# Pandemic or Not, Bitcoin is a Random Walk

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**Abstract:** Since the onset of the current Pandemic, Bitcoin has achieved a number of important milestones that have cemented its standing as the "King" of cryptocurrencies. A few of them are the following: all time high daily price of US$57,539.94 per coin, all time high of US$1.72T capitalization, all time high daily return of 17.18%, giant companies like Amazon, Tesla, Microsoft, KFC, etc. are accepting Bitcoin as payment, endorsement of well-known personalities like Elon Musk of Tesla, Jack Dorsey of Twitter, Bill Gates of Microsoft, etc. These signposts, all happening during the pandemic era incentivize speculators, investors and even the general public to try their luck on Bitcoin for that familiar "get rich quick" cliché.

With its mass appeal and its desirable attributes such as a store of value, medium of exchange, hedge against inflation, and a viable investment opportunity Bitcoin enjoys unparalled popularity. Although there remains skepticism and a lack of understanding of this cryptocurrency, people should be warned about the possibility of adverse events that may come their way once they join the "Bitcoin Bandwagon". One way of warning the would-be Bitcoin speculator is to empirically show that Bitcoin is a fair game, or more technically a "Random Walk" even during the pandemic. Employing state-of-the-art econometric and statistical procedures, the study concludes that Bitcoin truly is a Random Walk under pandemic conditions or not.

**Key Words:** Pandemic; Bitcoin; Random Walk; Efficient Market Hypothesis; Martingale Difference Sequence

## 1. INTRODUCTION

Since the onset of the current Pandemic, Bitcoin has achieved a number of important milestones that have cemented its standing as the "King" of cryptocurrencies. These are, but not limited to the following events: all time high daily price of US$57,539.94 per coin, all time high of US$1.72T capitalization, all time high daily return of 17.18%, giant companies like Amazon, Tesla, Microsoft, KFC, etc. accepting Bitcoin as payment, endorsement of well-known personalities like Elon Musk of Tesla, Jack Dorsey of Twitter, Bill Gates of Microsoft, etc. These signposts, all happening during the pandemic era incentivize speculators, investors and even the general public to try their luck on Bitcoin for that familiar "get rich quick" cliché.

With its mass appeal and its desirable attributes as a store of value, medium of exchange, hedge against inflation, and a viable investment opportunity Bitcoin enjoys unparalled popularity. Although there remains skepticism and a lack of understanding of this cryptocurrency, people should be warned about the possibility of adverse events that may come their way once they join the "Bitcoin Bandwagon". One way of warning the would-be Bitcoin speculator is to empirically show that Bitcoin is a fair game, or more technically - Bitcoin is a "Random Walk" even during the pandemic.

## 2. METHODOLOGY

The empirical strategy employed in the study is to demonstrate that Bitcoin exhibits the *martingale difference sequence* (MDS) properties during the periods in under review (Pre-Pandemic, Pandemic and Full Sample). This can be accomplished by meeting the following specific objectives:

- To uncover the *unit root component* of Bitcoin during the periods, and
- To provide empirical evidence for the presence of *uncorrelated increments of Bitcoin Returns* for each time period.

MDS is a special form of Random Walk under the stylized fact of volatility clustering of returns observed in most financial markets (Escanciano and Lobato, 2009) and Random Walk is a hallmark of the so-called Efficient Market Hypothesis (EMH). Thus, market prices meeting the above two MDS requirements are deemed to be informationally efficient of the weak kind where all available information are already factored into the market prices, and no one can take advantage of publicly available information to amass abnormal profit.

### *2.1 Stylized Facts Analysis and Testing for the ARCH Effect*

Daily closing prices (P) and Returns (r) of Bitcoin within the sample horizon are subjected to a battery of graphical and descriptive analyses of their first four representative moments (Mean, Standard Deviation, Skewness and Kurtosis) over the two sub-periods. In quantifying the returns series, the continuously confounded rate of return formula is used in this study:

$$r_t = 100 * \ln(P_t / P_{t-1}) \qquad (1)$$

To ascertain the presence of the so-called ARCH Effect or volatility clustering, the Lagrange Multiplier (LM) test is implemented on the return series. Normality testing of the series is undertaken via the Jarque-Bera (JB) test.

### *2.2 Individual Unit Root Tests*

To achieve the first objective, three powerful Unit Root testing procedures are used – the Augmented Dickey-Fuller (ADF), Philips-Perron (PP) and the Elliot-Rothenberg-Stock (ERS) point optimal unit root tests to truly ascertain whether Bitcoin price contains a single unit root during the pre-pandemic, pandemic periods. All of these tests operate under the null hypothesis the series being tested is integrated of order 1 (*I(1)* ), which means that when the series or its logarithmic form is differenced once, the resulting variable is stationary.

### *2.2 Variance Ratio Tests*

Lo and MacKinlay (1988) provided the seminal basis for the Variance ratio (VR) test, which has been used extensively in testing market efficiency of the weak form. This empirical procedure explores the validity of the random walk hypothesis (RWH) by testing the property that the variance of random walk increments is linear in all sampling intervals (that is, the variance of q-period return is q times the variance of one-period return) (Charles and Darne, 2009). Hence, the VR at lag q which is defined as the ratio between (1/q) of the q-period return to the variance of the one-period return should equal to 1 for all q.

If $r_t$ is assumed to be a realization of a stochastic process $R_t$ that follows a martingale difference sequence (MDS), which is known to be uncorrelated and may or may not be conditionally heteroscedastic. Lo and MacKinlay (1988) formulated two test statistics to undertake the VR test for the RWH. The first statistic works under the strong assumption of iid (identically and independently distributed) $R_t$ with constant variance, while the other downgraded the iid assumption to permit general types of time varying volatility which are often seen in financial time series (aka ARCH effect). The associated null hypothesis under the heteroscedastic assumption is presented below[1].

From the Variance Ratio (VR) statistic

[1] We focus only on the test statistic robust under heteroscedasticity as return series displays ARCH effect during the periods under review.

$$VR(r_t;\mathrm{q}) = \frac{\sum_{t=q}^{T}[\mathrm{r}_t + \ldots + r_{t-q+1} - q\bar{r}]^2}{q\sum_{t=1}^{T}[\mathrm{r}_t - \bar{r}]^2} \qquad (2)$$

with $\bar{r} = \sum_{t=1}^{T} r_t / T$

the Variance Ratio (VR) test statistic $M(r_t, \mathrm{q})$ (shown to be asymptotic standard normal z) under the assumption of conditional heteroscedasticity (MDS null) proposed by Lo and Mackinlay (1988) is given by

$$z = M(r_t, \mathrm{q}) = \frac{VR(r_t, \mathrm{q}) - 1}{\sqrt{\psi(q)}} \quad \text{with}$$

$$\psi(\mathrm{q}) = \sum_{k=1}^{q-1}\left[\frac{2(\mathrm{q}-k)}{q}\right]^2 \xi(k)$$

$$\text{and } \xi(k) = \frac{\sum_{t=k+1}^{T}[r_t - \bar{r}]^2[r_{t-k} - \bar{r}]^2}{\sum_{t=1}^{T}[r_t - \bar{r}]^2} \qquad (3)$$

Since the variance ratio restriction holds for every q difference (or logarithmic difference) of the underlying currency series, for q ≥ 1, it is customary to evaluate this test statistics at several selected values of q (in this study q = 2, 4, 8, and 16).

Chow and Denning (1993) proposed a test statistic used to examine the absolute values of a statistic set of multiple variance ratio statistics (for the different set values of q). The main purpose of this is to control the size (type I error probability) of a joint variance ratio test to be implemented.

The null hypothesis for the Chow-Denning multiple VR test is set as the joint statement:

$$VR(q_i) = 1 \text{ for i = 1, 2, …, m} \qquad (4)$$

against the alternative hypothesis that $VR(q_i) \neq 1$ for some holding period $q_i$. The Chow-Denning test statistic can be written as:

$$CD = \max\left|M(\mathrm{r}_t; q_i)\right| = \max(|\,z\,|) \qquad (5)$$

for $1 \le i \le m$, where

$$MV(\mathrm{r}_t; q_i) =$$

$$(VR(q_i) - 1)\{\sum_{j=1}^{q-1}\left[\frac{2(q_i - j)}{q_i}\right]^2 \xi_{q_i}\}^{-0.5} \qquad (6)$$

$$\text{and } \xi_{q_i} = \frac{\sum_{t=q_i+1}^{T}[r_t - \bar{r}]^2[r_{t-k} - \bar{r}]^2}{\sum_{t=1}^{T}[r_t - \bar{r}]^2}$$

The Chow-Denning (CD) test is anchored on the idea that any decision on the null hypothesis can be based on the maximum absolute value of the individual VR statistic under the MDS assumption of Lo and McKinlay (1988). Under such assumption CD statistic follows the studentized maximum modulus (SMM) distribution with m and T degrees of freedom (Chow and Denning, 1993), whose critical values are tabulated in Stoline and Ury (1979). The p-value for the CD statistic is bounded from above by the p-value for the SMM distribution with parameters m and T, with T approaching infinity.

To implement the individual and joint MDS tests, the Wild Bootstrapping procedure is used as alternative to the normal approximation because of its superior small sample properties (e.g. Charles et. al, 2011)

## *2.3 Data*

The data used in the study is sourced from the website www.*CoinMarketCap.com* and is composed of the daily closing price of Bitcoin (in US$ per coin) and its continuously compounded rate returns (in %). A total of 720 daily observations from March 16, 2019 to March 6, 2021 are extracted. This full sample period is subdivided into two subperiods (Pre-pandemic and Pandemic) using March 11, 2020 – when the WHO formally announced the onset of the Covid-19 Pandemic. This day of pandemic announcement constitute the breakpoint of the timeline.

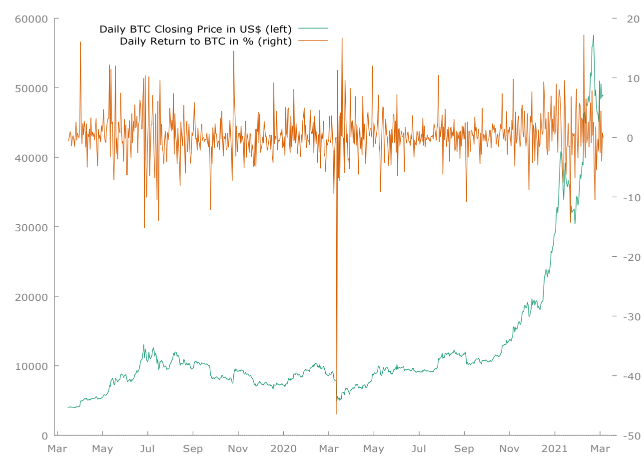
# 3. RESULTS AND DISCUSSION

## *3.1 Descriptive Analysis*

Initial assessment of the time graph of the price and return series of Bitcoin over a sample horizon of 720 days reveals a great deal of special stylized facts. Shown in Figure 1 below, daily closing price appears to be on a sustained uptrend that has become steeper during the more recent part of the Pandemic period. Daily returns on the other hand for the entire sample period somewhat cluster around a constant value. The time graph of the return series also reveals a phenomenon known as volatility clustering, as evidenced by episodes of wild swings and tranquil periods. As seen here, wild swings exceed calm episodes. It may be noted that the Pre-pandemic and Pandemic eras are separated conveniently by an extreme negative return which occurred a day after the Pandemic announcement by WHO (March 12, 2020). That day also appears to start a steady bull run in Bitcoin price which culminated in successive all-time highs towards the later pandemic period.

All-time highs on the price and return series are observed during the pandemic period of $57,540 and 17.18% respectively. Differences between era means of price and returns produce Z test statistics of 12.93 ($p<0.001$) for price and 1.98 ($p>0.05$). Highly significant ARCH effects are noted during both the Pre-pandemic and Pandemic period in daily returns (LM tests) which also exhibit non-normality according to JB tests. Please refer to Table 1.

**Figure 1.** Daily Bitcoin Price (US$) and its Continuously Compounded Rate of Return (%) March 16, 2019 to March 6, 2021




## *3.2 Unit Root Analysis*

The first objective of the study is to empirically establish the presence of unit root in the Bitcoin price series. Theory requires that if a time series is to be considered a random walk, its level value or its logarithmic transformation must contain a unit root so that when differenced once, the resulting time series is deemed stationary.

**Table 1.** Stylized Facts and Relevant Statistical Tests

| Time Period | Mean | SDev | Min | Max | Z-Stat | JB-Stat | ARCH-LM(p-value) |
|---|---|---|---|---|---|---|---|
| Pre-pandemic (T = 362 days) | | | | | | | |
| Daily Price (US$) | 8,440 | 1942.7 | 3,963 | 13,016 | 12.93*** | 12.322** | xxxxx |
| Daily Return (%) | 0.1856 | 3.6042 | -15.182 | 16.004 | $1.18^{ns}$ | 230.546*** | 0.00154** |
| Pandemic (T = 358 days) | | | | | | | |
| Daily Price (US$) | 16,953 | 12502.54 | 4,971 | 57,540 | xxxx | 160.13*** | xxxxx |
| Daily Return (%) | 0.53769 | 4.4186 | -46.473 | 17.182 | xxxx | 19477.3*** | 0.00153** |

Figures reflected in the last two columns are p-values of the Difference Between two Means Z-test, JB Normality test and the ARCH-LM test of ARCH effects respectively (ARCH stands for Auto Regressive Conditional Heteroscedasticity – a phenomenon characterized by volatility clustering)
**p<0.01 ***p<0.001 ns-not significant (p>0.10)

**Table 2**. Individual Unit Root Tests on the Daily Price and Return on Bitcoin During Pre-pandemic and Pandemic Periods (p-values are in brackets)

| | Unit Root Tests | | |
|---|---|---|---|
| Time Period | ADF | Philips-Perron | ERS |
| **Pre-Pandemic (3/16/19 – 3/11/20)** | | | |
| **BTC Close** | -2.081774 | -2.023250 | 28.91920 |
| | [0.5537]ns | [0.5862]ns | [>0.10]ns |
| **BTC Daily Return** | -19.36095 | -19.36095 | 0.520623 |
| | [0.0000]*** | [0.0000]*** | [<0.01]** |
| **Pandemic (3/12/20 – 3/6/21)** | | | |
| **BTC Close** | -0.883783 | -0.919497 | 51.99991 |
| | [0.9554]ns | [0.5862]ns | [>0.10]ns |
| **BTC Daily Return** | -21.18889 | -21.17266 | 0.82396 |
| | [0.0000]*** | [0.0000]*** | [<0.01]** |

Null Hypothesis: Closing Price/Return is *I(1)*
ns – not significant **significant at 0.01 level ***significant at 0.001 level

**Table 3**. Variance Ratio Test for Random Walk of Daily Closing Price of Bitcoin (BTC) Using Wild Bootstrap

| Ho: BTC_Pandemic is a Martingale | | Lo-MacKinlay Individual Variance Ratio Tests (3/12/20 – 3/06/21) | | | | |
|---|---|---|---|---|---|---|
| Chow-Denning Joint Variance Ratio Test | | Holding Period (q) | | | | |
| | | *Period* | 2 | 4 | 8 | 16 |
| | | Var. Ratio | 0.998952 | 1.063461 | 1.129282 | 1.271821 |
| Max \|z\| | 0.652593 | Std. Error | 0.088421 | 0.170393 | 0.274751 | 0.416524 |
| Degrees of Freedom | 360 | z-Statistic | -0.011848 | 0.372440 | 0.470545 | 0.652593 |
| p-value | 0.8690 | p-value | 0.9980 | 0.7060 | 0.6560 | 0.5270 |

| Ho: BTC_Pre_Pandemic is a Martingale | | Lo-MacKinlay Individual Variance Ratio Tests (3/16/19 – 3/11/20) | | | | |
|---|---|---|---|---|---|---|
| Chow-Denning Joint Variance Ratio Test | | Holding Period (q) | | | | |
| | | *Period* | 2 | 4 | 8 | 16 |
| | | Var. Ratio | 0.942367 | 0.937302 | 0.934656 | 0.939058 |
| Max \|z\| | 0.569790 | Std. Error | 0.101149 | 0.184530 | 0.272314 | 0.370848 |
| Degrees of Freedom | 361 | z-Statistic | -0.569790 | -0.339769 | -0.239959 | -0.164331 |
| p-value | 0.8910 | p-value | 0.7560 | 0.7410 | 0.8350 | 0.8670 |

### *3.3 Results of the Variance Ratio Tests*

The highlight of the study is the accomplishment of the second objective – to provide empirical evidence for the presence of *uncorrelated increments of Bitcoin Returns* during each era. The results are revealing and are succinctly reported in Table 3 which shows the wild bootstrap implementation of the Lo-MacKinlay and the Chow-Denning Variance Ratio tests. It may be noted that the MDS null hypothesis, individually (across different holding periods) and jointly (for all holding periods) during both the Pre-pandemic and Pandemic eras are not rejected under any levels of significance. These results empirically validate the presence of uncorrelated increments of returns under the condition of time varying volatility. Hence, it is safe to conclude, without loss of generality that Bitcoin is truly a Random Walk, pandemic or not and the market for Bitcoin is informationally efficient even during the COVID-19 Pandemic. All procedures are implemented via the software EViews 11.

## 4. CONCLUSION

Exactly one day after Bitcoin experienced its highest ever daily drop in return, which incidentally occurred a day after the formal announcement of the COVID-19 Pandemic, the market immediately recovered and commenced a prolonged bull run which is still in progress. This baffling phenomenon happened despite wanton destruction of almost all aspects of the global economy. This paradox caught the attention of many, especially those who may want to benefit from it by speculating on this cryptocurrency.

Speculation is a dangerous enterprise, specially in a market which is not so well understood, and skepticism abounds, during an era when almost everyone can not afford to lose meager resources. This study hopes to help in bringing sanity back to those who are on the verge of getting pulled in by the Bitcoin Bandwagon. Its avowed aim is to show that the Bitcoin market is informationally efficient even during the Pandemic, and no one can amass abnormal profit from it by using publicly available information (Samuelson, P. (1965), Rufino (2013)). By using an improved version of the Variance Ratio test – the gold standard in testing for the validity of the Efficient Market Hypothesis (EMH), the study empirically showed that Bitcoin is a Random Walk – a hallmark of the EMH across the two study eras.

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