1. Introduction

One of the most recent innovations in the financial world is the creation of Bitcoins, a decentralized form of digital currency known as cryptocurrency. In the last year or so, the popularity of bitcoins has increased largely due to the global economic crisis. The lack of consumer confidence in traditional currency systems and increased uncertainty amongst investors has provided bitcoin with enough momentum to be viewed as profitable investment vehicle. However, the application of a decentralized anonymous currency in an economic system is causing scrutiny of this financial instrument as a tool for money laundering and other illicit activities. Bitcoins are relatively new, and not much formal public literature regarding the topic is even in circulation. The following paper will be a review of Bitcoins and the concepts behind digital currencies and the internet economy. This paper will also be an attempt to investigate whether there are any significant relationships between Bitcoins and traditional macroeconomic variables in the U.S. financial market, using econometric modeling.

2. Review of Literature

2.1 What is Digital Currency?

Digital currency is essentially electronic money that serves as an alternative currency in digital or online transactions. The purpose of this financial instrument is “to create units of purchasing power that are fully usable and transferable electronically” (Cohen, 2001). In other words, “the aim is to create digital money that can be employed as easily as conventional currencies to acquire real goods and services," (Cohen, 2001). Digital currency is often confused with virtual currency, but it's important to know the difference. "Digital money used in our economy differs from virtual money used in virtual economies due to its use in transactions with real goods and services" (Bitcoin Wiki). Virtual currencies are "limited to circulation within the virtual economies of online games" (Bitcoin Wiki). The concept of digital currency began in the 1980's with a paper written by Chaum in 1985. In it he" proposed an anonymous form of digital cash, but one which required a single central bank to verify electronically the authenticity of each "coin" when it was used" (Chaum, 1985). This was the seminal paper that began the quest of finding a functional, widely accepted digital currency, and this could be considered as the source of inspiration for all future forms of digital currency. Some forms of digital currency have already started up such as e-cash and egold. The difference between these forms of digital currency and Bitcoins is the latter can operate with no central authority. This highlights the fact there are two types of digital currency, cryptocurrencies and non-cryptocurrencies.

Non-cryptocurrencies include e-cash, e-gold, and e-bullion. These types of currencies are the earlier forms of digital currency and "are often backed by a promise to pay a set amount of gold or silver bullion in exchange for each of its units. Others float against whatever individuals are willing to exchange for it" (Bitcoin Wiki). Essentially, these currencies have either a gold or silver standard, or they are tied to government backed currencies through a floating exchange rate. They are not "produced by government-endorsed central banks nor directly backed by national currency" (Melik, 2013). The institutions that have created and support these forms of currencies are regulated by U.S. Treasury Department. The regulations apply to any and all non-cryptocurrencies, which implies they can be shut down or eliminated at any time by the U.S. government. Although this type of digital currency was the first to be adopted and created, lack of popularity and momentum has caused most of these types of currencies to fail and become inactive. "Such network-based systems such as DigiCash (later eCash), CyberCoin, and NetCash, which operate on the principle of full prepayment by users has functioned as not much more than a convenient proxy for conventional money. Few have caught on with the general public, and many have already passed into history" (Cohen, 2001).

Cryptocurrencies, on the other hand, are a type of decentralized, peer-to-peer digital currency that is based on cryptography for security. This is the most recent form of digital currency created with Bitcoin being the very first cryptocurrency of its kind, invented in 2009 by Satoshi Nakamoto. Cryptocurrencies "rely on cryptography, usually alongside a proof-of-work scheme, in order to create and manage the currency, and also making it difficult to counterfeit," (Bitcoin Wiki). Cryptocurrencies are also designed to provide anonymity to users, as well as to ensure that funds can neither be frozen nor seized by government authorities. Besides the 'freedom' associated with the anonymity of transactions, "another objective is anonymity so individuals' buying histories cannot be collected and sold to marketing agencies " (Mackie-Mason, 1994). In the current events of today, privacy issues are at the forefront with internet usage as a battleground. Many businesses like Amazon and online tech companies like Google and Facebook have been highlighted as examples of organizations that gather information on consumers and sell their consumption patterns to third parties. The importance of these current social issues are aiding in the propulsion of popularity Bitcoins and the cryptocurrency model amongst supporters of free market economics.

This leads to the issue of currency decentralization and the political implications of such. "Cryptocurrency is an attempt to bring back a decentralized 'currency of the people,' one that is not subject to inflationary moves by a central bank"(Jannsen). This statement was made by one of the original proponents of Bitcoins, which illustrates the political and economic viewpoints of cryptocurrency supporters. Supporters of this type of currency tend to be of the right-wing political spectrum and classical economists. Some of the underlying beliefs of this school of thought are limited government intervention in the free market(especially central bank intervention), anonymity and freedom of transactions, as well as a fixed supply monetary system that works similar to that of a gold standard. The appeal of cryptocurrencies is that they are intrinsically "designed to have no inflation (once all the currency has been produced), in order to keep scarcity and hence value" (Bitcoin Wiki). This is possible by limiting the amount of supply of the currency to a predetermined fixed amount. "In the case of Bitcoin, the most prominent functioning example of cryptocurrency, its value is determined by supply and demand in the market. As such this currency behaves much like gold and other precious metals" (Jannsen).

2.2 Why is Electronic Commerce important?

With the proliferation of internet use in the last twenty years, electronic commerce (or e-commerce) has become essential for many businesses. "Electronic commerce substantially increases productivity by reducing the time and other transactions costs inherent in commerce" (Mackie-Mason, 1994). As time has passed, e-commerce markets have been becoming more innovative and more efficient, thus further reducing transactions costs. The importance of online marketplaces is increasing, and as technology continues to advance so will the volume of digital transactions. A recent study issued by Google regarding the internet's economic impact shows that "in 2010, ecommerce transactions totaled $684 billion, or 4.7% of all U.S. economic activity," and "across the G-20 it already amounted to 4.1% of GDP or 2.3 trillion dollars" (Boston, 2013). The same study also notes that "government contributed $625 billion or 4.3% to the United States' economic output" (Boston, 2013), which indicates that ecommerce activity contributes more to U.S. GDP than aggregate government spending. This trend shows no sign of slowing down or reversing, "by 2016, there will be 3 billion internet users globally, and the internet economy will reach $4.2 trillion in the G-20 economies"(Boston, 2013).

This evidence implies that the internet economy will continue to expand. "One important requirement for a complete electronic commerce economy is an acceptable form of electronic payment," (Mackie-Mason, 1994). As the internet economy increases in size, so will the need for increased payment facility, transaction efficiency, and transaction cost reduction. "Costs and payment uncertainties can be avoided in person by using physical currency, but no mechanism exists to make payments over a communications channel without a trusted party," (Satoshi, 2009). Currently, the predominant form of online payment system in place is the use of third party payment processing companies like Paypal. Although some large internet retail companies like Amazon have their own in-house payment processing departments, many companies like Ebay rely solely on the use of third party systems, so much so that Paypal became a wholly owned subsidiary in 2002. Paypal charges a fee for processing every transaction, somewhere between 2% and 3% of the total price, which can be viewed as a relatively high cost compared to physically purchasing something with fiat money. Although there is sales tax applied to both cases, the scenario involving payment with fiat currency doesn't involve any processing fees or transactions costs. "In 2008 Paypal's transaction volume was $60 billion, representing nearly 9 percent of global e-commerce and 15 percent of U.S. e-commerce"(Paypal). Despite the increasing size of the internet economy, transactions aren't being facilitated in a cost-efficient manner relative to physical transactions with fiat currency, which also means there's room for improvement. "As electronic commerce (e-commerce) expands, it seems only a matter of time before various innovative forms of money, based on digital data and issued by private market actors, begin to substitute in one way or another for customary means of payment" (Cohen, 2001).

2.3 What are Bitcoins?

Bitcoins are an experimental decentralized digital currency that enables instant payments to anyone, anywhere in the world. They are a cryptocurrency form of digital currency that allows for secure and anonymous transactions in the e-commerce economy as well as the real world economy. The concept of bitcoins was created by Satoshi Nakamoto, a pseudonym for an anonymous person who set up the entire system. It is interesting to note that although the name Satoshi Nakamoto sounds Japanese and the Mt. Gox is located in Tokyo, the person who created bitcoins is considered to be American because the entire report was published in perfect English. Some people even believe this person to be American, citing that there are American idioms found within the original report.

Actual bitcoins were created in May of 2010, by the start of the chain log, which is a software licensed by MIT. The chain log is “a shared public transaction log on which the entire Bitcoin network relies. All confirmed transactions are included in the block chain with no exception. This way, new transactions can be verified to be spending bitcoins that are actually owned by the spender” (Bitcoin Project). This type of software helps prevents fraud and accounting problems with double spending. This is also where the cryptography mentioned earlier comes into play, by protecting the chain log from any type of hacking or fraud. “The integrity and the chronological order of the block chain are enforced with cryptography” (Bitcoin Project). There are only 21 million bitcoins allowed to be produced, and they are done so bitcoin mining operations. Bitcoin mining involves using computing power and an evolving hash rate to verify each and every transaction made without exception. The miners are rewarded by receiving bitcoins issued by the chain log as an incentive to continue supporting the bitcoin system. Mining, “enforces a chronological order in the block chain, protects the neutrality of the network, and allows different computers to agree on the state of the system” (Bitcoin Project). The bitcoin system relies heavily on peer-to-peer technology, in order to maintain independence from any one government organization. It is “designed to ensure that funds can neither be frozen nor seized,” (Satoshi, 2009).

Bitcoin is not the first digital currency to be created, but it is the only digital currency to gain enough momentum to be viewed as a viable currency. “In March 2013, Bloomberg valued the entire alternative world currency at over $600 million; it is now estimating the total value of Bitcoin at over $2 billion” (RT News, 2013). One explanation for this is the global economic crisis. The recent Cyprus bailout caused the price of bitcoins to surge past $200 from around

$40. Some experts argue that "the digital currency is safer to use than real money, since it is not altered by politics as the people in Cyprus found out," (RT News, 2013). As consumer confidence in government organizations and central banks is dissipating in large part because of the global economic crisis, bitcoins are becoming more and more popular. Now, investors and consumers alike are becoming more and more attracted to bitcoins. Investors look at bitcoins as a form of hedge against other currencies or as an investment vehicle. Consumers look at it as a way to protect their money from inflation and monetary policy applied by central banks. Bitcoins are so popular there are several websites that have charts of bitcoin prices similar to those in the financial world. These charts include tools and features like volume bars, candlestick charts, oscillators, moving average indicators and all of the other tools analysts using when looking at financial charts.

2.4 Criticisms of Bitcoins and Cryptocurrency

Although Bitcoins are becoming increasingly popular, it's invention has created quite a variety of concerns. "The effects of digital currency and new payment systems on central banks and their money supplies, as well as the increased potential for criminal activity and tax evasion have garnered the most interest," (Gladstone, 1997).

One of the main criticisms of cryptocurrencies is the lack of any state sponsorship. Our current currency system which has been in place much longer than digital currency, is reliant on money that is backed by the 'full faith and credit' of a nation, government, or central bank. "Many believe that general acceptability can derive only from the sovereign power of the state, as the German economist George Knapp contended nearly a century ago," (Cohen, 2001). Cryptocurrency on the other hand, is based on the 'full faith and credit' of the free market, or in other words, it isn't backed by any tangible asset or organization. Many people view this type of financial instrument as essentially worthless. Supporters of Bitcoins argue the same against fiat currency, since the intrinsic value of it is only worth the paper it's printed on. Both arguments boil down to which one has more support by the personal opinion of the consumer, or which one has more consumer confidence. It is cited that "consumer confidence is critical for the widespread use and acceptance of digital currencies," (Gladstone, 1997).

Another concern regarding Bitcoins is the role of government and central banks in regulating them. This is reflected in the following statement that "private e-currencies will make it difficult for central bankers to control or even measure or define monetary aggregates. At the extreme, currencies issued by central banks may no longer matter" (Cohen, 2001). Some economists like Benjamin Friedman go so far as to say that "with the development of e-money, monetary policy is at risk of becoming little more than a device to signal the authorities' preferences" (Cohen, 2001). Although I believe that the viewpoints expressed in these statements are a little extreme, these concerns are widespread. Some economists argue the opposite, "concerns for the role of central banks are exaggerated. Even such radical changes as might someday develop are unlikely to interfere with the conduct of monetary policy," (Cohen, 2001). Concerns over regulation also include the topics of criminal activity, money laundering and tax evasion. The anonymity of transactions has incited many criminals to use Bitcoins as an electronic payment system for illicit goods and services. In recent news, FinCEN had released a statement regarding virtual and digital currencies on March 18, 2013, which essentially applied the same laws and regulations regarding these topics that are imposed on banks towards Bitcoin exchange markets. This document states what Bitcoin merchants need to legally comply with in order to remain in business. Many people in the media claim that Bitcoin will be shut down by federal authorities, but a recent article states that federal authorities “apparently don't have plans to crack down on all digital currencies as long as all rules are followed” (Kerr, 2013). This suggests that concerns over Bitcoin regulation are overemphasized by its opponents, and that government seems to have a steady control over the digital currency in the present time.

3. Purpose

This paper is a multipurpose analysis of the Bitcoin market. Since Bitcoins are relatively new, I will first conduct a thorough review of the literature, information and news regarding the state of Bitcoins at the present time. I will also be investigating to see whether or not the Bitcoin market is efficient, and if I can formulate a model in order to forecast future prices. I will be looking for significant relationships between the current price of Bitcoins and its previous prices as well as other variables such as the volume of Bitcoins, a measure of stock market volatility and U.S. interest rates. Since Bitcoins are currently being viewed as an investment vehicle, I have included the VIX, which is a measure of market volatility in the S&P500, to see if increasing volatility in the U.S. stock market will have any effect on the price of Bitcoins. My logic is that there is a positive relationship between Bitcoin prices and market volatility, which implies as the stock market becomes more volatile, more risk averse investors will seek other investment vehicles including Bitcoins. Since Bitcoin uses basic supply and demand in order to find its equilibrium, money moving from the stock market into the Bitcoin market will cause demand to increase, as well as the price. For the next variable of U.S. interest rates, I will be using the 1-year bank discount rate to measure this. Since Bitcoin is a currency, and the majority of transactions using bitcoin are denominated in USD, I want to investigate to see whether or not changing interest rates would affect the price. It should be noted that in theory, "because it is not tied to any country, its value cannot be affected by a central bank," (Jannsen). Therefore, if interest rates aren't significant in any way in relation to the price of Bitcoins, then the statement that its value can't be affected by a central bank would seem to hold true. If there is a significant relationship, then this theory would be false and we could conclude that the actions of central banks do have an effect on the price of Bitcoins. Although Bitcoins are supposed to be a decentralized currency, this could be explained through the predominance of the USD for transactions in the Bitcoin market.

4. Data

The data I will be using is time series observations of financial indicators related to Bitcoins. The variables included are the price of Bitcoins (in dollars), the volume of Bitcoins (in dollars), the VIX of the S&P 500 and the bank discount rate set by the Federal Reserve. The analysis will be using weekly data, from the date Mt. Gox began operaions for bitcoin (7/19/10) until the present day (6/10/13). The price and volume of Bitcoins are based on the data from the Mt. Gox online exchange, which is the largest Bitcoin exchange and handles over 85% of all bitcoin market activity. It should be noted that data collected from the bitcoin chain log provides information on 100% of bitcoin transactions. However, I will not be using data from this source because it doesn't represent a single exchange market. Bitcoins can be bought and sold and transferred through many mediums that aren't necessarily financial markets, which include ebay, online auctions, and online blogging sites. This paper is investigating bitcoins as a financial instrument, and as such it should look at transactions and prices in the predominant centralized exchange that handles the majority of its activity, the Mt. Gox. I will also be using market indicators from the traditional financial world to see how bitcoins interact with them. As a measure of volatility in the stock market I will use the VIX closing prices from the time bitcoins were created to the present. As a measure of influence from Fed policy I will include the variable YR, which is the one year Fed bank discount rate. I will also include the variable VOL, which is a measure of the dollar transaction volume of BTC in the Mt. Gox bitcoin exchange.

BTC = closing price of Bitcoins

VOL = dollar transaction volume of Bitcoins

VIX = volatility in the S&P 500

YR = one year bank discount rate set by the Fed

5. Methodology

I will begin the econometric analysis of Bitcoins by conducting Phillips-Perron tests on each individual variable to determine whether each respective time series has a unit root which tells us if it's stationary or non-stationary. I will then conduct Engle-Granger tests on BTC and each explanatory variable to find evidence of cointegration. The Johansen's test will be used on the entire equation with all of the variables included to see if the entire equation is cointegrated. If the entire equation is cointegrated I will not take the differences of the non-stationary variables. "If we find a cointegrating relationship between the variables, then it's possible to estimate the regression equation using levels, preserving information on the levels of the variables" (Yuhn, p.117). The next step is obtaining the CUSUM and CUSUMSQ to see whether or not the parameters and the variance of the error term have structural stability. A combination of linear and linear log regressions will be run after this, both with and without a time variable included to monitor the effects of the variables on BTC before and after detrending. It is my hypothesis that since bitcoins are a decentralized currency, any actions by the Fed on interest rates will have no significant effect on BTC price. Since bitcoins are a currency and not categorized as equity like stocks, stock market volatility should also have no significant effect on BTC. If my hypothesis is correct, then I will drop the VIX and YR variables from the formulation and continue investigation by conducting regressions, ARCH (1), ARCH (2) and GARCH (1, 1) estimations with the remaining variables. If it isn't and there is a significant relationship between all of the variables, then I will proceed with ARCH family estimations for the entire equation.

6. Testing

6.1 Test for unit root and stationarity (Phillips perron)

Phillips-Perron tests

```
. pperron btc, regress

Phillips-Perron test for unit root                 Number of obs   =       151
                                                   Newey-West lags =         4

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -3.310           -19.970           -13.802           -11.068
 Z(t)            -0.863            -3.493            -2.887            -2.577
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.8001

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         btc |
         L1. |   .9475316   .0323077    29.33   0.000     .8836912    1.011372
             |
       _cons |   1.521456   1.131502     1.34   0.181    -.7144071     3.75732
------------------------------------------------------------------------------
```

BTC – H0: Unit Root present, Non-stationary $DF_{\tau} < DF_{crit}$

H1: Unit root not present, Stationary $DF_{\tau} > DF_{crit}$

DF_{τ} = -0.863

DF_{crit} = 2.887

0.863 < 2.887 $DF_{\tau} < DF_{crit}$

We accept the null hypothesis, and conclude that there is a unit root present and the series is non-stationary. BTC is integrated of order I (1)

```
. pperron vol, regress

Phillips-Perron test for unit root                 Number of obs   =       151
                                                   Newey-West lags =         4

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -32.551           -19.970           -13.802           -11.068
 Z(t)            -4.144            -3.493            -2.887            -2.577
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0008

------------------------------------------------------------------------------
         vol |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         vol |
         L1. |   .7739313   .0533459    14.51   0.000      .668519    .8793436
             |
       _cons |   280924.9   169653.9     1.66   0.100    -54313.38    616163.3
------------------------------------------------------------------------------
```

VOL - H0: Unit Root present, Non-stationary $DF_{\tau} < DF_{crit}$

H1: Unit root not present, Stationary $DF_{\tau} > DF_{crit}$

DF_{τ} = 4.144

DF_{crit} = 2.887

4.144 > 2.887 $DF_{\tau} > DF_{crit}$

We reject the null hypothesis, and conclude that there is no unit root present and the series is stationary. VOL is integrated of order I (0)

```
. pperron  vix, regress

Phillips-Perron test for unit root                 Number of obs   =       151
                                                   Newey-West lags =         4

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -13.941           -19.970           -13.802           -11.068
 Z(t)            -2.718            -3.493            -2.887            -2.577
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0709
```

vix	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
vix L1.	.8914444	.0369968	24.10	0.000	.8183383	.9645505
_cons	2.091939	.7647243	2.74	0.007	.5808339	3.603045

VIX - H0: Unit Root present, Non-stationary $DF_\tau < DF_{crit}$

H1: Unit root not present, Stationary $DF_\tau > DF_{crit}$

$DF_\tau = 2.718$

$DF_{crit} = 2.887$

$2.718 < 2.887$ $DF_\tau < DF_{crit}$

We accept the null hypothesis, and conclude that there is a unit root present and the series is non-stationary. VIX is integrated of order I (1).

```
. pperron   yr, regress

Phillips-Perron test for unit root                 Number of obs   =       151
                                                   Newey-West lags =         4

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -7.370           -19.970           -13.802           -11.068
 Z(t)            -2.102            -3.493            -2.887            -2.577
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.2436
```

yr	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
yr L1.	.9229157	.0302399	30.52	0.000	.8631612	.9826702
_cons	.0126263	.0055395	2.28	0.024	.0016802	.0235723

YR - H0: Unit Root present, Non-stationary $DF_\tau < DF_{crit}$

H1: Unit root not present, Stationary $DF_\tau > DF_{crit}$

$DF_\tau = 2.102$

$DF_{crit} = 2.887$

$2.102 < 2.887$ $DF_\tau < DF_{crit}$

We accept the null hypothesis, and conclude that there is a unit root present and the series is non-stationary. VIX is integrated of order I (1).

BTC, VIX, and YR are characterized by random walks because they're non-stationary. VOL is stationary.

6.2 Cointegration Tests (Engle Granger)

reg btc vol

Dickey-Fuller test for unit root Number of obs = 151

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-7.360	-3.493	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.0000

BTC VOL- H0: There is unit root, residuals are non-stationary. $Z(t)_\tau > EY_{crit}$

H1: There is no unit root, residuals are stationary. $Z(t)_\tau < EY_{crit}$

$Z(t)_\tau = -7.360$

EY_{crit} (2,150) ADF= -3.17

-7.360 < -3.17 $Z(t)_\tau < EY_{crit}$

We reject the null hypothesis, and conclude that there is no unit root present so the residuals are stationary and there is evidence of cointegration between BTC and VOL.

reg btc vix

Dickey-Fuller test for unit root Number of obs = 151

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.903	-3.493	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.3305

BTC VIX- H0: There is unit root, residuals are non-stationary. $Z(t)_\tau > EY_{crit}$

H1: There is no unit root, residuals are stationary. $Z(t)_\tau < EY_{crit}$

$Z(t)_\tau = -1.903$

EY_{crit} (2,150) ADF= -3.17

-1.903 > -3.17 $Z(t)_\tau > EY_{crit}$

We accept the null hypothesis, and conclude that there is s unit root present so the residuals are non-stationary and there is no cointegration between BTC and VIX.

reg btc YR

```
. dfuller resid, regress

Dickey-Fuller test for unit root                   Number of obs   =       151
```

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.130	-3.493	-2.887	-2.577

MacKinnon approximate p-value for Z(t) = 0.2325

BTC YR- H0: There is unit root, residuals are non-stationary. $Z(t)_\tau > EY_{crit}$

H1: There is no unit root, residuals are stationary. $Z(t)_\tau < EY_{crit}$

$Z(t)_\tau = -2.130$

EY_{crit} (2,150) ADF= -3.17

-2.130 > -3.17 $Z(t)_\tau > EY_{crit}$

We accept the null hypothesis, and conclude that there is s unit root present so the residuals are non-stationary and there is no cointegration between BTC and YR.

The Engle-Granger tests tell us that BTC is cointegrated with VOL, but it isn't cointegrated with the VIX and YR. This implies that VOL would be a good predictor of bitcoin prices, but VIX and YR wouldn't be.

6.3 Cointegration (Johansen's Maximum Likelihood Test)

For BTC VOL VIX YR equation using 9 lags

```
. vecrank btc vol vix yr, lags(9) max levela

                      Johansen tests for cointegration
Trend: constant                                          Number of obs =     143
Sample:  1960w11 - 1962w49                                        Lags =       9
```

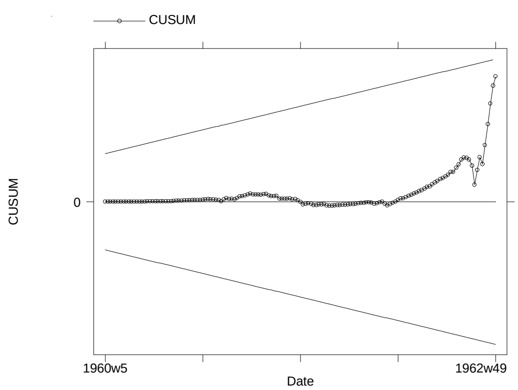
maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value	1% critical value
0	132	-2511.6458		53.9485*1	47.21	54.46
1	139	-2496.7762	0.18777	24.2092*5	29.68	35.65
2	144	-2488.5117	0.10916	7.6804	15.41	20.04
3	147	-2484.6904	0.05204	0.0377	3.76	6.65
4	148	-2484.6716	0.00026			

maximum rank	parms	LL	eigenvalue	max statistic	5% critical value	1% critical value
0	132	-2511.6458		29.7393	27.07	32.24
1	139	-2496.7762	0.18777	16.5289	20.97	25.52
2	144	-2488.5117	0.10916	7.6426	14.07	18.63
3	147	-2484.6904	0.05204	0.0377	3.76	6.65
4	148	-2484.6716	0.00026			

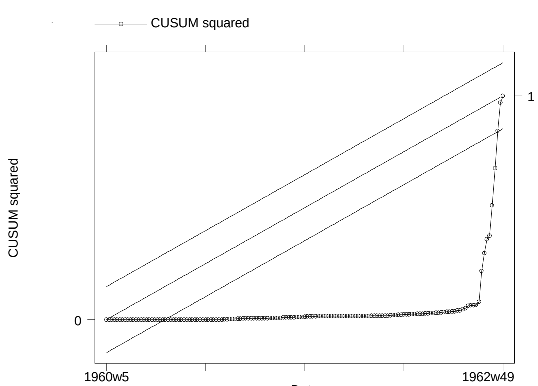
H0: r = 0 Max Stat. < Crit. Value
H1: r ≠ 0 Max Stat. > Crit. Value
Max Stat. = 29.7393
Crit. Value = 27.07
29.7393 > 27.07 Max Stat. > Crit. Value
We reject the null hypothesis and conclude that there is evidence of cointegration between VOL, VIX, YR and BTC and r ≠ 0. You are able to predict the future path of Bitcoin prices up to 9 lags using this formulation, and you can further test for long-run equilibrium relationships. This suggests that Bitcoin prices aren't random and the market is inefficient. An inefficient market signifies that profits can be made in Bitcoin investments.

6.4 CUSUM tests

CUSUM test for parameter stability



CUSUMSQ test for stability in the variance of the error term



The CUSUM test has shown that there is no structural change in the parameters or there is parameter stability when bitcoins are regressed against its volume of transactions. However, the CUSUMSQ test has shown that there is a very significant structural break in the variance of the error term of the model for the majority of the time bitcoins have been in existence. This suggests that making predictions using bitcoin price and volume is not possible.

6.5 LS regressions

6.5.1 Linear Regressions (using BTC VOL VIX and YR) with and without trend stationary process

a) Simple LS regression

```
. reg btc vol vix yr

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  3,   148) =  102.60
       Model |  105835.309     3  35278.4362           Prob > F      =  0.0000
    Residual |  50890.0283   148  343.851542           R-squared     =  0.6753
-------------+------------------------------           Adj R-squared =  0.6687
       Total |  156725.337   151  1037.91614           Root MSE      =  18.543

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         vol |   7.16e-06   5.52e-07    12.97   0.000     6.07e-06    8.25e-06
         vix |  -1.008736   .2597332    -3.88   0.000       -1.522   -.4954714
          yr |  -130.4368   30.82816    -4.23   0.000     -191.357   -69.51654
       _cons |   51.02753   9.004788     5.67   0.000     33.23296    68.82209
------------------------------------------------------------------------------
```

```
. reg btc date vol vix yr

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  4,   147) =   83.97
       Model |  109015.345     4  27253.8362           Prob > F      =  0.0000
    Residual |  47709.9923   147  324.557771           R-squared     =  0.6956
-------------+------------------------------           Adj R-squared =  0.6873
       Total |  156725.337   151  1037.91614           Root MSE      =  18.015

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .1871993   .0598046     3.13   0.002     .0690116    .3053871
         vol |   6.90e-06   5.43e-07    12.71   0.000     5.83e-06    7.97e-06
         vix |  -.3095954   .3369914    -0.92   0.360     -.975569    .3563781
          yr |  -21.75843   45.85292    -0.47   0.636    -112.3745    68.85764
       _cons |   4.277274   17.30895     0.25   0.805    -29.92924    38.48379
------------------------------------------------------------------------------
```

The linear regressions shows that simple LS estimation provides significant relationships between all of the variables and the constant with bitcoin price. From the first regression we see that bitcoins have a negative relationship with the VIX and YR. This indicates that when stock market volatility or the bank discount rate increases the price of bitcoin decreases. However, when a time variable is added for detrending, the VIX, YR and constant are no longer significant.

b) Simple LS (Current BTC against one lagged variables)

```
. reg btc  volt1 vixt1 yrt1

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  3,   148) =   72.17
       Model |  93089.6621     3  31029.8874           Prob > F      =  0.0000
    Residual |  63635.6749   148  429.970777           R-squared     =  0.5940
-------------+------------------------------           Adj R-squared =  0.5857
       Total |  156725.337   151  1037.91614           Root MSE      =  20.736

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       volt1 |   6.78e-06   6.09e-07    11.14   0.000     5.58e-06    7.98e-06
       vixt1 |  -.9551614   .2723225    -3.51   0.001    -1.493304   -.4170187
        yrt1 |  -119.6763   32.20559    -3.72   0.000    -183.3185   -56.03407
       _cons |   48.59993   9.059515     5.36   0.000     30.69721    66.50264
------------------------------------------------------------------------------

. reg btc date volt1 vixt1 yrt1

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  4,   147) =   63.62
       Model |   99340.122     4  24835.0305           Prob > F      =  0.0000
    Residual |   57385.215   147  390.375612           R-squared     =  0.6338
-------------+------------------------------           Adj R-squared =  0.6239
       Total |  156725.337   151  1037.91614           Root MSE      =  19.758

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .2112964   .0528053     4.00   0.000     .1069408    .3156519
       volt1 |   6.21e-06   5.97e-07    10.41   0.000     5.03e-06    7.39e-06
       vixt1 |  -.3970582   .2945912    -1.35   0.180    -.9792391    .1851226
        yrt1 |  -25.46452   38.67858    -0.66   0.511    -101.9024    50.97337
       _cons |   5.749235   13.75487     0.42   0.677    -21.43359    32.93206
------------------------------------------------------------------------------
```

When running a regression of BTC against the previous period's values for VOL, VIX and YR we see that all variables including the constant are significant. The VIX and YR variables still have significant negative relationships with BTC, but when we detrend the regression by adding the date, they no longer have a significant impact.

c) Simple LS using logs of VIX and YR

```
. reg btc vol lvix lyr

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  3,   148) =  107.52
       Model |  107430.999     3  35810.3329           Prob > F      =  0.0000
    Residual |  49294.3382   148  333.069852           R-squared     =  0.6855
-------------+------------------------------           Adj R-squared =  0.6791
       Total |  156725.337   151  1037.91614           Root MSE      =   18.25

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         vol |   6.89e-06   5.57e-07    12.38   0.000     5.79e-06    7.99e-06
        lvix |  -27.80334    5.94107    -4.68   0.000    -39.54362   -16.06306
         lyr |  -22.67691   5.158022    -4.40   0.000    -32.86979   -12.48403
       _cons |   49.60895   16.65573     2.98   0.003     16.69518    82.52272
------------------------------------------------------------------------------

. reg btc date vol lvix lyr

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  4,   147) =   85.52
       Model |  109620.818     4  27405.2044           Prob > F      =  0.0000
    Residual |  47104.5194   147  320.438907           R-squared     =  0.6994
-------------+------------------------------           Adj R-squared =  0.6913
       Total |  156725.337   151  1037.91614           Root MSE      =  17.901

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .1501654   .0574432     2.61   0.010     .0366443    .2636865
         vol |   6.76e-06   5.48e-07    12.32   0.000     5.67e-06    7.84e-06
        lvix |  -13.34417   8.034356    -1.66   0.099    -29.22194    2.533588
         lyr |  -9.023626   7.271463    -1.24   0.217    -23.39373    5.346482
       _cons |   20.34223   19.80484     1.03   0.306    -18.79677    59.48122
------------------------------------------------------------------------------
```

When including the log values of the VIX and YR variables, we still see that all of the estimations are significant, and there is still a negative relationship between the VIX and YR against BTC. However, when including the time variable for detrending we find that VIX and YR are no longer significant.

d) Simple LS using one period lag of logs of VIX and YR and one period lag of VOL

```
. reg btc volt1 lvix1 lyr1

      Source |       SS       df       MS              Number of obs =     151
-------------+------------------------------           F(  3,   147) =   81.80
       Model |  97848.5255     3  32616.1752           Prob > F      =  0.0000
    Residual |  58615.8616   147  398.747358           R-squared     =  0.6254
-------------+------------------------------           Adj R-squared =  0.6177
       Total |  156464.387   150  1043.09591           Root MSE      =  19.969

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       volt1 |   6.12e-06   6.15e-07     9.96   0.000     4.91e-06    7.34e-06
       lvix1 |  -33.14412   6.501259    -5.10   0.000    -45.99213   -20.29612
        lyr1 |   -26.2894   5.644277    -4.66   0.000    -37.44381   -15.13499
       _cons |   60.02812   18.22832     3.29   0.001      24.0047    96.05153
------------------------------------------------------------------------------

. reg btc date volt1 lvix1 lyr1

      Source |       SS       df       MS              Number of obs =     151
-------------+------------------------------           F(  4,   146) =   64.84
       Model |  100110.472     4  25027.6179           Prob > F      =  0.0000
    Residual |  56353.9154   146  385.985722           R-squared     =  0.6398
-------------+------------------------------           Adj R-squared =  0.6300
       Total |  156464.387   150  1043.09591           Root MSE      =  19.647

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .1538825   .0635673     2.42   0.017     .0282516    .2795135
       volt1 |   6.01e-06   6.07e-07     9.91   0.000     4.81e-06    7.21e-06
       lvix1 |  -18.29627   8.861909    -2.06   0.041    -35.81047   -.7820765
        lyr1 |  -12.32279   8.007808    -1.54   0.126    -28.14899    3.503405
       _cons |   29.76187   21.86217     1.36   0.176    -13.44535    72.96908
------------------------------------------------------------------------------
```

When running the previous model which includes the log values of VIX and YR at one period lags we find that all of the variables are significant. The variables for VIX and YR still have a significant negative relationship to the price of bitcoins. However, when including a time trend variable to make the series trend stationary, the VIX variable now has a significant effect on the price of bitcoins. The YR variable is still insignificant.

After looking at all regressions, I have determined that after making each regression a trend stationary process by including a time variable for detrending, the 1 year bank discount factor and volatility of S&P500 are never significant. Along with the testing results of no cointegration between the bank discount rate, or the VIX against bitcoin prices, this is evidence that Fed interest rates and volatility in the U.S. stock markets have no significant effect on the price of Bitcoins. The implications are that bitcoins are indeed a decentralized currency and Fed policy has no effect on its price movement. Since this is the case, I will drop the YR and VIX variables from any future formulation or testing.

6.5.2 Test for Spurious Regression

```
. dwstat

Durbin-Watson d-statistic(  4,   152) =  1.079499
```

All of the R^2 values are less than the calculated Durbin Watson statistic which suggests that there is no evidence of spurious regressions.

6.5.3 Linear Regressions (using BTC against lags of itself and VOL) with and without trend stationary process

```
. reg btc btc1 btc2 vol1 vol2

      Source |       SS       df       MS              Number of obs =     150
-------------+------------------------------           F(  4,   145) =  289.47
       Model |  138815.454     4  34703.8636           Prob > F      =  0.0000
    Residual |  17383.6936   145  119.887542           R-squared     =  0.8887
-------------+------------------------------           Adj R-squared =  0.8856
       Total |  156199.148   149  1048.31643           Root MSE      =  10.949

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        btc1 |   .5911362   .0727181     8.13   0.000     .4474118    .7348606
        btc2 |   .4048228   .0872094     4.64   0.000      .232457    .5771885
        vol1 |  -1.66e-06   5.55e-07    -3.00   0.003    -2.76e-06   -5.66e-07
        vol2 |   1.74e-06   5.20e-07     3.34   0.001     7.10e-07    2.77e-06
       _cons |   1.058494   1.008083     1.05   0.295    -.9339415     3.05093
------------------------------------------------------------------------------
```

```
. reg btc  date btc1 btc2 vol1 vol2

      Source |       SS       df       MS              Number of obs =     150
-------------+------------------------------           F(  5,   144) =  235.74
       Model |  139194.136     5  27838.8272           Prob > F      =  0.0000
    Residual |  17005.0119   144  118.090361           R-squared     =  0.8911
-------------+------------------------------           Adj R-squared =  0.8874
       Total |  156199.148   149  1048.31643           Root MSE      =  10.867

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .0453972   .0253512     1.79   0.075    -.0047114    .0955058
        btc1 |   .5663447   .0734869     7.71   0.000     .4210923     .711597
        btc2 |   .3822537    .087466     4.37   0.000     .2093706    .5551369
        vol1 |  -1.57e-06   5.53e-07    -2.84   0.005    -2.67e-06   -4.80e-07
        vol2 |   1.77e-06   5.16e-07     3.42   0.001     7.47e-07    2.79e-06
       _cons |  -1.859397   1.912088    -0.97   0.332    -5.638783     1.91999
------------------------------------------------------------------------------
```

After conducting the AIC to determine the appropriate lag length, I found that two lag lengths for each variable BTC and VOL are significant. As is shown in the regression, all of the variables have a significant effect on the current price of bitcoins except for the constant. After introducing a time variable to make the series trend stationary, I find that all of the variables except the constant and the time variable are significant.

6.5.4 Linear Regressions (using BTC against lags of itself) with and without trend stationary process

```
. reg btc btc1 btc2 btc3

      Source |       SS       df       MS              Number of obs =     149
-------------+------------------------------           F(  3,   145) =  374.07
       Model |  138088.236     3  46029.4119           Prob > F      =  0.0000
    Residual |  17842.2444   145  123.049961           R-squared     =  0.8856
-------------+------------------------------           Adj R-squared =  0.8832
       Total |   155930.48   148  1053.58433           Root MSE      =  11.093

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        btc1 |   .4547666   .0808282     5.63   0.000     .2950128    .6145203
        btc2 |   .2897065   .0863077     3.36   0.001     .1191228    .4602902
        btc3 |    .284083   .0849431     3.34   0.001     .1161964    .4519696
       _cons |   .9729118   1.020222     0.95   0.342    -1.043516     2.98934
------------------------------------------------------------------------------
```

```
. reg btc date btc1 btc2 btc3

      Source |       SS       df       MS              Number of obs =     149
-------------+------------------------------           F(  4,   144) =  285.22
       Model |    138454.7     4  34613.6751           Prob > F      =  0.0000
    Residual |  17475.7798   144  121.359582           R-squared     =  0.8879
-------------+------------------------------           Adj R-squared =  0.8848
       Total |   155930.48   148  1053.58433           Root MSE      =  11.016

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .0448876   .0258314     1.74   0.084      -.00617    .0959452
        btc1 |    .434388   .0811233     5.35   0.000     .2740418    .5947343
        btc2 |   .2784285   .0859582     3.24   0.001     .1085257    .4483314
        btc3 |   .2781803    .084426     3.29   0.001      .111306    .4450546
       _cons |  -1.954183   1.965687    -0.99   0.322     -5.83951    1.931144
------------------------------------------------------------------------------
```

When running a regression on BTC against the past values of itself, I found that up the three previous period's prices have significant effects on the current price of bitcoins. After introducing the time variable to detrend the non-stationary series, I found that the three lag periods still have a significant impact on the current price of bitcoins. The constant is never significant in either model, and the time trend variable is also not significant.

6.6 Arch Formulation

6.6.1 Arch(1) model

```
ARCH family regression

Sample: 1960w2 - 1962w49                          Number of obs   =        152
Distribution: Gaussian                            Wald chi2(1)    =   52684.69
Log likelihood = -390.3246                        Prob > chi2     =     0.0000
```

btc	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
btc						
vol	8.28e-06	3.61e-08	229.53	0.000	8.21e-06	8.35e-06
_cons	.0586824	.0019822	29.60	0.000	.0547974	.0625674
ARCH						
arch L1.	2.727005	.1949139	13.99	0.000	2.344981	3.109029
_cons	.0000304	.0000193	1.57	0.116	-7.52e-06	.0000682

ARCH (1)

$BTC_t = 0.0586824 + 0.836\ VOL_t + e$

The coefficient of 0.836 suggests that when the volume of Bitcoin transactions increase by $100,000, the price of bitcoins increases by $0.836.

$\sigma^2_t = .0000304 + 2.727005\ e^2_{t-1} + u_t$

$\sigma^2_t = \quad \phi_0 \quad + \quad \phi_1\ e^2_{t-1} \quad + u_t$

Non-negativity Constraint: $\phi_0 \geq 0$ and $\phi_1 \geq 0$

$.0000304 \geq 0$ and $2.727005 \geq 0$

All parameters ϕ are non-negative.

Stability Constraint: $\phi_1 + \phi_2 < 1$

$.0000304 + 2.727005 = 2.7270354 > 0$

All of the parameters are greater than one when added together which indicates that it is not stable or is non-stationary.

```
. estat archlm
LM test for autoregressive conditional heteroskedasticity (ARCH)
```

lags(*p*)	chi2	df	Prob > chi2
1	83.490	1	0.0000

H0: no ARCH effects *vs.* H1: ARCH(*p*) disturbance

H0: LM < X^2 -No ARCH effect

H1: LM > X^2 -There is ARCH effect

LM = 83.49 X^2 (1) = 3.84

83.49 > 3.84 LM > X^2 (1) -reject H0

After conducting an LM test, we reject the null hypothesis and conclude that there are significant ARCH(1) effects present in the PV model.

6.6.2 Arch (2) Model

```
ARCH family regression

Sample: 1960w2 - 1962w49                     Number of obs   =        152
Distribution: Gaussian                       Wald chi2(1)    =    2553.73
Log likelihood = -370.0464                   Prob > chi2     =     0.0000
```

btc	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
btc						
vol	8.22e-06	1.63e-07	50.53	0.000	7.90e-06	8.54e-06
_cons	.0581762	.002381	24.43	0.000	.0535094	.0628429
ARCH						
arch L1.	1.071097	.2427648	4.41	0.000	.5952871	1.546908
L2.	.5858411	.243568	2.41	0.016	.1084565	1.063226
_cons	.0000397	.0000285	1.39	0.164	-.0000162	.0000955

ARCH (2)

$BTC_t = .0581762 + 0.822\ VOL_t + e$

The coefficient of 0.822 suggests that when the volume of Bitcoin transactions increases by $100,000, the price of bitcoins increases by $0.822.

$\sigma^2_t = .3708723 + 1.071097\ e^2_{t-1} + .5858411\ e^2_{t-2} + u_t$

$\sigma^2_t = \phi_0 + \phi_1 e^2_{t-1} + e^2_{t-2} + u_t$

Non-negativity Constraint: $\phi_0 \geq 0$ and $\phi_1 \geq 0$

.0000397 ≥ 0 and 1.071097 ≥ 0 and .5858411

All parameters ϕ are non-negative.

Stability Constraint: $\phi_1 + \phi_2 < 1$

.0000397 + 1.071097 + .5858411 = 2.0278104 > 0

All of the parameters are greater than one when added together which indicates that it is not stable or is non-stationary.

```
. estat archlm, lags(1/2)
LM test for autoregressive conditional heteroskedasticity (ARCH)
```

lags(p)	chi2	df	Prob > chi2
1	83.490	1	0.0000
2	83.154	2	0.0000

H0: no ARCH effects *vs.* H1: ARCH(*p*) disturbance

H0: LM < X^2 -No ARCH effect

H1: LM > X^2 -There is ARCH effect

LM = 83.154 X^2 (1) = 3.84

83.154 > 5.99 LM > X^2 (2) -reject H0

After conducting an LM test, we reject the null hypothesis and conclude that there are significant ARCH(2) effects present in the PV model.

6.6.3 GARCH (1, 1) Model

```
ARCH family regression

Sample: 1960w2 - 1962w49                    Number of obs   =        152
Distribution: Gaussian                      Wald chi2(1)    =      22.32
Log likelihood = -410.8994                  Prob > chi2     =     0.0000
```

btc	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
btc						
vol	1.32e-06	2.79e-07	4.72	0.000	7.72e-07	1.87e-06
_cons	.2180796	.0161198	13.53	0.000	.1864852	.2496739
ARCH						
arch L1.	1.291687	.3265067	3.96	0.000	.651746	1.931629
garch L1.	9.39e-07	.0363356	0.00	1.000	-.0712156	.0712174
_cons	.0006719	.001001	0.67	0.502	-.00129	.0026339

GARCH (1, 1)

$BTC_t = 0.2180796 + 0.132\ VOL_t + e$

The coefficient of 0.132 suggests that when there is an increase in the volume of transactions of $100,000 then the price of bitcoins increases by 0.132.

$\sigma^2_t = 0.0006719 + 1.291687\ e^2_{t-1} + .000000939\ \sigma^2_{t-1} + u_t$

$\sigma^2_t = \phi_0 + \phi_1 e^2_{t-1} + \psi_1 \sigma^2_{t-1} + u_t$

```
. reg btc vol

      Source |       SS       df       MS              Number of obs =     152
-------------+------------------------------           F(  1,   150) =  246.19
       Model |  97387.5136     1  97387.5136           Prob > F      =  0.0000
    Residual |  59337.8234   150   395.58549           R-squared     =  0.6214
-------------+------------------------------           Adj R-squared =  0.6189
       Total |  156725.337   151  1037.91614           Root MSE      =  19.889

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         vol |   8.36e-06   5.33e-07    15.69   0.000     7.30e-06    9.41e-06
       _cons |   7.139994   1.713067     4.17   0.000     3.755136    10.52485
------------------------------------------------------------------------------

. predict residual, r

. gen residualsq = residual* residual

. reg residualsq l.residualsq

      Source |       SS       df       MS              Number of obs =     151
-------------+------------------------------           F(  1,   149) =  184.27
       Model |   209049106     1   209049106           Prob > F      =  0.0000
    Residual |   169038393   149  1134485.86           R-squared     =  0.5529
-------------+------------------------------           Adj R-squared =  0.5499
       Total |   378087499   150  2520583.32           Root MSE      =  1065.1

------------------------------------------------------------------------------
  residualsq |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  residualsq |
         L1. |   .7455028   .0549193    13.57   0.000     .6369816     .854024
             |
       _cons |   108.6756   89.16692     1.22   0.225    -67.51938    284.8706
------------------------------------------------------------------------------
```

H0: $\phi_1 = \psi_1 = 1$ LM < χ^2 -No ARCH effect

H1: $\phi_1 \neq \psi_1 \neq 1$ LM > χ^2 -There is ARCH effect

LM = $T*R^2$ = 83.49 T=151 R^2 = 0.5529 χ^2 (1) = 5.99

83.49 > 5.99 LM > χ^2 (2) -reject H0

After conducting an LM test, we reject the null hypothesis and conclude that there are significant GARCH effects present in the PV model except the GARCH t statistic is completely insignificant.

7. Empirical Results

7.1 All Variables Included

The results of testing showed that bitcoins aren't cointegrated with the VIX and YR, although the entire equation seems to be cointegrated. The CUSUM tests show that the estimated parameters are stable for the entire time period under investigation, but the variance of the error term is structurally unstable. This is an indicator that the model is not a good predictor of bitcoin prices. After running the regressions I have found that the VIX and YR variables are significant in a simple least squares regression, but after make the regression trend stationary to account for cyclical effects they lose their significance. My hypothesis that stock market volatility and Fed policy have no effect on bitcoin price seems to be supported by my findings. This is conclusive evidence that bitcoin is indeed a decentralized currency that isn't affected by the Federal Reserve or U.S. equity markets.

7.2 Bitcoin Price and Volume

The results of testing show that volume is the only variable incorporated into this analysis that has a significant effect on bitcoin price. Volume of bitcoin transactions is cointegrated with the bitcoin price, which indicates there is an equilibrium relationship between the two. It also means that volume is a good predictor of bitcoin prices. After conducting the ARCH (1), ARCH (2), and GARCH (1, 1) tests I found that there is evidence of significant ARCH effect. This suggests that there is a heteroskedastic variance across units or over time. There are ambiguous results over whether or not GARCH effects are present in the model. The LM test suggests that there are GARCH effects, but the t statistic implies otherwise. The result of the t test is absolutely zero significance. This leads me to believe that there are no GARCH effects, so I believe the test to be inconclusive. The ARCH and GARCH tests also show that the stability constraint is never satisfied, which indicates that the variance of the error term is non-stationary. Further testing is needed to see is the stability constraint can be met through the assignment of positive weights to the squared sample residuals. After conducting the AIC test I found that two lags to both BTC and VOL is appropriate when estimating the parameters. The estimated equation is given by the following STATA table.

```
. reg btc  date btc1 btc2 vol1 vol2

      Source |       SS       df       MS              Number of obs =     150
-------------+------------------------------           F(  5,   144) =  235.74
       Model |  139194.136     5  27838.8272           Prob > F      =  0.0000
    Residual |  17005.0119   144  118.090361           R-squared     =  0.8911
-------------+------------------------------           Adj R-squared =  0.8874
       Total |  156199.148   149  1048.31643           Root MSE      =  10.867

------------------------------------------------------------------------------
         btc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        date |   .0453972   .0253512     1.79   0.075    -.0047114    .0955058
        btc1 |   .5663447   .0734869     7.71   0.000     .4210923     .711597
        btc2 |   .3822537    .087466     4.37   0.000     .2093706    .5551369
        vol1 |  -1.57e-06   5.53e-07    -2.84   0.005    -2.67e-06   -4.80e-07
        vol2 |   1.77e-06   5.16e-07     3.42   0.001     7.47e-07    2.79e-06
       _cons |  -1.859397   1.912088    -0.97   0.332    -5.638783     1.91999
------------------------------------------------------------------------------
```

Although the constant is the only term that isn't significant, the model suggests that the levels of bitcoin prices and volume for up to two lag periods have a significant effect on the price of bitcoins in the current period. Further investigation is necessary in order to obtain a significant constant to make the model fully functional in forecasting future bitcoin prices.

8. Conclusion

Bitcoins are indeed a decentralized currency, and it is not affected by Fed policy and stock market volatility. The only things that effect the price of bitcoins is the two previous periods prices of bitcoins and the two previous periods volume of bitcoin transactions. This implies bitcoin is an investment vehicle that is independent of any and all outside financial market activity. There might be issues with the data covering to short of a time period, but due to the relatively short amount of time that it has existed. I feel that more time needs to pass in order to obtain more accurate and precise test results and estimations. Despite the riskiness of owning a currency with no physical assets underlying it, bitcoins are still being traded and used as an investment vehicle. As long as the global economic crisis continues, and consumer confidence in banking and government institutions decreases, bitcoins will continue to be popular amongst those with faith in the free market. Whether or not bitcoin will become a predominant currency is hard to say, "in the short term, it may be difficult for us to determine whether profitable and popular new products are actually efficient alternatives to official paper currency or simply a diversion of seigniorage from the government to the private sector." (Greenspan, 1997).

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