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# Did the introduction of Bitcoin futures crash the Bitcoin market at the end of 2017?☆

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ABSTRACT

At the end of 2017, the Bitcoin price dropped significantly by approximately 70% over the two months. Since the introduction of Bitcoin futures coincided with this market crash, it is said that the new financial instrument might have caused the market crash. The literature states that the futures enabled investors to easily take a short position and hypothesizes that the selling pressure from futures could have potentially crashed the Bitcoin market. To evaluate this assumption, we investigate the empirical relationship between futures trading and the Bitcoin price by using high-frequency data. We find that Bitcoin futures trading was not significantly related to the returns on Bitcoin futures and spot returns. Therefore, we conclude that Bitcoin futures did not lead to the crash of the Bitcoin market at the end of 2017.

## 1. Introduction

Since the introduction of Bitcoin futures markets coincided with the Bitcoin market crash, it is said that this new financial instrument might have caused the crash. Hale et al. (2018) emphasize that Bitcoin futures enabled investors to take short positions more easily, and the selling pressure from the futures could have potentially crashed the Bitcoin market. If this is the case, the selling pressure from Bitcoin futures trading should have significantly influenced the depreciation of the spot market, meaning that Bitcoin futures trading and the spot price should have been significantly correlated. However, there is no empirical research that directly verifies this comovement.

Our paper is the first to fill this gap by exploiting intraday data. We use the Bitcoin spot price from Gemini, a leading cryptocurrency exchange; match this price with the Bitcoin futures trading volume at 5-minute intervals; and check whether the introduction of Bitcoin futures could affect the Bitcoin spot and futures prices. We find that Bitcoin futures trading was not significantly related to Bitcoin futures returns and spot returns. This evidence casts doubt on the view that the crash was induced by the introduction of Bitcoin futures. Our findings can thus change the biased view on the introduction of Bitcoin futures since mass media criticized the

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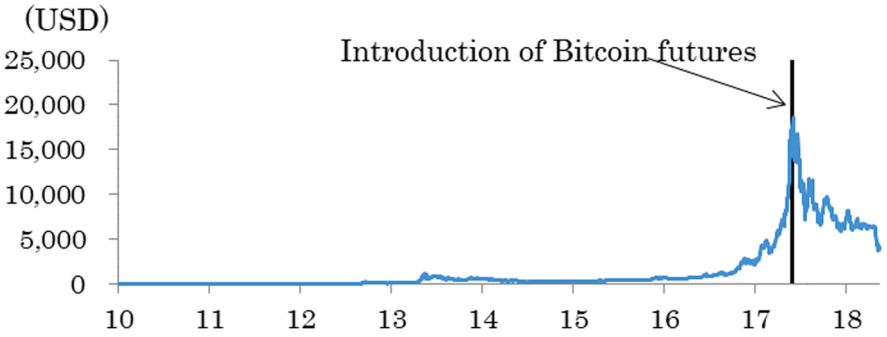



**Fig. 1.** Bitcoin closing prices. Source: Bloomberg.

introduction of Bitcoin futures without any empirical evidence.[1]

As our methodology, we first rely on Liu et al. (2020) who also discuss the effect of the introduction of Bitcoin futures on Bitcoin returns. We regress Bitcoin returns on futures trading to assess whether this introduction affects Bitcoin returns. Our baseline regression is based on the 5-minute returns for shares traded on Gemini, but we also use different intervals, such as the 15- and 30-minute returns. To check the robustness of our results, we use different data sources, such as Coinbase and Kraken, both of which are leading Bitcoin exchanges, where hourly data are available.[2]

To evaluate the persistent effect on Bitcoin returns, we employ a vector autoregressive (VAR) model to investigate how Bitcoin futures trading affected the Bitcoin spot market. We find an insignificant accumulated response of Bitcoin spot and futures with the shock of Bitcoin futures trading.

***Literature Review***: Our paper is related to previous studies on price discovery between Bitcoin futures and spot markets.[3] Some claim that the Bitcoin futures market dominates the price discovery process (Karkkainen, 2018; Kapar & Olmo, 2019) whereas others claim that the spot market dominates (Corbet et al., 2018; Baur & Dimpfl, 2019). Following these results, we investigate how Bitcoin futures trading affected the Bitcoin spot market and vice versa. Hattori and Ishida (2020) examine how investors arbitrage the Bitcoin spot and futures markets.

Several studies investigate the impact of the introduction of Bitcoin futures (Fassas et al., 2020; Kim et al., 2020; Jalan et al., 2019). Among them, Liu et al. (2020) address the same research question as our paper and find a significant and negative relationship between the introduction of Bitcoin futures and Bitcoin returns. Note that Liu et al. (2020) use daily data covering the period from June 2017 to June 2018 where we focus on the crash period (December 2017 to January 2018) using high-frequency data. We find that our results are robust, even when we use a model with high-frequency data similar to that of Liu et al. (2020).

Hale et al. (2018) emphasize that Bitcoin futures enabled investors to take a short position more easily; and from a theoretical point of view, the selling pressure from the futures could have potentially crashed the Bitcoin market. They draw comparisons to the rise and collapse of the home financing market in the 2000s in which the mortgage boom was driven by financial innovations in securitization and groupings of bonds that attracted optimistic investors (Fostel & Geanakoplos, 2012).

Therefore, the main contribution of our paper is that it is the first empirical research study to explore whether the introduction of Bitcoin futures crashed the Bitcoin market. Hale et al. (2018) study this issue, but to the best of our knowledge, no empirical research exists on this subject. Since the futures market is essential for mature financial markets, investigating how the introduction of futures affected Bitcoin is important for a sound Bitcoin market. However, we find little evidence that the introduction of Bitcoin futures crashed the Bitcoin market.

The remainder of this paper is organized as follows. Section 2 explains the Bitcoin futures and arbitrage conditions. Section 3 describes the empirical strategy and data. Sections 4 and 5 report the empirical results. Finally, Section 6 concludes the paper.

## 2. Bitcoin market crash at the end of 2017 and the introduction of Bitcoin futures

### *2.1. Crash in the Bitcoin market at the end of 2017*

Bitcoin experienced a drastic price surge during 2017 from less than 1,000 BTC/USD to approximately 20,000 BTC/USD (Fig. 1). However, this trend has reversed since December 2017, with the largest decline being from December 2017 to February 2018.[4] Its price is currently approximately 14,000 BTC/USD (as of November 4, 2020) (Fig. 1).

Since this price decline coincided with the launch of the major Bitcoin futures markets (the Chicago Board Options Exchange's

[1] See Kelleher, Kevin (2018) "Bitcoin Futures Killed the Bitcoin Rally (and Will Keep It from Returning), Economists Say." Fortune, July 2.

[2] Ranked by trading volume, Coinbase and Kraken are the 3rd and 4th largest exchanges worldwide, respectively (as of July 27, 2020, see https://coinmarketcap.com).

[3] Alexander et al. (2020) study the price discovery for Bitcoin futures using BitMEX (a leading cryptocurrency exchange in Hong Kong).

[4] From approximately 20,000 USD/BTC (December 17, 2017) to 6,000 USD/BTC (February 6, 2018) (https://coinmarketcap.com).

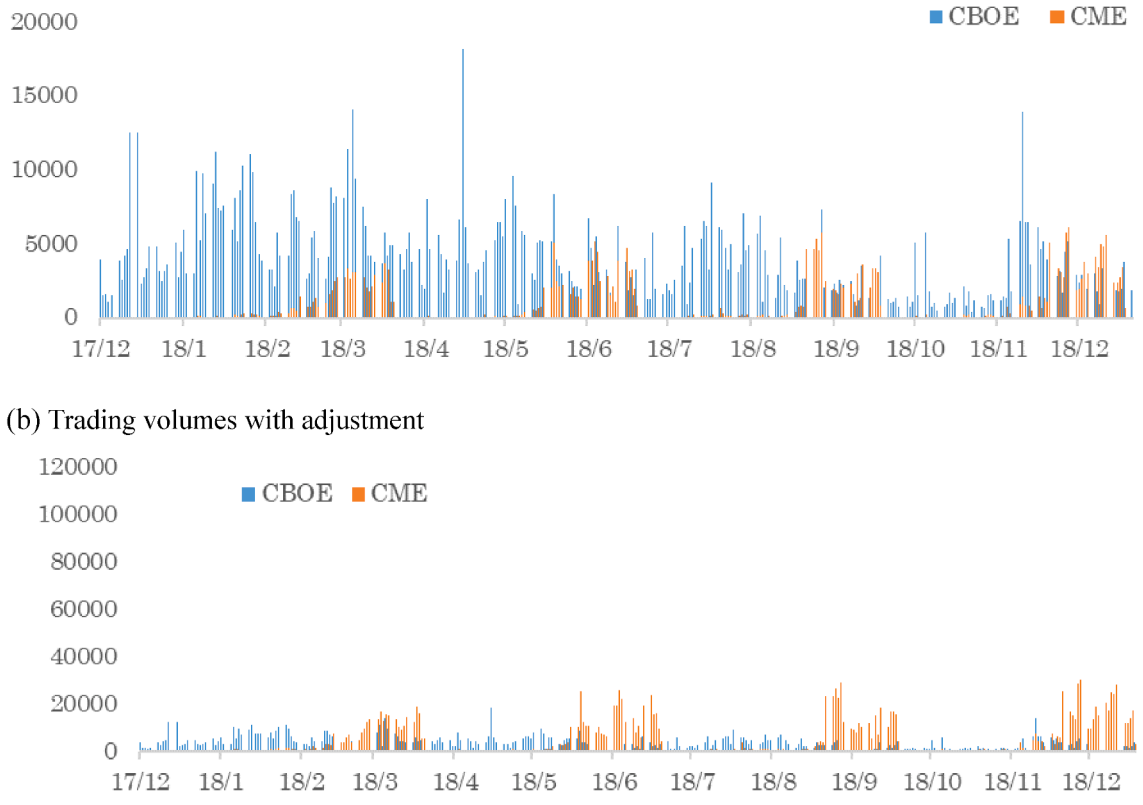



**Fig. 2.** Trade volume of CBOE's and CME's Bitcoin futures. (a) Trading volumes without adjustment. (b) Trading volumes with adjustment. Note: In Fig. 2 (b), the contract unit of Bitcoin futures in CME and CBOT is adjusted. The contract unit of CBOE futures is 1 BTC while the contract unit of CME futures is 5 BTC. Source: Bloomberg.

[CBOE] market launched on December 10, 2017, and the Chicago Mercantile Exchange's [CME] market launched on December 18, 2017), several studies suspect that the introduction of the futures market affected the Bitcoin spot market price. For example, Hale et al. (2018) claim that the futures market encouraged institutional investors to short sell Bitcoins, which led to a sharp decline in the Bitcoin price. Similar opinions were expressed by mass media.

However, other studies argue against this claim. For instance, Köchling et al. (2019) believe that the launch of the Bitcoin futures market made the Bitcoin market more informationally efficient. A CME managing director stated that the futures market is not to be blamed for the bear market.[5] Such opinions are also reported in the mass media.

Nevertheless, neither opinion is supported by empirical evidence. Therefore, our study is the first to provide statistical evidence on this issue. Surprisingly, both opinions are (somewhat) supported by the empirical findings. In the short run, the former opinion could be supported, whereas the latter is valid in the long run. Moreover, there were arbitrage opportunities between the futures and spot markets immediately after the launch of the futures market, indicating that our findings support the latter opinion.

### *2.2. The features of the CBOE's Bitcoin futures: Why we use CBOE futures instead of CME futures*

Bitcoin futures are cash-settled based on Gemini's auction price for Bitcoin and denominated in USD. Gemini Trust Company LLC (Gemini) is a leading cryptocurrency exchange in New York that deals with five major cryptocurrencies including Bitcoin. CBOE Bitcoin futures are priced off the Gemini auction at 4 PM ET on the final settlement date, that is, two business days prior to the third Friday of every month. The margin requirement is 40% of the daily settlement price, reflecting the relatively high volatility of the Bitcoin price. Moreover, the minimum required speculative customer initial margin is 44% of the daily settlement price.

The contract unit of CBOE futures is 1 BTC, which is significantly smaller than the contract unit of CME futures of 5 BTC. The

[5] See https://www.coindesk.com/dont-blame-bitcoin-futures-for-bear-market-cme-exec-says.

**Table 1**
Descriptive statistics for Bitcoin returns and Bitcoin futures trading.

| | Mean | Median | Max | Min | Std. Dev. | Skewness | Kurtosis | Num of Obs |
|---|---|---|---|---|---|---|---|---|
| Bitcoin futures return | −0.00003 | 0 | 0.112 | −0.084 | 0.006 | 0.718 | 30.768 | 9316 |
| Bitcoin futures trading | 19.23645 | 11.000 | 365 | 1 | 26.289 | 4.121 | 30.923 | 9316 |
| Bitcoin return | −0.00003 | 0.000 | 0.089 | −0.103 | 0.006 | 0.757 | 33.173 | 9316 |

Notes: This table shows the descriptive statistics of Bitcoin returns and Bitcoin futures trading. The data are 5-minute based.

CBOE's regular trading hours are from 9:30 AM ET to 4:15 PM ET on weekdays. Extended hours are from 6 PM ET on Sundays to 9:30 AM ET on Mondays and from 4:30 PM ET on Mondays to 9:30 AM ET on Fridays. Although there are other leading cryptocurrency exchanges, such as Binance, Huobi Global, and Coinbase, a salient characteristic of Gemini is that it holds a double auction between cryptocurrencies and the USD.[6] The BTC/USD auction is held at 4 PM ET every day, including weekends and holidays, where only registered Gemini customers may participate. This auction starts accepting orders at 8 AM ET, runs the first auction simulation at 3:50 PM ET, and then runs auction simulations from 3:51 PM ET to 3:59 PM ET every minute. The minimum quantity to participate in this auction is 10 BTC.

We use the data on CBOE futures instead of CME futures for the following reasons. First, we can only obtain intraday data on the trading volume and closing price for CBOE futures. Second, the schemes of these products are almost identical with a few differences (i.e., the correlation coefficient of the prices is approximately 1.0). Third, the trading activity of CBOE far exceeds that of the CME based on Bloomberg data. Fig. 2(a) shows the trading volumes of CBOE and CME futures. As we described above, the contract unit of CBOE futures is 1 BTC, which is smaller than that of CME futures (5 BTC). Fig. 2(b) adjusts for this difference. Fig. 2(a) and (b) confirm that the trading volume of the CBOE is far greater that of the CME from December 2017 to January 2018.

## 3. Empirical strategy and data description

### 3.1. Data

We use the 5-minute data for Bitcoin returns from CryptoDataDownload and the 5-minute data for the CBOE futures price and trading volume on active contracts from Bloomberg. Table 1 shows the descriptive statistics of the variables used in our analysis. The Bitcoin futures and spot returns are negative during this period. Because we use 5-minute data, the number of observations is 9,316. The mean Bitcoin futures trade is approximately 19 with a maximum of 365 and a minimum of 1.

For robustness, we also use the Bitcoin prices for trades on Coinbase and Kraken, although these prices does not underly Bitcoin futures. For Coinbase and Kraken, we can obtain hourly data; thus, we use hourly data for the robustness of this baseline estimation.

### 3.2. Baseline model with the intraday trade data of Bitcoin futures

To detect whether the introduction of Bitcoin futures crashed the Bitcoin spot market, we first use a model based on Liu et al. (2020):

$$R_t = \alpha + \beta R_{t-1} + \gamma R_{t-2} + \delta futures_t + \varepsilon_t \tag{1}$$

where $R_t$ is the Bitcoin spot return, $futures_t$ is Bitcoin futures trading, and $\varepsilon_t$ is the error term at time $t$. As we discuss in the Introduction, our analysis uses high-frequency data whereas Liu et al. (2020) use daily data from a relatively longer period. The data of Liu et al. (2020) cover the period from June 11, 2017, to June 10, 2018, comprising half a year before and after the futures launch.

We use the 5-, 15-, and 30-minute data from Gemini. Then, we use the hourly data from Coinbase and Kraken, where only hourly data are available, in addition to the hourly data from Gemini.

Due to the importance of investor sentiment, we include the Google search volume for "Bitcoin", as included in Liu et al. (2020), and estimate the equation as follows:

$$R_t = \alpha + \beta R_{t-1} + \gamma R_{t-2} + \delta futures_t + \theta Google_{t-1} + \varepsilon_t \tag{2}$$

where $Google_t$ is the Google search volume for "Bitcoin" at time $t$. Because the Google search volume data obtained by *Google Trends* are produced daily, we conduct this regression on a daily basis.

### 3.3. VAR using the intraday trade data of Bitcoin futures

To investigate the effect of persistence, we examine the empirical relationship between Bitcoin returns and transaction activity using a VAR model, which is widely used in the literature on the asset pricing of cryptocurrencies. For example, Koutmos (2018)

[6] Ranked by trading volume, Binance, Huobi Global, and Coinbase are the 1st, 2nd, and 3rd largest exchanges worldwide, respectively, while Gemini is the 67th largest exchange worldwide (as of July 27, 2020, https://coinmarketcap.com).

**Table 2**
Estimation results based on 5-, 15-, and 30-minute data.

| | 5 min | | 15 min | | 30 min | |
|---|---|---|---|---|---|---|
| | Dec 19, 2017-Dec 30, 2017 | Dec 10, 2017-Jan 30, 2018 | Dec 10, 2017-Dec 30, 2017 | Dec 10, 2017-Jan 30, 2018 | Dec 10, 2017-Dec 30, 2017 | Dec 10, 2017-Jan 30, 2018 |
| $R_{t-1}$ | −0.0544 | −0.0416 | −0.0355 | −0.0270 | −0.0238 | 0.0108 |
| | (−1.352) | (−2.116) | (−0.642) | (−0.921) | (−0.560) | (0.399) |
| $R_{t-2}$ | −0.0600 | −0.0192 | 0.0806 | 0.0383 | 0.0454 | −0.0133 |
| | (−1.776) | (−0.942) | (1.723) | (1.331) | (0.567) | (−0.284) |
| $Futures_t$ | 0.0000101 | 0.0000009 | 0.0000085 | 0.0000011 | 0.0000076 | 0.0000010 |
| | (1.230) | (0.319) | (1.307) | (0.337) | (1.120) | (0.286) |
| Constant | −0.0001 | 0.0000 | −0.0004 | −0.0001 | −0.0007 | −0.0003 |
| | (−1.031) | (−0.618) | (−1.088) | (−0.640) | (−1.017) | (−0.638) |
| Obs | 3467 | 9314 | 1153 | 3102 | 575 | 1549 |
| R2 | 0.0063 | 0.0017 | 0.0077 | 0.0013 | 0.0001 | −0.0016 |

*Note:* This table shows the estimation results based on Eq. (1). The t-statistics based on Newey and West (1987) are in parentheses.

**Table 3**
Estimation results based on 5-, 15-, and 30-minute data using log (futures trading) as an independent variable.

| | 5 min | | 15 min | | 30 min | |
|---|---|---|---|---|---|---|
| | Dec 10, 2017-Dec 29, 2017 | Dec 10, 2017-Jan 30, 2018 | Dec 10, 2017-Dec 29, 2017 | Dec 10, 2017-Jan 30, 2018 | Dec 10, 2017-Dec 29, 2017 | Dec 10, 2017-Jan 30, 2018 |
| $R_{t-1}$ | −0.0537 | −0.0416 | −0.0341 | −0.0270 | −0.0223 | 0.0105 |
| | (−1.337) | (−2.115) | (−0.628) | (−0.921) | (−0.542) | (0.388) |
| $R_{t-2}$ | −0.0596 | −0.0192 | 0.0827 | 0.0384 | 0.0437 | −0.0138 |
| | (−1.764) | (−0.942) | (1.745) | (1.330) | (0.550) | (−0.295) |
| $Futures_t$ | 0.00005 | 0.00000 | 0.00018 | 0.00002 | −0.00001 | −0.00022 |
| | (0.395) | (0.046) | (0.444) | (0.106) | (−0.014) | (−0.532) |
| Constant | −0.0001 | 0.0000 | −0.0006 | −0.0002 | 0.0000 | 0.0008 |
| | (−0.405) | (−0.284) | (−0.475) | (−0.242) | (0.015) | (0.447) |
| Obs | 3467 | 9314 | 1153 | 3102 | 575 | 1549 |
| R2 | 0.0053 | 0.0017 | 0.0059 | 0.0013 | −0.0028 | −0.001465 |

*Note:* This table shows the estimation results based on Eq. (1). In this regression, we take the log of futures trading, which is one of the independent variables. The t-statistics based on Newey and West (1987) are in parentheses.

examines the empirical linkages between Bitcoin returns and transaction activity using the VAR with Cholesky decomposition. Urquhart (2018) and Shen et al. (2019) use a VAR model to conduct Granger causality testing.

To estimate the VAR model, we use two endogenous variables: the Bitcoin futures trading volume and Bitcoin returns (Bitcoin futures and Bitcoin spot returns). To compute the impulse response function, we first order the Bitcoin futures trading volume using Cholesky factorization, and we also use different orders of the variables. We determine the lag length based on the Schwarz–Bayesian information criterion.[7]

This is a widely used strategy to change the ordering of the variables to compute the impulse response function when the shock is identified by Cholesky factorization, although this is still restrictive. Therefore, for robustness, we compute the generalized impulse response proposed by Pesaran and Shin (1998). Unlike Cholesky factorization, this approach does not require the orthogonalization of shocks and is invariant to the ordering of the variables in the VAR.

## 4. Empirical results

### *4.1. Regression results based on 5-, 15-, and 30-minute data*

Table 2 shows the estimation result based on Eq. (1). In this estimation, we use the 5-, 15-, and 30-minute data for the Bitcoin price for Bitcoin traded on Gemini. The periods are (i) from December 10, 2017 to December 30, 2017 and (ii) from December 10, 2017 to January 30, 2018. Even when we use different intervals and periods, these results suggest that the trading of Bitcoin futures has an insignificant effect on Bitcoin spot returns. Compared with our results, Liu et al. (2020) find that the launch of Bitcoin futures was responsible for the Bitcoin crash.

Because futures trading is skewed, we take the logarithm of this variable as an independent variable. Table 3 shows the estimation result when we take the log of futures trading. This result suggests that Bitcoin futures trading has an insignificant effect on Bitcoin spot returns, which is consistent with Table 2.

[7] The information criterion used five as the lag length.

**Table 4**
Estimation results based on daily data.

| | Dec 2017-Jan 2018 | Dec 2017-March 2018 | Dec 2017-June 2018 | Dec 2017-Dec 2018 |
|---|---|---|---|---|
| $R_{t-1}$ | −0.3613 | −0.1547 | −0.0646 | −0.0561 |
| | (−2.867) | (−1.802) | (−0.897) | (−0.965) |
| $R_{t-2}$ | −0.5548 | −0.1238 | −0.0492 | −0.0831 |
| | (−3.734) | (−0.915) | (−0.516) | (−1.070) |
| $Google_{t-1}$ | −0.0011 | −0.0004 | −0.0002 | −0.0001 |
| | (−1.579) | (−0.884) | (−0.613) | (−0.503) |
| $Futures_t$ | −0.000010 | −0.000006 | −0.000004 | −0.000003 |
| | (−2.430) | (−1.848) | (−2.091) | (−2.447) |
| Constant | 0.0804 | 0.0349 | 0.0161 | 0.0118 |
| | (2.448) | (1.469) | (1.515) | (1.962) |
| Obs | 32 | 72 | 136 | 261 |
| R2 | 0.1796 | 0.0134 | 0.0126 | 0.0278 |

*Note:* This table shows the estimation results based on Eq. (2). The t-statistics based on Newey and West (1987) are in parentheses. Daily data are used in this regression.

### *4.2. Regression results based on daily data (including search volume)*

To check the results using daily data, we conduct the regression based on Eq. (2). Following Liu et al. (2020), we include the Google search volume for Bitcoin. The periods are (i) from December 10, 2017 to January 30, 2018, (ii) December 10, 2017 to 31 March 2018, (iii) December 10, 2017 to June 31, 2018, and (iv) December 10, 2017 to December 30, 2018. In contrast to Table 2, Table 4 suggests that Bitcoin futures trading has a significantly negative significant effect on Bitcoin spot returns. From December 2017 to March 2018, the results are significant at the 10% level, while the other results are significant at the 5% level. This is the same result as Liu et al. (2020). Table 4 shows that the coefficient for the Google search is insignificant, which is also consistent with Liu et al. (2020).

These results show that the coefficient of futures trading is statistically negative for Bitcoin returns. In addition, this relationship is not robust when we use more detailed data, such as 5-minute data. If the introduction of Bitcoin futures crashed the market, trading should have negatively affected the returns, even if we examine the relationship in more detail.

Our result might be biased because we use the data on Bitcoin traded on Gemini. Our result might be a consequence of the low ranking of the Gemini exchange. Therefore, we use the hourly data of the Bitcoin prices for Bitcoin traded on Coinbase and Kraken. We obtain the result that futures trading does not affect Bitcoin returns, which is consistent with the results of Table 3.

## 5. Empirical results of the VAR analysis

We examine the connection between the trading of Bitcoin futures and the Bitcoin futures and spot returns. The hypothesis that the crash is due to the introduction of futures could be empirically supported if the impulse response of Bitcoin trading to Bitcoin futures and spot returns is significantly negative. If the impulse response is not significant, the data should not support the hypothesis that the crash is caused by the introduction of the futures.

Fig. 3(a) shows the accumulated response of Bitcoin spot returns with the shock of the Bitcoin futures trading volume. We use a one standard deviation shock to compute the impulse response function. We also compute the accumulated response based on the impulse response function. Fig. 3(a) suggests that the trade of futures does not have a significant effect on the price.

Fig. 3(b) depicts the accumulated response of Bitcoin spot returns with the shock of the Bitcoin futures trading volume when the ordering of variables is reversed (the Bitcoin spot return is first), which suggests that the trading of futures does not have a negative impact; thus, the neutrality of Bitcoin futures is robust despite the different order. As a robustness check, we compute the generalized impulse response, which does not depend on the order of variables. Fig. 3(c) shows the generalized impulse response of Bitcoin futures returns with the shock of the Bitcoin futures trading volume, which shows that futures trading is insignificant at the 5% significance level in the long run. Our results are also robust if we use a different lag length for the VAR.

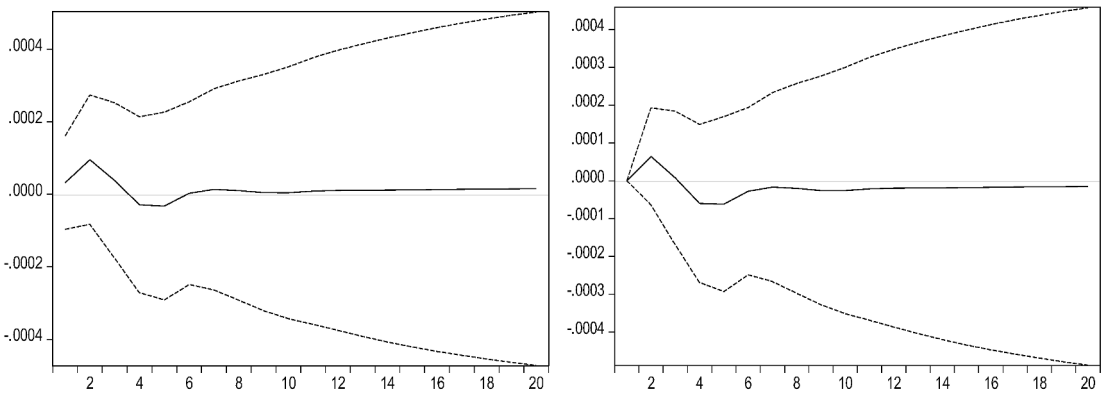
## 6. Conclusions

Our study analyzes how the introduction of Bitcoin futures affects the Bitcoin price, suggesting that their effect is neutral in the long run. We match the data on the Bitcoin futures market with those on the Bitcoin spot market to create 5-minute data. We find that Bitcoin futures trading was not significantly related to the returns on Bitcoin futures and spot returns. As a result, we conclude that the introduction of Bitcoin futures did not crash the Bitcoin spot market at the end of 2017.

## Declaration of Competing Interest

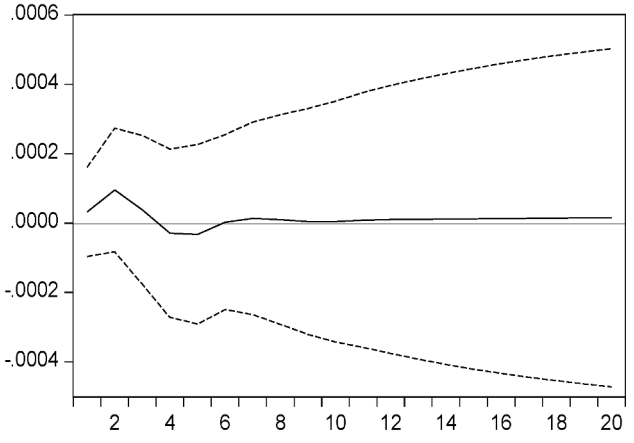
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

(a) Bitcoin futures trade ordered first (b) Bitcoin futures return ordered first




Note: Shocks are defined as Cholesky one standard deviation innovations. The dashed lines show the ±2 standard error bands around the impulse response.

(c) General impulse response




Note: Shocks are defined as one standard deviation innovations. The dashed lines show the ±2 standard error bands around the impulse response.

**Fig. 3.** Accumulated response of Bitcoin returns with the shock of Bitcoin's futures trading. (a) Bitcoin futures trade ordered first. (b) Bitcoin futures return ordered first. Note: Shocks are defined as Cholesky one standard deviation innovations. The dashed lines show the ±2 standard error bands around the impulse response. (c) General impulse response. Note: Shocks are defined as one standard deviation innovations. The dashed lines show the ±2 standard error bands around the impulse response.

## References

Alexander, C., Choi, J., Park, H., & Sohn, S. (2020). BitMEX bitcoin derivatives: Price discovery, informational efficiency, and hedging effectiveness. *Journal of Futures Markets, 40*(1), 23–43.
Baur, D. G., & Dimpfl, T. (2019). Price discovery in Bitcoin spot or futures? *Journal of Futures Markets, 39*(7), 803–817.
Corbet, S., Lucey, B., Peat, M., & Vigne, S. (2018). Bitcoin futures—What use are they? *Economics Letters, 172*, 23–27.

Fostel, A., & Geanakoplos, J. (2012). Tranching, CDS, and asset prices: How financial innovation can cause bubbles and crashes. *American Economic Journal: Macroeconomics, 4*(1), 190–225.
Fassas, A., Papadamou, S., & Koulis, K. (2020). Price discovery in Bitcoin futures. *Research in International Business and Finance, 52*, 1011160.
Hale, G., Krishnamurthy, A., Kudlyak, M., & Shultz, P. (2018). *How futures trading changed Bitcoin prices*. Federal Reserve Bank of San Francisco: FRBSF Economic Letter.
Hattori, T., & Ishida, R. (2020). The relationship between arbitrage in futures and spot markets and Bitcoin price movements: Evidence from the Bitcoin markets. *Journal of Futures Markets*.
Jalan, A., Matkovskyy, R., Urquhart, A., 2019. What if Bitcoin futures had never been introduced? Working Paper.
Kapar, B., & Olmo, J. (2019). An analysis of price discovery between Bitcoin futures and spot markets. *Economics Letters, 174*, 62–64.
Karkkainen, T., 2018. Price discovery in the Bitcoin futures and cash markets. SSRN Working Paper 3243969.
Kim, W., Lee, J., & Kang, K. (2020). The effects of the introduction of Bitcoin futures on the volatility of Bitcoin returns. *Finance Research Letters, 33*, Article 101204.
Köchling, G., Müller, J., & Posch, P. N. (2019). Does the introduction of futures improve the efficiency of Bitcoin? *Finance Research Letters, 30*, 367–370.
Koutmos, D. (2018). Bitcoin returns and transaction activity. *Economics Letters, 167*, 81–85.
Liu, R., Wan, S., Zili, Z., & Xuejun, Z. (2020). Is the introduction of futures responsible for the crash of Bitcoin? *Finance Research Letters, 34*, Article 101259.
Newey, W., & West, K. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica, 55*(3), 703–708.
Pesaran, H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters, 58*(1), 17–29.
Shen, D., Urquhart, A., & Wanga, P. (2019). Does twitter predict Bitcoin? *Economics Letters, 174*, 118–122.
Urquhart, A. (2018). What causes the attention of Bitcoin? *Economics Letters, 166*, 40–44.