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Dynamic Principal Market Determination: Fair Value Measurement of Cryptocurrency

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Abstract

Cryptocurrencies and blockchain technology are disruptive innovations at the vanguard of a new wave of the digital revolution. The far-reaching appeal, global reach, unprecedented mobility of capital, and multitude of trading venues have created a marketplace like no other. The economic fundamentals underlying this market are yet to be fully comprehended, as evidenced by the often-contradicting guidelines recommended by accounting firms, government agencies, and standard setters. Many of the definitions and models used for classical markets cannot be applied directly to cryptocurrency. Basic concepts must be reinterpreted, and models must be modified to fit the mechanics of these markets. In this article, we focus on one such concept: that of *fair value*. We argue that in light of the fragmentation of cryptocurrency markets and the global dispersion of trading venues, a principal market may be difficult to identify. The primary objective of this article is to present a methodology to dynamically designate principal markets and derive fair value prices for financial reporting using this designation.

Keywords

cryptocurrency, fair value measurement, principal market

Introduction

The market for cryptocurrencies is significant and is expected to expand rapidly over the next few years. In early 2019, market capitalization of crypto assets was more than US$90 billion (European Central Bank, 2019). Cryptocurrencies are currently measured at fair value with gains and losses reported in earnings for entities holding such assets as qualified investment companies. The same accounting treatment is afforded to broker-dealers who own cryptocurrencies. Therefore, there is a need to properly measure cryptocurrencies at fair value[AQ: 1].

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ASC 820 and IFRS 13 are the most recent guidelines designed to establish a uniform definition of ''fair value'' and provide a consistent framework for its application. However, with fragmented markets, it may be difficult to determine how existing standards can be used to reflect market realities. In particular, the *principal or most advantageous markets* may be difficult to establish in fragmented, globally dispersed markets.

The objective of this article is to develop a methodology to identify the principal market to be used for proper fair value measurement, classification, and disclosure of investments in cryptocurrencies and to ensure that this methodology is aligned with Financial Accounting Standards Board (FASB) ASC 820 and IAS 13.

This article is organized as follows. Following the Introduction, we next provide an overview of the relevant standards governing fair value measurement. Then, our proposed model is developed and discussed and illustrated in the next section. Next, we conduct an empirical test that demonstrates the model's ability to properly discern the principal market. The final section of this article provides a brief summary and conclusions.

Fair Value Measures for Financial Reporting

The definition of fair value for financial reporting is based on an exit price concept. The exit or exchange price is defined as the price that can be obtained on the disposal of an asset or the amount paid for the transfer of an obligation in an orderly transaction between market participants at the measurement date. The concept of an orderly transaction assumes that the hypothetical transaction used to measure fair value will be one in which the seller of an asset or the transferor of an obligation has the usual access to markets and would not assume a forced sale as in the case of a liquidation or bankruptcy.

When measuring assets to be used in exchange at fair value, we must identify the *principal market* (FASB, 2011; International Accounting Standards Board [IASB], 2011). Only if a principal market cannot be identified, then the most advantageous market should be used. As is the case of cryptocurrencies, assets may be traded in different, active markets at different prices. If an entity enters into transactions in multiple markets and can access prices in those markets for the asset at the measurement date, then those markets can be assessed in terms of volume and level of activity.

According to current accounting standards, the principal market is the market with the greatest volume and level of activity for the asset (FASB 2011; IASB 2011). The fair value of the asset would be measured using the price that would be received in that market. The main objective of our model is to dynamically identify the principal market and once that market is obtained, source all price information employed either as a spot or as a benchmark from that exchange.[1]

Specifically, ASC 820 (FASB, 2011) indicates that if there is a principal market for the asset or liability, the fair value measurement shall represent the price in that market (whether that price is directly observable or estimated using another valuation technique), even if the price in a different market is potentially more advantageous at the measurement date. Moreover, to be relevant, the benchmark price should be at least approximately tradable on an accessible market.

The Fair Value Model for Financial Reporting: An Application of FASB ASC 820

The fair value model for financial reporting requires that we follow several steps in determining the fair value of an asset or obligation. In the case of cryptocurrency, the unit of

account is simply one unit of the digital currency measured as either a single digital coin or a fraction of a digital coin. In addition, because cryptocurrencies cannot be used in production or in conjunction with other assets, the highest and best use is in exchange. The valuation technique used in the case of cryptocurrencies is the market approach.

As a result of employing the market approach, our first valuation issue is to determine the principal or most advantageous market at a specific point in time. When we identify a principal or most advantageous market, we will use a market approach that identifies observed prices. Because the identified price is an observed input, the reliability of the inputs used in our fair value measure should be a Level 1 measure and disclosed as such in the fair value hierarchy.

Determining the Principal Market and Fair Value

The primary purpose of this article is to develop methodology that first, identifies the principal market and second, extracts a fair value for financial reporting purposes from that principal market. As will be discussed, the markets for cryptocurrencies are fragmented and may have limited and / or inaccurate measures of volume. In addition, the reliability of the data extracted from certain exchanges may have to be used with caution. However, we believe that there are several factors that can be considered to improve the reliability of the volume and price information obtained from the cryptocurrency exchanges. These factors include the level of exchange oversight, the microstructure efficiency, transparency, and data integrity. Our proposed methodology will take these and other factors into account and allow for the efficient identification of the principal market and the determination of the fair value of the cryptocurrency at the measurement date.[2]

Market Fragmentation and the Challenge of Identifying the Principal Market

As noted earlier, one of the key characteristics of the cryptocurrency market is its high level of fragmentation. The main cryptocurrencies, Bitcoin and Ethereum, are traded on over 100 exchanges worldwide, with a large variety of underlying mechanisms. As such, the possibility exists that there may be no single exchange that is dominant in terms of volume, price discovery, or any other attribute that would make it an obvious principal market.

Moreover, either due to the difference in trading rules, and/or to the lack of active arbitrageurs at the current phase of market development for many exchanges, there can be significant differences in the prices between the exchanges, and due to geographic disparity, a constant shift in the volume prominence throughout the day. Some of the less-liquid currencies are traded over one or two exchanges, in particular, currencies that are issued by the exchanges themselves. Most of the liquid currencies are likewise traded over several different exchanges with a likelihood that no single exchange can be designated as the principal market.

Several other exchange-traded assets have either a designated principal exchange or a de facto principal exchange that dominates all other exchanges in terms of volume or visibility and serves as a focal point in the price discovery process. The situation is quite different for cryptocurrency where there may not exist a single dominant exchange in terms of volume.

To illustrate, Table 1 shows the average daily volume over the first quarter of 2019, on four hypothetical exchanges. As we can see, none of these exchanges clearly dominate the market. Assuming that only four exchanges exist, Exchange 1 controls less than 50% of the market and that percentage level may not be considered significant enough to dominate the

Table 1. BTC-USD Average Daily Volumes (in Millions of USD).

Average daily BTC-USD volume (millions of USD) Q1 2019	
Exchange 1	78.6
Exchange 2	48.3
Exchange 3	36.5
Exchange 4	27.1

Note. The table reflects the average daily volume of four hypothetical exchanges used in our simulation. We assume that the average daily volume is measured for the first quarter of 2019. BTC = Bitcoin; USD = U.S. dollars.

entire market. Moreover, volume reporting does not follow any standard, and it has long been suspected that some of the numbers reported by some of the exchanges do not reflect real volume.[3]

It is important to note that the time of day over which we measure fair value is also critical in determination of a principal exchange. Depending on time of day, some exchanges may dominate certain hours while other exchanges dominant others. Figure 1 shows the average intra-day volume of Bitcoin–U.S. dollar (USD) trades in millions of dollars in trades per hour (time of day). The data presented in Figure 1 indicate that during certain hours, Exchange 4 is clearly dominant while during other times during the day, Exchanges 1 and 2 have more significant trades.

Given the fragmented nature and variability noted on some of the cryptocurrency exchanges, it may be difficult to identify a principal market. So, careful attention must be given to the accounting guidelines for valuation at fair value, and proper interpretations must be made for this setting.

Following both U.S. Generally Accepted Accounting Principles (GAAP) and IASB requirements in such cases, when a principal market cannot be identified, we must consider the most advantageous market from the point of view of the holder of the assets (i.e., the market participant). The most advantageous market is the market where the entity would yield the highest net amount received on sale, after deducting estimated transactions costs. Note that although transactions costs are used to determine the most advantageous market, they are not included in prices used in determining fair value.

There are various considerations as to what would be the principal or most advantageous exchange for a particular currency pair and a particular investor, including the jurisdiction under which an exchange operates, the level of regulation and other exchange oversight, as well as liquidity and mechanism details.

As noted earlier, our proposed fair value measurement methodology for cryptocurrencies is a valuation technique that utilizes observable inputs, prices, and other relevant transaction data directly from exchanges. Therefore, a critical step in the valuation process is to identify either the principal or the most advantageous market.

We believe that the use of a principal market is most appropriate because a fair value measurement generally assumes that transactions take place in a principal market. Only in the absence of a principal market should the most advantageous market be used.[4]

Determination of a principal market is based on independent analyses performed at the organizational level and can vary among entities and businesses within a single entity. So, the identification of a principal market is entity specific, and can vary among specific entities within a consolidated group.

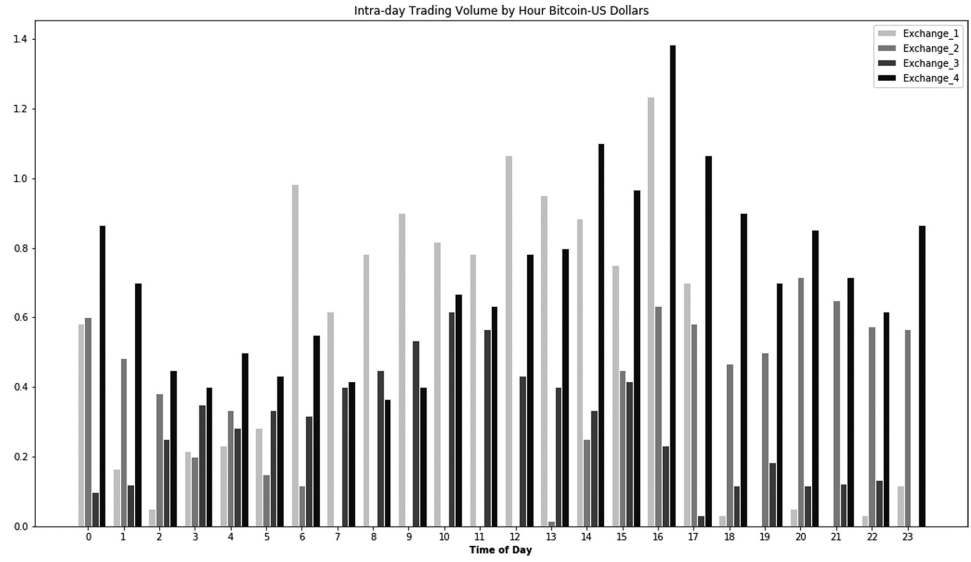

Figure 1. Intra-day trading volume by hour Bitcoin–U.S. dollars (in millions of U.S. dollars).
Note. This figure reflects the simulated data for our four exchanges. The volume indicated is the average intra-day volume of Bitcoin–U.S. dollars trades per hour.

The standards do not provide specific guidance regarding how an entity should designate a principal market. In addition, the entity is not required to engage in an extensive search of all markets and should incorporate readily available information such as volume. Overall, the principal market is typically presumed to be the market or markets that the entity will normally use to sell an asset or transfer a liability. It is likely, particularly in the case of cryptocurrencies, that an entity will need to reassess its designated principal market as events or activities change and the information extracted from various markets must be both available and reliable.

Therefore, it is important that we ensure that the data extracted from the designated principal market are as reliable as possible. Due to the rapid shifts in trading volume noted earlier and the fact that some exchanges lack proper oversight or are unregulated, the exchange data reported may not be highly reliable. As a result, we need to develop a systematic methodology that can be used to score and rank the exchanges and ultimately identify the principal market. Specifically, we propose a methodology to designate a principal market by considering characteristics such as exchange oversight, microstructure efficiency, transparency, data integrity, frequency of trades, and overall volume. By taking these characteristics into account, the data extracted from the designated principal market will be more reliable.

The proposed methodology for determining a principal market is presented in the next section of this article.

Proposed Methodology to Determine a Principal Market and Measure the Spot Fair Value

Our proposed methodology to designate a principal market for fair value measurement uses a ranking approach that considers several exchange characteristics, including oversight, and

the volume and frequency of trades.[5] Specifically, to rank the credibility and quality of each exchange, we dynamically assign a score to the key characteristics for each exchange by employing a five-step process. The five-step weighting process for identifying a principal exchange and the last price on that exchange is presented below.

Step 1: Assign each exchange for each pair of currencies a Base Exchange Score (BES) reflecting static exchange characteristics such as oversight, microstructure, and technology.
Step 2: Adjust the BES based on the relative monthly volume each exchange services. This new score is the Volume Adjusted Score (VAS).
Step 3: Decay the adjusted score based on the time passed since last trade on exchange. Here, we are assessing the level of activity in the market by considering the frequency of trades. The decay factor reflects the time since the last trade on the exchange.[6] This is the final decayed volume adjusted score (DVAS).
Step 4: Rank the exchanges by the DVAS and designate the highest-ranking exchange as the *Principal Market* for that point in time.
Step 5: Designate the price of the last transaction on the principal market as the primary spot price at that point of time.

That is, after we designate the principal market, the spot fair value assigned to the cryptocurrency is measured at the time and date of the financial report. The mathematical specification of this process, along with illustrations, are presented in the following sections.

BES. The BES reflects the fundamentals of an exchange, given equal volume and equal decay. The BES will determine which exchange should be designated as the principal market at a given point of time. This score is determined by computing a weighted average of the values assigned to four different exchange characteristics. These characteristics are as follows:

1. Exchange Oversight
2. Microstructure Efficiency of the Exchange
3. Data Transparency
4. Data Integrity

Exchange oversight. This score reflects the rules in place to protect and to give access to the investor. The score assigned for exchange oversight will depend on parameters such as jurisdiction, regulation, ''Know Your Customer and Anti-Money Laundering Compliance'' (KYC/AML), and so on. For example, we account for ''jurisdiction'' by using a basic hierarchy. Here, a Level 1 jurisdiction is assigned a score of 100 and that score is reduced by 20 points for each subsequent level.[7] A sample jurisdiction hierarchy is presented in Table 2.

Microstructure efficiency of the exchange. The second exchange characteristic is microstructure efficiency. Based on prior research (Roll, 1984), we take the effective bid ask spread as a proxy for efficiency. For each exchange and currency pair, we take an estimate of the ''effective spread''[8] relative to the price in ''pips.''[9] The score for exchange $i = 0, \ldots, n$ is computed as

Table 2. Exchange Oversight-Jurisdiction Hierarchy.

Level	Jurisdiction	Oversight score $[s^{ov}]$
Level 1	The United States, European Union, Japan, Switzerland, Australia, New Zealand, Singapore	100
Level 2	The United Kingdom, Israel, South Korea, Hong Kong	80
Level 3	Latam, China, India, Russia, Eastern Europe	60
Level 4	South Africa, South East Asia	40
Level 5	Africa, Middle East	20

Note. The oversight scores are developed from our simulation using factors such as location and regulation. In addition, the levels were developed by referring Standard and Poor (S&P) Sovereign Foreign-Currency Ratings, S&P Institutional and Economic assessment, and if the local currency is restricted.

$$s_i^{eff} = 100 \times \frac{\max_j \left(sp_j\right) - sp_i}{\max_j \left(sp_j\right) - \min_j \left(sp_j\right)}, \tag{1}$$

where $sp_0, sp_1, \ldots, sp_n$ are the spreads of the relevant exchanges measured as pips (1/10,000) of the asset price.

Data transparency. Transparency is the term used for a quality score that is determined by the level of detail of the data offered by an exchange and is based on the hierarchy provided in Table 3.

Similar to the jurisdiction hierarchy, Level 1, the highest level in the transparency hierarchy, is assigned 100 points and is reduced by 20 points for each subsequent lower level. Exchanges considered within the transparency hierarchy are also evaluated in terms of data integrity by computing a data integrity score that includes the impact of order reconstruction, minute volume matching, and daily volume matching. The data integrity score is discussed below.

Data integrity. Integrity is evaluated on three time scales, on tick level, short term (minutes), and daily, with the following scores:

s_{ord}—order reconstruction
s_{minute}—minute volume matching
s_{day}—daily volume matching

A weighted average of these scores will give the data integrity score. The weights are based on the *relative importance* of each factor at a point in time as assessed by the entity. Relative importance is a subjective term, which may be weighted differently by different practitioners and valuation specialists. FASB ASC 820 does not provide guidance regarding the use of a specific approach, but only requires the consistent use of the methodology selected. The weights used in this article are based on extensive discussions with practitioners, valuation specialists, and crypto asset portfolio managers as to the relative importance they may attribute to each factor. Determination of weights definitely merit an informed discussion once the structure and regulation of this market becomes clearer and further experience with the methodology is gained.

Table 3. Transparency Hierarchy.

Level	Data detail	Score $[s^{tran}]$
1	Orders	100
2	Order Book/TAQ[a]	80
3	Trades	60
4	Candles	40
5	None	20

Note. The transparency hierarchy is developed based on data detail available and the integrity of the data extracted. The integrity score is simulated by including the impact of order reconstruction, minute volume matching, and daily volume matching. The data integrity score included in this simulation is a weighted average of order reconstruction and the time scales. The weights are based on the relative importance of each factor assigned by the entity.[AQ: 2]

[a]This is a limit order book or the aggregate inside quote for each exchange.

$$s^{int} = \omega_{ord} \cdot s_{ord} + \omega_{minute} \cdot s_{minute} + \omega_{day} \cdot s_{day}. \tag{2}$$

These scores, s_{ord}, s_{minute}, s_{day}, are defined in the same way in the following sections.

Order reconstruction. Exchanges with Level 1 transparency will provide for each transaction a corresponding ''Order ID'' with size information on the order. An order for which we can identify all transactions that were completed as part of the order (including cancelation) is considered a ''reconstructed order.'' Let the volume weighted fraction of reconstructed orders be $p_{ord}>0$, then the corresponding score is

$$s_{ord} = 100\times(1 - e^{-\nu \cdot p_{ord}}) \text{ for } \nu>0. \tag{3}$$

Minute volume matching. Level 3 transparency will provide tick-by-tick data for trades, Level 4 transparency will provide candle data. Let $p_{min}>0$ be the fraction of the volume on the time bar accounted by individual trades, then the corresponding score is

$$s_{minute} = 100\times(1 - e^{-\nu \cdot p_{min}}) \text{ for } \nu>0. \tag{4}$$

Daily volume matching. Daily volume matching is the same as the minute volume matching except that it is determined for daily volume.

Mathematical Specification of the Principal Market Designation Process

The computations below are all done per currency and as a result, even the BES could vary from one currency to another. Although, top exchanges generally tend to be ranked high on all the currencies they service.

The mathematical specification of the principal market designation process is presented below.

Step 1: The BESs for exchange $ex_1, \ldots, ex_n$ is computed as follows:

$$s_{ex_i}^{BES} = \omega_{ov} \cdot s_{ex_i}^{ov} + \omega_{eff} \cdot s_{ex_i}^{eff} + \omega_{tran} \cdot s_{ex_i}^{tran} + \omega_{int} \cdot s_{ex_i}^{int}. \quad (5)$$

Again, the weights are based on the relative importance of each factor and their direct impact on the overall quality of the exchange based on managements' assessment. For example, it is likely that oversight and efficiency would typically have more weight than transparency and data integrity.

Step 2: For computing the VASs, let $vol_0, \ldots, vol_n$ be the monthly volumes of these exchanges, the VAS is then

$$s_{ex_i}^{VAS} = \frac{vol_{ex_i}}{\sum_j vol_{ex_j}} \cdot s_{ex_i}^{BES}. \quad (6)$$

Step 3: For computing the decayed score (DVAS) at time T, let $\{p_t^{ex_i} : t>0\}$ the time series of prices provided by exchange ex_i, and let t_{ex_i} the timestamp on the most recent trade observed on the exchange, namely, $t_{ex_i} = \max\{0<t<T : \{p_\tau^{ex_i} : t<\tau<T\} \neq \varnothing\}$, then the decayed weight is given by

$$s_{T,ex_j}^{DVAS} = e^{-|T-\tilde{t}_{ex}|} \cdot s_{ex_i}^{VAS}. \quad (7)$$

Step 4: The principal market is the exchange with the highest decayed score (DVAS):

$$ex^{principal} = argmax\{s_{T,ex_j}^{DVAS} : ex_1, \ldots, ex_n\}. \quad (8)$$

Step 5: Prime spot price is the last price as of time T on the principal exchange:

$$p_T^{lukka} = p_{t_{ex^{principal}}}^{ex^{principal}}. \quad (9)$$

Illustration: Identification of the Principal Market and Assigning a Fair Value

In this section, we demonstrate how to identify a principal exchange and assign a fair value for financial reporting by using our methodology.

We assume the market is made up of four exchanges operating in different locations worldwide. The numbers and scores attributed to these exchanges are for illustrative purposes only.[10] We also assume that we will measure a spot price of a cryptocurrency at the end of the first quarter. The following illustration will follow our five-step methodology using data created for the four hypothetical exchanges. The methodology will be used to determine the principal market and designate the spot price on the measurement date for financial reporting.

Step 1: Assign each exchange for each pair of currencies a BES reflecting static exchange characteristics such as oversight, microstructure, and technology.

The BES measures for our hypothetical exchanges are presented in Table 4.

Table 4. Base Exchange Scores.[AQ: 3]

		1. Oversight	Effective	2. Efficiency	Order reconstruction			3. Integrity	4. Transparency	
Exchange	Location	35%	Spread	30%	Tick	Minute	Day	25%	10%	BES
Exchange 1	Antwerp	100	18	0.00	73	92	100	84.19	Order book 100	*66.05*
Exchange 2	Seoul	60	3	93.75	63	78	98	81.35	Order book 100	*79.46*
Exchange 3	Tel Aviv	80	2	100.00	82	97	100	85.29	Order book 100	**89.32**
Exchange 4	New York	100	9	56.25	81	98	100	85.33	Order book 100	*83.21*

Note. "Oversight" reflects the exchange rules in place to protect and give access to the investor. The score includes factors such as jurisdiction, regulation, and KYC/AML requirements. "Effective Spread" on any exchange is defined as pips (1/10,000) of the asset price. "Order reconstruction" or a reconstructed order is defined as an order for which we can identify all transactions that were completed as part of the order (including cancelation). Reconstruction is based on the level of orders and minute and daily volumes. "Integrity" is the weighted average of order reconstruction and the time scales. The weights are based on the relative importance of each factor assigned by the entity. "Transparency" is the term we use for the quality score that is determined by the level of detail of the data offered by an exchange. The percentage weights included below the variable titles are determined by management. BES = base exchange score; KYC/AML = Know Your Customer and Anti-Money Laundering Compliance.

As noted in Table 4, the exchange with the highest BES is Exchange 3. The BES is the weighted average of the four key exchange characteristics: Oversight, Efficiency, Data Integrity, and Transparency. The weights used in this computation are noted below the exchange characteristic column on the table. In our example, the BES for Exchange 1 would be computed as follows:

$$BES_{Exchange\ 1} = (35\% \times 100) + (30\% \times 0) + (25\% \times 84.19) + (10\% \times 100) = 66.05.$$

This score must now be adjusted for volume. This is done in Step 2.

Step 2: Adjust the BES based on the relative monthly volume each exchange services. This new score is the VAS.

The volume adjusted BES amounts for sample exchanges are presented in Table 5. In our illustration, the VAS for Exchange 1 would be determined as follows:

$$VAS = (\%\ Volume \times BES) = (26.9\% \times 66.05) = 17.77.$$

At this point in implementing our methodology, Exchange 4 has the highest VAS at 21.70. This illustrates the fact that an exchange with a high BES can be less dominant due to lower volume. In this case, the principal exchange shifted from Exchange 3 to Exchange 4. However, that score is to be adjusted for the potential decay or time lag between trades. The DVASs are computed in Step 3.

Step 3: Decay the adjusted score based on the time passed since last trade on exchange. Here, we are assessing the level of activity in the market by considering the frequency of trades. The decay factor reflects the time since the last trade on the exchange. This is the final DVAS.

Table 5. VAS.

Exchange	Monthly volume (millions of U.S. dollars)	Percent volume represented by each exchange	BES	VAS
Exchange 1	48.6	26.9	66.05	17.77
Exchange 2	48.3	26.7	79.46	21.25
Exchange 3	36.5	20.2	89.32	18.08
Exchange 4	47.1	26.1	83.21	**21.70**
Total	180.5	100.0		

Note. The VAS is computed by weighting the BES by the percent of the total volume generated on each exchange. The monthly volume of each exchange was determined in our simulation. VAS = Volume Adjusted Scores; BES = base exchange scores.[AQ: 4]

We track the freshness of the data by tracking the most recent trades. An example is presented in Table 6.

We assume that we are measuring the spot price at a point in time, which could be the financial reporting date. In this example, we observe the arrival of new trades from approximately 30 min after midnight. Therefore, at 00:34.32.167 min after midnight Exchange 1 had the most recent trade on Line 4. Then, at 00:34.32.382, Exchange 4 had the most recent trade and therefore decayed less than the other exchanges at that point.

This is also seen in Figure 2. It shows a partial measurement period for the last minute considered from 34:00 min after midnight through 35:00 min after midnight.

Vertical discontinuity indicates arrival of new data (i.e., a fresh trade) and resets the DVAS for that exchange. When there are no trades, the DVAS decays.[11] Exchange 4 shows the highest DVAS (between 20.0 and 22.5) at 34:33 and the least decay relative to the other exchanges at that point which was the freshest piece of data. This is due to the fact that no other trades arrived between that point and the ''closing'' time of 35:00 min after midnight.

Step 4: Rank the exchanges by the DVAS and designate the highest-ranking exchange as the *Principal Market* for that point in time. Table 7 provides the final rankings and the identification of the principal exchange.

Exchange 4 is designated as the principal exchange based on the ranking of the DVAS amounts at the fair value measurement point. That is, at 34:33.510 min after midnight, Exchange 4 is the principal exchange as it has the ''freshest'' data or the exchange with the least decay at the time. Note that higher volume at that time of day could be due to activity in the Asian markets at that time.

Step 5: Designate the price of the last transaction on the principal market as the prime spot price at that point of time.

The prime spot price is US$3,810 and represents the fair value of the cryptocurrency extracted from Exchange 4 at 34:33.510 min after midnight at the end of the first quarter. This valuation is used to measure the investment in cryptocurrencies on the quarterly report for the first quarter.[12]

Table 6. Tracking Most Recent Trades.

Time	Exchange 1	Exchange 2	Exchange 3	Exchange 4
00:34:26.370	**00:34:26.370**	00:34:08.183	00:33:11.000	00:31:25.701
00:34:29.184	**00:34:29.184**	00:34:08.183	00:33:11.000	00:31:25.701
00:34:30.410	**00:34:30.410**	00:34:08.183	00:33:11.000	00:31:25.701
00:34:32.167	**00:34:32.167**	00:34:08.183	00:33:11.000	00:31:25.701
00:34:32.382	00:34:32.167	00:34:08.183	00:33:11.000	**00:34:32.382**
00:34:33.510	00:34:33.510	00:34:08.183	00:33:11.000	**00:34:32.382**

Note. The times presented in Table 6 are simulated and reflect the time when a new trade ("fresh" data) arrives. The times noted in bold indicate a new trade or the exchange with the "freshest" data.

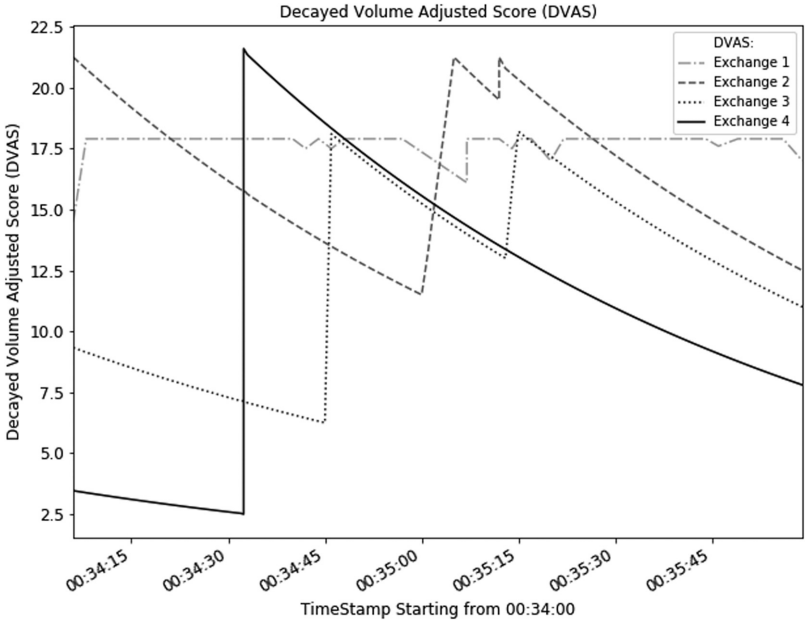

Figure 2. Decayed volume adjusted scores over 5-min window from 00:34:00 to 00:36:00 min after midnight.

Note. Figure shows the partial results of simulating the arrival of new trades over a period of approximately 30 min after midnight on the reporting date. The figure captures the time starting with 34 min after midnight and ending at 36 min after midnight. However, we assume that the standard designated "closing" time adopted in practice will be 35 min after midnight. Vertical discontinuity indicates arrival of new data (i.e., a fresh trade) and resets the DVAS for that exchange. When there are no trades, the DVAS decays. Exchange 4 shows the highest DVAS (between 20.0 and 22.5) at 34:33 and the least decay relative to the other exchanges at that point which was the freshest piece of data. This is due to the fact that no other trades arrived between that point and the "closing" time of 35:00 min after midnight. DVAS = decayed volume adjusted score.

Determining the Principal Market: An Empirical Demonstration

In this section, we illustrate the ability of the proposed methodology (the ''Model'') to determine a principal market and extract the price of the last market transaction for

Table 7. Principal Market Determination Based on Ranking of DVASs.[AQ: 5]

Time: Minutes after midnight	DVAS	Ranking: Principal market
00:34:26.370	17.80	Exchange 1
00:34:29.184	17.80	Exchange 1
00:34:30.410	17.80	Exchange 1
00:34:32.167	17.80	Exchange 1
00:34:32.382	21.25	Exchange 4
00:34:33.510	**21.25**	**Exchange 4**

Note. The DVASs reported in Table 7 are the approximate DVAS amounts extracted from the graph presented in Figure 2. These scores are also confirmed by our simulation results. DVAS = decayed volume adjusted score.

Table 8. Determination of the Designated Spot Price Reflecting the Price Shift as a Result of Decay (in U.S. Dollars).[AQ: 6][AQ: 7]

Time	Designated spot price	Exchange 1	Exchange 2	Exchange 3	Exchange 4
00:34:26.370	**3,811.47**	**3,811.47**	3,809.5	3,808.52	3,808.21
00:34:29.184	**3,811.47**	**3,811.47**	3,809.5	3,808.52	3,808.21
00:34:30.410	**3,811.47**	**3,811.47**	3,809.5	3,808.52	3,808.21
00:34:32.167	**3,811.47**	**3,811.47**	3,809.5	3,808.52	3,808.21
00:34:32.382	**3,810.00**	3,811.47	3,809.5	3,808.52	**3,810.00**
00:34:33.510	**3,810.00**	3,811.46	3,809.5	3,808.52	**3,810.00**

Note. "Designated spot price" is the spot price extracted from the exchange with the freshest data on the measurement date and time. In this case, the spot price extracted from Exchange 4 at 34:33.510 min after midnight is used for tax and financial reporting purposes. This assumes that 34:33.510 min after midnight is the point in time predetermined as the "closing" date and time for the tax or financial report.

financial reporting purposes. The methodology is consistent with the guidance found in both ASC 820 (FASB, 2011) and IFRS 13 (IASB, 2011).

To run our empirical demonstration, we collected real-time price quotes for the Bitcoin and USD (XBT-USD) pairs traded on six major exchanges (anonymized as Exchanges A–F).[13] We then ran a demonstration designed to illustrate the Model's ability to select the principal market using actual trade data. Finally, we determine the fair value derived by the Model from the last transactions for each minute from the exchanges used in our sample.[AQ: 8]

The results are reported in Figures 3 and 4. Figure 3 presents the tick price patterns of XBT-USD on the selected exchanges while Figure 4 shows the prices of the last transaction of XBT-USD on each minute on each exchange between 8:30 and 8:45 a.m. on June 26, 2019. In addition to the actual exchange prices for XBT-USD, we include the fair value measures derived from the Model in Figures 3 and 4. Six exchanges are split into two groups, Exchanges A to C in Panel A and Exchanges D to F in Panel B of Figures 3 and 4, according to their clustering characteristics.

In Panel A of Figure 3, the actual tick price patterns on Exchanges A to C were clustered together and the Model also appropriately followed this pattern in the 15-min time interval between 8:30 and 8:45 a.m. on June 26, 2019. The patterns from the remaining Exchanges D to F were separately clustered, shown in Panel B of Figure 3. In addition, the

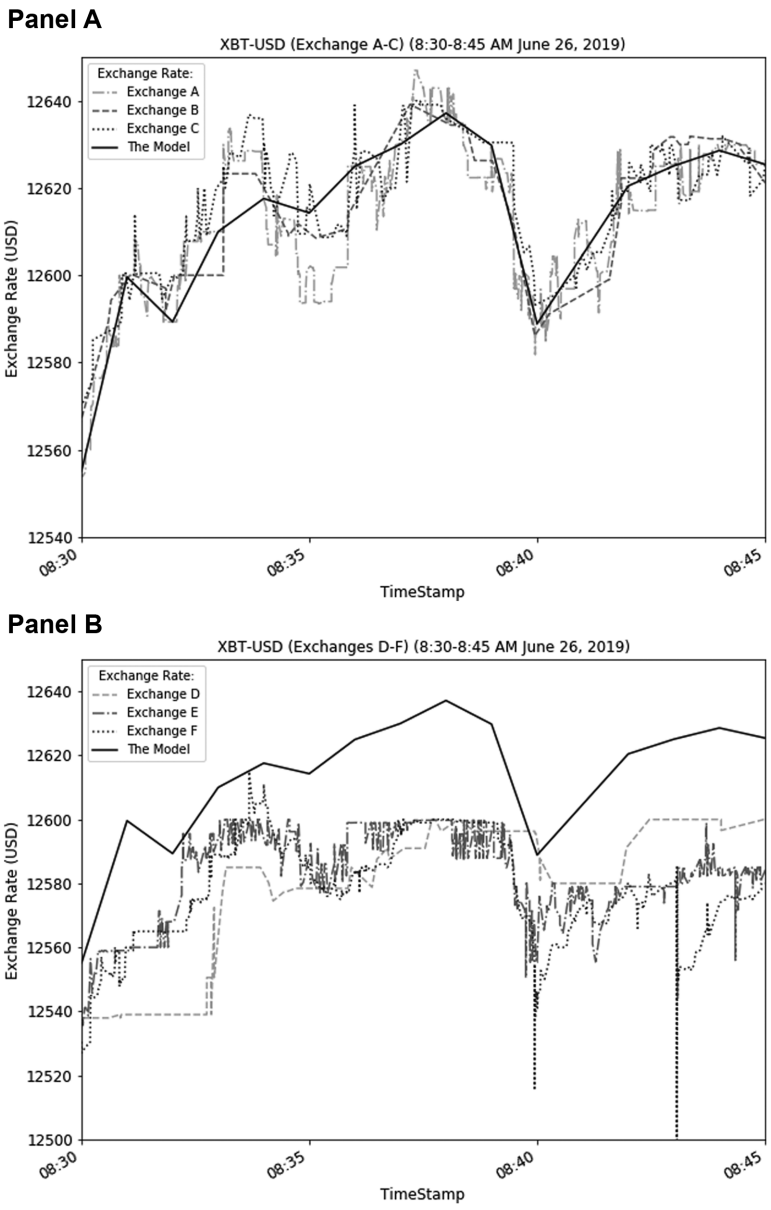

Figure 3. The actual tick prices of XBT-USD on the selected exchange with the fair value measure derived from the proposed methodology (the Model) from 8:30 to 8:45 a.m., June 26, 2019.
Note. XBT = Bitcoin; USD = U.S. dollars.

Model often selected Exchange A as the principal market for XBT-USD during the time intervals included except for 8:34, 8:35, 8:40, and 8:41 a.m. Here, Exchange C was determined as the principal market (Panel A of Figure 4). The change in principal market designation based on varied market conditions demonstrates the ability of the Model to

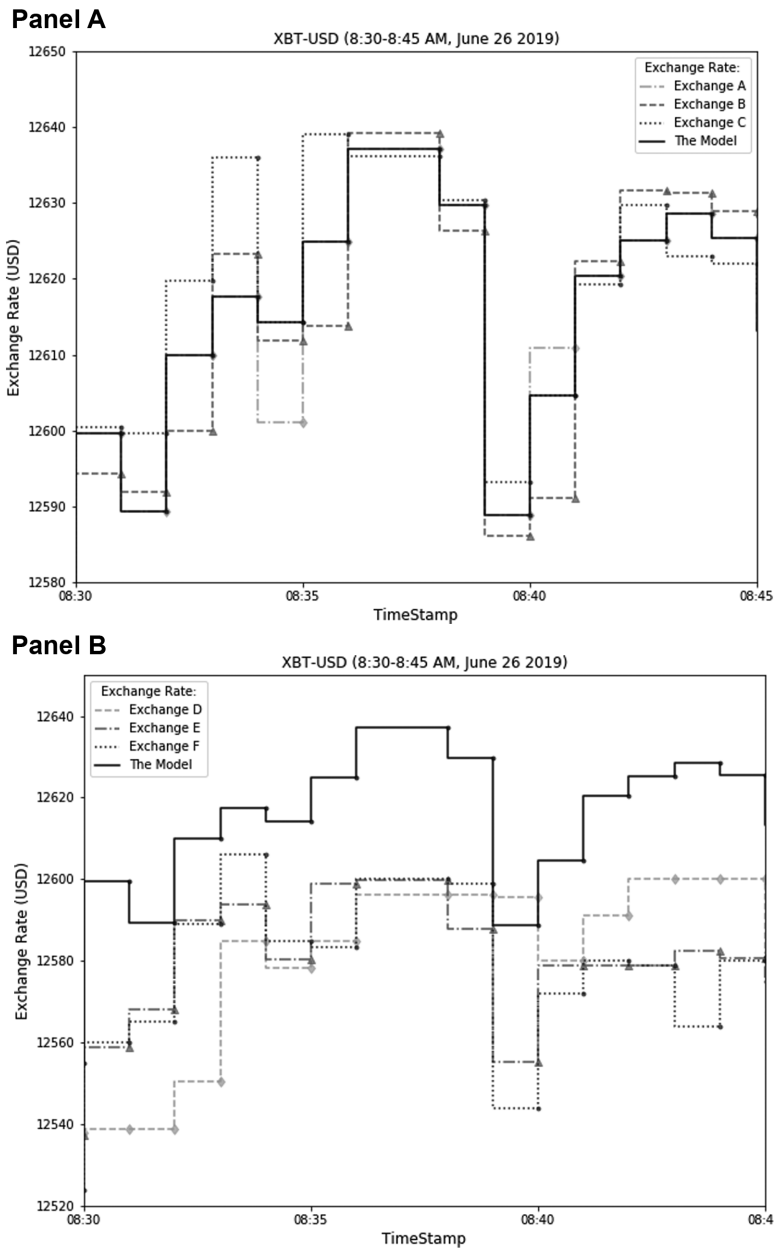

Figure 4. The prices of the last transaction of XBT-USD on each minute on the selected exchanges with the fair value measures derived from the proposed methodology (the Model) from 8:30 to 8:45 a.m., June 26, 2019.

Note. XBT = Bitcoin; USD = U.S. dollars.

Table 9. The Pearson Correlations Among the Price of Last Transaction of XBT-USD on Each Minute on the Selected Exchanges With the Fair Value Measures Derived From the Proposed Methodology (the Model) on June 26, 2019.[AQ: 9]

	Price_ Exchange A	Price_ Exchange B	Price_ Exchange C	Price_ Exchange D	Price_ Exchange E	Price_ Exchange F	The Model
Price_Exchange A	1.000000	.998900	.998723	.990858	.996870	.994050	1.000000
Price_Exchange B	.998900	1.000000	.998754	.989951	.998649	.995882	.998900
Price_Exchange C	.998723	.998754	1.000000	.990221	.997061	.994196	.998724
Price_Exchange D	.990858	.989951	.990221	1.000000	.987679	.982408	.990857
Price_Exchange E	.996870	.998649	.997061	.987679	1.000000	.996443	.996869
Price_Exchange F	.994050	.995882	.994196	.982408	.996443	1.000000	.994050
The Model	1.000000	.998900	.998724	.990857	.996869	.994050	1.000000

objectively and dynamically determine the principal market of a currency pair using real-time trade behavior on exchanges.

Figure 4 shows that the prices of the last transaction from the selected exchanges and the fair value measures from the Model (the dots on the graph are the last prices and the fair value measures) for the end of each minute over the 15-min interval (8:30–8:45 a.m.) are consistent. If the lines representing the Model and the exchange overlap, it indicates that the exchange was determined as the principal market at that specific minute. Consistent with the patterns exhibited in Figure 3, Exchange A was often determined as the principal market in the interval. However, the Model did not select Exchange A as the principal market from the six exchanges at 8:34, 8:35, 8:40, and 8:41 because the trade behavior on Exchange A real-time became more volatile and less reliable. Therefore, a different principal market, Exchange C, was selected.

Finally, Table 9 indicates that the fair value measures generated by the Model highly correlate with the prices of the last transaction of XBT-USD on the selected exchanges. The highest correlations were found between the model and Exchange A (corr. coef. = 1.000000), Exchange B (corr. coef. = .998900), and Exchange C (corr. coef. = .998724). This confirms the ability of the Model to discern the most reliable exchanges as the principal market in the determination of the fair value for financial reporting.

Summary and Conclusions

This article presents a theoretical model to implement the use of fair value accounting for measuring and reporting cryptocurrencies for qualified investment companies and broker-dealer owned holdings of cryptocurrency. Based on the theoretical model, we develop a methodology to assess the quality of digital currency exchanges and determine a principal market. With a principal market identified, a fair value is obtained to price the investment in cryptocurrencies.

Under the fair value model, cryptocurrencies are carried on the balance sheet at fair value with all unrealized gains and losses reported in current earnings. However, we acknowledge the difficulty of determining a principal exchange needed to extract a ‘‘true’’ price in a fragmented market. In response, we develop a dynamic system to assess the credibility of the exchange by considering characteristics such as jurisdiction, regulation, oversight, volume, and frequency of trades. The methodology is structured as a balance

between the ability to obtain data from reliable sources, typically the more highly credited exchanges and the timeliness of the data.

We begin our assessment of the exchanges by assigning a BES that includes values for the characteristics such as regulation, exchange microstructure, data quality, transparency, coverage, volatility, and other mechanisms, such as trading rules. Then, we weight the base score for volume and finally, reduce the score for infrequent trades or decay.

Our weighting methodology operates on two time scales. On the longer monthly time scale, we adjust a set of initial weights by the volume each exchange traded over the previous month, and on the shorter time scale, we decay the initial weight based on the time passed since last trade.

With a final or ''decay-weighted'' score, the principal exchange is selected. The point in time price needed for financial reporting and tax can then be extracted from the principal exchange. We provide empirical evidence to demonstrate the practicality of the model by demonstrating the model's ability to select the principal market and extract a fair value or price. Given that the price is observable and quoted on an exchange, the fair value will not only be relevant but will faithfully represent the asset's economic value. Because of the fact that our fair value measurement approach uses observable inputs, the valuation should be reported as a Level 1 measure in the fair value hierarchy.[AQ: 10]

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Data Availability

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Notes

1. We use a spot price in our illustration found in the section ''Illustration: Identification of the Principal Market and Assigning a Fair Value'' of this article. However, benchmarking or an averaging technique could also be employed after we designate the principal exchange.
2. The same approach to determine a principal market can be used for both financial reporting and tax purposes.
3. Available at: https://coinmarketcap.com/exchanges/volume/24-hour/ However, as noted by Bitwise in their presentation to the U.S. Securities and Exchange Commission (SEC), there are currently 10 reliable exchanges for Bitcoin (Bitwise 2019).
4. As noted earlier, the use of a principal market is preferred under U.S. Generally Accepted Accounting Principles (GAAP) and we also believe that a principal market should be identified in the case of the cryptocurrency exchanges. The use of the alternative, the most advantageous market, is questionable given the current stage of development of the cryptocurrency exchanges. Specifically, the exchange that yields the highest net amount on sale of a cryptocurrency could

be an exchange that although active, could lack proper oversight or generate data that are uncertain as to quality or integrity. One would tend to question whether an exchange with these characteristics is in fact ''most advantageous'' from the standpoint of the market participant.

5. We are using the spot price for illustrative purposes but other benchmarks or averaging techniques can be used to determine the price or fair value at the reporting date.
6. We call this the ''freshness'' of the data.
7. The hierarchy is based on the Standard and Poor (S&P) Sovereign Foreign-Currency Ratings, S&P Institutional and Economic assessment, and whether the local currency is restricted.
8. As the ticker size is very small for most cryptocurrencies on most exchanges, the gap between best bid and best ask can also be very small. However, as is often the case, there are extremely low volumes on these quotes and, as such, the spreads do not reflect actual transactions costs or efficiency. A better measure would be the price obtained if you run the book in both directions on a reasonable size order (say 1 BTC for a BTC-USD transaction). We refer to this spread as the *effective spread*.
9. Pip is the ''percentage in points'' and represents the smallest move possible based on exchange conventions.
10. Any resemblance to existing exchanges is by coincidence.
11. These data were selected to illustrate changes in the principal exchange and therefore, we used high decay levels in our computations. The decay levels would not be as extreme in an actual setting.
12. After the valuation and reporting the investment in cryptocurrencies in the financial statements at fair value, the accountant will need to disclose the level of reliability of the inputs used to measure the fair value in the hierarchy. We understand that this can be debated. One could argue that if the observed, quoted spot price is extracted from the principal market (as we define it in this article), then the fair value could be disclosed at Level 1. Conversely, if position is taken that this fair value is determined in a market that is less active, then a Level 2 disclosure could be used. It should be noted that management assumptions are used in determining the principal market and not the final fair value measurement. It is also important to recall that the standards do not provide strict guidance as to how the principal market is to be determined and also indicate that the entity does not need to engage in an extensive search to identify the principal market but should incorporate all available information.
13. The actual names of the exchanges were removed to anonymize the data. This was necessary to comply with requests from certain exchanges included in this study.

References

European Central Bank. (2019). *Crypto-assets: Implications for financial stability, monetary policy, and payments and market infrastructures* (Occasional Paper Series No. 223). https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op223~3ce14e986c.en.pdf

Financial Accounting Standards Board. (2011). *Fair value measurement* [Accounting Standards Codification Topic 820].

International Accounting Standards Board. (2011). *Fair value measurement* [International Financial Reporting Standard 13].

Roll, R. (1984). A simple implicit measure of the effective bid-ask spread in an efficient market. *The Journal of Finance*, *39*(4), 1127–1139.