|  |
| --- |
| UNCC |
| **Lead-Lag Relationship of CBOE Bitcoin Futures & Bitcoin Exchanges** |
| A Causality Analysis |

|  |
| --- |
| Manning Worthley  Spring 2018 |

**Lead-Lag Relationship of CBOE Bitcoin Futures & Bitcoin Exchanges**

1. **Introduction**

With the launch of the Chicago Board of Exchange’s Bitcoin futures in December 2017, the relationship between Bitcoin and Bitcoin futures has not been explored to a large extent in the academic literature. While these are not the first derivatives of Bitcoin as there have been prediction markets present for some time, the novelty to the CBOE Bitcoin Futures relies on the respectability of the exchange as a financial institution which provides a more legitimized means of investing in Bitcoin. Investors will likely find the new futures market more attractive than buying and selling Bitcoin directly as the futures settle in cash, have a unified reference price of bitcoin, are regulated by the Commodity Futures Trading Commission, and allow for the ability to short the asset. Because of this, the futures market price may be more efficient than the underlying market for Bitcoin and other exchanges. Thus, futures price movements may precede movements in Bitcoin prices. Thus, do Bitcoin futures Granger-cause Bitcoin and is there a lead-lag relationship between Bitcoin Futures and the underlying?

As CBOE Bitcoin futures are a relatively new instrument, there is no literature on this topic. However, the relationship between futures contracts and their underlying asset or spot has been explored to a reasonable extent. The method to study the relationship between both markets focuses on the Granger causality test as proposed in 1969 by Granger. Many authors have also explored non-linear granger causality models.

Studying the relationship between the futures and the spot of crude oil, Silvapulle and Moosa (1999) suggest that futures in this market lead the underlying asset. They propose a few explanations of why this may happen. For one, the futures market responds quicker to new information due to lower transactions costs and ease of shorting compared to transactions of the immediate commodity. For example, if the intention is to take a long position as an investor, buying a forward contract would be easier than purchasing and sourcing oil. Secondly, they lean on prior literature such as Garbade and Silber (1983) who found though analyzing intraday changes of futures and spot prices, they find that the futures markets across 7 commodities form the basis for price discovery on the underlying market. Using daily data, Silvapulle and Moosa (1999) validate these hypotheses by performing first, a granger causality test and then, a non-linear granger causality test. Evaluating the linear test, they find that the futures lead the spot market but the spot does not lead the futures. The non-linear test gives a different indication where they observe bi-directional causality. As proposed in the paper, some of the statistical significance driving the results for the non-linear granger causality model is related to heteroscedasticity. After controlling for the non-constant variance by scaling the data by an estimated varying variance, they find that the original statistical decreased for the non-linear test but still held the same results.

Like Silvapulle and Moose (1999) a more recent paper by Yao and Lin (2017) investigates the relationship between Chinese stocks and the futures markets. Basing their analysis on daily data, they study 1746 stocks listed in either the Shanghai Stock exchange or the Shenzhen stock exchange and these stocks’ relationship to the Shanghai 300 futures index, the Shenzhen 300 futures index, China securities index 500, and the Shanghai Stock 50 futures index. Employing a granger causality test for each stock on the corresponding futures index, they jointly test to see if there is a lead-lag relationship. Further, Yao and Lin investigate how the causal relationships between the stocks and the futures index are interconnected through a conditional granger causality test that estimates indirect causation for each stock to the futures index. They find that the information flows from futures to the stocks are slightly greater than stocks to futures.

As Bitcoin is now considered a commodity by the CBOE, this study will conduct a similar analysis as prior researcher have performed. Where the lead-lag relationship between CBOE Bitcoin futures and spot markets is explored with the use of linear Granger-causality tests and Vector Autoregression models.

1. **Data**

In this section, the data series used in this study are described and analyzed for stationarity. All series are observations of daily closing prices from December 12th 2017 to May 5th 2018 for a total of 94 observations. Summary statistics and a correlation matrix are represented in Table 1 and Table 2 in the appendix. All variables are highly correlated above the 80% level which is to be expected as they all represent the same fundamental asset, Bitcoin.

Bitcoin futures prices are taken from daily historical closing prices listed on the CBOE website for each monthly Bitcoin Future contract. These prices represent the closing price as of 4:00pm EST and are only published on weekdays during market hours. As the futures settle monthly, a price index is constructed to represent a continuous price of the futures by taking the price of the contract closest to the most recent settlement date. The futures contracts are linked to the underlying price of Bitcoin as determined in the Gemni exchange. Like the futures prices, Gemni’s price for bitcoin is published at 4pm. Different from other exchanges of Bitcoin, Gemni is recognized a licensed digital asset exchange and custodian which affords them the ability to deal with large institutional hedge funds.

For a point of reference other than the underlying exchange price that the futures contracts use, another exchange is explored to see if a lead-lag relationship exists between future returns to changes in price listed on other exchanges. The exchange Bitstamp has one of the largest volumes for Bitcoin and stores hourly data. As many Bitcoin price databases have closing prices as of 11:59 UTC (coordinated universal time) which leads eastern standard time by four hours, using Bitstamp’s database allows this study to use the last trading price of Bitcoin at 4pm EST as a proxy for a comparable closing price to the Gemni exchange and the Bitcoin future’s closing price.

To have reliable estimates of statistical significance, the stationarity of variables is explored. The Augmented Dickey – Fuller test results are listed in Table 3 where the differenced variables exhibit stationarity which will be used in this analysis.

1. **Methods**

As many authors on this topic have used, I will use the granger causality test to examine if a lead-lag relationship between Bitcoin and Bitcoin futures exists. As described in Granger’s 1969 paper, granger causality tests of the ability of lagged independent and dependent variables to predict the dependent variable. A mathematical representation of the underlying model bolstering the test is below where yt is the dependent variable and xt is the independent variable.

(1)

(2)

If the combination of the lagged independent variables or in model are jointly statistically different from zero and the inclusion of the independent variables helps to forecast the dependent relative to equation (1), then the variable yt Granger-causes the variable xt. Results for the granger causality tests are listed in Table 4.

In addition, a VAR model is estimated to obtain the magnitude of the relationship. The model is comprised of two equations shown below where yt is the returns of the Bitcoin futures and xt represents either the returns of the underlying Gemni exchange or the Bitstamp exchange or the CoinDesk Index. Parameter estimates are illustrated in Table 5 for the different models being tested. Multiple models with different lag orders are evaluated and the model used has the lowest AIC statistic.

1. **Results**

The expectation given findings from previous authors is that the futures markets would lead the underlying spot market. The reasons being that changes in the futures price are indicative of upcoming movements as futures are inherently representative of the expectation of price movements; and the futures markets are believed to be more liquid than the underlying due to lower transactions costs and ease of shorting the future. However, the results in Table 4 do not support the claim that the returns in the futures market for Bitcoin do Granger-cause the returns on the underlying asset as represented in the Gemni exchange. Meaning that previous returns of Bitcoin futures do not predict the price changes listed on the Gemni exchange. Market efficiency on this specific exchange could explain why there may be no relationship between the two markets.

The fee structure of the Gemni exchange disincentivizes the participants to cause illiquidity as what they refer to as liquidity makers pay less fees than one that takes away liquidity. They describe the liquidity maker as a buyer or seller who posts their order on Gemni’s order book which means that the order is outside of the range of the current orders. Unconstrained by a lack of liquidity from the incentive to place orders outside of the current price, the price on the exchange quickly moves to the current equilibrium price if there is any new information. Thus, intraday price changes in CBOE Bitcoin futures could quickly integrate into the Gemni exchange price.

Further, as the CBOE Bitcoin futures are directly linked to the Gemni exchange prices as it settles using the price listed on Gemni, investors probe for opportunities for arbitrage. If the Bitcoin futures returns predict the changes in the Gemni exchange, then one would quickly exploit the relationship to make a profit for less risk on the Gemni exchange.

Interestingly, when estimating a VAR model with 2 lags on the relationship between the CBOE Bitcoin futures returns and the returns on the Gemni exchange, the first lags of each variable are statistically significant at the 2% level. However, performing a Wald test on the joint significance of the Gemni lags, the coefficient estimates are found to not be statistically different from zero. Again, indicating that there is no Granger-causality between the two variables.

While the Gemni exchange returns and the CBOE futures returns are found to not have a lead-lag relationship, could there exist a relationship between the futures and other exchanges? Investors in Bitcoin may rely on an expectations signal as indicated by the futures. If futures prices increase, then the expectation for the future settlement price must be above the current price and Bitcoin is expected to appreciate. To test this, I perform a Granger-causality test between Bitcoin futures and the Bitstamp exchange returns. As shown in Table 4, the evidence supports the null hypothesis that Bitcoin futures returns do not Granger-cause Bitstamp returns can be reject. However, the opposite is not true. Bitstamp returns do not Granger-cause Bitcoin futures which indicates a single direction of causality from the futures to the exchange.

To estimate the magnitude of the effects of the interdependencies of the two variables, a VAR(1) model is constructed. As depicted in Table 5 underneath model 2 b, the coefficients of the first lags of both the futures returns ( *b*i ) and Bitstamp returns ( λi ) in predicting Bitstamp returns are statistically significant at the 2% level. This also supports that there is a lead relationship between Bitcoin futures returns and the exchange’s returns. Specifically, the coefficient for the lagged Bitcoin futures returns is 0.72. Because this estimate is positive, the Bitstamp returns move in the same direction as previous futures price innovations. Also, the estimate for the lagged Bitstamp returns is statistically significant in predicting the current returns which may allude to the exchange being inefficient.

1. **Conclusion**

In conclusion, there is evidence to support the notion that CBOE Bitcoin futures returns lead the Bitstamp exchange returns but not lead the Gemni exchange returns which is directly linked to the Bitcoin futures. Several explanations are postulated. The Gemni exchange may be more efficient due to how they incentive market participants to create liquidity in their exchange. Thus, the Gemni exchange can quickly incorporate Bitcoin futures price innovations relative to other exchanges. Also, arbitrage between the futures market and the Gemni exchange may help to explain the lack of a lead-lag relationship.

Future research on the lead-lag relationship between Bitcoin futures and its underlying Bitcoin exchange should explore intraday fluctuations as looking at daily data filters out smaller frequency lead-lag relationships. In addition, arbitrage opportunities should be investigated across different Bitcoin exchanges.

**Citations**

Garbade, K. D., and W. L. Silber, (1982), Price movements and price discovery in futures and

cash markets, Review of Economics and Statistics 64, 289-297.

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-

Spectral Methods.Econometrica(Pre-1986), 37(3), 424.

Silvapulla, P., Moosa, I.A., (1999). The Relationship Between Spot and Futures Prices: Evidence

from the Crude Oil Market. Journal of Futures Markets 19, 157–193.

Yao, C., & Lin, Q. (2017). The mutual causality analysis between the stock and futures markets.

Physica A: Statistical Mechanics and Its Applications, 478, 188-204.

**Appendix**



