a shock

Convergence to Equilibrium Price after Shock



Thank you for your attention

Any questions?