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An evaluation of the CME CF Ether-Dollar Reference Rate as a benchmark for regulated financial products

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Abstract

This study provides evidence that the CME CF Ether-Dollar Reference Rate (CME CF ETHUSD_RR), a UK and EU-regulated benchmark price of Ether, is replicable at volumes that are likely to be transacted by institutional financial market participants. When simulating a daily purchase of 500 Ether over 366 days at the CME CF ETHUSD_RR, transaction volumes averaged 12.94% of weekday Constituent Exchange volume, with a standard deviation of 7.97%. Evidence of the benchmark's market integrity is also presented. The highest average percentage effect on CME CF ETHUSD_RR when excluding contributions from individual Constituent Exchanges was 0.017%. This demonstrates that the CME CF ETHUSD_RR was not subject to manipulation via Constituent Exchange price manipulation. A pair-wise correlation analysis of CME CF ETHUSD_RR Constituent Exchanges showed a clustering of coefficients towards 1.00, indicating the absence of manipulation within individual Constituent Exchanges. Average transaction volume at the benchmark price during a daily one-hour transaction window over 366 trading days amounted to 0.00005% of Ether free float volume per day. Quantitative analyses support the replicability of purchasing 500 Ether at the same price as the CME CF Ether-Dollar Reference Rate within the volume limits indicated.

Introduction

At the time of writing in February 2021, Ether remains the second largest cryptocurrency by market value after Bitcoin. Just like the price of Bitcoin, the price of Ether rose rapidly in late 2020 and early 2021 amid an intensification of public interest in digital assets. Investors were seeking alternatives to assets that were expected to decline in value in real terms in the wake of loosening fiscal and monetary policy aimed at remediating the effects of the coronavirus pandemic. However, with free-float capitalisations of Bitcoin and Ether estimated by CF Benchmarks in January 2021 to be around $440 billion and $123.175 billion respectively, their aggregate market value continued to dwarf the combined value of several lower-tier digital assets. Their preeminent market values helped to explain, anecdotally at least, why demonstrable interest from institutional market participants in the digital asset class was observed to be at its strongest in relation to Bitcoin and Ether than for other digital assets. Yet both of these major assets present considerable barriers to entry in terms of active participation by financial institutions. Chiefly, for firms looking to create and manage financial products, there are doubts over price discovery, market integrity and the perception that a lack of capital markets regulations being applied to cryptocurrency trading venues implies risks inherent to the process of participation that are too material to tolerate.

This paper proposes a framework through which regulated financial product providers can overcome these risks by utilising the CME CF Ether-Dollar Reference Rate (CME CF ETHUSD_RR) as the settlement, valuation and performance benchmark for financial products that will hold Ether or offer financial exposure to Ether.

This paper will first outline the various risks that a product issuer might be subject to, then describe in detail how they are mitigated through the use of the CME CF ETHUSD_RR. The paper will then describe a practical application of the CME CF ETHUSD_RR by demonstrating that the slippage that is likely to be incurred relative to the CME CF ETHUSD_RR when trading Ether at scale would be low. The qualities of the CME CF ETHUSD_RR and tracking error analysis outlined herein will thereby demonstrate how to deploy the CME CF ETHUSD_RR as the benchmark or reference value for Ether-related financial products in a way that keeps those risks to a satisfactory minimum.

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Ether emerges from Bitcoin's shadow

Bitcoin vs. Ether: a condensed overview

According to CF Benchmarks' monthly supply assessment of leading cryptocurrency assets for January 2021, Bitcoin's free float market capitalisation was approximately $440bn near the end of that month.[1] Ether's free float market capitalisation was assessed at approximately $123.175bn. The two most valuable crypto markets thereby maintained the respective ranks they had occupied since the Ethereum blockchain went live in July 2015. This primary and secondary status respectively, in terms of Bitcoin's and Ether's market value, reflects one of several factors that play a role in defining the extent of institutional demand for Ether as an investment asset.

- **Bitcoin's 'first-mover' advantage -** Bitcoin's implementation in 2009 preceded Ethereum's proposal by programmer Vitalik Buterin by around four years, initiating a developmental interval between the two assets that has had long-lasting consequences. As the oldest cryptocurrency, it follows that Bitcoin enjoys a 'first mover' advantage to an extent that is pertinent to Ether's perceived development relative to Bitcoin. In turn, such perceptions probably shape Ether's perceived investability and consequently, its market value.
- **Guiding principles -** Although the Bitcoin and Ethereum projects share several fundamental characteristics including, peer-to-peer functionality, transactional messaging, decentralization and incentivization, their related assets are underpinned by different guiding principles, and it is the guiding principles that appear to have a more significant impact on their notional investment cases than the fundamental characteristics. Summarized very approximately, the essential differences in their guiding principles are that Bitcoin was intended as digital, decentralized and permissionless money, whilst Ethereum was intended to be a decentralized, permissionless 'world computer'[2].
- **Investment theses -** It is quite cogent to assume that the ideological frameworks from which Bitcoin and Ether emerged[3,4] and that continue to permeate their functional focus, play a role in determining the scope of their investment theses. It is also credible to expect Bitcoin and Ether to be furnished with more than one major investment case each. Nevertheless, anecdotally, Bitcoin has frequently been characterized as a form of 'digital gold' that is a 'store of value' just like the precious metal of gold as a physical asset is held to store value. Therefore, whilst cases for Bitcoin and Ether may veer quite closely to classic patterns of asset accumulation in anticipation of value appreciation, Ether's investment case also implies a greater admixture of expected value that may be attributable to future innovations and use cases through technological advancement. This paper is not the place to explore such themes in detail, though in the authors' view, it was important to highlight the distinction outlined above, because the difference is likely to continue helping to shape Ether's investment case, and in turn institutional demand for Ether instruments and products.

Crypto adoption lifts prices

Deepening corporate and institutional engagement in cryptocurrency ownership, custody and investment coincided with the rapid elevation of prices of Bitcoin and Ether in the second half of 2020. On 14th February 2021, the CME CF Bitcoin Reference Rate, published by regulated benchmark administrator CF Benchmarks, logged a record price of $48,606.98. At the time of writing, it was the latest among numerous price records of recent months and compared with the Bitcoin Reference Rate price on 2nd October 2020 of $10,529.71, at that time, a one-month low. The CME CF Ether Dollar Reference Rate reached its own cycle peak on 13th February 2021 of $1,819.01. Ether's U.S. dollar price had appreciated more than six-fold since recording a notable trough at the beginning of October 2020, together with Bitcoin. These remarkable price movements followed in the wake of significant milestones for the top two crypto assets on the path towards mass-market adoption in 2020. The milestones included PayPal becoming the first major consumer payments platform to offer individuals the ability to transact with cryptocurrencies, large U.S. corporations announcing significant Bitcoin investments and Wyoming regulators awarding licenses to two firms associated with cryptocurrencies that enabled them to become Special Purpose Depository Institutions, essentially the first federally chartered crypto banks.[5,6]

Institutionalization begins

Professionalisation of the Ether market anecdotally lagged that of the Bitcoin market in 2020. For example, Ether's secondary position in that respect was demonstrated by the lower amount of announcements and instigations of Ether investment products from large institutions compared with those of Bitcoin investment products. Nevertheless, the Ether investment market still showed unmistakeable signs of moving beyond its innovation phase and of becoming more anchored in traditional institutional use cases. Examples include Grayscale Ethereum Trust becoming an SEC Reporting Company[7] and the CME Group launching cash-settled Ethereum futures on 8th February 2021, using the CME CF Ether Dollar Reference Rate as the settlement index.[8]

Grayscale Ethereum Trust

Grayscale Ethereum Trust[9] (GET) is an OTC traded, closed-ended fund, shares of which reflect the value of ETH held by the trust, less expenses and other liabilities. GET's holdings are weighted 100% to ETH. Under the Alternative Reporting Standard for companies, it is not required to register with the Securities and Exchange Commission (SEC), and like all such products, it can only be marketed to accredited investors. This class of participants includes corporate institutions undertaking investments on their own behalf and on behalf of third parties. The existence of Grayscale Ethereum Trust in itself helps underline the growing institutional appetite for exposure to Ether.

CME Ether Futures launched

CME Group, the largest derivatives marketplace in the world by volume of contracts traded, announced in December 2020 that it would launch trading of Ether futures contracts in February 2021. The Ether contracts[10] are formulated much like the exchange's first cryptocurrency product, CME Bitcoin Futures. Like CME Bitcoin Futures, CME's Ether Futures are cash-settled to an independent reference rate. For Ether, that will be the CME CF Ether-Dollar Reference Rate, a UK-authorised benchmark index provided and administered by CF Benchmarks. (The UK regulatory regime has equivalence with the EU regime post-Brexit). Trading hours of the exchange's Ether contracts will be similar to those of most other CME futures, although The Last Day of Trading for expiring Ether contracts will be 4pm London time. That is the same contract termination arrangement as for CME Bitcoin Futures. It is clear that CME Ether Futures specifications were designed to closely align with established futures contracts utilised by financial and industrial participants to manage risk or gain exposure to the U.S. dollar price of Ether. Note that the CME is regulated by the U.S. Commodity Futures Trading Commission (CFTC) and that the CME CF Ether-Dollar Reference Rate is a Registered Benchmark authorised under UK Benchmark Regulation, with active oversight by the UK FCA, whilst deemed equivalent by EU regulation. Therefore, the CME's Ether Futures are the only fully regulated Ether derivative available to U.S. investors, just as CME Bitcoin Futures are the only fully regulated derivative of that asset for U.S. investors.

CME Bitcoin open interest bodes well for Ether

CME Bitcoin Futures provide a further corollary of institutional demand for CME Ether Futures. In mid-February 2021, open interest of CME Bitcoin Futures contracts stood at $2.81bn, the second highest compared to open interest volumes at 11 other large Bitcoin futures exchanges, according to data compiled by analytics provider skewAnalytics. CME Futures open interest volumes were recorded at $784m in October 2020[11]. Assuming a modicum of the demand seen for CME Bitcoin Futures, the exchange's Ether counterpart may see similar growth. Likewise, a tendency for institutional market participants to keep Bitcoin Futures positions open for longer on regulated exchanges – including the CME - than on unregulated ones[12], was also suggestive of market share growth for the CME's Ether contract once launched.

In summary, the launch of CME Ether Futures and their initial reception - over $30m of contracts were traded on their first full day of trading compared to $4.7m on the first day of CME Bitcoin contracts trading in October 2017 - is another indication of demand for institutional participation in the Ether market.

An Ether market with integrity

Having presented satisfactory indications that an institutional investment market for Ether exists, the next important consideration is how such a market can be delivered to institutional participants in a manner that is compliant and commercially satisfactory. As detailed in the paper *'An analysis of the suitability of the CME CF BRR for the creation of regulated financial products'*[13] published in December 2020, cryptocurrency exchanges and price instruments are more variable in the degree to which they adhere to principles of market and price integrity and in the extent of their compliance with capital markets regulations, compared with venues and prices for more established asset classes. Consequently, regulated financial entities that are obliged to transact in instruments and at venues demonstrating unequivocal adherence to securities regulations are faced with an unsatisfactory set of choices if they intend to purchase Ether at scale. They can either stand aside from the Ether market entirely or shoulder an unacceptable increase in market and regulatory risk by participating in Ether markets where integrity has not been established.

Contributing to the resolution of this dilemma is the principal aim of this publication. In a manner that is analogous with the methodology by which institutional market participants can purchase Bitcoin at scale, as exemplified in the paper on the BRR referenced above, the current publication will propose a framework by which institutional investors can purchase Ether at scale in a manner that is compliant and commercially satisfactory.

More specifically, this paper will first detail the CME CF Ether-Dollar Reference Rate (CME CF ETHUSD_RR), a transparent, regulated Ether benchmark. Next, evidence of the representativeness of the CME CF ETHUSD_RR of the verifiable Ether market will be presented. Subsequently, measures pursued to ensure that the CME CF ETHUSD_RR is possessed of price integrity and, in particular, is free of manipulation of any kind, will be described. Finally, the replicability of the ETHUSD_RR's benchmark prices will be demonstrated in terms of the achievability of CME CF ETHUSD_RR prices when purchasing Ether 'at scale' at any time of the trading day.

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Representation

CME CF Ether-Dollar Reference Rate

The CME CF Ether-Dollar Reference Rate is a once-a-day benchmark index price for Ether denominated in U.S. dollars. Input data is obtained from major cryptocurrency exchanges that conform to the CME CF Constituent Exchange Criteria. Calculated every day since its launch on 14th May 2018, the CME CF ETHUSD_RR is a highly trusted source of Ether pricing and the pre-eminent price benchmark for Ether risk settlement, being a Registered Benchmark under the European Union's Benchmark Regulation regime. The CME CF ETHUSD_RR has become the settlement index for Ether futures contracts listed by CME Group and has been the settlement index for Ether-U.S. dollar futures traded on the Crypto Facilities MTF since 2018.

Calculation Methodology

The CME CF ETHUSD_RR calculation methodology aggregates transactions of Ether in U.S. dollars conducted only on the most liquid markets for which data is publicly available, operated only by exchanges that meet the CME CF Constituent Exchange Criteria. Constituent Exchanges at the time of writing were Bitstamp, Coinbase, Gemini, itBit and Kraken. Information about changes to the composition of this list are available at the following URL:

https://www.cfbenchmarks.com/docs/CME+CF+Constituent+Exchanges.pdf

The full methodology is also available:

www.cfbenchmarks.com/docs/CME+CF+Constituent+Exchanges+Criteria.pdf

The methodology can be summarised thus:

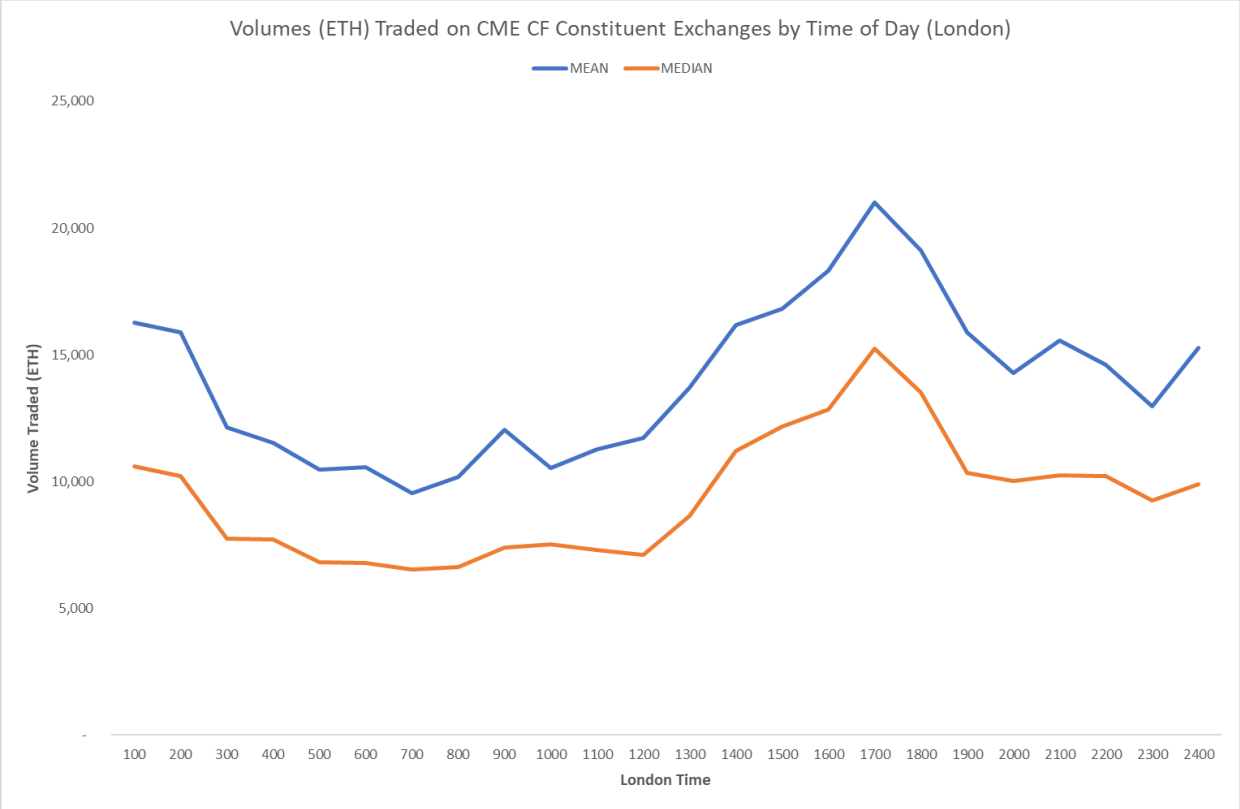
- Transactions conducted on Constituent Exchanges are observed during a one-hour window from 15.00 to 16.00 London Time
- The one-hour window is divided into 12 partitions of equal length (five minutes each)
- For each partition, a volume-weighted median (VWM) is calculated

The index value is expressed as the arithmetic mean of the 12 VWMs calculated in the previous step.

Suitability of 16.00 London Time as CME CF Ether-Dollar Reference Rate calculation time

The graph in Figure 1 illustrates the rationale of calculating the CME CF Ether-Dollar Reference Rate at 16.00 London Time. For the data set illustrated, Ether-U.S. dollar transaction volumes on Constituent Exchanges were measured over an observation period of 1st January 2020 to 31st December 2020.

Figure 1



Ether can be traded at any time of the day. But the trading data graphed above suggests that Ether market participation volume adheres closely to times when traditional markets tend to experience their own highest trading volumes.

The most liquid time of the day for Constituent Exchange volumes, together with the typical 4pm traditional market closing time of several large European cities, pointed to an optimal time of 15.00 to 16.00 London Time to measure transactions for an Ether risk settlement benchmark.

The question of volume sufficiency

For the CME CF ETHUSD_RR to be deemed a valid benchmark, the volume observed in its calculation must be sufficient for that purpose. From a practical perspective, the CME CF ETHUSD_RR needs to have sufficient volume in its calculation in order to be replicable by institutional market participants and institutional product and service providers. These prerequisites are addressed by data presented in Tables 1 and 2 below.

The tables describe the volume of transactions per day during the observation period in both Ether and U.S. dollar terms. The parameters provided are range, median and average transactions per day. It is important to note that the CME CF ETHUSD_RR is calculated every day of the year, including public holidays, due to the market trading 24 hours a day, 365 days a year. The data summaries below include all CME CF ETHUSD_RR calculations from throughout the observation period.

Table 1

Metrics	Trades	Volumes (ETH)	Volumes ($)
MIN	373.00	1,175.79	187,879.48
MAX	27,468.00	128,251.70	56,474,645.71
MEAN	4,134.77	18,305.82	5,829,964.62
MEDIAN	3,030.50	12,897.09	3,519,200.68

Note that on average 18,305.82 Ether were traded over an average of about 4,134 transactions, worth an average $5,829,964.62 during the one-hour observation window of 15.00 to 16.00 London Time. (Prices were contemporaneous with when the trades were observed. As such, the data are free of distortions from asset price inflation.) Although this appears to qualify as significant volume prima facie, the average transaction volume needs to be regarded in context of the Ether market's free-float market capitalisation of about $123.175 billion towards the end of January 2021. The average sum transacted was equivalent to less than 0.00005% of Ether free float volume. On the other hand, in the cryptocurrency market, determining the size of a typical intended institutional transaction, and then the scope of an order that an institutional market participant would generally undertake, is problematic. This is partly due to the dearth of research covering institutional crypto transaction volumes. In turn, that paucity is a consequence of the emergent nature of the market. Parallels with institutional behaviour patterns in traditional markets, enabling extrapolation to crypto, may be possible. However, any such conceptual connections will be tenuous in lieu of definitive research.

A 2013 analysis of institutional equity transaction sizes, citing data compiled by post-trade analytics firm Ancerno[14], may be pertinent. It noted that average order sizes were nearly three times the average transaction size in a sample of 847 unique institutional investors. The average daily position change was nearly double the average order size. Incidentally, the average

transaction size in the analysis was $151,216 (5,359 shares). The researchers concluded that position changes were largely achieved by means of multiple orders and that orders were typically executed with multiple transactions. This coheres with widely observed institutional transaction patterns in many asset classes.

Current research permits only limited conclusions

Without extensive research it is difficult to determine conclusively whether such patterns are also present in institutional cryptocurrency transactions. For now, the data presented in the current publication provide a guide as to the minimum hypothesized size of institutional Ether transactions that can replicate the CME CF ETHUSD_RR price. Furthermore, in view of the expectation that cryptocurrency orders at institutional scale will—like those in other asset classes—be completed through multiple transactions, data presented here are also suggestive of the minimum transaction size at which the CME CF ETHUSD_RR remains replicable. The authors propose that the analysis in this publication represents a useful increment to a conclusive model for replicating CME CF ETHUSD_RR at institutional scale. Nevertheless, the authors also concede that design flaws of the research reported in this publication may have limited the scope of conclusions relating to replicability possible from the dataset presented.

Integrity

This section will address the extent of market integrity of the CME CF Ether-Dollar Reference Rate in the specific sense of securities regulations. The practical imperative is that a benchmark requires integrity because it will be used for asset valuation and settling financial risk. Specifically, the benchmark must be free of manipulation. Furthermore, it must be administered and calculated in a manner that deters and impedes manipulation.

The methodological design underlying the CME CF ETHUSD_RR and its system of administration incorporate measures that promote integrity as outlined in the sub-sections below.

Data integrity by data selection

CF Benchmarks exclusively sources input data from Constituent Exchanges that meet published criteria as set out in its Constituent Exchanges Criteria. The criteria are available at this link: https://www.cfbenchmarks.com/docs/CF+Constituent+Exchanges+Criteria.pdf

Particular attention is drawn to the following statement from the Constituent Exchanges Criteria document (part 3 of Section 5, page 4: 'Eligibility Criteria'):

"*The venue has published policies to ensure fair and transparent market conditions at all times and has processes in place to identify and impede illegal, unfair or manipulative trading practices.*"

CF Benchmarks ascertains the presence of fair and transparent market conditions and processes to identify and impede illegal, unfair or manipulative practices by conducting a thorough review of any exchange under consideration for inclusion as a Constituent Exchange. The arrangements of all Constituent Exchanges are reviewed annually to ensure that they continue to meet all criteria. This due diligence is documented, and the information is distributed to CF Benchmarks' oversight committees and provided to its regulator, the UK Financial Conduct Authority (FCA).

Manipulation resistance by design

Resistance to manipulation is a priority aim of the design methodology underlying the CME CF Ether-Dollar Reference Rate. The methodology takes an observation period and divides it into equal partitions of time. The volume-weighted median of all transactions within each partition is then calculated. The benchmark index value is determined from the arithmetic mean of the volume-weighted medians, equally weighted. The benefits of this process with respect to achieving manipulation resistance are outlined below.

- **Use of partitions**

Individual trades of large size have limited effect on the Index level as they only influence the level of the volume-weighted median for that specific partition

A cluster of trades in a short period of time will also only influence the volume-weighted median of the partition or partitions they were conducted in

- **Use of volume-weighted medians**

Use of volume-weighted medians as opposed to volume-weighted means ensures that transactions conducted at outlying prices do not have an undue effect on the value of a specific partition

- **Equal weighting of partitions**

By not volume weighting partitions, trades of large size or clusters of trades over a short period of time will not have an undue influence on the index level

- **Equal weighting of constituent exchanges**

CF Benchmarks applies equal weight to transactions observed from constituent platforms. With no pre-set weights, potential manipulators cannot target one platform for the conduct of manipulative trades

- **Use of arithmetic mean of partitions**

Using the arithmetic mean of partitions of equal weight further denudes the effect of trades of large size at prices that deviate from the prevailing price having undue influence on the benchmark level

Manipulation resistance by exclusion of input data

A specific procedure for dealing with potentially erroneous data is incorporated into the methodology of the CME CF ETHUSD_RR. Although volume-weighted medians of transaction prices from individual data sources are not a part of the benchmark determination process, they are calculated as a means of quality control and manipulation resistance.

In the event of an instance of index calculation in which a Constituent Exchange's volume-weighted median transaction price exhibits an absolute percentage deviation from the volume-weighted median price of other Constituent Exchange transactions greater than the potentially erroneous data parameter (10%), then transactions from that Constituent Exchange are deemed potentially erroneous and excluded from the index calculation. (Since the inception of the CME CF Ether-Dollar Reference Rate in May 2018, its potentially erroneous data parameter has never been triggered.) Any instances of data excluded from a calculation will trigger a Benchmark Surveillance Alert that is investigated.

An analysis of the volume-weighted median per exchange during the observation period of the research reported in this publication produced the results in Table 3. The results illustrate that during the observation period, no Constituent Exchange's input data needed to be excluded due to exhibiting potential manipulation.

Table 1

Metric	Absolute VWM Deviation %				
	Bitstamp	Coinbase	Gemini	ItBit	Kraken
MIN	0.00	0.00	0.00	0.00	0.00
MAX	2.21	-1.23	-1.61	4.06	-1.57
MEAN	0.11	0.07	0.11	0.18	0.10
MEDIAN	0.05	0.03	0.06	0.08	0.05

Benchmark Surveillance

Although a series of measures have been undertaken to mitigate the risk of benchmark manipulation, CF Benchmarks remains vigilant against attempted benchmark manipulation and monitors input data continuously. To that end, CF Benchmarks has implemented a benchmark surveillance programme for the investigation of alerts. Instances of suspected benchmark manipulation are escalated through appropriate regulatory channels in accordance with CF Benchmarks' obligations under European Union Benchmark Regulation (EU BMR). Regarding benchmark manipulation, Article 14 of the EU BMR, Reporting of Infringements, states:

1. An administrator shall establish adequate systems and effective controls to ensure the integrity of input data in order to be able to identify and report to the competent authority any conduct that may involve manipulation or attempted manipulation of a benchmark, under Regulation (EU) No 596/2014.

2. An administrator shall monitor input data and contributors in order to be able to notify the competent authority and provide all relevant information where the administrator suspects that, in relation to a benchmark, any conduct has taken place that may involve manipulation or attempted manipulation of the benchmark, under Regulation (EU) No 596/2014, including collusion to do so."

As a Regulated Benchmark Administrator, CF Benchmarks is subject to supervision by the UK FCA. This supervision ensures CF Benchmarks is in compliance with all aspects of EU BMR requirements.

Furthermore, CF Benchmarks' Control Procedures with respect to compliance with the EU BMR have been audited by 'Big Four' accountancy firm Deloitte. The Independent Assurance Report

on Control Procedures Noted by CF Benchmarks Regarding Compliance with EU Benchmark Regulation as of 31 July 2020 is available at the following link:

www.cfbenchmarks.com/docs/Deloitte_CF+Benchmarks+SOC1+Audit+Report.pdf

This further verification of CF Benchmarks' compliance with EU BMR places the CME CF Bitcoin Reference Rate on the same level of scrutiny applied to widely used traditional financial benchmarks like ICESWAP, SONIA and ICE LIBOR.

Assessing CME ETHUSD_RR values and input data for signs of manipulation

The CME CF ETHUSD_RR was designed and is administered to the highest standards, including efforts to uphold provisions of EU BMR. Nevertheless, further analysis of the benchmark price data has been undertaken to better ensure the instrument's integrity.

Were there to be a lack of integrity in the input data that could in turn affect the integrity of the benchmark, one would expect to see one of a number of phenomena reflected in the input data provided by Constituent Exchanges. One potential example would be significant price dislocations between Constituent Exchanges.

What happens when an exchange is removed from the calculation?

- The CME CF Ether-Dollar Reference Rate methodology aggregates trades observed on Constituent Exchanges during a one-hour observation period between 15.00 and 16.00 London Time
- One means of detecting dislocations in price between different Constituent Exchanges is to recompute the CME CF ETHUSD_RR calculation without the participation of one of the exchanges and to repeat this process for each of the exchanges in turn. This process gives a strong indication of how closely the exchanges track each other in terms of price per unit of volume transacted
- In the period analysed – 1st January 2020 to 31st December 2020 – absolute impacts exhibited when each exchange was removed from the index calculation versus index values are summarised in Table 4 below

Table 2

Metric	Absolute Diff W/O Exchange				
	Bitstamp	Coinbase	Gemini	ItBit	Kraken
MIN	0	0	0	0	0
MAX	0.32	0.33	0.12	0.2	0.21
MEAN	0.021	0.048	0.009	0.005	0.029
MEDIAN	0.01	0.04	0.01	0	0.02

- As well as the absolute impact of removing individual exchanges from the index calculation, the proportionate impact on the CME CF ETHUSD_RR from the same exercise in the same period can also be shown, as in Table 5 below

Table 3

Metric	Percentage Diff W/O Exchange				
	Bitstamp	Coinbase	Gemini	ItBit	Kraken
MIN	0.000%	0.000%	0.000%	0.000%	0.000%
MAX	0.063%	0.086%	0.052%	0.039%	0.077%
MEAN	0.007%	0.017%	0.003%	0.001%	0.010%
MEDIAN	0.005%	0.012%	0.002%	0.000%	0.006%

It is clear that Constituent Exchanges exhibit very similar price action to each other when analysed through the lens of the CME CF ETHUSD_RR methodology. This in turn demonstrates that the CME CF ETHUSD_RR has not been subject to manipulation through manipulation of prices on individual Constituent Exchanges.

Even so, examination of relationships between Constituent Exchange price characteristics can be taken a step further. The pair-wise correlation between each Constituent Exchange can also be scrutinised. This may reveal indications of potential manipulation within CME CF ETHUSD_RR Constituent Exchange prices that may be occurring on a subtler or smaller scale than would be captured by the potentially erroneous data parameter and by which the CME CF ETHUSD_RR index value itself is not impacted due to its aggregating heuristic.

How well corelated are Constituent Exchange prices?

An analysis was undertaken of the pair-wise correlation of prices from Constituent Exchanges on a per-minute basis (the price difference between transactions for each minute at each exchange) during the observation period. The results of this analysis are shown in Table 6.

Table 4

Pair-Wise Correlation of Constituent Exchanges to the ETHUSD_RR			
Constituent Pair Platform	**Mean Correlation %**	**Median Correlation %**	**Standard Deviation**
Bitstamp - Coinbase	93.79%	96.55%	7.68%
Bitstamp – Gemini	89.82%	93.62%	10.76%
Bitstamp – ItBit	72.92%	84.32%	30.89%
Bitstamp – Kraken	92.69%	95.65%	8.70%
Coinbase – Gemini	91.10%	94.56%	10.14%
Coinbase – ItBit	73.43%	85.29%	31.02%
Coinbase – Kraken	94.95%	96.99%	6.08%
Gemini – ItBit	74.82%	85.43%	30.00%
Gemini - Kraken	91.88%	94.89%	9.11%
ItBit - Kraken	75.50%	86.56%	29.50%

The clustering towards correlation coefficients of 1.00 demonstrate strong price correlation between the Constituent Exchanges.

Replicability and Implementation

The final characteristic of the CME CF Ether-Dollar Reference Rate that this paper will examine with respect to its merits as a benchmark price is its replicability. In other words, that the CME CF ETHUSD_RR benchmark price can be transacted in practice on any given day.

How to purchase 500 Ether each day at the CME CF ETHUSD_RR price

To begin demonstrating the replicability—or to use another term, the achievability—of the strategy presented in this paper for purchasing Ether 'at scale', observations taken whilst modelling the purchase of a notional large amount of Ether are presented below. The purchase of 500 Ether was simulated on each day between 1st January and 31st December 2020, an observation period of 366 days. It was decided that the purchase of 500 Ether was an adequate scale to represent a large Ether trade of the kind that institutional traders might need to undertake for a major client, or that an issuer of a financial product (such as an ETF or a derivative) would be required to execute, in order to facilitate trading of that product. A simple replication simulation was thereby conducted to exemplify the extent of slippage that implementation of the CME CF ETHUSD_RR would probably encounter.

It is worth noting that in the 'real world', institutions deploy algorithmic systems to execute large-scale asset purchases. It is probable that conducting the exercise presented here by means of algorithmic systems would have produced outcomes more favourable than those described in this paper. For research purposes, a simplified simulation methodology was favoured.

Simulation Methodology

- Trades are executed on *n* (5) Constituent Exchanges, during a 3,600-second calculation window
- One trade is executed every second and the price achieved is assumed to be the last execution price observed in that second. Its associated volume is assumed to be the volume executed during that second
- If no trade is completed in any single-second period, then the price achieved is assumed to be the price achieved in the previous second, but the associated volume from the previous second is not added to the volume executed in the latest second

The results of this exercise are displayed in Figure 3. The data are summarised in Table 7.

Figure 2

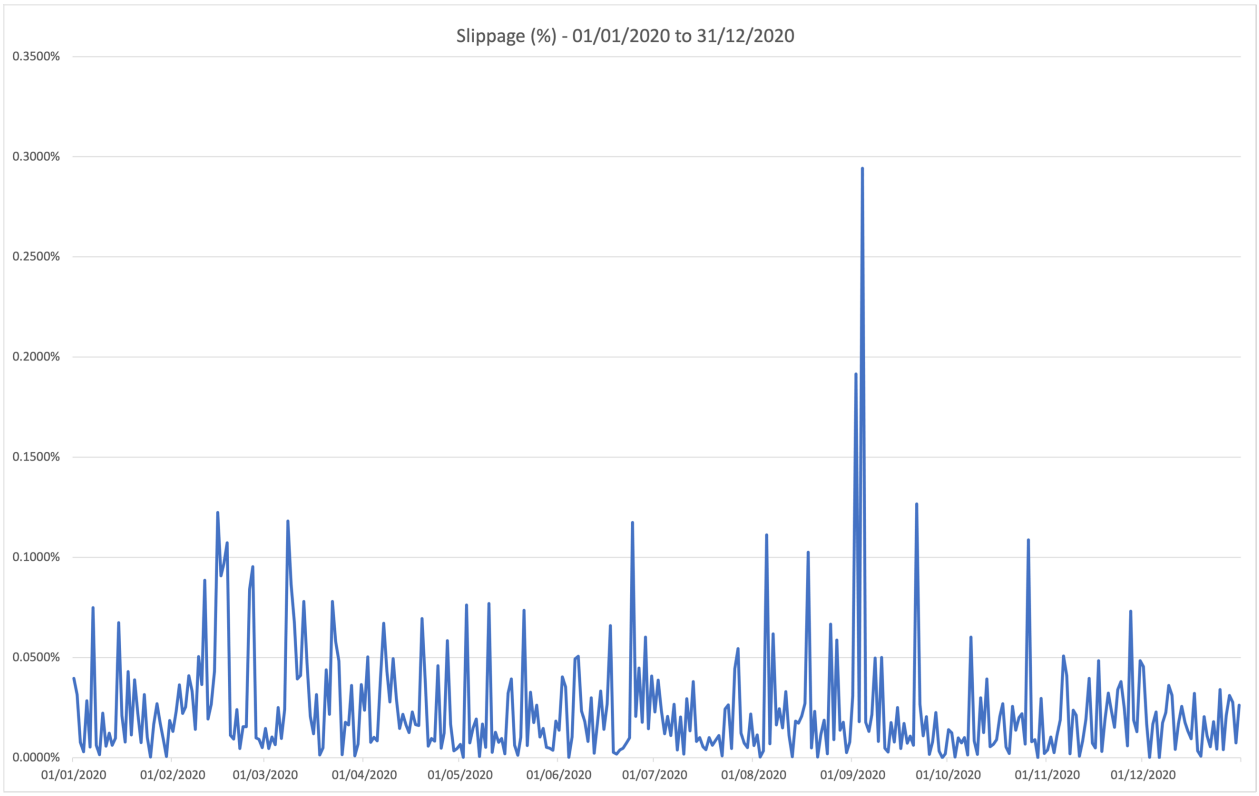


Table 5

Slippage %	
MAX	0.2943%
MIN	0.0000%
MEDIAN	0.0167%
MEAN	0.0243%
STANDARD DEVIATION	0.000288719

The need to restrict information leakage

Information leakage can often exacerbate slippage during 'real world' transactions. In order to measure the level of slippage that would probably occur when transacting 500 Ether as per our simulation, an estimate of the market impact of a trade of 500 Ether within a 3,600-second calculation window of our simulation was required.

Table 8 below contains maximum, minimum, median, arithmetical mean and spread (standard deviation) represented by the purchase of 500 Ether during the observation period as percentages of total CME CF ETHUSD_RR volume.

Table 6

Daily CME CF ETHUSD_RR volume represented by 500 Ether (%)		
Metric	**All Days**	**Weekdays Only**
Maximum	104.29%	50.40%
Minimum	1.66%	1.66%
Median	12.40%	11.41%
Mean	16.32%	12.94%
Standard Deviation	13.30%	7.97%

Conclusion

Considering the profile of CME CF ETHUSD_RR trading volumes suggested by Figure 1, it is clear that the liquidity of the Ether market peaks at times that cohere with traditional market trading times. It is therefore reasonable to suggest that weekdays are more pertinent for the exercise of purchasing Ether 'at scale', as working days are the likeliest times that institutional participants would seek to do so. On that basis, the salient data in the exercise presented here are the maximum and average weekday CME CF ETHUSD_RR Constituent Exchange volumes that would be represented by the purchase of 500 Ether during the observation period, together with the standard deviation of the percentage of volumes represented over the observation period.

The maximum volume of the CME CF ETHUSD_RR that would have occurred during weekdays was 50.40%. The average weekday volume over the observation period was 12.94%. The spread between all weekday volumes observed was 7.97%. These figures indicate reasonable ease to achieve (or replicate) the CME CF ETHUSD_RR, albeit with the provisos relating to replicable volume noted under the section above titled 'The question of volume sufficiency.'

Table 9 presents the rate at which some discrete percentages of CME CF ETHUSD_RR volume occurred during the observation period. As stated above, weekday volumes are the most salient. On that basis, a 0.38% rate of occurrence of 50% of the weekday volume traded on CME CF Ether-Dollar Reference Rate Constituent Exchanges when purchasing 500 Ether, demonstrates a low proportion of days when that purchase represented a relatively high market volume.

In turn, it is indicated that purchasing 500 Ether when it was a relatively low proportionate volume of a verified market occurred frequently, whilst it was only possible to make such purchases when they were a relatively large proportion of that market very infrequently.

Combined, the readings from Tables 8 and 9 support the replicability of purchasing 500 Ether at the same price as the CME CF Ether-Dollar Reference Rate within the volume limits indicated.

Furthermore, the readings support the position that purchases of the stated amount of Ether by deployment of the strategy outlined in this paper will reduce to a minimum the kind of slippage that can be caused by third-party participants being alerted to such trades. The analysis presented here assumes that trading is confined to the Constituent Exchanges and is not executed on other venues such as those in the OTC market.

If the OTC market were to be taken into account, it is likely that the measured price impact of attempts to replicate the CME CF ETHUSD_RR would be lower than that described in this paper.

Table 7

Days on which 500 Ether exceeded 10%, 25%, 50% of CME CF ETHUSD_RR volume		
Percentage	All Days	Weekdays Only
10%	62.13%	56.65%
25%	15.26%	6.46%
50%	2.72%	0.38%

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