DIGITAL ASSET RESEARCH

Lead-Lag Report
9-Feb-2021

BTC SPOT PRICE DISCOVERY UPDATE – Q4 2020

SUMMARY

- **Q4 2020** quarterly update of DAR's public lead-lag study, evaluating price discovery in the **BTC spot market** using volatility events. See Appendix 1 for links to prior reports.
- **111 exchanges** were included, and **181 Volatility Events** were analyzed
- Includes **17** Vetted exchanges and **13** Watchlist exchanges
- Watchlist exchanges were price leaders **53.51%** of the time, and Vetted Exchanges were price leaders **34.35%** of the time
- In Q4 2020, **87.87%** of the time a Vetted or Watchlist exchange was in the top 3 exchanges to lead price discovery
- In Q4 2020, Vetted exchanges gained close to 10% of price leadership share over Disqualified exchanges compared to the Q3 2020 period
- Please contact DAR for analysis of other crypto asset markets

OVERVIEW

One of the concerns in the lightly regulated digital asset markets is where price discovery happens. DAR's lead-lag study intends to help illuminate and show where price formation is occurring in the bitcoin spot market. Each quarter, DAR looks at distinct moments of price volatility and, for each of those moments, determines which exchanges were first to experience that event (lead), and which exchanges followed (lag.)

METHODOLOGY RECAP

DAR utilizes a multistep quantitative process designed to measure the lead-lag relationship of Bitcoin trading between various spot exchanges inspired by multiple academic papers[1]. DAR looks for volatility events, defined as a change in the price of Bitcoin by more than $100 in a 5.5-minute window. For each volatility event, DAR determines the correlation value between each exchange that experienced that event. The exchange's reported trades in that time window are then incrementally shifted forward and backward in time. The relative time shift needed to reach the highest possible correlation value indicates which exchange experienced the volatility event first and which reflected that price discovery after. For a full discussion of the methodology, please refer to the initial study.

There are multiple methods to assess lead-lag relationships and this method is by no means the only applicable one.

Exchange Vetting

DAR uses a vetting methodology that looks at both quantitative and qualitative criteria to classify exchanges into the following categories: Vetted, Watchlist and Disqualified. Vetting results are updated each quarter. A full vetting methodology is available from DAR upon request.

Vetted Exchanges have passed all quantitative and qualitative criteria. These are the most trustworthy exchanges that are not known to report inflated volumes and have robust policies and practices in place to prevent manipulative practices by clients.

Watchlist Exchanges have passed only DAR's preliminary vetting, which includes data science testing and some qualitative diligence. These exchanges are not known to report inflated volumes or have manipulated trades but may not have the institutional policies and practices in place in order to prevent future manipulation and to pass full vetting.

Disqualified Exchanges fail to meet the requirements of our vetting process, failing data science tests for manipulation, qualitative diligence, or a liquidity threshold.

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[1] de Jong, F.C.J.M. & Donders, M.W.M., 1996. "**Intraday Lead-Lag Relationships between the Futures-, Options and Stock Market**," Discussion Paper 1996-108, Tilburg University, Center for Economic Research; de Jong, Frank & Nijman, Theo, 1997. "**High frequency analysis of lead-lag relationships between financial markets**," Journal of Empirical Finance, Elsevier, vol. 4(2-3), pages 259-277, June; Kawaller, Ira G & Koch, Paul D & Koch, Timothy W, 1987. " **The Temporal Price Relationship between S&P 500 Futures and the S and P 500 Index**," Journal of Finance, American Finance Association, vol. 42(5), pages 1309-1329, December.

RESULTS

This quarter 111 exchanges were included in the study, and 181 volatility events were analyzed. For each event, the first 5 exchanges to experience an event are considered "Price Leaders" for that single event. Out of **111** exchanges analyzed, the following entities appeared as Price Leaders in Q4 2020.

FIGURE A – *BTC PRICE LEADER TALLY*

Vetted	
Exchange	Price Leader Appearances
Liquid	150
VCC Exchange	93
Bitstamp	60
Zaif	38
Coinbase	34
Bitflyer	18
Luno	14
Gemini	4
Bitfinex	3
Okcoin	3
Binance US	2
Kraken	2
Bitbank	1

Watchlist	
Exchange	Price Leader Appearances
Huobi	166
Binance	145
ZB	69
Bequant	49
HitBTC	43
Bhex	41
Bitrue	22
Oceanex	9
Coinex	6
Lakebtc	6
Cointiger	5
Gateio	5
Latoken	4
Poloniex	2

Disqualified	
Exchange	Price Leader Appearances
Kucoin	55
Bithumb	52
Coinone	35
Whitebit	22
Bitmart	17
C2cx	9
Korbit	5
Yobit	5
Gopax	2
Zbg	2
Bitz	1
Bleutrade	1
Exmo	1

Source: Digital Asset Research

This quarter, Watchlist exchanges were price leaders **53.51%** of the time, and Vetted Exchanges were price leaders **34.35%** of the time.

FIGURE B – *TOP 10 PRICE LEADER APPEARANCES*

Figure D shows the 10 most frequent Price Leaders for each quarter going back to Q1 of 2020, with "n" representing the number of volatility events analyzed in that quarter.

Exchange	Price Leader Appearances
Binance	35
Liquid	25
Huobi Russia	21
HitBTC	19
Bequant	19
Huobi	17
Coinbase	13
LMAX	8
Gemini	6
Bitstamp	6

Q1 2020 Price Leader Appearances (n=39)

Exchange	Price Leader Appearances
Liquid	10
Bitstamp	9
Huobi	8
Huobi Russia	8
Binance	5
Tagz	5
Bequant	5
HitBTC	5
Coinbase	4
Kucoin	3

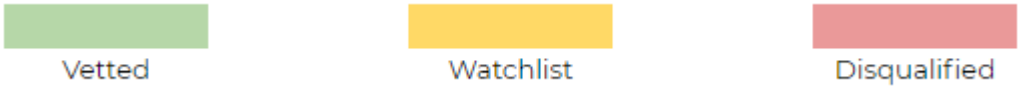
Q2 2020 Price Leader Appearances (n=15)

Exchange	Price Leader Appearances
Binance	18
Huobi	16
Okex	16
Liquid	13
Bitstamp	11
Bequant	6
HitBTC	6
Bhex	4
Catex	4
MXC	3

Q3 2020 Price Leader Appearances (n=21)

Exchange	Price Leader Appearances
Huobi	166
Liquid	150
Binance	145
VCC Exchange	93
ZB	69
Bitstamp	60
Kucoin	55
Bithumb	52
Bequant	49
HitBTC	43

***Q4 2020** Price Leader Appearances (n=181)*



Source: Digital Asset Research

See Appendix 3 for a list of exchange participation by quarter. Not all exchanges have been considered each quarter.

Figure C, below, shows the number of times each of the 10 most frequent Price Leaders were first, second, third, fourth or fifth, to experience a volatility event. Out of the top ten Price Leaders, Vetted or Watchlist exchanges were first to experience the event **87.87%** of the time, and **92.64%** of the time a Vetted or Watchlist exchange was in the top 3 exchanges to lead price discovery.

FIGURE C – *FREQUENCY OF APPEARANCES*

	Number of Times Ranked				
Exchange	First	Second	Third	Fourth	Fifth
Huobi	40	58	43	20	5
Liquid	45	36	30	24	15
Binance	39	45	40	15	6
VCC Exchange	38	33	17	5	0
ZB	3	5	21	23	17
Bitstamp	5	6	8	22	19
Kucoin	0	7	13	14	21
Bithumb	6	7	10	10	19
Bequant	1	7	8	10	23
HitBTC	1	6	6	9	21

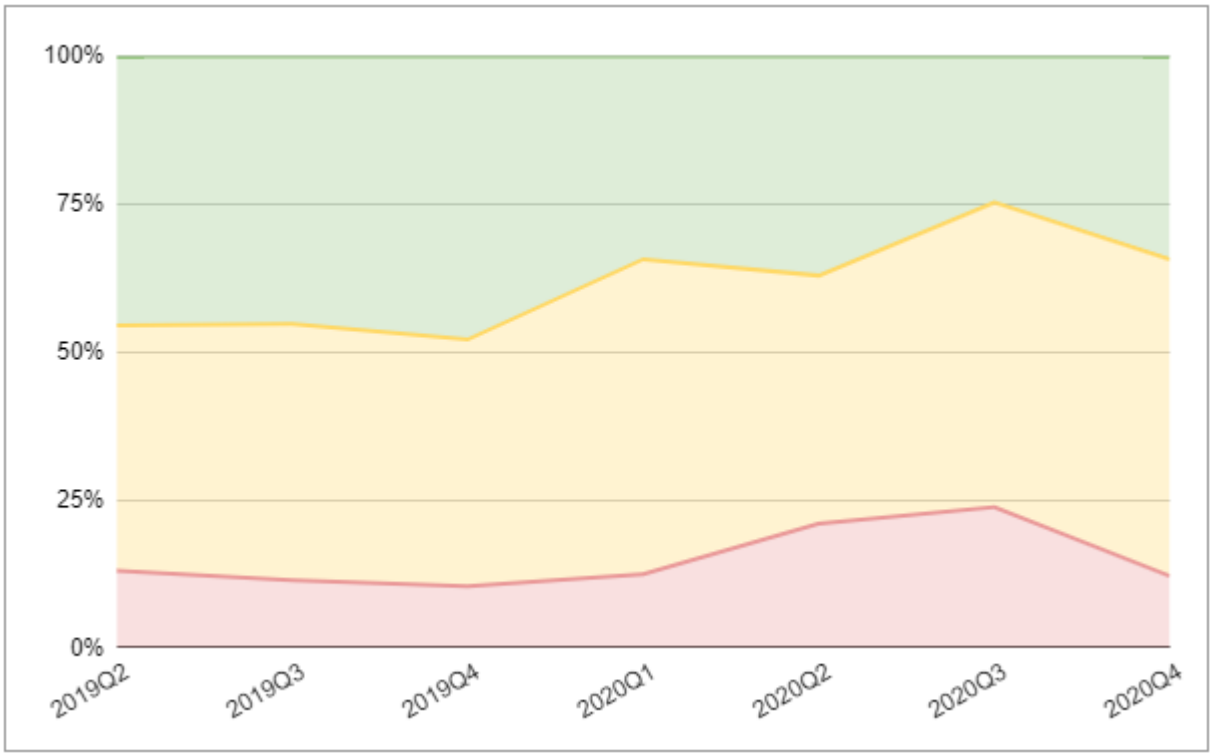
Vetted Watchlist Disqualified

Source: Digital Asset Research

HISTORICAL COMPARISON

Figure D shows the breakdown of volatility events amongst Disqualified, Watchlist, and Vetted exchanges for each quarter going back to Q2 of 2019.

FIGURE D – *QUARTERLY COMPARISONS*

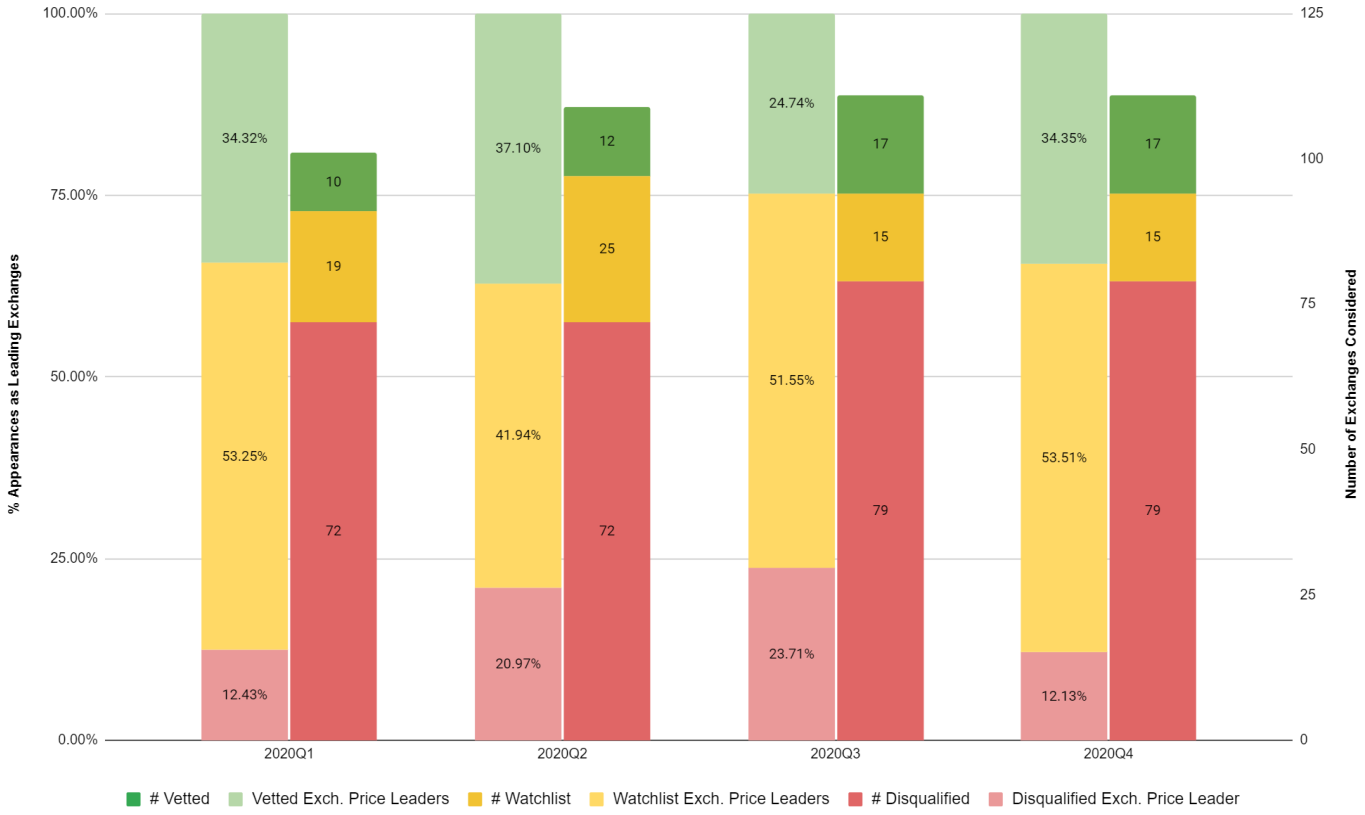


**See Appendix 3 for quarterly exchange participation. Not all exchanges have been evaluated in all quarters.*

Source: Digital Asset Research

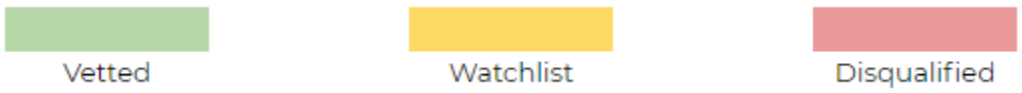
Although each quarter has seen different Price Leaders, the lead-lag test results from the past four quarters showed a relatively stable distribution of Price Leaders between Vetted, Watchlist, and Disqualified exchanges. In Q4 2020, Vetted exchanges gained close to 10% over Disqualified exchanges and Watchlist exchanges stayed relatively the same as shown in Figure E, below.

FIGURE E – *PRICE LEADERS DISTRIBUTION*



** Figure E does not include perpetuals. Exchanges were added or removed according to DAR's methodology. See Appendix 3 for quarterly exchange participation.*

**The percentages show the distribution of price leaders and the numerical values show the number of exchanges assessed in each category over time.*



Source: Digital Asset Research

PERPETUALS

In the digital asset markets, derivatives increasingly play an important role within the trading ecosystem, including perpetual products. DAR's Q4 20 Lead-Lag study included 5 of the market's largest Bitcoin perpetual products.

Please contact DAR for analysis of price discovery in other derivative markets and contract types.

FIGURE F – *TOP 10 PRICE LEADERS PERPETUAL COMPARISON*

Exchange	Price Leader Appearances
Huobi	166
Liquid	150
Binance	145
VCC Exchange	93
ZB	69
Bitstamp	60
Kucoin	55
Bithumb	52
Bequant	49
HitBTC	43

***Q4 2020** Price Leader Appearances Without Perpetuals*

Exchange	Price Leader Appearances
Huobi	163
Liquid	147
Binance	143
VCC Exchange	93
ZB	60
Bitstamp	52
Binance^P	49
Bithumb	49
Kucoin	44
Bequant	38

***Q4 2020** Price Leader Appearances With Perpetuals*

Perpetual	
Exchange	Price Leader Appearances
Binance^P	49
Okex^P	36
Deribit^P	3
BitMEX^P	0
Bybit^P	0

Vetted Watchlist Disqualified Perpetual

Source: Digital Asset Research

APPENDIX

1.0 Prior Lead-Lag Reports

- An Analysis of Price Discovery in Bitcoin Spot Markets (Initial Report)
- BTC Spot Price Discovery Update Q1 2020
- BTC Spot Price Discovery Update Q2 2020
- BTC Spot Price Discovery Update Q3 2020

2.0 Volatility Event Example Analysis

Figure G shows an example of a volatility moment that happened on 17-Dec-2020. The red line shows the price of Bitcoin across all exchanges in this study during the time period and the black line is the polynomial utilized to test the volatility moment. The full green rows on the heat map shows that Korbit led other exchanges during this specific volatility event.

FIGURE G – *VOLATILITY MOMENT 17-DEC-2020 20:30:56*

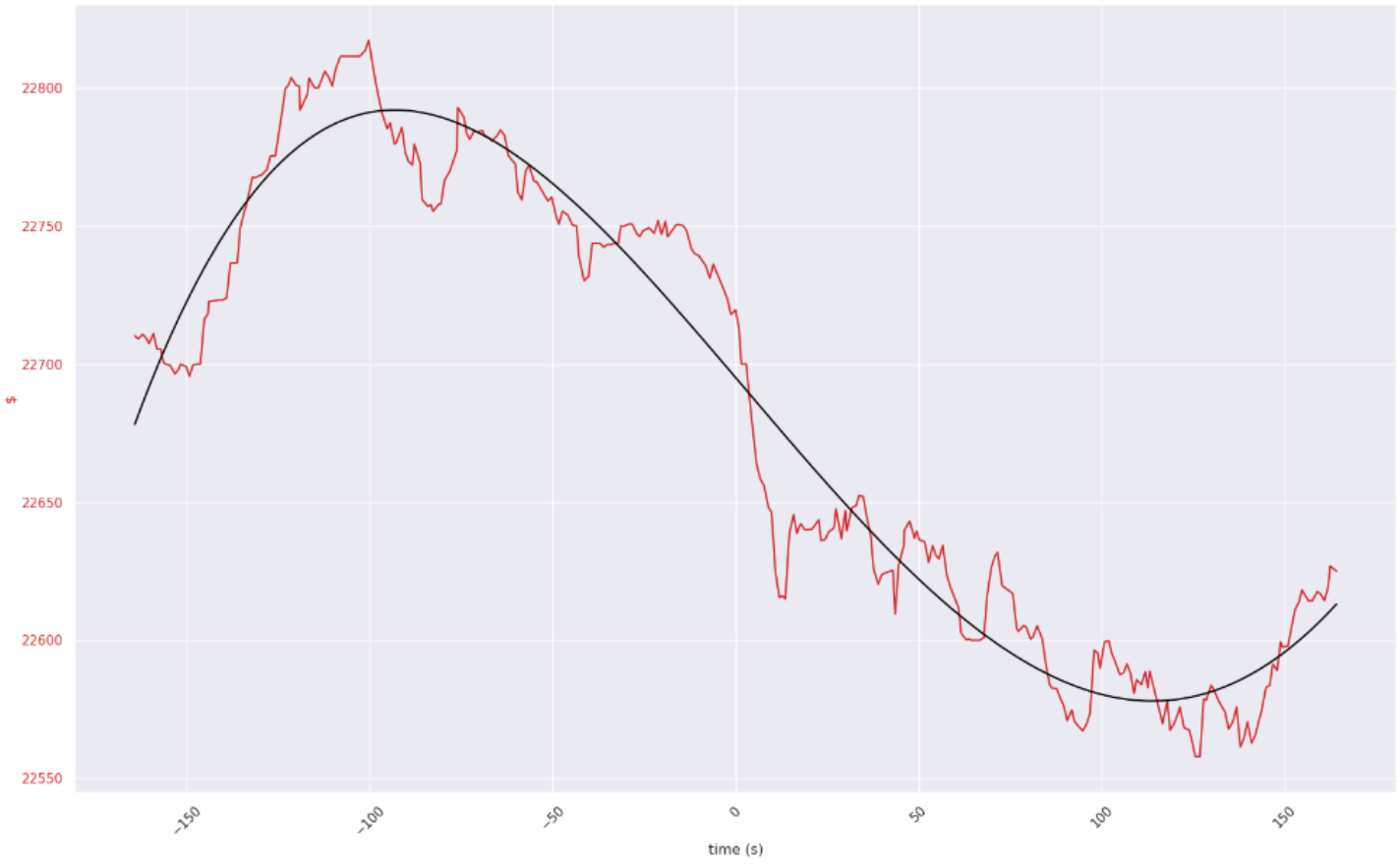
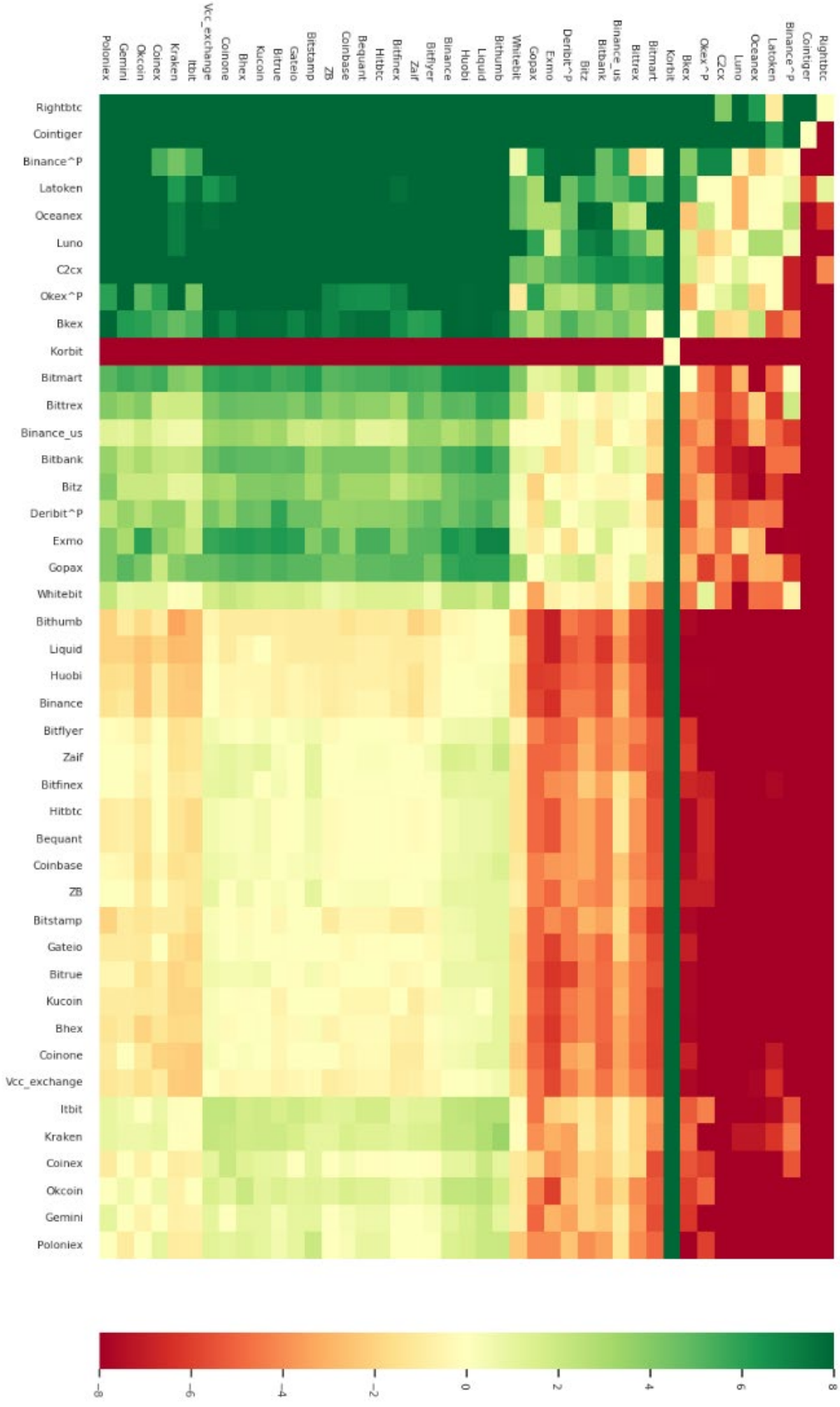


FIGURE H – *EXCHANGE HEATMAP 17-DEC-2020 20:30:56*

FIGURE I – *EXCHANGE HEATMAP 17-DEC-2020 20:30:56 WITH PERPETUAL*



3.0 Lead-Lag Exchange Universe

Exchange	Q4 2020	Q3 2020	Q2 2020	Q1 2020	Q2-Q4 2019
Alterdice	x	x	x		
BBX	x	x	x	x	
BCEX	x	x	x	x	
Bequant	x	x	x	x	
BHEX	x	x	x	x	x
Bibox	x	x	x	x	x
BigONE	x	x	x	x	
Biki	x	x	x	x	
Bilaxy	x	x	x	x	
Binance	x	x	x	x	x
Binance US	x	x	x		
Binance^P	x	x	x		
Bitasset	x	x	x	x	
Bitbank	x	x	x	x	x
Bitbay	x	x	x		
Bitfinex	x	x	x	x	x
BitFlyer	x	x	x	x	x
Bitforex	x	x	x	x	x
Bithumb	x	x	x	x	x
BitKonan					x
Bitlish					x
BitMarket					x
Bitmart	x	x	x	x	x
Bitmax	x	x	x	x	
BitMEX^P	x	x	x		x
Bitrue	x	x	x	x	
Bitso	x	x	x	x	
Bitstamp	x	x	x	x	x
Bittrex	x	x	x	x	x
Bitubu	x	x	x	x	
BitZ	x	x	x	x	x
BKEX	x	x	x	x	
Bleutrade	x	x	x	x	x
BTC-Alpha	x	x	x	x	
BTC Markets	x	x	x	x	
BTCBox	x	x	x	x	x
BTCTurk	x	x	x	x	
BW	x	x	x	x	x
Bybit^P	x	x	x		
C2CX	x	x	x	x	
Catex	x	x	x	x	
CBX	x	x	x	x	
CCX Canada	x	x	x		
Cexio	x	x	x	x	x
Chaoex	x	x	x	x	
Cobinhood					x
Coinall	x	x	x		
Coinbase	x	x	x	x	x
Coinbene					x
Coincheck*	x	x			
Coineal	x	x	x	x	
Coinegg	x	x	x	x	
Coinex	x	x	x	x	
Coinfield	x	x	x	x	
Coinfloor					x
Coingi					x
Coinhe	x	x	x	x	
Coinmate	x	x	x	x	x
Coinmex	x	x	x	x	
Coinnest					x
Coinone	x	x	x	x	x
Coinsbank	x	x	x	x	x
Coinsbit	x	x	x	x	
Coinsuper	x	x	x		

Exchange	Q4 2020	Q3 2020	Q2 2020	Q1 2020	Q2-Q4 2019
Cointiger	x	x	x	x	x
COSS					x
CRXzone					x
Cryptology	x	x	x	x	
Deribit^P	x	x	x		
Digifinex*	x	x		x	
DSX	x	x	x	x	x
EXMO	x	x	x	x	x
Exrates	x	x	x	x	
EXX	x	x	x	x	x
Fifty Five	x	x	x	x	
GateIO	x	x	x	x	x
GDAC	x	x	x	x	
Gemini	x	x	x	x	x
Gopax	x	x	x	x	
Graviex					x
Hcoin	x	x	x	x	
HitBTC	x	x	x	x	x
Huobi	x	x	x	x	x
Huobi Russia	x	x	x	x	
IDAX	x	x	x		x
IDCM	x	x	x	x	
Independent Reserve					x
Indodax	x	x	x	x	
itBit	x	x	x	x	x
Korbit	x	x	x	x	x
Kraken	x	x	x	x	x
Kryptono	x	x	x	x	
KuCoin	x	x	x	x	x
LakeBTC	x	x	x	x	x
LATOKEN	x	x	x	x	
LBANK	x	x	x	x	
Liquid	x	x	x	x	x
Livecoin	x	x	x	x	x
LMAX	x	x	x	x	
Luno	x	x	x	x	
Mercado Bitcoin	x	x	x	x	
Mercatox	x	x	x		
MXC	x	x	x	x	
OceanEx	x	x	x	x	
OKCoin	x	x	x	x	x
OKEx	x	x	x	x	x
OKEx^P	x	x	x		
OMGFIN	x	x	x	x	
p2pb2b	x	x	x	x	
Poloniex	x	x	x	x	x
Probit	x	x	x	x	
RightBTC	x	x	x	x	
Simex	x	x	x	x	x
Sistemkoin	x	x	x	x	
SouthXchange					x
STEX	x	x	x	x	x
TagZ	x	x	x	x	
TheRockTrading	x	x	x	x	x
Tidebit	x	x	x	x	
Tidex	x	x	x	x	x
Tokok	x	x	x	x	
Upbit	x	x	x	x	x
VCC Exchange	x	x	x	x	
Vindax	x	x	x	x	
Whitebit	x	x	x	x	
Yobit	x	x	x		x
Zaif	x	x	x	x	x
ZB	x	x	x	x	x
ZBG	x	x	x	x	

Vetted Watchlist Disqualified Perpetual

4.0 Definitions

Terminology Definitions	
Disqualified Exchanges*	Digital Asset Exchanges that fail to meet the vetting process requirements failing data science tests for manipulation, qualitative diligence, or a liquidity threshold.
Know Your Customer (KYC)	A process implemented by financial services firms to verify customers' identities in order to identify and prevent market manipulation and other fraudulent activities.
Lead-Lag Relationship	A means to determine where price formation occurs by looking at the correlation of price movements between exchanges during a specific time window, and determining which exchange(s) saw the price movement first (lead), and which saw the price movement at a later time (lag.)
Price Leaders	Digital asset exchanges that were among the first 5 exchanges to experience price movement in a single volatility event.
Vetted Exchanges*	Digital Asset Exchanges that have passed all of DAR's quantitative and qualitative criteria. These are the most trustworthy exchanges that are not known to report inflated volumes and have robust policies and practices in place to prevent manipulative behavior by customers.
Volatility Events	A change in the price of bitcoin of more than $100 in either direction within a 5.5-minute window, identified by looking at trades on a 30 second rolling basis. Qualifying events are also filtered by shape and must-see price movement in both directions.
Watchlist Exchanges*	Digital Asset Exchanges that have passed only DAR's preliminary vetting, which includes data science testing and some qualitative diligence. These exchanges are not known to report inflated volumes or have manipulated transactions but may not have institutional policies and practices in place in order to prevent future manipulation and pass full vetting.

*Contact DAR for full details on the Vetting criteria and process

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