RULEBOOK

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Kaiko Digital Assets Rates

Kaiko
smart data

CONTENT

Version	Publication date	Comments
1	20/09/2022	Created
2	05/01/2023	Addition of Benchmark Reference Rates
3	28/03/2023	Partitioning scheme added
4	14/05/2024	Rates name change applied. Update of review calendar format.

INTRODUCTION

The following document covers the methodology of the Kaiko Digital Asset Rates - specifically the Kaiko Reference Rates and the Kaiko Benchmark Reference Rates (together, the “Kaiko Rates”). Designed to bring greater transparency to pricing, these are solely based on executed trades from centralised exchanges. **Calculation and dissemination:** All Kaiko Rates are calculated in real-time (every 5 seconds), as well as being published as daily fixings covering three different time zones:

- Europe - London time - 16:00 UTC
- North America - New York time - 20:00 UTC
- Asia - Singapore time - 08:00 UTC

The list of all rates can be found on this webpage.

REVIEW CALENDAR

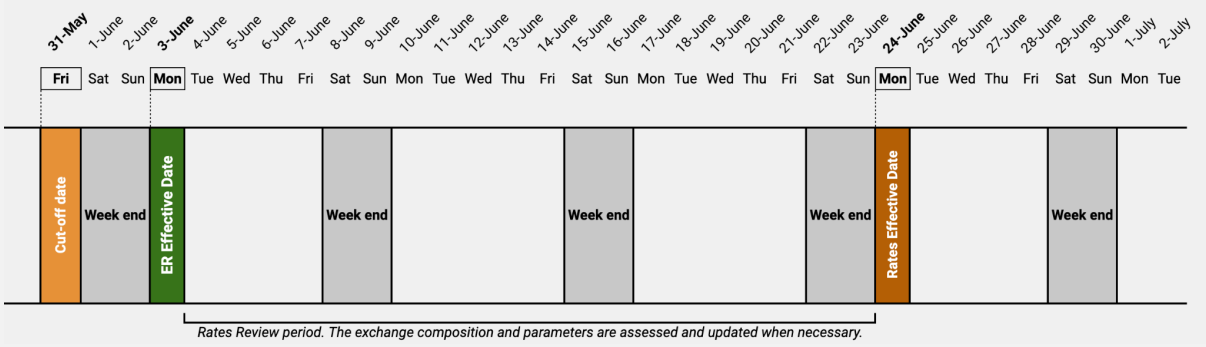
Scheduled Review and Rebalancing

Rebalancing is a scheduled, regular process designed to ensure that the Kaiko Rates are composed of the most relevant price data feeds and comply with the methodology detailed in this document, including initial vetting, liquidity and optimization requirements.

All families of Kaiko Rates will follow the same quarterly rebalancing calendar (March, June, September and December) with cut-off and effective dates structuring the data collection and processing periods followed by publication periods (the calendar dates and weekdays do not account for any holidays).

Event	Date	Description	Example with June 2024 rebalancing
Cut-off Date	Last day of the month preceding the Rebalancing Month.	Data collection for composition determination stops on that day.*	*31st of May, 2024*
ER Effective Date	First business day of the Review Month	Publication of the new version of the exchange ranking	*3rd of June, 2024*
Effective Date	Monday after the third Friday of the Rebalancing Month. Usually between 20:00 and 23:00 UTC.	The new exchange composition becomes effective in the calculation of the rates.	*24th of June, 2024*

**For instance, if a 3-month Average Daily Traded Volume must be calculated, the covered period will start 3 months before the cut-off date and end on the cut-off date (including the cut-off date, up to UTC 00:00).*



Extraordinary Review

On the basis of its qualified and expert judgement, Kaiko reserves the right to exclude or replace an exchange selected during the Scheduled Review. Such extraordinary event would happen if an exchange has been found to experience an exclusion action such as:

- Fraud
- Market manipulation
- Significant loss of volume or liquidity

In such cases, the Kaiko Index Administration Committee (IAC) will publish its findings and exclude the exchange from the calculation of the rate within 3 days after the initial public communication.

METHODOLOGY

Kaiko Rates is composed of two types of rates: ReferenceRates focused on broad asset coverage, and Benchmark Reference Rates emphasising data quality and liquidity. Before any rate can be computed, each eligible exchange is screened for both quantitative and qualitative aspects. Said screenings compose a key element to ensure the reliability and authenticity of each and every rate.

Data Source

The Kaiko Rates levels are based on the tick-by-tick trade data provided by Kaiko.

Kaiko is the leading source of cryptocurrency market data, providing businesses with industrial-grade and regulatory-compliant data. Kaiko empowers market participants with global connectivity to real-time and historical data feeds across the world's leading centralized and decentralized cryptocurrency exchanges. Kaiko's proprietary products are built to empower financial institutions and cryptocurrency businesses with solutions ranging from portfolio valuation to strategy backtesting, performance reporting, charting, analysis, indices, pre and post-trade.

Exchange Selection Model

Markets in crypto assets are by nature highly fragmented, with hundreds of exchanges spread over different geographical areas, each with their own regulatory framework. Each exchange operates independently, and as such, official statistics and research data are often not publicly available.

As a global digital asset market data provider, Kaiko covers more than a hundred cryptocurrency exchanges. However, not all exchanges offer the same level of standards in terms of legal and compliance, infrastructure security, liquidity, data quality or even technology. The Exchange Selection Model leverages specific parameters of Kaiko Exchange Ranking to make sure only high-quality data are incorporated in the computation of each rate. The Exchange Selection Model is implemented at each quarterly review.

For the purpose of the Kaiko Rates computations, only centralised spot exchanges are considered.

1. Asset-agnostic Vetting

Asset-agnostic vetting is built on Kaiko Exchange Ranking parameters. This vetting mechanism differs depending on the type of rate being constructed.

Criteria	Reference Rate	Benchmark Reference Rate
Absent from any sanction list	Yes	Yes
Has been operating for the past	-	5 Years
Located in a stable and open country	-	Yes
Regulated by an independent government body	-	Yes
KYC/AML controls	-	Strong
Trading policies	-	Significant
Offers REST API & WebSocket data feeds	-	Yes
Offers live & historical trade data	-	Yes
Provide cold storage for customers' funds	-	Yes

All exchanges fulfilling **all** criteria in the above table constitute the initial Kaiko Vetted Exchanges List (KVEL) for the respective rate. For each review, the Kaiko Vetted Exchanges List will be linked to the associated version of the Exchange Ranking. As the exchange ranking history started in January 2022, older rebalancing periods for

Kaiko rates prior to January 2022 are associated with the January 2022 Exchange Ranking Review. All quarterly exchange selections after January 2022 are associated with the respective quarterly Exchange Ranking Review.

2. Asset-specific Vetting

Liquidity

The 3-month volume history of the relevant pair (e.g. BTCUSD) is extracted for each exchange and, for each month, an average daily trading volume as a percent of the total average trading volume from the initial KVEL is computed. The monthly average values are in turn averaged, and all exchanges whose average liquidity is strictly below 1% are not considered relevant in terms of liquidity and thus are excluded from the KVEL.

Additional Liquidity Layer

When the list of exchanges following the liquidity and market quality assessment is above 10 exchanges, we apply a limitation layer that selects only the 10 most liquid exchanges in terms of contribution to the global volume for a specific asset during the relevant period.

Minimum Exchanges Number

For an asset pair to be eligible for rate computation, a minimum number of exchanges trading it and passing all criteria mentioned above needs to be reached.

Rate Type	Minimum Exchange(s) Number
Reference Rate	**1**
Benchmark Reference Rate	**3**

3. Further Optimization

Individual Exchange Analysis

From the KVEL after asset-specific vetting, further optimization is computed based on the number of zero-volume buckets of the relevant pair in each rolling window during the period. A zero-volume bucket is defined as a timestamp for which no trades in the relevant pair are observed during the rolling window considered. Thus, the aim behind this step is to individually analyse exchanges and classify them based on the number of zero-volume buckets compared to the level of liquidity. This optimization step completes the following combination analysis when deciding between two similar combinations in terms of minimum coverage or liquidity.

Combinations Analysis and Ranking

This step is dedicated to extracting the final combination of up to 5 exchanges generating the best liquidity: minimum number of zero-volume buckets and average volume per interval. These combinations are ranked according to those parameters. From this step, the list of exchanges that will be considered in the calculation of the rate is finalised. Note, in order to mitigate turnover in exchanges, a buffer rule (as described in section *Buffer Rules*) is applied to all Benchmark Reference Rates.

Publication Events

Each rate is composed of two types of publication events: real-time and fixing publications. The parameters involved in the calculation of both events can either be entirely static or updated during quarterly reviews (dynamic) according to minimum liquidity coverage and market price representativity. For the latter, buffer rules (as described in section *Buffer Rules*) are in place to minimise short-term market effects.

The two parameters subject to changes are:

- **Publication interval**: frequency at which each rate is computed then updated. Ex: Every 5 seconds.
- **Calculation window**: time period in which transaction data are considered for the calculation of said rate. Ex: the 300 seconds before the rate computation.

All Reference Rates use the same parameters that are static while the Benchmark Reference Rates parameters can be updated during quarterly reviews.

1. Real-Time Publications

Real-time rates are defined by publication events occurring at a granularity faster than a minute. The parameters can take the following values:

- Publication interval: 5s
- Calculation window: 15s, 20s, 30s, 60s, 120s, or 300s before rate computation

Rate Type	Publication Interval	Calculation Window
All Reference Rates	5 seconds	Static at 300 seconds
All Benchmark Reference Rates	5 seconds	Dynamic - possible quarterly update

2. Fixing Publications

Fixing publications are defined as recurring events occurring with a granularity slower than a minute. We assume those fixing events to occur on a daily basis with three different timings corresponding to 3 timezone fixings (US, EMEA, APAC):

- Europe - London time - 16:00 UTC
- North America - New York time - 20:00 UTC
- Asia - Singapore time - 08:00 UTC

Like Real-time Publications, the calculation window can take several values: 300s, 600s, 900s, 1200s, 1800s or 3600s before rate computation.

Rate Type	Publication Interval	Calculation Window
All Reference Rates	Daily fixings NY, SG, UK	Static at 3600 seconds
All Benchmark Reference Rates	Daily fixings NY, SG, UK	Dynamic - possible quarterly updates

Buffer Rules

The buffer rules are only applied to Benchmark Reference Rates.

1. Dynamic Windowing

Benchmark Reference Rates are designed with a dynamic windowing feature which aims at securing a minimum liquidity level depending on the market conditions. In practice, it means that for each rebalancing period, a specific rolling window will be selected from a predefined set of eligible windows according to a liquidity score.

- Real-time set: [15s, 20s, 30s, 60s, 120s, 300s]
- Fixing set: [300s, 600s, 900s, 1200s, 1800s, 3600s]

2. Exchange Combination Buffering

An additional buffering feature is associated with dynamic windowing to mitigate the exchange turnover in the rebalancing. Kaiko Benchmark Reference Rates are designed to facilitate the methodology replication and therefore the turnover of exchanges in the combination, from one period to the next one, is controlled. As the windowing might impact the exchange selection and the combinations, both are considered in the implementation of rules.

3. Dual Buffering

Summary

The Benchmark Reference Rates are built with dual buffering which entails dynamic windowing combined with an optimisation of the combinations. The process enables both a maximisation of the liquidity and the stability of the rate composition. To materialise such method, a specific set of rules has been designed based on threshold levels. If the current combination and rolling window start to underperform or outperform a target threshold, the rules will help to better calibrate the rolling window and the combination of exchanges.

Threshold Levels

Name	Abbreviation	Value
Target Threshold of Zero Volume	*Target_ZV*	10%
Buffer current set up	*Buffer_C*	5%
Upgrade threshold current set up *(Target_ZV - Buffer_C)*	*Up_C*	5%
Downgrade threshold current set up *(Target_ZV + Buffer_C)*	*Down_C*	15%
Buffer next set up	*Buffer_N*	2.5%
Upgrade threshold next set up *(Target_ZV - Buffer_N)*	*Up_N*	7.5%
Upgrade threshold next set up *(Target_ZV + Buffer_N)*	*Down_N*	12.5%

Methodology

Historical window and combination

- The initial rolling window is defined as the smallest from the eligible set of windows. The percentage of zero-volume bucket over the past three months is calculated along with all the possible combinations from the KEVL.
- If any of the exchange combinations shows less than 10% zero-volume bucket, the current window size is defined as the first window. If not, the next smallest window is selected, and so on until the condition is met.
- If there are more than one exchanges combinations with less than 10% of zero-volume bucket, choose the combination with the highest trading volume.

Quarterly review

The quarterly rebalancing relies on a performance assessment of the current setup based on the percentage of zero-volume buckets. However, for the stability of the exchange combination and window size, buffering rules are applied in the following order:

- **Number of exchanges in the current combination**
    - If the number of exchanges in the current combination is less than 5, the combination will be changed based on the new vetted exchanges for the pair.
    - If the number of exchanges in the combination is equal to or above 5, the optimization step is applied as for the first window and combination: checking percentage of zero-volume bucket and trading volume.

- **Rolling window size**
  The percentage of zero-volume bucket with current rolling window size is calculated:
    - If it is between the upgrade threshold of the current setup (*Up_C*) and the downgrade threshold for the current setup (*Down_C*), no change will be made in rolling window size and exchanges.
    - If the percentage of zero-volume bucket is lower than the upgrade threshold of the current setup (*Up_C*), the rate might be subject to a decrease of the rolling window to increase the market sensibility. The percentage of zero-volume bucket with the next smaller window is computed. If it is below the upgrade threshold for the next setup (*Up_N*) for two consecutive quarters, the rolling window will be decreased to the next smaller.
    - If the percentage of zero-volume bucket is higher than the downgrade threshold of the current setup (*Down_C*), the rate might be subject to an increase of the rolling window to capture more liquidity. The percentage of zero-volume bucket with the next larger window is computed. If it is above the downgrade threshold for next setup (*Down_N*) for two consecutive quarters, the rolling window will be increased to the next larger.
    - If the percentage of zero-volume bucket is higher than the downgrade threshold of the current setup (*Down_C*) and that of next bigger window is higher than the downgrade threshold for the next setup (*Down_N*), a change in the combination should be considered. The percentage of zero-volume buckets of all the possible combinations of vetted exchanges is calculated.
        - If any of the combinations show less than the downgrade threshold for the next setup (*Down_N*) of zero-volume bucket with current calculation window, the combination is changed.
        - if not, the current combination is maintained and the rolling window is increased if the percentage of zero-volume bucket is higher than the downgrade threshold of the current setup (*Down_C*) next quarter.

Rates Calculation

The aggregation methodology consists of splitting the calculation window considered into equal-size partitions and, for each of them, extracting the most representative trade whose price will be used for the final rate calculation.

All trades in the relevant pair for the relevant exchange are pooled together and grouped into relevant time partitions. For each partition, the most representative trade is defined as the volume median one.

1. Step-by-step Methodology

- At calculation time (end of each publication internal for real-time, and at set times for daily fixings), collect all executed trades in the calculation window (before the calculation time) on all selected exchanges.
- Merge all the executed trades from the different exchanges in the same dataset sorted by prices in ascending order.
- Create K partitions of S_{part} size from the calculation window (eg. 1h calc. window with 10 partitions of 6 min).
- Each partition is then subject to a Volume Weighted Median (outlier resistant by nature). A detailed description of this aggregation method is provided below.
- A time weight is associated with each partition's volume-weighted median (more weights to the last partitions which are the most recent).
- Aggregation of those weighted prices (eg. 10 prices aggregated on 1h calc. window) to obtain the reference price for this publication event.

2. Inputs

Symbol	Name	Description
t	Event	The timestamp at which the fixing price (FP) is calculated.
S_{wind}	Calculation Window Size	Size of the calculation period for which trades are collected and aggregated.
S_{part}	Partition Size	Size of each partition in the calculation window.
K	Number of Partitions	The number of partitions is an integer calculated as S_{wind}/S_{part}.
k	Partition Number	k_{th} partition.
I_k	Partition Trade Distribution	List of trades included in partition k and ordered by ascending price.

p_i^k	Partition Trade Price	i^{th} trade price in the k_{th} partition (price-ordered distribution).
v_i^k	Partition Trade Volume	i^{th} trade volume in the k_{th} partition (price-ordered distribution).
VWM_k	Volume-Weighted Median	Volume-weighted median of the k_{th} partition.
WP_t	Window Price	Window price (WP) at time t.

3. Volume Weighted Median

The volume-weighted median (VWM_k) is calculated as the price (p_j^k) of the j^{th} trade where the j^{th} trade is the trade that lies at 50% of the cumulative volume for the partition k. VWM_k is calculated for each partition in S_{wind}:

$$VWM_k = p_j^k \text{ where } j \text{ satisfies } \sum_{i=0}^{j-1} v_i^k < \frac{\sum_{i=1}^{I_k} v_i^k}{2} \text{ and } \sum_{i=j+1}^{I_k} v_i^k \leq \frac{\sum_{i=1}^{I_k} v_i^k}{2}$$

$$\text{If } \exists\ j : v_j^k > \frac{\sum_{i=1}^{I_k} v_i^k}{2} \text{ then } VWM_k = p_j^k$$

$$\text{If } \exists\ j : \sum_{i=j+1}^{I_k} v_i^k = \frac{\sum_{i=1}^{I_k} v_i^k}{2} \text{ then } VWM_k = \frac{p_j^k + p_{j+1}^k}{2}$$

4. Window Price

The Window Price (WP) is calculated as a time-weighted average price (TWAP) of all the VWM_k of all the K partitions. We implement a sensitivity calibration method on partitions to increase the weight of the most recent prices included in the calculation window.

First, we apply a specific weighting function to obtain weights that are inversely proportional to time t. It gives:

$$w_k = \frac{1}{n} \sum_{j=0}^{I_k} 1_{j \leq k}$$

The weights are then normalised:

$$\overline{w_k} = \frac{w_k}{\sum_j w_j}$$

Thus, the window price is equal to:

$$FP_T = \sum_{k=1}^{K} (VWM_k \times \overline{w_k})$$

5. Partitioning Scheme

Each rate breaks down the window size into n partitions of equal size. Here is a summary of all the window size/partitions number combinations:

- Real-time set: [15s/5p, 20s/10p, 30s/10p, 60s/10p, 120s/10p, 300s/10p]
- Fixing set: [300s/10p, 600s/10p, 900s/10p, 1200s/10p, 1800s/10p, 3600s/10p]

6. Data Rounding

All rates are calculated with all available decimals but published with two decimals.

7. Blockchain Forks

In the event of a fork of the blockchain, the ticker used on each constituent exchange may be adjusted to represent the relevant instrument. In the event of a fork of the blockchain, the Index Administration Committee (IAC) will determine if the new asset pair is significant and whether any adjustments are to be made with respect to the affected rate. Such a decision will be publicly announced prior to implementation.

8. Data Gaps

Missing Data

At the time of the calculation (t), some relevant transactions may be missing for an array of reasons. If no relevant transactions are recorded on the relevant partition, the corresponding partition is excluded from the calculation and weights are adjusted accordingly. If no relevant transactions are recorded in the entire calculation window, the price is not published.

Delayed Data

If for any reason Kaiko was unable to retrieve any relevant transactions at the calculation time, the corresponding partition is excluded from the calculation.

Spurious Data

If for any reason any transactions were identified as potentially suspect within a partition, such transactions may be adjusted to disregard the spurious data.