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Investigating the Efficiency of Bitcoin Futures in Price Discovery

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ABSTRACT

The present study investigates the efficiency of the Bitcoin futures in the price discovery process by assessing the lead-lag relationship between the futures and spot prices of Bitcoin. The study tests whether the Bitcoin futures market is leading the price discovery mechanism for the Bitcoin spot market. The study considers daily closing prices of both Bitcoin spot and future indices from December 12, 2017 to December 31, 2020. The stationarity of the 2 time-series variables is tested using Augmented Dickey-Fuller test while the long-run co-integrating relationship is tested using Johansen Co-integration test. To test the long-run causality, the Error Correction Mechanism framework (ECM) is used while the Wald test is applied to assess the short-run causality between the Bitcoin future and spot prices. The results of trace and max-eigen statistics indicate that there is long term co-integrating relationship between Bitcoin futures and Bitcoin spot markets. The negative significant coefficient of error correction term indicates that there is long-run causality from the Bitcoin futures towards the Bitcoin spot market. The significant Chi-square test statistics of the Wald test suggest that there is short-run causality from the Bitcoin futures towards the Bitcoin spot market. This shows that the Bitcoin futures market is acting as a leading indicator and the Bitcoin spot market as a lagging indicator. Thus, it is concluded that the price discovery is taking place between Bitcoin futures and the Bitcoin spot market. With the entrance of the new information in the cryptocurrency market, it is first observed in the Bitcoin futures followed by the Bitcoin spot prices.

Keywords: Bitcoin, Efficiency of Bitcoin Futures, Causality, Error Correction Mechanism, Johansen Co-integration Test
JEL Classifications: C01, C22, D53, G13, G14

1. INTRODUCTION

Over the past 2 years, the preference of investors towards digital assets has increased significantly. The trend also indicates that out of other digital assets, the volumes of trades received by the cryptocurrencies are significantly higher than other asset classes. Among the cryptocurrencies, some of the popular ones are Bitcoin, Litecoin, Ethereum, Zcash, Dash, Ripple, and Monero, etc. Being the pioneer in the field, Bitcoin enjoys the largest volume and market share among all cryptocurrencies. As of February 22, 2021, the market capitalization of Bitcoin is above US $1000 billion, and it has become very popular among investors especially since the beginning of 2016 when it has gained multifold in terms of price and volume (Statista, 2021). This surge is mainly due to the digital nature of cryptocurrencies that reduces the chances of frauds, not many legal formalities required, lower transaction fees, decentralization of governing power, and efficient mode of payment across the globe. On 10th December 2017, the futures contract on Bitcoin was launched and made available for trading on Chicago Board Options Exchange (CBOE) with the ticker symbol of "XBT". Following this, on 17th December 2017, the Bitcoin futures contracts were launched on Chicago Mercantile Exchange (CME) with the ticker symbol of "BTC." With the introduction of Bitcoin futures in the market, the futures prices witnessed a surge of 19% after the first day of trading (Imbert and Cheng, 2017). As suggested in the existing literature of price discovery, future prices should act as a leading indicator for all the spot market transactions (Silber, 1981). With the launch of the futures contract on Bitcoin, it is expected in the cryptocurrency market that the futures contract on Bitcoin will ensure price discovery in the market and become an important source of information for the Bitcoin spot price movements.

The study tests whether the prices of the futures contract on Bitcoin lead to the spot prices of the underlying using the time series data of both markets. The study found that there is a presence of both long-run and short-run causality from the Bitcoin futures towards the Bitcoin spot prices. This confirms that the price discovery is taking place in Bitcoins. The Bitcoin futures are acting as the leading indicators while the Bitcoin spot as the lagging indicator. With additional new information in the cryptocurrency market, it is first observed in the futures followed by the spot prices of Bitcoins. The traders in the futures market try to materialize on this price disparity and this further leads to price equilibrium in two markets. Thus, it can be concluded that with the higher efficiency, the futures contracts on Bitcoins play a very pivotal role in guiding the spot prices and further lead to ensure price discovery in the cryptocurrency market.

2. LITERATURE REVIEW

The existence of futures contracts on any security in any economy is primarily to cater to two major building blocks, price discovery and hedging. According to the price discovery mechanism, the prices of futures contracts reflect the expectations of the investors in the market in near future and this information should be incorporated in the prices of underlying securities. As a result of same, future prices should act as a leading indicator for all the spot market transactions (Silber, 1981).

In the existing literature, the researchers have tried to assess the same for different financial securities and suggested that the future market act as the leading indicator for the spot market indices. In the case of equities, Cornell and French (1983) considered the price disequilibrium between the futures and spot prices of the S&P 500 index and assessed the pricing efficiency of equity futures in the US context. Another study by Kawaller et al. (1987) tried to provide empirical evidence on the same in S&P 500 using intraday (minute-wise) data. In the Indian context using S&P CNX daily data, Rajput et al. (2012) analyzed the price discovery dynamics while in the context of Vietnam, Nhung et al. (2019) assessed and confirmed the existence of price discovery using VN 30 Index daily data. The study conducted by Sharma et al. (2020) confirmed the pricing efficiency of a futures contract in the case of BRICS countries. Similar evidence can be witnessed in the case of the commodities market where Beck (1994) tried to confirm the price discovery process by taking the sample data of eight commodities available. In another study, Yang et al. (2001) tested the pricing efficiency of commodity futures using the two types of commodities (storable and non-storable). The study found that the commodity futures prices lead the commodity spot prices and there is no effect on the storage of commodities. The issue of price discovery in the context of the energy market was assessed and confirmed by Shrestha (2014). In the Indian context, Mahalik et al. (2010) confirmed the pricing efficiency of commodity futures while in the case of metals and energy and agriculture commodities, the price discovery process was assessed by Chinn and Coibion (2014) and Dimpfl et al. (2017).

In the case of the currency market, the presence of price discovery was tested by various earlier studies conducted by Chen and Gau (2010), Osler et al. (2011), Rosenberg and Traub (2009), Kumar (2018), and Sharma and Chotia (2019). The study by Chen and Gau (2010) tried to test the same between US dollar versus Euro and Japanese Yen in presence of announcement of macro-economic news. The study found that the futures contracts on these currencies are leading the prices of underlying currencies in the spot market. The study by Osler et al. (2011) assessed the price discovery after considering the role of customers and interdealers in the market. As the output of this study, the researcher suggested the two-tier process of price discovery in the currency market.

Rosenberg and Traub (2009) assessed the same in the context of US dollar considering the data of Chicago Mercantile Exchange, Kumar (2018) analyzed using the data of USD and three currencies such as INR, ZAR, and BRL, while in the Indian context, the same was analyzed by Sharma and Chotia (2019). These studies confirmed that the prices of futures contracts on the equities, commodities, and currencies act as the leading indicator and the spot market as the lagging indicator. These studies also confirmed that there is a long-run causal relationship between the prices of futures contracts and the spot market in case of different underlying such as equities, currencies, and commodities.

The existing pieces of evidence in the cryptocurrencies are largely limited to the prediction of the efficiency of spot market time-series returns of cryptocurrencies (Brauneis and Mestel, 2018), assessment of the predictable patterns of cryptocurrencies (Phillip et al., 2018), the assessment of risk-return dynamics of cryptocurrencies (Bariviera, 2017) and assessment of information sharing among different cryptocurrencies (Qureshi et al., 2020). Although some of the existing studies have assessed the efficiency of futures prices in leading the spot prices in cryptocurrencies, these studies have not assessed the long-run causal relationship between the futures and spot prices of bitcoin using the longer-dated daily time series data. Baur and Dimpfl (2018) has assessed the same using the high-frequency trading volume and trading hours data till October 18, 2019, of the spot and futures prices of bitcoins. The study found the reverse causal relationship from spot prices to futures prices of bitcoins. The spot prices of bitcoins were acting as a leading indicator and the future as a lagging indicator. The study by Alexander and Hecky (2020) assessed the price discovery of bitcoins in the case of unregulated markets by using the used minute-level multi-dimensional information. The study found that there exists causality between the two markets with bitcoin futures leading the bitcoin spot market prices on these unregulated exchanges. In another study by Alexander et al. (2020) found that the BitMEX (a perpetual swap traded in the OTC market) is acting as a leading indicator for both volume and price level changes in the cryptocurrency market. These results were also sensitive to the different time effects such as "day-of-week and time-of-day effects."

During the initial phase of the announcement of the trading on the bitcoin futures, Karkkainen (2018) tried to assess the price discovery process between the futures and spot market prices of bitcoins using the data of the initial few months for the period as 13 December 2017 and 16 May 2018. The study concluded that the futures contracts on bitcoin were leading the spot prices in the initial few months of the introduction of bitcoin futures on CBOE followed by CME. As a robustness measure, the study also used intraday data to validate the results. The results of the intraday data were consistent with the analysis of the daily data of the initial few months. The study also supported the "role of informed traders in the bitcoin futures market to act as a leading indicator for the spot market prices." Kapar and Olmo (2019) assessed the same in the case of bitcoins by analyzing the daily time series data for the period of December 2017 to May 2018. The study computed the common factor component based on the information sharing components and found that there are certain common factors affects that affect the prices of both markets such as futures and spot prices. The price discovery equilibrium is more useful in assessing the spot prices rather than the future prices of bitcoin.

Another study by Fassas et al. (2020) used the data between January 2, 2018, and December 31, 2018, and concluded that every additional information in the bitcoin market is first reflected in the futures prices followed by the spot prices of bitcoin. The study also found the bi-directional causality between the futures and spot prices of bitcoin.

By using the high-frequency data, Akyildirim et al. (2020) used the high-frequency data to assess the pricing efficiency of futures contracts over spot prices of bitcoins and confirmed the existence of the same. The study found that the future prices lead the spot market prices in the case of bitcoin. The study also compared the efficiency of the bitcoin futures on two exchanges CBOE and CME and confirmed that the bitcoin futures on CBOE are more efficient than the one listed on CME. From the above discussion, it is evident that the efforts made to assess the price discovery process in the cryptocurrency market are limited to low sample sizes.

3. METHOD

The present study considers Bitcoin as a sample and the futures and spot prices of Bitcoin are selected for analysis of the study. The daily time series data of spot and futures (closing price) of Bitcoin are considered for the period 12th December 2017 till 31st December 2020. The data is downloaded from the financial database "investing.com." After the extraction of the data, the following standard time series methodology is used to assess the price discovery process in cryptocurrency.

3.1. Test of Stationarity

The study used the "Augmented Dickey-Fuller test (ADF)" proposed by (Dickey and Fuller, 1981) and the "Phillips and Perron test (PP)" proposed by (Phillips and Perron, 1986) to test the stationarity of spot and futures prices of Bitcoin. The standard equations of these two tests are tested and inferences were drawn considering the null hypothesis as the time series variable is stationary.

3.2. Test for Long-run Causality

To assess the order of integration between these 2 time-series variables, the study used the co-integration test proposed by Johansen and Juselius (1990). The study used Hasbrouck (1995) "Vector Error Correction Mechanism (VECM)" to examine the long-term causal relationship between the 2 time-series variables. The VECM model is estimated using the following equations 1 and 2. The "VECM framework allows comprehending the dynamic characteristics of long-run equilibrium relationship between the 2 time-series cointegrating variables" (Hasbrouck, 1995).

If the estimated error correction term (ECT) of the VECM equation is significant and negative, it directs that there is long-run causality between the two variables. The direction of the causality will be decided based on which variable is used as a dependent variable while assessing the same. The equations to test the error correction term are given below.

$$\Delta\left(Bitcoin\_S\right)_t = \alpha_1 + \sum_{i=1}^{i=n}\beta_{S,i}\Delta\left(Bitcoin\_S\right)_{t-i} + \sum_{i=1}^{i=m}\gamma_{S,i}\Delta\left(Bitcoin\_F\right)_{t-i} + \lambda_1 e_{t-1} + v_{1t} \qquad (1)$$

$$\Delta\left(Bitcoin\_F\right)_t = \alpha_1 + \sum_{i=1}^{i=n}\beta_{F,i}\Delta\left(Bitcoin\_F\right)_{t-i} + \sum_{i=1}^{i=m}\gamma_{F,i}\Delta\left(Bitcoin\_S\right)_{t-i} + \lambda_1 e_{t-1} + v_{1t} \qquad (2)$$

In Equations 1 and 2, the Δ is used to represent the first-order differencing of both bitcoin futures and bitcoin spot series, the lagged error values are presented in these equations as e_{t-1}. The β shows the coefficient of the speed adjustment of convergence of the ECT while the in the long-term equilibrium and □ shows the short-term speed adjustment coefficient. For the selection of the optimal lag length, the study used the VAR framework and assessed the optimal number of lags by considering the lowest AIC and SIC Values as criteria.

3.3. Test for Short-run Causality

After the assessment of long-run causality between future and spot prices of Bitcoin, the Wald (1943) test is applied to examine the short-run causality between the 2 time-series variables. This test assumes that the coefficients of the lagged values of the ECT are equals to zero. In the case of equation 1, where the objective is to assess the causality from bitcoin futures to bitcoin spot prices, the following null hypothesis is tested.

Null:
CD(FUTURE(−1))=CD(FUTURE(−2))=CD(FUTURE(−3))CD (FUTURE(−4))=CD(FUTURE(−5))=CD(FUTURE(−6))=0

Where CD(FUTURE(−1)) is the coefficient of the first lagged values of bitcoin futures, CD(FUTURE(−2)) is the coefficient of the second lagged value of bitcoin futures, and so on.

If the Wald test statistic is significant, then this null hypothesis will be rejected. This confirms that there is strong evidence to support the short-run causality from futures to spot prices of Bitcoin.

4. RESULTS

The time-series movement of the Bitcoin futures and Bitcoin spot for the sample period of 12th December 2017–31st December 2020 are given below (Figure 1). The chart is clearly showing that both the Bitcoin futures and Bitcoin spot prices have witnessed high volatility over 4 years.

The stationarity of the daily closing price of Bitcoin futures and Bitcoin spot were tested using ADF and PP test (Table 1). From the table, it is evident that both ADF test statistics for Bitcoin futures and Bitcoin spot were insignificant at the level as the P-values were higher than 0.05. This confirms that both the variables are having problems of unit root at the level. After this, the stationarity of both the time series is tested on the first difference. The results are showing that the ADF test statistics for Bitcoin futures and Bitcoin spot are −30.91 and −31.16 with P = 0.000 and 0.000 respectively. This shows that the test statistics are significant and confirms that there is no problem of a unit root in the 2 time-series variables. This also confirms the order of integration between the two variables as I(1). Similar results were also found by the PP test statistics where it was non-stationary at the level in case of both variables while the results of PP-test become significant at first difference.

To test the co-integration between the Bitcoin futures and Bitcoin spot prices, Johansen and Juselius (1990) test of co-integration is used. The results of Trace Statistics (Table 2) indicate that with the Trace Statistics of 101.63 and P = 0.0001, the null hypothesis of "no co-integrating relationship between the Bitcoin futures and Bitcoin spot prices" is rejected while the results fail to reject the next null hypothesis of "At most 1 co-integration relationship between Bitcoin futures and Bitcoin spot prices" (as the Trace statistics for this hypothesis is 2.355 with a P = 0.1248. The results of Max Eigen Statistics (Table 3) supported these findings. These findings are supported by the results reported in Table 3 (Max Eigen Statistic). The Max Eigen statistics also concluded that "there is At most 1 co-integration relationship exists between the Bitcoin futures and Bitcoin spot prices."

Figure 1: Time series plot of bitcoin spot and future prices

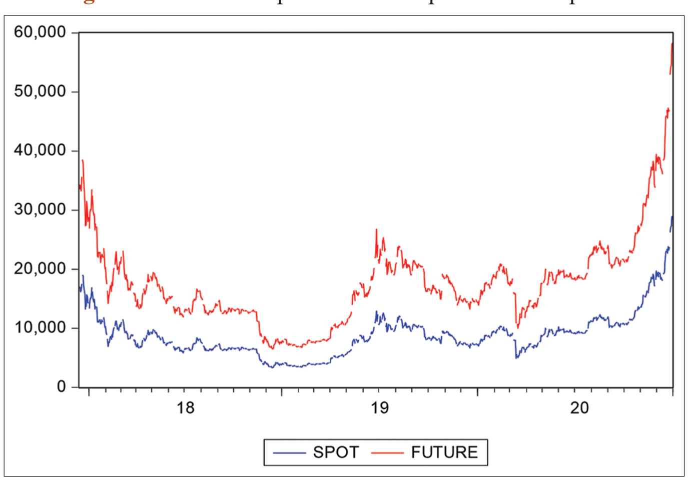

Table 1: Unit root test

Variable	ADF	P-value	PP	P-value
Bitcoin_Spot				
Level	1.71544	0.9997	1.74548	0.9997
First Difference	−30.9120**	0.0000	−30.9221**	0.0000
Bitcoin_Futures				
Level	1.76394	0.9997	1.74827	0.9997
First Difference	−31.1660**	0.0000	−31.1767**	0.0000

**Significant at 1% level of significance

After confirming the co-integration relationship between the two variables, the error correction mechanism (ECM) is used to investigate the long-run causality between the futures and spot prices of Bitcoin. The results (Table 4) show that the coefficient of the ECT is −0.3314 with a respective P = 0.039. This shows that the ECT is negative and significant at a 5% level of significance. This confirms the long-run causality between the futures and spot prices of Bitcoin. The futures contracts on Bitcoin lead the spot market prices of Bitcoin in the long run.

The results of the Wald test (Table 5) indicate that the value of the Chi-square test is significant with statistics of 20.76 with a P = 0.0020. This directs to reject the null hypothesis that the first six lagged coefficients of Bitcoin futures are like each other and equivalent to zero. Thus, it is concluded that there is short-run causality between the futures prices and the spot market prices of Bitcoin.

Table 2: Trace statistics

Null	Eigenvalue	Trace statistic	0.05 Critical value	Prob.**
None *	0.100030	101.6370	15.49471	0.0001
At most 1	0.002498	2.355859	3.841466	0.1248

Table 3: Max Eigen statistics

Null	Eigenvalue	Max Eigen statistic	0.05 Critical value	Prob.**
None *	0.100030	99.28109	14.26460	0.0000
At most 1	0.002498	2.355859	3.841466	0.1248

Table 4: Results of error correction mechanism

CointEq1	−0.331416 (1.98352)	0.917570 (5.37072)
D (SPOT(−1))	−0.586281 (−3.36168)	−0.138280 (−0.81660)
D (SPOT(−2))	−0.641510 (−3.78840)	−0.342253 (−2.08160)
D (SPOT(−3))	−0.357447 (−2.23464)	−0.121318 (−0.78112)
D (SPOT(−4))	−0.306780 (−2.10891)	−0.173880 (−1.23106)
D (SPOT(−5))	−0.267082 (−2.13093)	−0.253790 (−2.08544)
D (SPOT(−6))	0.027630 (0.30297)	−0.032463 (−0.36661)
D (FUTURE(−1))	0.586831 (3.47514)	0.173205 (1.05637)
D (FUTURE(−2))	0.652751 (3.95198)	0.321976 (2.00766)
D (FUTURE(−3))	0.387316 (2.47177)	0.187492 (1.23232)
D (FUTURE(−4))	0.280710 (1.97570)	0.149753 (1.08552)
D (FUTURE(−5))	0.227732 (1.84152)	0.247491 (2.06116)
D (FUTURE(−6))	0.011080 (0.12765)	0.053979 (0.64051)
C	11.81144 (0.85604)	10.91578 (0.81479)

Table 5: Wald test statistics

Test statistic	Value	df	Probability
F-statistic	3.460793	(6, 928)	0.0022
Chi-square	20.76476	6	0.0020

5. DISCUSSION AND CONCLUSION

From the results reported in the previous section, it is evident that both the time series variables are having the first order of integration. The results of both trace statistics and max-eigen statistics of Johansen and Juselius (1990) also confirm that there is long term co-integrating relationship between futures and spot prices of Bitcoin. The results of ECM indicate that there is long-run causality between the futures and spot prices of Bitcoin. The Bitcoin futures lead the Bitcoin spot market prices in the long run. The evidence also supports the presence of short-run causality between the Bitcoin futures prices and the Bitcoin spot prices. Thus, the findings reject the hypothesis that no price discovery process takes place between futures and spot markets prices of Bitcoin. This also confirms that the futures prices of Bitcoin are more efficient than the spot prices. The expectations of the investors are first reflected in the Bitcoin futures followed by the Bitcoin spot market. This is due to the exploitation of the price mismatch between the two markets by the traders and arbitrageurs. The traders try to book arbitrage profit due to the price mismatch between the two markets and this leads to the equilibrium of prices between the two markets.

The present study aims to assess the price discovery process between the Bitcoin futures and Bitcoin spot markets. The study tries to assess the long-run and short-run causality between Bitcoin futures and spot markers using the daily time-series data since the inception of Bitcoin futures till the end of 2020. The results reported in the study show that both the Bitcoin futures and Bitcoin spot markets are co-integrated with each other. There is strong evidence to support the presence of both long-run and short-run causality from the Bitcoin futures towards the Bitcoin spot market. As the present study tries to investigate the price discovery process in cryptocurrencies, the study concludes that price discovery is taking place in the Bitcoin futures market. The Bitcoin futures market is acting as the leading indicator while the Bitcoin spot market is acting as the lagging indicator in the lead-lag relationship between the Bitcoin futures and Bitcoin spot market. With additional new information in the cryptocurrency market, it is first observed in the Bitcoin futures followed by the Bitcoin spot prices. The traders in the futures market try to take advantage of this price mismatch and this further leads to price equilibrium in two markets. Thus, it can be concluded that with the higher efficiency, the Bitcoin futures market plays a very significant role in the price discovery process in the cryptocurrency market. The importance of Bitcoin futures in the price discovery process further increases with the fact that the overall volume traded in the futures market is much lower than the Bitcoin spot market. This confirms that there is a greater level of transparency in the Bitcoin futures market as compared to the spot market and this leads to reflection of the expectations of the investors in futures prices first followed by the spot prices of Bitcoins.

The findings of the study can be utilized by the regulators of financial markets in different economies as in many economies, cryptocurrencies are not yet allowed to trade. Since the study reveals that the investors are keen to express their expectations in the cryptocurrency futures market, the stock exchanges of the different economies can start offering futures contracts on the different cryptocurrencies such as Bitcoin, Litecoin, Ethereum, Zcash, Dash, Ripple, and Monero so that more trading options are available to the investors and it is further leading to more liquidity in the cryptocurrency market.

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