

BNC High Frequency Pricing

Index Methodology

Version history:

Version	Date	Update
1	2019-09-15	First methodology
2	2020-02-01	Added anomaly detection methodology
3	2020-09-17	Added governance section

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1. Introduction

The BNC High Frequency Index family (BNC:HF) tracks the real-time market price of cryptocurrencies using orderbook data. Launched in September 2019, this institutional-grade index product is amongst the first in the world to provide cryptocurrency price discovery at sub-second frequency.

The index is owned and administered by Brave New Coin under the principles:

Representative	The index should closely track the target asset and represent an adequate sample.
Transparent	The index should be transparent in its design and reproducible in its calculation.
Robust	The index should be robust to disruptions such as erroneous data or pricing source outages, and be resistant to manipulation.

BNC's High Frequency Pricing (HFP) service calculates cryptocurrency price indices in real time from the orderbooks of approved pricing sources. Where other BNC price indices rely on executed transactions (trades), due to its high frequency of calculation the HFP service uses only executable transactions (bids and asks).

As such, HFP rates are forward looking in nature, reflecting market participants intent to trade at a single point in time. This methodology delivers greater transparency into current market liquidity and price discovery within markets that may not trade as regularly as other constituents.

2. Eligibility

2.1 Eligible Pricing Sources

To ensure transactions used in Brave New Coin pricing and indices are formed by the competitive forces of supply and demand, particular attention is applied to the quality of exchange venues from which these transactions are sourced. Qualified pricing sources must demonstrate the existence of an active market, consisting exclusively of bona fide, arms-length transactions.

Criteria
Compliance Show compliance with applicable laws and regulations, including but not limited to client money custody, anti-money-laundering (AML), know-your-customer (KYC) and money transmission regulations.
Trade Surveillance Transparent policies and evidence, such as a 'trading rulebook' and trade surveillance systems that monitor transactions for market manipulation or fraud, and prevent illegal trading practices.
Operations Exhibit a track record of uninterrupted customer deposits & withdrawals, identity verifications, wire transfers & payment methods, wallet maintenance, network upgrades and connectivity issues.
Transparent Data Provision Provide a stable REST and web-socket API for live and historical ticker, raw gapless trades and unaggregated order book data. Proof of solvency or reserves of hot and cold wallet addresses is also required to determine solvency.
Arms-length transactions Show no evidence of wash-trading. This criteria is determined using in-spread & volume sensitivity analysis. Qualified pricing sources must claim some 'cost-to-trade'; for example trading fees; and not employ any trade mining schemes or like practises.

Given that our pricing sources are third-party organizations operating in a volatile marketplace, the Index Governance Committee reviews its pricing sources quarterly to ensure adherence to the above criteria. The index does not rely on submission.

2.2 Reference Assets

After the eligible pricing sources have been selected, only markets on these exchanges which are quoted by one of the below reference assets can be used as inputs to our price indices.

Ticker	Name
USD *	United States Dollar
BTC	Bitcoin
USDT	Tether (USD)

* preferred

3. Index Calculation

Order book snapshots and updates are collected from each pricing source via secure websocket subscription. A price calculation is triggered from an orderbook update to any constituent market. As such, the index frequency depends on the liquidity of the asset being priced, but could be anywhere from once a second to 100 times a second.

Once an order book update is received on a constituent market, the pricing calculation begins.

- The order book is sanity checked against preset thresholds.
- Each side of the order book is organized in descending order from the best bid/ask.
- A bid VWAP and ask VWAP is calculated as a weighted average price of all order levels within the significant depth, using the order size as the weighting.

$$P^{bid} = \frac{\sum_i^D (p_i^{bid} \times a_i^{bid})}{\sum_i^D a_i^{bid}}$$

Where:

P_i^{bid} = the price in quote currency of the i^{th} bid order level

a_i^{bid} = the size in base asset of the i^{th} bid order level

D = the number of order levels within the significant depth

$$P^{ask} = \frac{\sum_i^D (p_i^{ask} \times a_i^{ask})}{\sum_i^D a_i^{ask}}$$

- For any non USD markets, for example XRP/BTC, the bidVWAP and askVWAP are converted to USD by multiplying by a reference asset USD “rate”, for example BTC/USD.
- A simple mid price is calculated as the midpoint between the bidVWAP and askVWAP.

$$P^{mid} = \frac{P^{bid} + P^{ask}}{2}$$

This results in a mid price for each market constituent of the index. For example, to calculate the BTC High Frequency Index price, a mid price is calculated for the 6 market constituents.

Name	BidVWAP	AskVWAP	Mid	OF
bitfinex: btc/usd	13055.5658	13065.5515	13065.5587	0.9830
bittrex: btc/usd	13047.7613	13073.8958	13067.8286	0.9861
coinbase-pro: btc/usd	13068.3715	13069.9900	13069.1805	0.9907
kraken: btc/usd	13069.8724	13077.3695	13073.6012	0.9907
bitstamp: btc/usd	13068.9759	13079.9153	13074.4454	0.9873
gemini: btc/usd	13073.0033	13077.7962	13075.3847	0.9585

The last step is to combine the market mid prices into a single BTC index using an outlier weighted average. The weight used is called the ‘outlier factor’ (OF), a number between 0 and 1, which is intended to de-weight markets with outlying prices. An outlier factor of 0 completely excludes the market from the index.

$$P^{index} = \frac{\sum_{i=m}^M (P_m^{mid} \times OF_m)}{\sum_{i=m}^M OF_m}$$

Where:

P_m^{mid} = the mid price in USD of the m^{th} market constituent.

OF_m = the outlier factor of the m^{th} market constituent

M = the number of market constituents

3.1 Sanity Checks

Before the above calculation is initiated, sanity checks are performed on each incoming orderbook to protect against erroneous data such as:

- Empty orderbook (bid or ask)
- Zero or negative best bid or ask
- Negative spread between best bid and ask
- Spread breaching a predefined threshold, “maxSpread”
- A stale orderbook, older than a predefined threshold.

Sanity checks are also performed on the bidVWAP and askVWAP for each market once they are calculated, to check for:

- Negative BidVWAP or AskVWAP

- Negative spread between BidVWAP and AskVWAP
- Spread breaching a predefined threshold, “maxVWAPSpread”

If any sanity check fails, the price calculation is halted until another orderbook update is received.

3.2 Price Anomaly Factor

Outliers are detected by calculating an outlier factor for each market constituent, based on its price deviation from the cohort. Market constituents with high deviation will receive an outlier factor near zero, reducing its effect on the index price. Once the constituents deviation exceeds a preset threshold it is excluded from the index calculation completely with an outlier factor of zero. .

The outlier factor follows a similar calculation to a modified z-score, a robust measure of outliers that performs well even with a low number of observations (trades). This is particularly important to ensure the index can be calculated efficiently during low liquidity periods, when outliers have the most influence.

The outlier factor (OF) is calculated as,

1. calculate absolute deviation from median (as a % of median)

$$d_m = \frac{|P_m^{mid} - \text{median}(P_m^{mid})|}{\text{median}(P_m^{mid})}$$

2. convert absolute deviation to a PAF (price anomaly factor) using linear function

$$\begin{aligned} OF_M &= 1 - \frac{d_m}{\text{threshold}} \\ &= 0, \text{ when } d_m \geq \text{threshold} \end{aligned}$$

3.3 Significant Depth

The significant depth is the depth of the order book we take on either side (bid and ask) to use in the pricing calculation. This parameter, expressed in units of the index asset, is set for each index independently based on available liquidity for that asset and its constituent markets. The significant depth parameter is reviewed at each periodic meeting, and is subject to change.

4. Governance

4.1 Index Oversight Committee

The BNC Index Governance Committee is responsible for the oversight and transparency of all aspects relating to the provision of benchmarks administered by Brave New Coin Limited.

The primary function of the Governance Committee is to maintain orderly index calculation and management, and to undertake regular review of the methodology to ensure that the index and any modifications satisfy customer needs and comply with applicable regulatory requirements.

The Governance Committee is composed of five voting members with appropriate experience to provide effective review of the processes and procedures related to the creation and management of derivative indices.

4.2 Periodic Review

The BNC Index Governance Committee meets quarterly to perform review procedures and ensure sustained and adequate representation of the interest being measured.

Review procedures undertaken at periodic meetings include but are not limited to:

- a. Scoping potential markets for inclusion or exclusion.
- b. Review benchmark error logs
- c. Motion material methodology changes or advise investigation where a methodology change is required.
- d. Summarise pricing source incidents, for example outages or transaction delays, wire transfers issues, wallet maintenance, withdrawal & deposits issues or security concerns.
- e. Update relevant eligibility criteria concerning pricing sources.