Coin Metrics Principal Market Price (PMP) Methodology

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1 Introduction

This document describes our first implementation of Coin Metric's Principal Market price calculation Methodology. It was developed taking into account the requirements of IFRS 13 and ASC 820 accounting guidelines defining what a Principal Market is and how it should be selected. These guidelines also allow for additional controls to verify the market is active and trades are orderly. As we acquire new data in the future (for example, when a forced liquidation occurs) it is possible some of the steps below will be elaborated in the future to ensure we are calculating a fair market value.

As Coin Metrics already provides a proprietary Reference Rate methodology to price crypto-assets which we believe to be robust and stable, it is worth briefly describing the philosophy behind producing a Principal Market Price to supplement the Reference Rates. The first and most significant criteria is that certain regulatory agencies require a methodology consistent with the aforementioned accounting principles. These principles clearly describe the preferred 'fair market value' calculation as one which identifies a Principal Market by trade volume and tracks executed trades in that market.

Beyond external requirements the benefits for a Principal Market methodology are that it is that it is clearly defined and auditable. The price is always taken from a single market, which tends to remain constant, and can easily be traced and double checked for a given time stamp. We minimize computations being done on the price, which reduces the likelihood of unforeseen behavior. Additionally, the trades are always taken from the exchange where the most of the activity is happening, which is setting customers are most likely to be interested in.

Like all things in life, this comes with some trade offs. Our Reference Rates look for a central tendency among several markets. In some cases this can avoid volatility if the Principal Market deviates from the global average, but it also means that the final price may be taken from comparatively insignificant market that is sandwiched between markets of larger volume. With these trade-offs in mind, our methodology seeks err on the side of trusting the largest market by volume of trades, and only exclude a market in extreme situations.

We also to avoid numerical comparisons of the price between markets in the methodology, in order to minimize the possibility that a price anomaly could affect teh calculation of other markets. Our Reference Rate by contrast chooses to combine multiple markets to identify a more stable price representative of the global environment.

2 Methodology

1. Consider list of approved constituent markets already in use for Coin Metrics Reference Rates
   (a) Market Selection uses data and human review to ensure inclusion of high-quality exchanges and data feeds
   (b) Summary can be found here and specific details here
2. Identify any inactive markets, drop all trades associated with the inactive market. A market is considered inactive if it meets the following conditions:
   (a) The last trade was *more* than 1-minute ago AND
   (b) The last trade was either:
      i. Longer than 10-minutes ago (no markets without trades for 10 minutes will be considered) OR
      ii. Longer than $100 * [mean\ trade\ interval]$
         A. The mean trade interval is defined as: The the average of all intervals between sequential trades in the past 1-hour. For example, if trades happen at times [00:02, 00:12, 0:37, 1:15] the MTI will be $mean[10s, 25s, 38s] = 23.3sec$
         B. Investigation shows the *maximum* trade interval in a given hour is often around 20-30x the *mean* trade interval. It is very rare to see a gap of more than 50x the mean interval in trading, especially in the highest volume market.
   (c) If there are no active markets (no market has a trade in the past 10 minutes), then the PMP will forward-fill the last non-null value available.
      i. We have not yet identified a situation where all markets go down simultaneously.
3. Check if any trades in the markets are not considered orderly (IFRS 13.B37-B38). Drop any non-orderly trades from the calculation.
   (a) This is done by looking 2 windows ago (60-120 min before calculation time) to calculate a reference standard deviation of prices in each market separately.
      i. If there are not sufficient trades to calculate a standard deviation in the 60-120 minute window, then all trades are considered orderly (i.e. no trades are dropped if there is sparse data).
   (b) Then we divide the most recent window (0-60 min from calc. time) into 60 1-minute slices and calculate how far each trade is from the mean price of trades in that market in the same 1-minute slice.
   (c) Finally, we exclude trades that occur more than *three* reference standard deviations from the mean price of trades within that minute.
   (d) We also require at least *five* trades occur in that minute in order to exclude any. The two paramters (3 reference deviations and 5 trades) may be adjusted in the future.

4. Identify the active market with the largest volume of orderly trades in the past 1-hour time window. This will serve as the Principal Market. (IFRS 13.16, ASC 820-35-5)

5. Use the most recent orderly trade on the PM and publish as the PMP.

3 Investigation and Verification

3.1 2022-07-01: Performs as Expected Under Typical Conditions (Figure 1)

Figure 1 demonstrates the desired and most observed behavior of the Principal Market Rate. There is a clear largest market, and it's trade price is published as the PMP (Coinbase has about 70% of global volume). Because all the markets are trading within a narrow range, the price largely matches the CoinMetrics Reference Rate.

The parameters we use to consider a trade orderly (within 3 reference standard deviations of the mean price in that same minute, with at least 5 trades occurring that minute), result in 0-3000 trades excluded at any given time. This is out of 40,000-50,000 which occurred in the previous hour. Those dropped trades do not meaningfully affect the Principal Market selection.

Figure 1: Typical Pricing Behavior. Principal Market is largest by a large margin. Principal Market Price matches trade price of largest market (Coinbase). Because all markets are trading close to each other it also is very close to the BTC Reference Rate

3.2 2021-02-22: Reacting to Anomalous Behavior on Principal Market (Figure 2 and 3)

For this example (Fig 2), we were looking for a situation where a market had an incident. Because the incident occurred on Kraken which was not the Principal Market, we

artificially inflated the volume of each Kraken trade such that the total traded over the period was 10% greater than the trade on Coinbase. Although this scenario is artificially constructed, it demonstrates how our methodology would behave when the largest market behaves anomalously.

What we see is that Kraken has a series of very unusual trades for about five minutes, from 14:20-14:25 until coming back in sync with the other markets around 14:30. This incident is short lived, and the PM Price does not react as the incident happens. The intention of the PMP methodology is to have a clearly defined market from which we are taking pricing data; as a result we want to err on the side of being conservative and preserving the highest-volume market. It is very difficult to accurately identify anomalous behavior within a 5-minute window without becoming overly reactive during normal periods of volatility.

Nevertheless, at 14:40, twenty minutes after the onset of the incident, we see that our methodology has reacted and shifted away from the Kraken price. The transition is highlighted with a pink circle in Fig 2. The blue line in the plot (representing Kraken trades) becomes visible because the PMP is no longer super-imposed.

In the first example, the Kraken price has returned close to equilibrium with the other markets but if the incident had continued longer than five minutes we would have selected a different Principal Market even sooner. We tested this possibility by adding noise to the Kraken price in Fig 3 making the price appear volatile for a longer period. We see in this example, our methodology switches off of Kraken as the PM at around 14:32 (12 minutes after the onset of volatility).

This behavior is conditional on the overall market volumes, in this case Kraken had 5-10% more volume than Coinbase over the preceding hour. If the Principal Market has sufficient volume it is possible we won't switch off it unless the incident lasts for a long time. However in the situation where the largest market by overwhelming amount exhibits strange behavior we can't be certain what is truly happening at a global level (in this case, what is the "true" price?). We expect that Kraken will once again be selected as the Principal Market about an hour after the incident has ended.

3.3 2022-05-25 (DOT): Excluding disorderly trades improves stability of Principal Market (Fig 4 and 5

Here we want to highlight two outcomes of our methodology. The first is that changes in the Principal Market can be handled smoothly without a major disruption to the price time series. Our PMP is ultimately selected from a recent trade. In general different markets differ little under normal conditions, and when multiple markets are competing to be the largest by volume they are even more likely to be priced in sync. This means when the Principal Market changes, there is not an obvious discontinuity in the price.

This is shown in Fig 4, which shows the PMP for DOT over a one hour period with multiple PM shifts. For this example we did *not* exclude any disorderly trades in order to demonstrate the effect of the changing Principal Market.

The other effect is that when we turn *on* the outlier (aka. disorderly trade) exclusion, we see that the PM selection becomes more stable (Fig 5). Only a single Principal Market is selected over the entire period. This is because although two markets were close in raw-volume count, one clearly had a consistent edge when it came to orderly trades.

Figure 2: *Top*: Proportion of Volume each market trades over 1-minute windows. Used as input during calculation. Historical data has been inflated to make Kraken compete as largest market. *Middle*: Prices of individual markets. *Bottom*: Kraken incident begins around 14:20 and mostly ends by 14:25. At 14:40 (pink circle), our PM Methodology shifts over to Coinbase as the largest market after excluding the disorderly Kraken trades (pink circle).

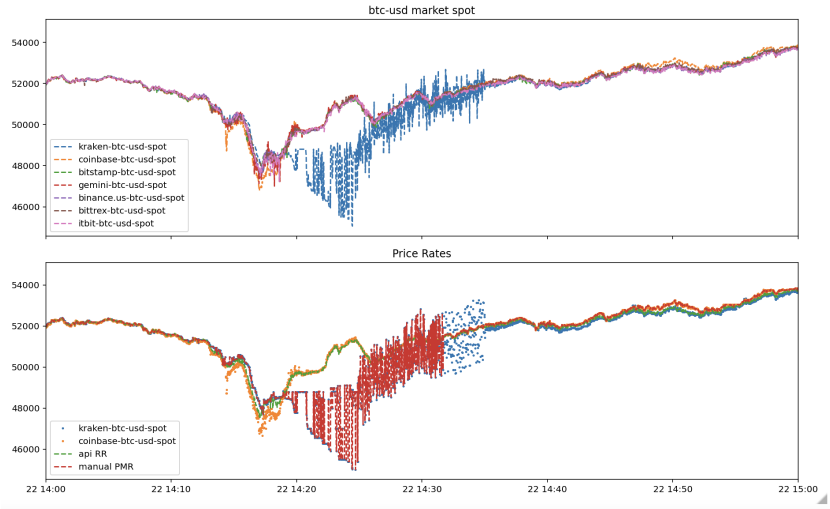

Figure 3: Similar to Fig 2, but with noise added to price to extend the incident. Volume calculation moves off Kraken at 14:32 due to dropping disorderly trades.

	time	price	market
0	2022-05-25 06:00:00	10.040000	coinbase-dot-usd-spot
656	2022-05-25 06:10:56	9.960796	binance-dot-btc-spot
2187	2022-05-25 06:36:27	9.990000	coinbase-dot-usd-spot
2188	2022-05-25 06:36:28	9.986837	binance-dot-btc-spot
2212	2022-05-25 06:36:52	9.990000	coinbase-dot-usd-spot
2217	2022-05-25 06:36:57	9.988801	binance-dot-btc-spot
2218	2022-05-25 06:36:58	9.990000	coinbase-dot-usd-spot
2233	2022-05-25 06:37:13	9.987960	binance-dot-btc-spot
2775	2022-05-25 06:46:15	9.990000	coinbase-dot-usd-spot
2798	2022-05-25 06:46:38	9.997106	binance-dot-btc-spot
2820	2022-05-25 06:47:00	10.000000	coinbase-dot-usd-spot
2830	2022-05-25 06:47:10	9.997691	binance-dot-btc-spot
2857	2022-05-25 06:47:37	10.000000	coinbase-dot-usd-spot

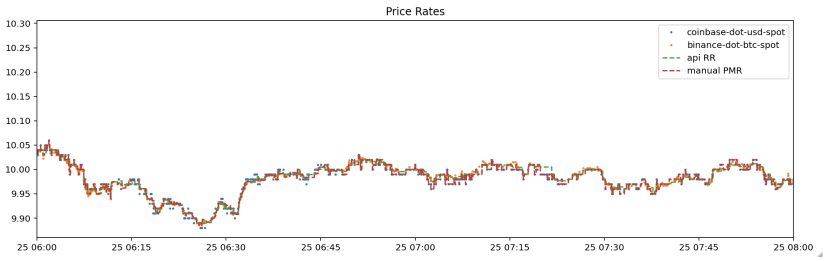

Figure 4: Despite several changes in the Principal Market around 6:37 and 6:47, overall time series looks consistently and reliable.

	time	price	market
0	2022-05-25 06:00:00	10.04	coinbase-dot-usd-spot

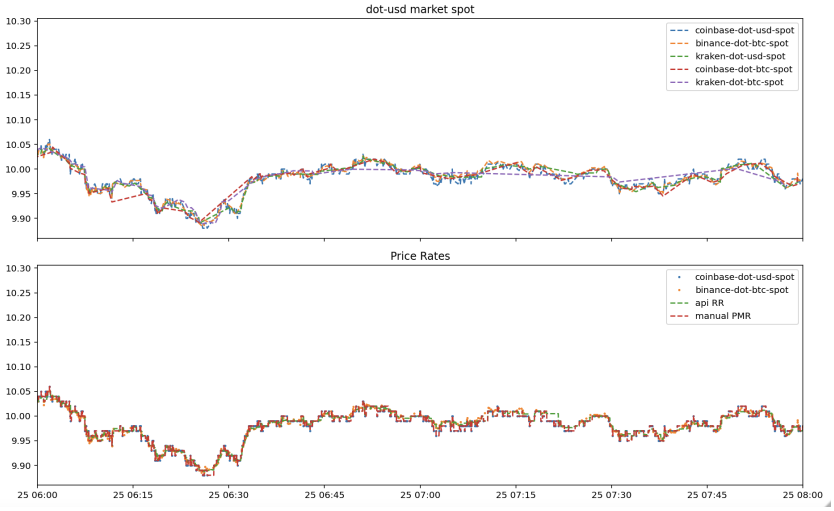

Figure 5: When we exclude trades that do not appear orderly, we only get a single Principal Market selected throughout the entire window.