Time varying long term dependence of Bitcoin.

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Bitcoin is a peer-to-peer payment system and digital currency introduced as open source software in 2009 by pseudonymous developer Satoshi Nakamoto. Satoshi proposed a way to transfer money to anywhere in the world using a trustless system . This was possible due to the combination of blockchain, P2P ,cryptography and distributed computing.. Bitcoin is a network that runs on a protocol known as the blockchain. The block chain is a shared public ledger on which the entire Bitcoin network relies., The basics of blockchain technology is the idea to internally timestamp information as they arrive and be immutable to change.. A blockchain is a collection of information that is not held by one entity but rather distributed across all computers in the network known as nodes. All confirmed transactions are included in the block chain and are updated continuously thus anyone can verify the ledger . Bitcoin users and investors both perceive a huge financial opportunity in bitcoin thus leading to unprecedented growth in the price of bitcoin and its popularity.

Bitcoin is new , speculative and volatile currency without a regulatory agency.
The bitcoin market is a highly speculative market and is incredibly sensitive to news whether true news like shift in regulations , politics etc and fake news . The bitcoin price is highly volatile due to lack of regulations for investment or trading ,which adds uncertainty of transactions leading to excessive volatility to traditional currencies and assets although it is often disputed by bitcoin enthusiasts whether it is a currency or store of value . Unlike traditional currencies bitcoin is the only devaluing currency instead of inflating one although we are at very early stage to study its effects . This provides us incredible opportunity to study a unique system where there is no central authority and which is at a very early stage of adoption .

The efficiency of market is the degree to which a market provides the true value of a commodity. This means when a market is efficient the price includes the past as well as the future value of the commodity in its price.
This does not mean a market will always reflect its true value , the market can deviate from its true value but it should do it randomly without any trend or memory. So even if market is efficient it possible to find undervalued or overvalued commodities in it . This implies that no investor should beat the markets consistently with a strategy but this does not mean that no one can beat the market consistently , some investors will beat the market in the long run not

because they were using the correct strategy rather because of the laws of probability . These investors were the few lucky people who beat the market over long period of time but they will be disproportional to the number of those who didn't even if they used the same strategy.
The efficient market hypothesis (EMH) is a theory in economics which states that all the important deterministic information is fully reflected in the stock price. It originated in the 1960s and thanks to the work of economist Eugene Fama. This hypothesis holds it is impossible to beat the stock market because the price already includes all the relevant information of the stock which may affect the price of the stock in the future .As per this hypothesis a investor plays a game of chance rather than skill when investing.
There are three type of market efficiencies -
1) Weak form says that prices on traded assets (e.g., stocks, bonds, or property) already reflect all past publicly available information.
2) Semi-Strong form claims that prices reflect all publicly available information and that prices instantly change to reflect new public information.
3) Strong form claims that prices instantly reflect even hidden insider information.

The efficiency of stock markets has been studied in various papers . Ito and Sugiyama (2009) find that
inefficiency varies through time in the US stock market. from 1955 to 2006. . Bariviera (2011) fins that there is a weak relationship between market capitalization and the efficiency of the market in the Thai stock market.,. Cajueiro et al. (2009) shows that the financial market liberalization introduced in the beginning of the 1990s in Greece has changed the degree of market development (efficiency). These changes in financial market liberalization has had increased degree of development of stock markets .Jae Kim (2011) returns are predictability driven by changing market conditions but no statistically significant return predictability is observed during market crash.
[14] In the dynamical behavior of the US stock markets is characterized on the basis of the Hurst exponent estimated with detrended fluctuation analysis (DFA) shows erratic behavior and effect of various policies.

The efficiency bitcoin market has been studied in [6] Bartos studies that bitcoin follows market efficient market hypothesis and reacts immediately to public information. [7] A. Urquhart. evidence reveals that returns are significantly inefficient over our full sample, but when we split

our sample into two subsample periods, we find some tests indicate that Bitcoin is efficient in the latter period. [8] Y. Kurihara, The empirical results show that the Bitcoin market is not efficient. However, the empirical results show that Bitcoin transactions are becoming efficient.
[9] S. Nadarajah, shows here that a simple power transformation of the Bitcoin returns do satisfy the hypothesis through the use of eight different tests.
[10] A.F. Bariviera, This study compares Bitcoin and standard currencies dynamics and focuses on the analysis of returns at different time scales. We detect that Hurst exponents changes significantly during the first years of existence of Bitcoin, tending to stabilize in recent times.
The efficiency of bitcoin market has been studied in the various papers with some of the papers claiming that bitcoin market is becoming efficient over time while some arguing there are pockets of inefficiency .

In this paper we study the time-varying long term dependence of bitcoin market based on the work of HE hurst.
HE hurst was a British hydrologist and a civil servant who studied the river Nile for 62 years earning the title of 'Father of Nile'. Hurst was looking to model the level of river Nile so that architects could build a appropriate sized dam for the storage of water to last through the harsh winters during which the flow of river decreases.
Analyzing the records of over 846 Years hurst noticed that a high flood would be followed by even heavier flood and a light flood by even lighter flood meaning that the natural events would appear in bunches of a flood followed by flood and drought by drought. This resulted in the hurst phenomena which was that natural events do not occur randomly but rather have periods of highs and lows. As, result of this he was able to design a water storage reservoir which protected Egypt from severe droughts.

The value of Hurst exponent(H) always lies between 0 and 1.

$0<H<0.5$ denotes an Anti-Persistent Time Series i.e. it has a tendency to revert to the long-term mean value. The closer the value of H lies to 0, the stronger the anti-persistent behavior. It represents negative Correlations.

$H=0.5$ denotes a Brownian Time Series i.e. random, where there is no correlation existing between the observations made. No predictions can be made for such series.

$0.5<H<1$ denotes a Persistent Time Series. The closer the value of H lies to 1, the stronger is the persistent behavior. Thus, it indicates a positive correlation.

The Hurst exponent can be calculated by rescaled range analysis (R/S analysis). For a time series, $X = X_1, X_2, \ldots Xn$, R/S analysis method is as follows:

(1) Calculate mean value m.

$$m = \frac{1}{n} \sum_{i=1}^{n} X_i$$

(2) Calculate mean adjusted series Y

$$Y_t = X_t - m, \qquad t = 1, 2, \ldots, n$$

(3) Calculate cumulative deviate series Z

$$Z_t = \sum_{i=1}^{t} Y_i, \quad t = 1, 2, \ldots, n$$

(4) Calculate range series R

$$R_t = max(Z_1, Z_2, \ldots, Z_t) - min(Z_1, Z_2, \ldots, Z_t) \; t = 1, 2, \ldots, n$$

(5) Calculate standard deviation series S

$$t$$

$$S_t = \sum_{i=1}^{n} (X_i - u)^2 \quad t = 1, 2, \ldots,$$

Here u is the mean value from X_1 to X_t.

(6) Calculate rescaled range series (R/S)

$$(R/S)_t = R_t/S_t \qquad t = 1, 2, \ldots, n$$

Hurst found that (R/S) scales by power-law as time increases, which indicates

$$(R/S)_t = c*t^H$$

Here c is a constant and H is called the Hurst exponent. To estimate the Hurst exponent, we plot (R/S) versus t in log-log axes. The slope of the regression line approximates the Hurst exponent.

The R/S simple analysis has been modified by [11]Andrew Lo(1991) to work better for smaller datasets [12] VadimTeverovskya report on an empirical investigation of the modified *rescaled adjusted range* or *R/S* statistic that was proposed by Lo, 1991. [13] RafałWeron testa R/S analysis, Detrended Fluctuation Analysis and periodogram regression methods on samples drawn from Gaussian white noise. The DFA statistics turns out to be the unanimous winner. [15] Ingve Simonsen propose a method for (global) Hurst exponent determination based on wavelets..[16] L. Lacasa1 propose a brand new methodology to quantify long-range dependence in these series. Its reliability is confirmed with numerical simulations and analytical developments.

The Hurst exponent gives us a idea about the underlying long term memory in the system and hurst not only applied it to the flow of nile which gave H=0.72 but incredibly to a variety of different natural

phenomena which all gave a hurst exponent near 0.7 like rainfall, temperature and pressure , sunspot numbers , wheat prices and even tree rings although this results were only on small set of samples .

The hurst phenomena answers the question why do things occur in bunches and more importantly gives a method which does not rely on the gaussian model , which assumes that all events are independent of other and statistical models are modelled after this assumption that all events are independent of the previous events . This theory does not work in case of systems which have a underlying memory like stock markets and bitcoin prices so we use the hurst exponent to find out the memory and the persistence in the system or markets .

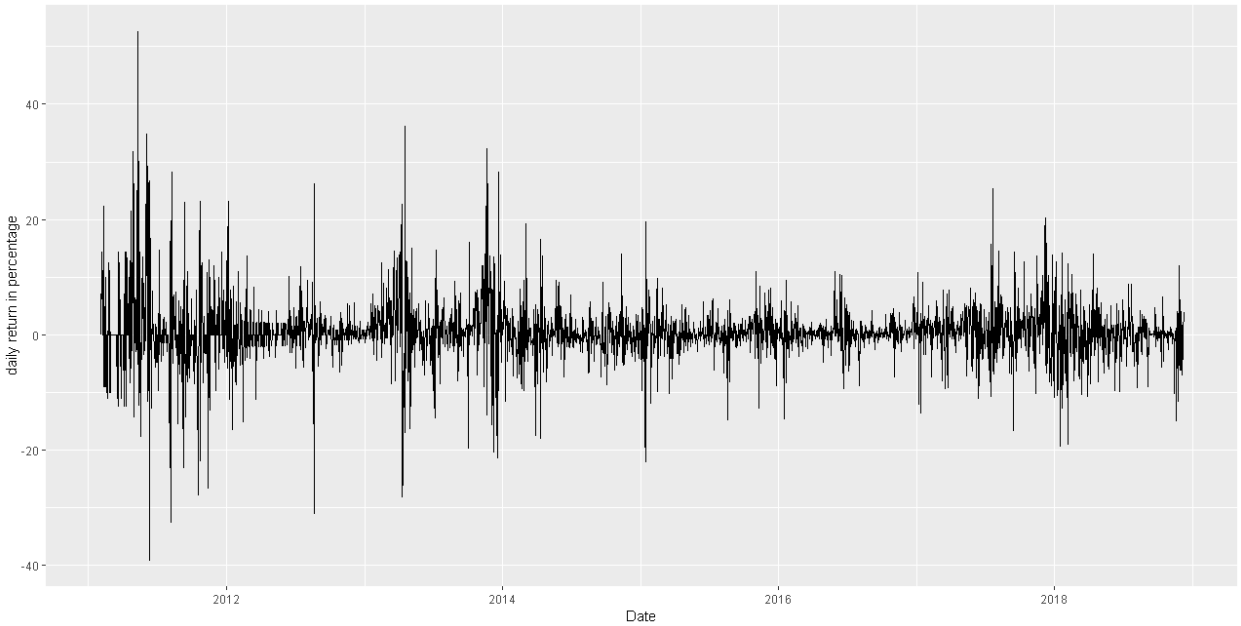
Data and Methodology-

The first transactions of bitcoin started from 2009 but since bitcoin barely had few transaction in the early days and since it was relatively unknown to most of the public , it makes sense to leave out the transactions before bitcoin actually has a sizable amount of data and price fluctuations per day. The data for bitcoin price and volume is obtained from investing.com .We have considered daily close value for the days..We take our time period from February 2011 to December 2018 which gives us 2862 data points about a 7 year time series of bitcoin prices . This should give us a idea about the trends and the efficiencies of the bitcoin network over the time.

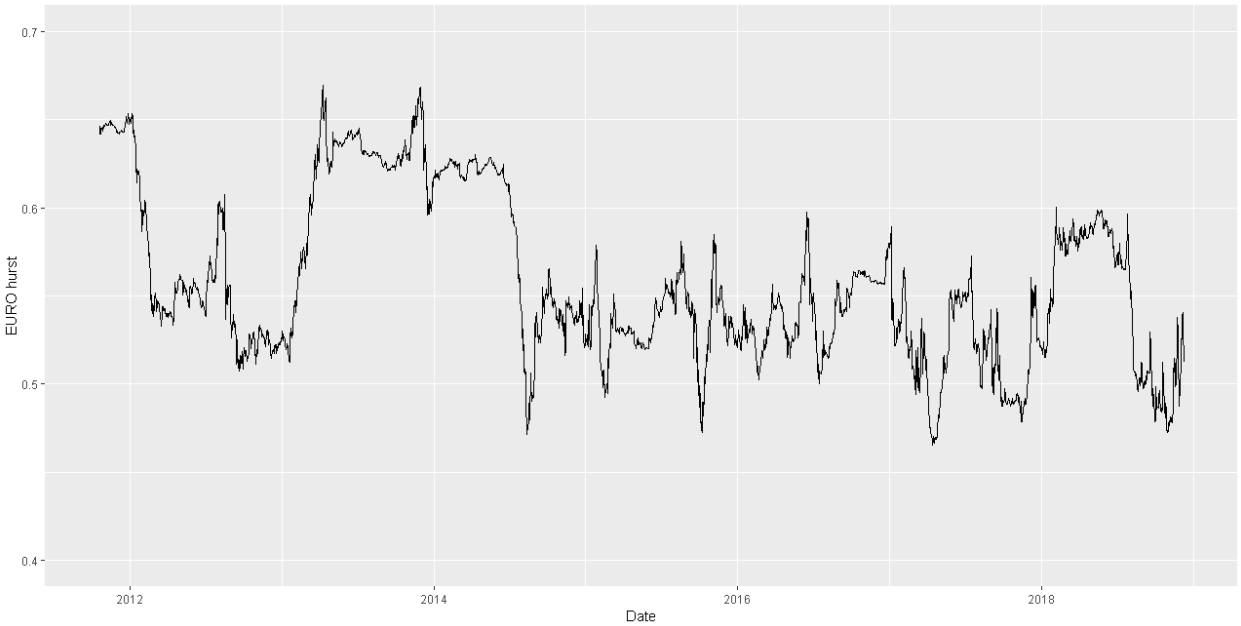
We use a rolling hurst instead of a static hurst exponent like in other papers because we have time varying system it is best to use a time varying hurst to model [7] a time varying market thus we are using a 256 rolling window .
We use a sliding window 256 points where we use rescaled range method of hurst thus we get a hurst exponent then we move the window and discard the last point and move on to the next point and compute the hurst exponent. This method was used successfully in papers [in Cajueiro and Tabak (2006)].

[cite paper]. We find out that minimum number of points for reliable hurst exponent is 128.
We use a 256 data point which is about a 8 and half month window . This gives a understanding of dynamic system like bitcoin. We also take returns on bitcoin price with the (Rtn+1 - Rtn)/Rtn * 100 . We plot this thus we get the volatility of the system .

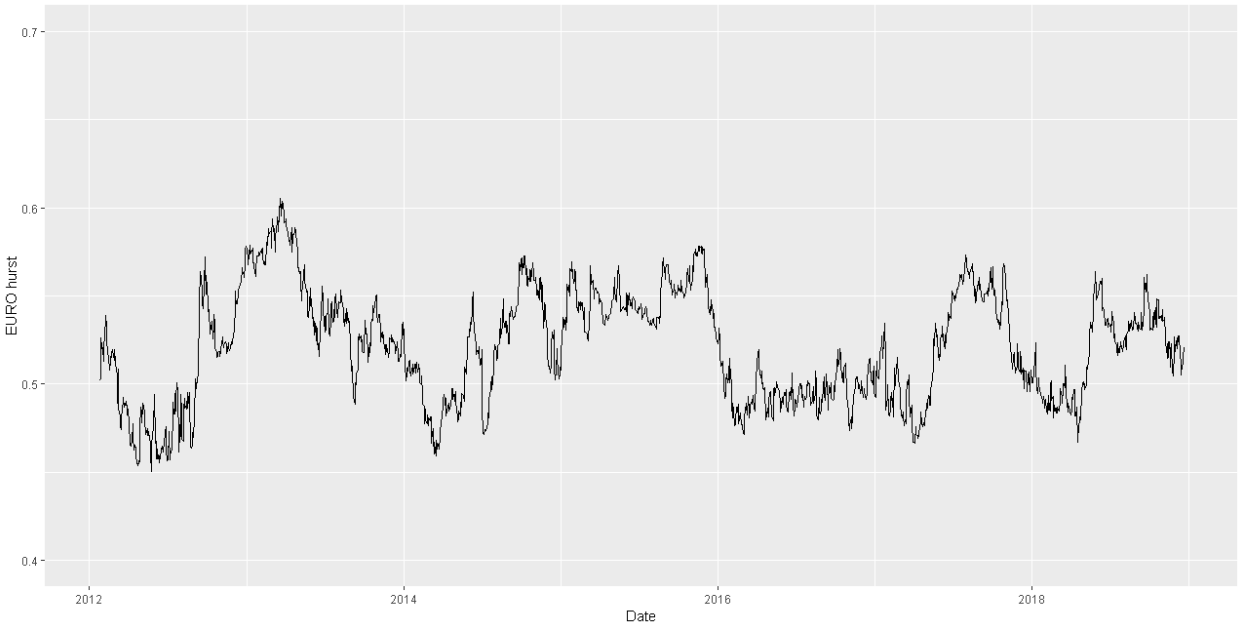
We also use the same sliding window on the returns of bitcoin , thus we get around 2500 points of hurst exponents thus we plot the data.



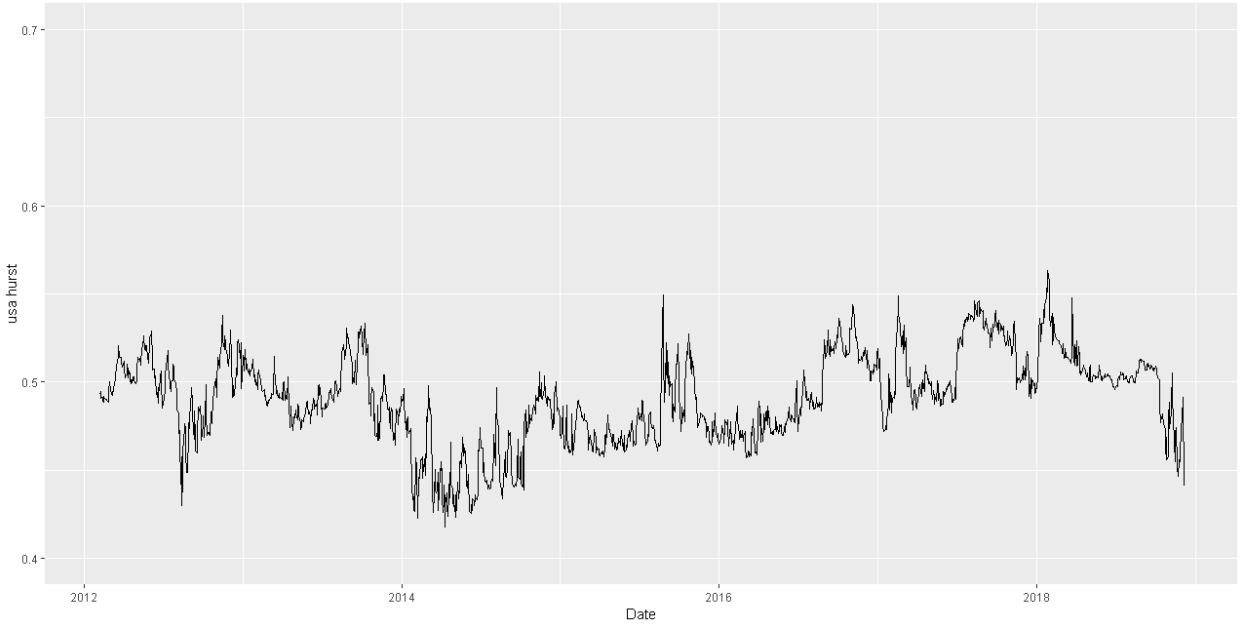
a) Daily return of Bitcoin



b) Bitcoin Hurst



Euro/usd Hurst



d)US stock market

Table 2
Hurst exponent and correlation for the experimented markets.

Exchange	Hurst exponent
EUR	0.5223
BTC	0.5583

USA 0.4905

Empirical Results –

Figure A and Figure B shows the returns of Bitcoin and EUR respectively. The Bitcoin market indicates far more volatility then the EUR/USD from figure A and B . The use of the rolling window allows us to observe the time varying component in financial time series and quantifying it . The R/S simple method is used to estimate hurst exponent shown in figure c and d . In the first sub-period bitcoin [till late 2014] shows persistence as H>0.5 .After 2014 in the second sub-period bitcoin hurst varies between 0.48 and 0.56 .This second sub-period of bitcoin [late 2014 to 2018]corresponds to the EUR hurst . The shift of bitcoin from first to second period was notable and Bariviera et al. (2017) did not find any relation to hurst and trading volume. We find that second period of hurst exponent is very close to 0.5 thus being compatible to EMH . Our findings the suggest that bitcoin is becoming efficient and very close to efficiency of established forex like EURO even though the bitcoin has far more volatility then euro.
The figure D shows the hurst exponent of US stock market , it interesting note that the hurst exponent of us stock market is very close to 0.5 from 2012 . The US stock markets has a hurst exponent of 0.49 which signifies that the US stock market is highly efficient from 2012 to 2018. Euro although established currency still is inefficient compared to the us stock market . The Euro has a higher degree of persistence thought out our period while also showing higher inefficiencies.

Conclusion-

In this study , we apply the compute the hurst using rolling window method as such a time varying approach makes easier to compute the dynamic system like bitcoin and any other financial time series. Bitcoin is a market is a emerging financial and is considered to be a currency , a assets as well as a bank. Our results suggest that bitcoin has had period inefficiency in the first period and has been efficient in the second period even considering the rapid rise and bust during 2018. The results show that bitcoin has become efficient in the recent times even during the recent boom and bust . The Hurst exponent although higher than other forex currencies is still very close thus suggesting that bitcoin might be lucrative currency for trading considering the high volatility and higher inefficiency than its forex counterparts. The US stock market is a extremely efficient system due to robust infrastructure and a decades of trading ,insider trading ,scams etc. The nature of the market is such that it is self adapting . The European market although has been for long time ,unlike US it not homogenous . European counties can be added and leave in their economic system, these various countries without although may have common goal but each of these have varying degrees of inefficiency as result of each countries own policies. Bitcoin market in

someways resembles the Euro of a common currency but eliminates the various inefficiency that a singular country has on Euro. The acceptance of bitcoin by various countries and a wider adoption will end the uncertainty of bitcoin . The stabilizing of bitcoin price and its increasing efficiency might bring in the big institutional traders although the legality and taxation of Bitcoin is still unknown in most of the countries. Additional Research is required as to why bitcoin shifted from its inefficiency in 2014 and underlying long memory in the system.

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