Behavior of Bitcoin Returns and Adaptive Market Hypothesis (AMH)

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Abstract

The aim of the current study is to examine the varying degree of market efficiency of the Bitcoin market through AMH of (Lo, 2004). Due to investors' behavior and media in the recent years, Bitcoin has received much attention for investment purposes even though there remains a lack of understanding of this cryptocurrency. We divide our data into three equal sub-samples and employ a battery of linear and nonlinear tests. We find a strong evidence of inefficiency of the Bitcoin market in full and all sub-samples through both the linear and nonlinear tests. Thus we report that Bitcoin is an inefficient market and its efficiency does not vary over time and not supporting AMH.

Key worlds: Bitcoin; Market efficiency; Adaptive market efficiency; Nonlinear predictability

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1. Introduction

Due to increasing popularity, many different innovative features, simplicity and transparency, Bitcoin (cryptocurrency) has received significant attention. (Nakamoto, 2008) first time outlined Bitcoin in a paper while in 2009 it went online, since then there has been a 5000 percent rise up in the price of Bitcoin. Investors employ Bitcoin not only as currency but also for investment purposes and (Selgin, 2015) and (Baek & Elbeck, 2015) argue that rather than a currency Bitcoin should be used as a speculative commodity. According to (Urquhart, 2016) Bitcoin has not yet been investigated in terms of market efficiency within the notion of EMH of (Fama, 1970). According to the best of our knowledge, so far, the efficiency of bitcoin is not investigated through the notion of AMH of (Lo, 2004). Therefore we fill this gap with the application of a battery of linear and nonlinear tests to investigate the weak form efficiency of Bitcoin in the context of AMH of (Lo, 2004).

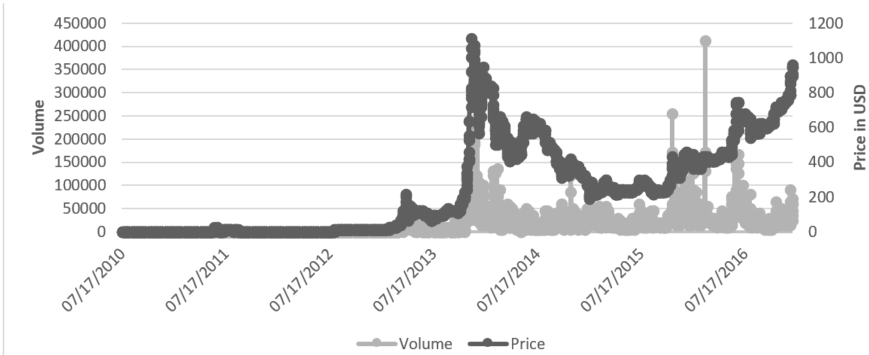
In efficient market research (Fama, 1970) is pioneer, who explains an efficient market as "A market in which prices always fully reflect information is called efficient market." Also, efficient market hypothesis (EMH) implies the prices of securities fully reflect all possible and available information regarding securities being traded in the market thus under weak form of EMH prediction about prices and returnare not possible for any market participant. Previous researchers have substantially examined the weak form of EMH for stocks and bonds (traditional financial assets) as well as for commodities' markets (Kristoufek & Vosvrds, 2014) and even art (David, Oosterlinck, & Szafarz, 2013). But Bitcoin is explored by (Urquhart, 2016) who employ a battery of robust test and find returns from Bitcoin are inefficient in full-sample, however as he breaks the sample size into two equal sized sub-samples he finds returns are more efficient in the latter period. The results drawn by (Urquhart, 2016) indicate that efficiency of Bitcoin varies over time so we fill this gap by studying efficiency of Bitcion through AMH, which facilitates market anomalies to co-exist with efficiency and allows market efficiency to evolve over time. To incorporate the varying degree of return predictability Lo (2004) proposes a new model "Adaptive Market Hypothesis (AMH)" that facilitate market anomalies to co-exist with market efficiency and enables market efficiency to evolve over time. The basic assertion of AMH model claims that efficiency of market is an "ever changing phenomenon" depending upon environmental conditions and market participants. Moreover, AMH proclaims market efficiency is not a guaranteed outcome as arbitrage opportunities to gain abnormal profit arise from time to time.

In the framework[1] of AMH (Lo, 2004);

1. Investors perform in favor of their self-benefits to protect their own self-interest.
2. So, investors make wrong judgments and make mistakes.
3. Investors pick up learning from their mistakes and adapt them to their behavior which is not explored by EMH.
4. Rivalry energies adaptation as well as innovation.
5. Then market ecology is shaped by natural selection.
6. Finally, evolution determine the dynamics of market

Initially studies documented literature on ethical, legal and safety aspects of Bitcoin, but recent studies investigate Bitcoin from an economic point of views. (Cheah & Fry, 2015) "argue that if Bitcoin were a true unit or account, or a form of store of value, it would not display such volatility expressed by bubbles and crashes". But (Cheung, Eduarda, & Su, 2015) discover three short lived and huge bubbles in which led Mt Gox exchange to dimise. Similarly, negative bubbles for Bitcoin are found by (Fry & Cheah, 2016). According to (Dwyer, 2015) Bitcoin exhibits greater monthly average volatility than currencies and gold, while it exhibits lowest monthly average volatilities lesser than the peaked monthly volatility for currencies and gold. For investors in dollars and gold, Bitcoin offers diversification benefits (Briere, Oosterlinck, & Szafarz, 2015) and significant hedging capabilities (Dyhrberg, 2016a) & (Dyhrberg, 2016b).

Figure 1: Log price and volume of Bitcoin over the full-sample period.



2. Methodology

Several Bitcoin-exchanges exist each with different currencies and varying popularity that Bitcoin is denoted in. So data is collected for aggregated Bitcoin price index from www.bitcoinaverage.com, which provides volume weighted average by aggregating rate available from all Bitcoin exchanges around the globe, thus providing a worldwide perspective on volume and price and hence the market efficiency of Bitcoin. In the current study we investigate the efficiency of Bitcoin through full sample from July, 2010 to June 2016, and further to investigate the varying degree of market efficiency we divide the data into three sub-samples of equal length of two years from July 2010 to June 2012, July 2012 to June 2014 and July 2014 to June 2016. Prices and volume of Bitcoin over the sample period are shown in figure 1 which shows that price levels are relatively stable before its peak levels in late 2013. In an adaptive market, behavior of returns goes under the periods of efficiency (independencies/unpredictability) and periods of inefficiency (dependencies/predictability). To investigate whether efficiency of Bitcoin swings between episodes of dependencies or independencies we employ a battery of linear and nonlinear tests. From linear tests first we applied an autocorrelation test. A null hypothesis of this test implies random walk process which means no autocorrelation. Second, we employ a runs test having null hypothesis of independence of returns (Wald & Wolfowitz, 1940). Thirdly, we employ (Lo & MacKinlay, 1988) variance ratio test, null hypothesis of this test implies price process follow a random walk. From nonlinear tests we first apply, a popular non parametric test, the BDS test (Brock, Scheinkman, LeBaron, & Dechert, 1996) for serial dependence in Bitcoin returns. Data generating processes are i.i.d[2] is the null hypothesis of BDS. The metric bounds and embedding dimensions from 2 to 5 are followed as specified in literature to a proportion of the standard deviation of the returns. (Patterson & Ashley, 2000) Secondly, (Engle, 1982) proposes a Lagrange Multiplier test[3] to detect ARCH disturbances. The null hypothesis is the asymptotically distribution. A series is said to be evident of nonlinear dependence or ARCH/GARCH effects if series rejects the null-hypothesis. The third nonlinear test we apply is a portmanteau McLeod Li test (McLeod & Li, 1983) [4] determines whether the "squared autocorrelation function of series of returns is non-zero". The independence of returns is the null hypothesis. If this null hypothesis is rejected, it reveals that the data set possesses ARCH/GARCH effects and nonlinear dependence. Finally (Tsay, 1986) offers Tsay-test to inspect the "quadratic serial dependence" in the data[5] if all zero is the null hypothesis.

Table 1 Descriptive statistics for the full sample period and sub-subsamples for bitcoin daily returns.

Sample-period	N	Mean	maximum	minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Full-Sample	2176	0.44	45.4214	-50.4021	5.2094	-0.182865***	19.44841***	24542.02***
July 2010- June 2012	715	0.6958	45.4214	-28.9943	6.6983	0.767355***	10.87713***	1918.718***
July 2012- June 2014	730	0.6235	22.579	-50.4021	5.431	-2.084452***	23.75416***	13630.16***
July 2014- June 2016	731	0.00659	15.4234	-19.5412	2.6893	-0.49483***	11.99359***	2493.444***

Source: Authors' own elaboration with data from Yahoo Finance and R Statistical Package. *** Indicates significance at 1%.

Linear and non-linear empirical tests are employed on daily returns of Bitcoin calculated in the following way; $r_t = [ln(P_t) - ln(P_{t-1})] \times 100.$ Where at time $t,$ the natural logarithm of returns is represented by $ln(P_t)$, while at $t - 1,$ natural logarithm is $ln(P_{t-1})$. Summary statistics of log returns are presented in Table 1 for full-sample as well for sub samples. Descriptive statistics show returns from Bitcoin are positive over the full and all sub-samples. Full and all sub-samples are evident of excess kurtosis and negative skewness except first sub-sample generates positive value of skewness. In the second sub-sample we find much greater values of kurtosis and skewness while smaller values of mean and standard deviation values in last sub-sample.

Table 2: Results are presented for linear AC (Autocorrelation test in column 2), non-parametric runs test (column 3) and Variance ratio test (columns 4). Columns 5 and 7present results for Ljung-Box test before and after fitting AR model (Columns 6) respectively. For results for non-linear tests to detect nonlinear dependence on AR filtered returns for Bitcoin, test statistics of BDS, Engle LM, McLeod Li & Tsay tests are presented in 8,9,10 & 11 columns respectively. All the results are presented for the full as well as 2-yearly sub-samples. Starting and ending dates of the subsamples are presented in first column.

Sample-period	AC	Runs	Var. Ratio	Q-Stat	AR	Q-Stat	BDS Statistic	Engel LM	McLeod Li	Tsay
Full-Sample	-0.264***	-11.68***	0.721532***	329.72***	14	17.027	20.2015***	455.35***	(000)	4.565***
July 2010- June 2012	-0.245***	-6.86***	0.727824***	92.905***	02	6.4825	10.0726***	104.11***	(000)	2.492***
July 2012- June 2014	-0.279***	-7.96***	0.723072***	199.44***	10	27.915	12.9715***	193.85***	(000)	5.668***
July 2014- June 2016	-0.303***	-3.80***	0.695934***	153.17***	11	14.931	9.4067***	179.68***	(000)	2.912***

Source: Authors' own elaboration with data from Yahoo Finance and R Statistical Package *** Indicates significance at 1%.

3. Empirical Results

The results of linear and non-linear tests are summarized in table-2. We find dependency (market inefficiency) in full and well as in all the sub-samples as the p-values are evident of significant dependencies; thus the efficiency of Bitcoin does not swing in episodes of dependencies (market inefficiency) and independencies (market efficiency) at linear empirical tests as all the three linear tests rejects the randomness of returns. Table 2 also presents Ljung-Box test statistic of pre and post implementing AR filter. The results are evidence of existence of temporal linear structure (significant autocorrelation with a level of 1% significance up to 20 lags) in full and in all sub samples. Thus, to inspect the non-linear dependence in the returns of Bitcoin, the linear dependence must be removed from returns. An AR-model (pre-whitening) for this purpose can serve as a filter to eliminate any remaining linear relationship and facilitate to investigate the non-linear structure in the series of returns (Bitcoin). Table 2 documents the estimated AR-models and

Figure 2: Statistics of linear test employed for Bitcoin daily returns in sub-samples. RUNS stands for z-statistic of the runs test. For lag 1, autocorrelation statistic is represented by AC(1), while, VA(2) stands for 2-period return of variance ratio test.

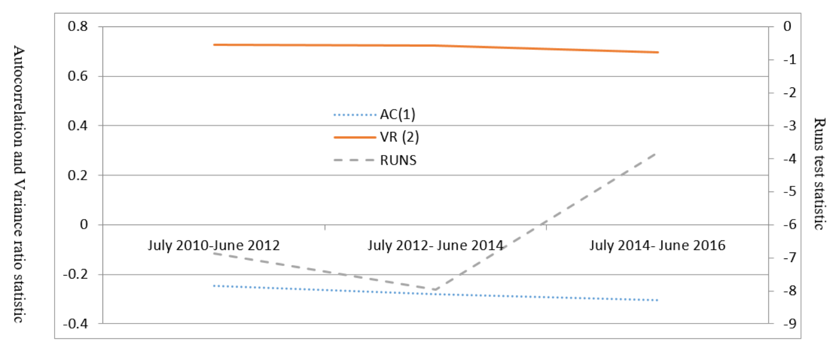
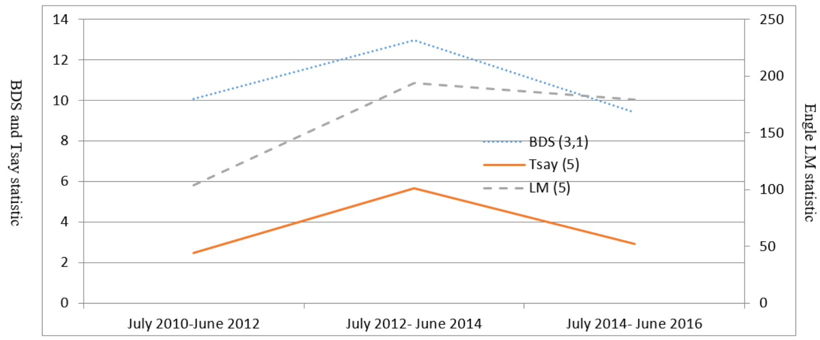


Figure 3: Statistics of non-linear test employed for Bitcoin daily returns in sub-samples. BDS (3,1) stands for dimension 3 along with 1σ embedding dimension for BDS test, up to lag 5, LM(5) represents Engle-LM tests statistics, while, Tsay(5) stands return predictability up to lag 5 for Tsay test.



shows successful elimination of linear structures from the series as the full and sub samples show no statistically significant correlation up to 20 lags. The filtered returns are then subjected to different non-linear tests (BDS test, Engle LM, McLeod Li test and Tsay-test discussed in the methodology) to detect non-linear dependency. All the nonlinear tests suggest that Bitcoin returns are inefficient in full as well as in the all sub-samples and nonlinear dependency of Bitcoin do not go under periods of dependencies (market inefficiency) and independencies (market efficiency) as p-values reject the null hypothesis.

4. Conclusion

The empirical linear and nonlinear results reveal that the Bitcoin market is weakly inefficient in full as well as in sub-sample periods. P-values providing quite strong evidence of inefficiency of Bitcoin thus results are not supporting AMH of (Lo, 2004) as the efficiency of Bitcoin do not go under periods of efficiency (independency) and Inefficiency (Dependencies). The inefficiency of the Bitcoin market is not surprising6 as it is an emerging market, comparatively a new asset for investment and still in its infancy. Efficiency of Bitcoin may be expected in the future as more investors analyze or trade it. Future work may compare Bitcoin with alternative investments and with other emerging markets.

References

Baek, C., & Elbeck, M. (2015). Bitcoins as an Investment or Speculative Vehicle? A First Look. *Applied Economics Letters, 22*, 30-34.

Bekaert, G., & Harvey, C. (2002). Research in Emerging Markets Finance: Looking to the Future. *Emerging Markets Review*(4), 429-448.

Briere, M., Oosterlinck, K., & Szafarz, A. (2015). Virtual Currency, Tangible Return: Portfolio Diversification with Bitcoin. *Journal of Asset Management, 16*(6), 365-373.

Brock, W. A., Scheinkman, J. A., LeBaron, B., & Dechert, W. D. (1996). A Test for Independence Based on the Correlation Dimention. *Econometric Reviews, 15*(3), 197-235.

Cheah, E.-T., & Fry, J. (2015). Speculative Bubbles in Bitcoin Markets? An empirical Investigation into the Fundamental Value of Bitcoin. *Economics Letters, 130*, 32-36.

Cheung, A., Eduarda, R., & Su, J. J. (2015). Crypto-currency Bubbles: An Application of thePhillips-Shi-Yu (2013) Methodology on Mt. Gox Bitcoin Prices. *Applied Economics, 47*(23), 2348-2358.

David, G., Oosterlinck, K., & Szafarz, A. (2013). Art Market Inefficiency. *Economics Letters, 121*(1), 23-25.

Dwyer, G. P. (2015). The Economics of Bitcoin and Similar Private Digital Currencies. *Journal of Financial Stability, 17*, 81-91.

Dyhrberg, A. H. (2016a). Bitcoin, Gold and Dollar-A GARCH Volatility Analysis. *Finance Research Letters, 16*, 85-92.

Dyhrberg, A. H. (2016b). Hedging Capabilities of Bitcoin. Is it the virtual Gold? *Finance Research Letters, 16*, 139-144.

Engle, R. F. (1982). Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica, 50*(4), 987-1008.

Fama, F. E. (1970). Efficient Capital Markets: A review of Theory and Empirical Work. *Journal of Finance, 25*(2), 383-417.

Fry, J., & Cheah, E.-t. (2016). Negative Bubbles and Shocks in Cryptocurrency Markets. *International Review of Financial Analysis, 47*, 343-352.

Kristoufek, L., & Vosvrds, M. (2014). Commodity Futures and Market Efficiency. *Energy Economics, 42*, 50-57.

Lo, A. W. (2004). The Adaptive Market Hypothesis. *Journal of Portfolio Management, 30*, 15-29.

Lo, A. W. (2004). The Adaptive Markets Hypothesis: Market Efficiency from an Evolutionary Perspective. *Journal of Portfolio Management, 30*, 15-29.

Lo, A. W., & MacKinlay, C. A. (1988). Stock Market Prices do not Follow Random Walks: Evidence from a Simple Specification Test. *The Review of Financial Studies, 1*(1), 41-66.

McLeod, A. I., & Li, W. K. (1983). Diagnostic checking ARMA time series models using squared-residual autocorrelations. *Journal of Time Series Analysis, 4*, 269-273.

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System.

Patterson, D., & Ashley, R. A. (2000). *A Nonlinear Time Series Workshop: A Toolkit for Detecting and Identifying Nonlinear Serial Dependence.* Boston, MA: Kluwer Academic.

Selgin, G. (2015). Synthetic Commodity Money. *Journal of Financial Stability, 17*, 92-99.

Tsay, R. S. (1986). Nonlinearity tests for time series. *Biom, 73*, 461–466.

Urquhart, A. (2016). The Inefficiency of Bitcoin. *Economics Letters, 148*, 80-82.

Urquhart, A., & Hudson, R. (2013). Efficient or Adaptive Markets? Evidence from Major Stock Markets using very Long-Run Historic Data. *International Review of Financial Analysis, 28*, 130-142.

Wald, A., & Wolfowitz, J. (1940). On a test Whether two Samples are form the same Population. *The Annals of Mathematical Statistics, 11*(2), 147-162.

Notes:

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1 AMH of Lo (2004) argues that behavior finance supports the presence of behavior biases in investors' sentiments, and these biases follow evolutionary trends. Finally, the evolutionary trends shape the levels of efficiency of market. Investors commit mistakes as rationality of investors is bounded while acting in their self-interests (Simon, 1955). If investors are unwilling to learn from their committed mistakes, the markets tend to exhibit levels of inefficiency of capital markets. However when investors willingly adapt to new conditions of market through their mistakes, the short term levels of market inefficiency will survive only for temporary periods of time. This process of learning and continues adaption will be determined by competition prevailing in the market among investors. However, the process of natural selection will select which investors can stay in the market and which one are driven out. This process of naturel selection provides shape to ecology of the market and dynamics of evolution. Lo (2004) states that "As long as there is no shock that causes market ecology to change, stock markets are fairly efficient. However, once a certain event triggers the process of competition and natural selection, markets become temporarily less efficient. Once the new market ecology is formed, efficiency of financial markets returns to pre-shock levels".

2 "Alternative hypothesis is an indication that the model is misspecified (Brock, Scheinkman, LeBaron, & Dechert, 1996)".

3 Engle proposes the test to detect ARCH disturbance, against GARCH alternatives, this test is more power full (Bollerslev, 1986).

4 Based on suggestions in (Granger & Anderson, 1978), (McLeod & Li, 1983) propose this test to detect ARCH-effects.

5 "Tsay-test (Tsay, 1986) is a generalization of (Keenan, 1985) test".

6 (Bekaert & Harvey, 2002) summarize the academic evidence for greater inefficiency in emerging markets.