The Determinants of the Virtual Currency Bitcoin: An Empirical Analysis

MONEY AND BANKING

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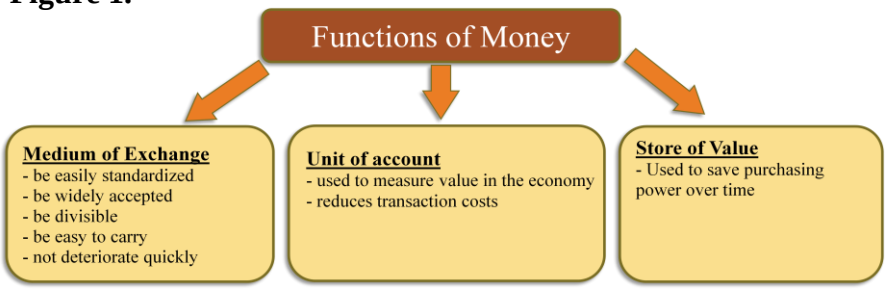
1. Introduction

Traditional "fiat" currencies are backed by people's trust in a central authority, such as the Bank of England. However, the virtual currency Bitcoin, has been gaining a large amount of attention in recent years due it being decentralized, anonymous, and having minimal transaction fees (Hobson, 2013). Thus, this coursework will examine whether or not Bitcoins can be considered a currency. Furthermore, we will conduct empirical research to find the determinants of the Bitcoin price in USD using variables with similar characteristics, such as gold and oil, and other investment options. Moreover, this research will also examine how the amount of connections to the darknet, where Bitcoins are used in criminal activities such as drug purchasing, affects the Bitcoin price.

2. Literature Review

Figure 1.



Around the eighteenth century, “commodity-backed” currency, which essentially is a receipt for a commodity (often gold), became prominent (ECB, 2012). Currently, however, the majority of currencies are known as “fiat” currencies; they are not redeemable for a commodity, instead they are backed by a central authority. Thus, the value of the currency is derived from the people’s trust in this central authority. Nevertheless, irrespective of the form of money, currency is often associated with three different functions shown in Figure 1: medium of exchange, unit of account, store of value.

In 2009, Satoshi Nakamoto created Bitcoin, a self-governing currency, which relies on cryptography and peer-to-peer networking to retain its integrity (Hobson, 2013). Since its inception, Bitcoin has exploded on the global stage; in 2013, a Bitcoin was worth over $1,200 on the Mt.Gox exchange, (Bitcointicker.co). Bitcoins, engineered to expand its supply only at a rate proportional to the technological discovery of prime numbers, promises that the total supply will never exceed 21 million Bitcoins. In many ways, it shares similar characteristics to Gold and Oil: they have to be “mined”, a finite supply that plateaus in the long run and is used to hedge against the dollar (Dyhrberg, 2016). However, is it a currency?

Some economists argue that for money to have value it must be backed by a governmental body (Krugman, 2013). Nonetheless, one could argue as long as the currency in question can be considered money as long as it fulfils the three functions of money (Figure 1). For example, Harford (2012) notes that cigarettes were widely traded in POW camps during World War II as a form of currency in exchange for wants such as razor blades and jam. While Germany in 1921 printed deutsche marks so rapidly that people stopped accepting government backed money and demanded gold or coal instead (Kosares, 1970).That being said Bitcoins are not widely accepted by vendors, nor it is a good store of value due to its volatility. Therefore, it does not fulfil the conditions for a currency.

Nevertheless, Bitcoins are widely used on the darknet in exchange for goods and services, due to its anonymity. Christin (2012) estimated that 4.5% to 9% of all Bitcoin transactions on all exchanges in the world were for drug trades on a lone darknet market named Silk Road. Other darknet products include money laundering services, hitmen and weapons. In order to reach these sites, one has to download and connect through the Tor client.

Bitcoins are also useful financially. Briere et al (2013) found that including Bitcoins in a diversified portfolio increases the Sharpe ratio, creating a higher mean-variance efficient frontier. Thus, an investor can achieve better portfolio returns for a given level of risk. Bitcoin is useful for diversification, however, it is known for high return therefore an investor can achieve large profits if they understand the determinants of Bitcoin.

Polasik et al (2015) found many insignificant coefficients; however, the number of articles mentioning Bitcoin and Google searches increases the Bitcoin returns. Furthermore, their model explained roughly 45% of the variation in Bitcoin returns. In this study, we will run regressions using some variables Polasik et al may have missed out such as, gold, oil, and total Tor clients. Then we will model Bitcoin returns in order to examine if we obtain similar results to Polasik et al.

3. Data

Table 1 shows each variable, their label and where the data is sourced: *Coindesk*, *Thomsonreuters*, *Federal Reserve*, *Google Trends*, and *Tormetrics*. All variables are daily observations starting from 19th of July 2010 to 11th of March 2016. However, Google trends only provided weekly data therefore the same weekly observation is repeated for the whole week. This method may skew the results, as the observation for a particular day in the week may not be the same as the weekly observation. The alternative would be to calculate the weekly average for each variable, however this results in loss of detail, consequently I chose the former method. Also note, the variable '*google*' and '*tor*' observations do not start until the 6th of February 2011 and 4th of October 2011 respectively.

Table 1. Variable Table

Variable name	Variable Label	Source
price	Bitcoin/USD spot rate	
vol	Number of daily Bitcoin transactions	Coindesk
diff	Difficulty mining Bitcoins	
nbit	Total number of Bitcoins in circulation	
gold	Thomson Reuter's gold spot price in USD (ozs)	
oil	NYMEX spot price of crude oil in USD (per barrel)	
sp	S&P 500 Index	Thomson reuters
euro	Euro/USD spot rate	
pound	GBP/USD spot rate	
fed	The effective federal funds rate (EFFR)	Federal Reserve
google	The number of google searches for 'Bitcoin'	Google Trends
tor	Total number of tor clients	Tor metrics
Dummysnowden	Dummy=1, after Edward Snowden released government spy documents (2nd of June 2013), Dummy=0 otherwise	
ltorDummysnowden	Interaction variable between 'ltor' and 'Dummysnowden'	
lprice	Log of price	
lvol	Log of vol	
ldiff	Log of diff	
lnbit	Log of nbit	
lgold	Log of gold	
loil	Log of oil	
lsp	Log of sp	
leuro	Log of euro	
lpound	Log of pound	
ltor	Log of tor	
lgoogle	Log of google	
Δlprice	Daily returns of Bitcoin (logs)	
Δlgold	Daily returns of gold (logs)	
Δloil	Daily returns of oil (logs)	
Δlsp	Daily returns of S&P 500 (logs)	
Δleuro	Daily returns of Euro/USD spot price (logs)	
Δlpound	Daily returns of Pound/USD spot price (logs)	

3.1. Correlation Analysis

Table 2: Correlation of variables

	Price	Vol	Diff	nbit	gold	oil	sp	euro	pound	fed	google	tor
price	1.0000											
vol	0.5546*	1.0000										
diff	0.3771*	0.8894*	1.0000									
nbit	0.6617*	0.8488*	0.6553*	1.0000								
gold	-0.6085*	-0.6689*	-0.5999*	-0.5380*	1.0000							
oil	-0.1775*	-0.7638*	-0.8516*	-0.4995*	0.5755*	1.0000						
sp	0.7297*	0.8284*	0.6555*	0.9359*	-0.7242*	-0.5196*	1.0000					
euro	-0.1711*	-0.7760*	-0.7839*	-0.6476*	0.5295*	0.8722*	-0.6227*	1.0000				
pound	0.2312*	-0.4758*	-0.5852*	-0.2305*	0.2352*	0.6764*	-0.1460*	0.7176*	1.0000			
fed	-0.1066*	0.3880*	0.5656*	0.0159	-0.1695*	-0.5276*	-0.0348	-0.4218*	-0.5525*	1.0000		
google	0.7591*	0.3186*	0.1002*	0.4143*	-0.4602*	-0.0566	0.4387*	-0.0007	0.1288*	-0.0991*	1.0000	
tor	0.6383*	0.3992*	0.2419*	0.5884*	-0.6566*	-0.1427*	0.6272*	-0.0524	0.2153*	-0.1420*	0.5102*	1.0000

* Indicate that the coefficient estimates are significantly different from zero at the 1% level. Source: From data collected

Table 2 shows the correlation between the different variables. We can see that all of variables are correlated with Bitcoin at the significance level of 1%, thus it is appropriate to use those variables for estimation[1].

3.2. Summary Statistics & Analysis

Table 3. Summary statistics, *19th of July 2010 to 11th of March 2016*

Variables	Observations	Mean	Std. Dev.	Min	Max
price	2,063	191.36	230.215	.0505	1147.246
vol	2,063	56064.7	53415.54	260	277094
diff	2,063	$1.75e^{+10}$	$3.10e^{+10}$	181.54	1.63e+11
nbit	2,063	$1.05e^{+07}$	3315920	3456300	$1.53e^{+07}$
gold	1,473	1397.64	209.968	1051.36	1898.99
oil	1,426	83.59	21.671	26.21	113.93
sp	1,423	1625.182	330.842	1047.22	2130.82
euro	1,475	1.286	0.105	1.049	1.4826
pound	1,475	1.579	.0577	1.387	1.7163
fed	2,063	0.129	.0607	.04	.38
google	1,861	14.179	15.278	0	100
tor	1,650	3498490	2174130	140356	$1.19e^{+07}$
Δlprice	2,062	0.004	0.0628	-0.491	0.425
Δlgold	1,177	0.00011	0.0107	-0.0558	0.042
Δloil	1,117	-0.00016	0.0209	-0.091	0.116
Δlsp	1,114	0.00061	0.00976	-0.049	0.0463
Δleuro	1,180	-0.000016	0.00623	-0.0265	0.0304
Δlpound	1,180	$-1.61e^{-06}$	0.0049	-0.0161	0.0156

Source: From data collected

[1] Bitcoin's highest correlated variable is with Google searches at 0.76, followed by the S&P 500 at 0.73. The lowest correlated variables are the US federal reserve rate and the price of oil at -0.12 and -0.18 respectively. Therefore one could diversify a portfolio by investing both oil and Bitcoin. Furthermore, the number of Bitcoins in circulation is highly positively correlated with the S&P 500 index, therefore saying when the supply of Bitcoin increases the S&P 500 index should increase as well.

Table 3 reports the mean price of Bitcoin is $191.36, and the lowest and highest price was $0.05 and $1147. Furthermore, the returns of Bitcoin are much higher than other investment alternatives, such as gold or oil. Figure 2 illustrates Bitcoin's high volatility against other investment alternatives by having the largest interquartile range and maximum and minimum[2]. While Figure 3, shows the change in Bitcoin price following a similar path to the change in oil. Additionally, gold price and Euro/USD have a relatively smaller variance, which meant their value did not fluctuate as drastically as Bitcoin's.

Figure 4, shows Google searches move closely with the Bitcoin price, noticeably late 2013 when the Bitcoin price increased substantially so did Google searches. Figure 5, shows people accessing the dark web through Tor with the Bitcoin price. In August 2013, there was a sudden increase in Tor users accompanied by a Bitcoin price spike. One possible explanation is due to Edward Snowden revealing the governments' surveillance programs in June 2013, causing a widespread concern of privacy.

3.3. Dickey-Fuller Test

Table 4. Augmented Dickey-Fuller Test

	ADF Test Statistic	
Variables	**Level (Logs)**	**First Differences**
lprice	-2.53	-43.42***
lvol	-3.27**	-51.67***
ldiff	-4.74***	-36.82***
lnbit	-125.5***	-5.46***
lgold	-1.62	-28.5***
loil	-1.69	-32.72***
lsp	-1.54	-30.16***
leuro	-0.56	-28.8***
lpound	-1.74	-29.52***
fed	-4.05***	-50.35***
lgoogle	-2.4	-43***
ltor	-2.98**	-65.56***

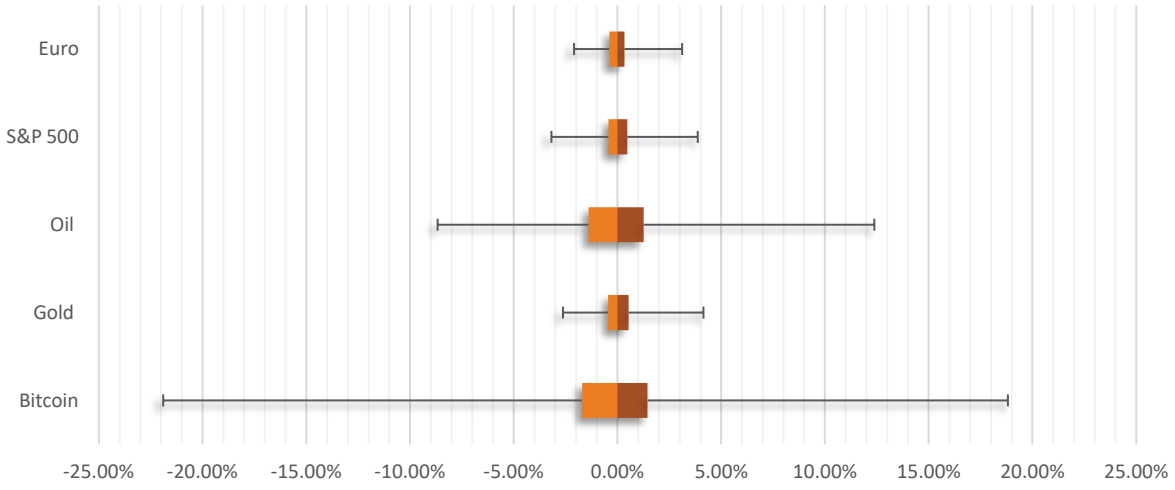
***/**/* indicate that the coefficient estimates are significantly different from zero at the 1%/5%/10% level. Source: From data collected

The null hypothesis is that the series has a stochastic trend, we can observe in Table 4 that most variables follows a unit-root process. It is unsurprising that the difficulty rate, and total number of Bitcoins are stationary, this is because its trend follows a predictable algorithm. Daily Bitcoin transactions and Tor connections also do not have a unit root at the 5% level. Furthermore, Figure 3 confirms how Bitcoin, oil, gold price and the S&P index follows a non-stationarity process.

We can deal with unit root by taking the first difference; consequently, all variables do not have a stochastic trend at the 1% level. Therefore, the regression analysis will include a returns model with selected variables. Appendix 1 illustrates histograms of the variables used in Model (3) following a normal distribution, as oppose to a bivariate distribution, after using first differences.

[2] The box plot started after the 1st of April 2014 because this is roughly after the Bitcoin bubble burst and returned to its fundamental value. The same is replicated for Figure 3.

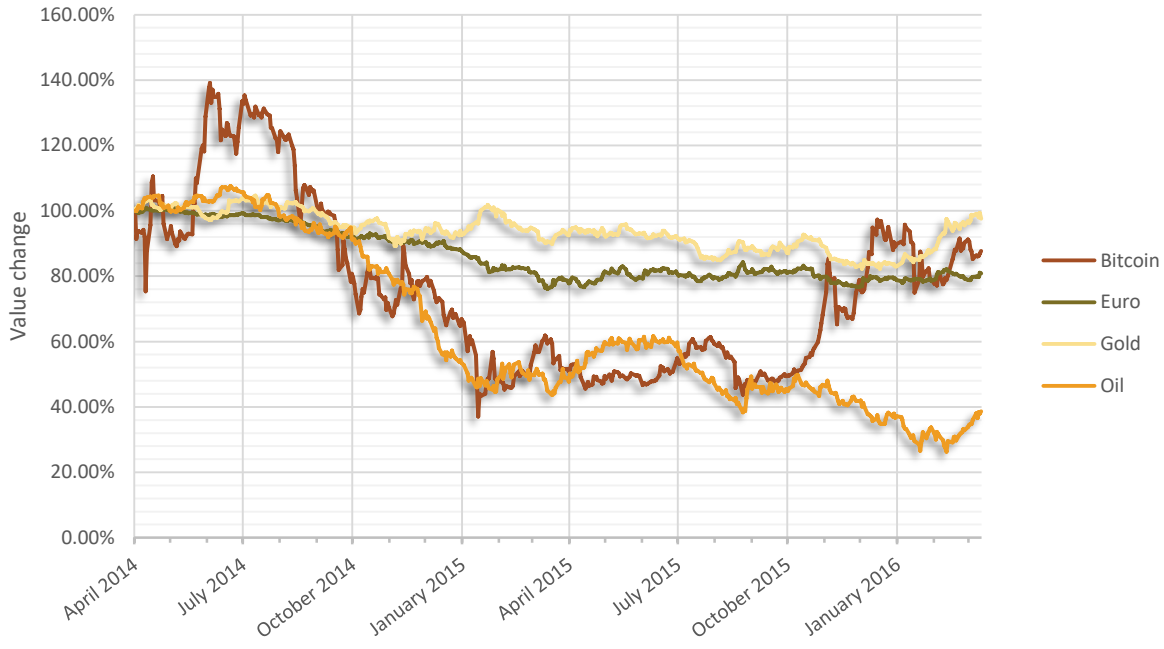
Figure 2. Daily Returns Box Plot *between 1st April 2014 to 11th March 2016*



Variable	Min	Q1	Median	Q3	Max	IQR
Euro	-2.09%	-0.39%	-0.04%	0.3%	3.08%	0.69%
S&P 500	-3.19%	-0.44%	0.03%	0.51%	3.9%	0.95%
Oil	-8.67%	-1.4%	-0.06%	1.2%	12.32%	2.6%
Gold	-2.63%	-0.45%	0.02%	0.52%	4.13%	0.97%
Bitcoin	-21.9%	-1.71%	-0.1%	1.35%	18.72%	3.06%

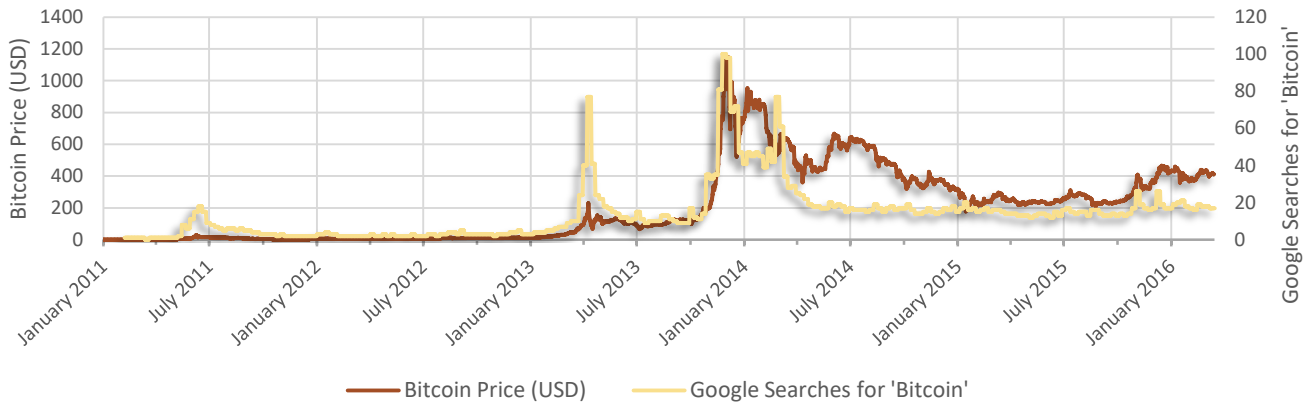
Source: From data collected

Figure 3. Index chart *between 1st April 2014 to 11th March 2016*



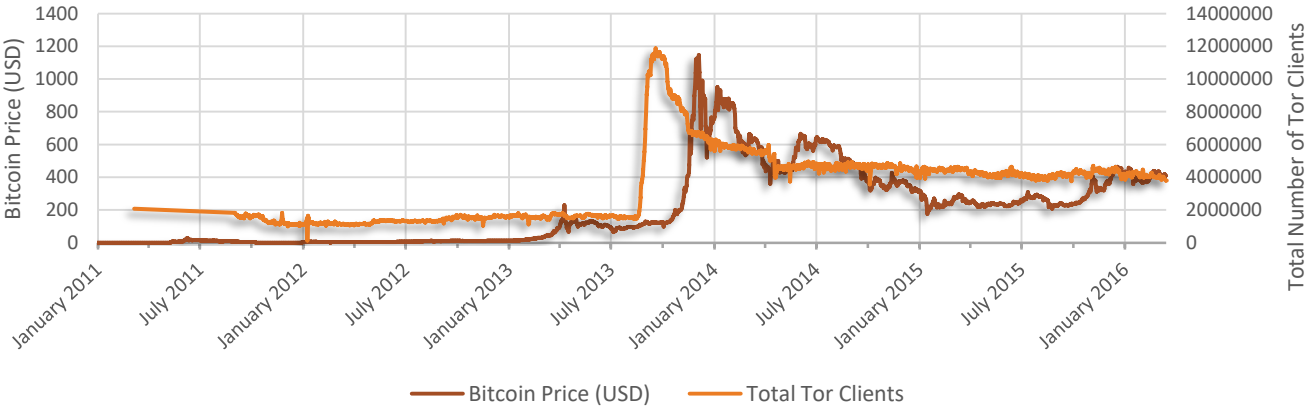
Source: From data collected

Figure 4. Bitcoin price (USD) and Google Searches for 'Bitcoin'



Source: From data collected

Figure 5. Bitcoin Price (USD) and Total Number of Tor Clients



Source: From data collected

4. Empirical Methodology

The t-value is derived from a normal distribution thus; logs are used for some variables in order to normalize them. Model (1) includes an interaction term between 'Dummysnowden' and 'ltor', this is to measure whether Edward Snowden and Tor users are related. Model (2) examines the effects if we add in two lags for 'lprice'. Model (3)'s dependent variable is the daily returns of Bitcoin modelled with the daily returns of the S&P 500, Euro/USD, and GBP/USD.

Early models were confirmed to suffer from heteroscedasticity, using the Breusch-Pagan test, which means we may have the wrong estimates of the standard errors for the coefficients and therefore their t-values. Thus, all models use robust standard errors to correct for heteroscedasticity.

$$lprice_{t+1} = \beta_0 + \beta_1 lvol_t + \beta_2 ldiff_t + \beta_3 lnbit_t + \beta_4 lgold_t + \beta_5 loil_t + \beta_6 lsp_t + \beta_7 leuro_t + \beta_8 lpound_t + \beta_9 fed_t + \beta_{10} lgoogle_t + \beta_{11} ltor_t + \beta_{12} Dummysnowden_t + \beta_{13} ltorDummysnowden_t + \varepsilon_t \quad \textbf{(1)}$$

$$lprice_{t+1} = \beta_0 + \beta_1 Lag(1).lprice_t + \beta_2 Lag(2).lprice_t + \beta_3 lvol_t + \beta_4 ldiff_t + \beta_5 lnbit_t + \beta_6 lgold_t + \beta_7 loil_t + \beta_8 lsp_t + \beta_9 leuro_t + \beta_{10} lpound_t + \beta_{11} fed_t + \beta_{12} lgoogle_t + \beta_{13} ltor_t + \beta_{14} Dummysnowden_t + \beta_{15} ltorDummysnowden_t + \varepsilon_t \quad \textbf{(2)}$$

$$\Delta lprice_{t+1} = \beta_0 + \beta_1 \Delta lsp_t + \beta_2 \Delta leuro_t + \beta_3 \Delta lpound_t + \varepsilon_t \quad \textbf{(3)}$$

5. Results & Discussion

Table 5. Determinants of the Bitcoin price (Robust Standard Errors)

	Regressed on lprice		*Regressed on Δlprice*
Variables	**(1)**	**(2)**	**(3)**
Intercept	-38.61***	-1.59	-0.006***
	(3.611)	*(0.936)*	*(0.002)*
Lag(1).lprice		1***	
		(0.*0739*)	
Lag(2).lprice		-0.0402	
		(0.0715)	
lvol	0.122***	0.015	
	(0.0316)	*(0.008)*	
ldiff	0.137***	0.0029	
	(0.00795)	*(0.00219)*	
lnbit	1.93***	0.124	
	(0.243)	*(0.0734)*	
lgold	-1.45***	-0.065	
	(0.178)	*(0.0506)*	
loil	0.884***	0.049	
	(0.0692)	*(0.0206)*	
lsp	0.806***	0.037	
	(0.226)	*(0.0544)*	
Δ*lsp*			0.12
			(0.249)
leuro	3.12***	0.13	
	(0.276)	*(0.088)*	
Δ*leuro*			0.24
			(0.434)
lpound	-0.941***	-0.13	
	(0.335)	*(0.0802)*	
Δ*lpound*			-0.086
			(0.551)
fed	1.308***	0.015	
	(0.136)	*(0.0401)*	
lgoogle	0.693***	0.028**	
	(0.02)	*(0.012)*	
ltor	0.44***	-0.036	
	(0.106)	*(0.0283)*	
Dummysnowden	6.698***	-0.68	
	(1.494)	*(0.411)*	
ltorDummysnowden	-0.465***	0.046	
	(0.105)	*(0.0287)*	
Observations	1,135	1,135	1,114
R-squared	0.9877	0.9991	0.0008
F-statistic	8075.24	9999.00	0.19
Prob>F	0.000	0.000	0.9062

***/**/* indicate that the coefficient estimates are significantly different from zero at the 1%/5%/10% level

5.1. Model (1)

Model (1) shows gold being highly significant. The coefficient states a 1% increase in the price of gold causes a change in the price of Bitcoin by -1.45%. Interestingly, oil has a positive relationship with Bitcoins. One could argue that because Bitcoins, oil and gold share very similar features, they should move in the same direction. We have seen this with oil and Bitcoin in Figure 3 and in the regression analysis. However, because gold and Bitcoin are related to each other more than to oil, they arguably have little intrinsic value and act as substitutes rather than complementary products.

The S&P 500 index has a positive coefficient; a 1% increase in the S&P 500 index causes a 0.81% increase in the price of Bitcoins. This may be due to a rise in the performance of US firms, which increases wealth for investors and their risk tolerance. Hallahan (2003), revealed wealth positively affects an individual's risk tolerance. And Briere et al (2013) showed that a slight increase in the investor's risk-tolerance is associated with a sharp increase in the average returns obtained for a given level of risk by including Bitcoins in a well-diversified portfolio – making it attractive to invest in Bitcoins.

When the total number of Bitcoins increases by 1% it causes the price to increase by 1.93%. Traditionally an increase in the monetary base causes a shift in the supply curve, depreciating the exchange rate. One rationalization is that a widely known mathematical algorithm governs Bitcoins supply, thus it is more predictable than policies of central banks. Therefore, future supply changes are already built in the current price.

$$lprice_{Dummysnowden=1} = -31.92 - 0.025ltor$$
$$lprice_{Dummysnowden=0} = -38.61 + 0.44ltor$$

The interaction variable coefficient is highly significant, showing that there is a relationship between Edward Snowden's leaks and Tor usage. If ltor=0, then the period after Snowden's document releases, Bitcoin has a premium of 6.7% over the previous period. Pre-Snowden, an increase of 1% in Tor increases the Bitcoin price by 0.44%. However, after Snowden, an increase of 1% in Tor decreases the Bitcoin price by -0.025%. The before period has a larger effect on Bitcoin price than afterwards. One theory is before Snowden, when Tor was relatively unknown, a larger percentage of Tor users could have been criminals, which traded Bitcoins causing a larger positive impact. However, afterward Snowden many regular people started using it for privacy reasons and did not need to purchase Bitcoins, causing Tor's effect to change sign and be very close to zero.

This model explains 98.8% of the variation in the Bitcoin price. Furthermore, the p-value of the model is zero, which indicates a statistically significant relationship between the independent and dependent variables.

5.2. Model (2)

It is clear that last year's Bitcoin price has a very significant positive effect on price; this is because there is multicollinearity. The only other significant variables are the Google searches. This indicates popularity is a strong factor in determining the Bitcoin price. However, one could argue that Google searches suffer from reverse causality.

5.3. Model (3)

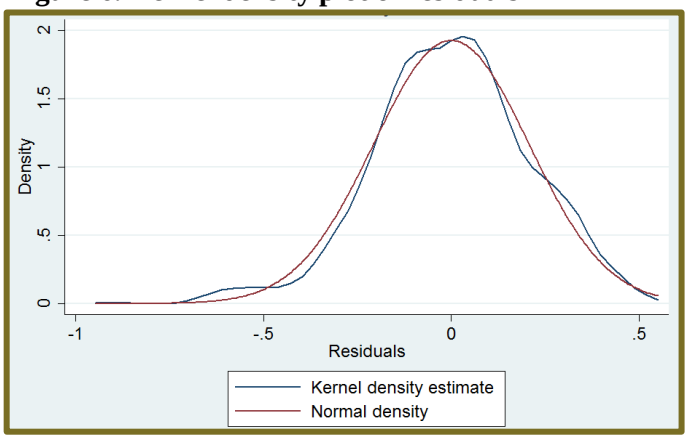
Model (3) explains 0.08% of the variation in the returns of Bitcoin, and all coefficients are insignificant. Thus, it echoes Polasik et al (2015) research that external factors do not have any significant impact on the Bitcoin market returns, implying the model suffers from endogeneity. Furthermore, the F-test is not statistically significant, which means the overall model is not statistically significant.

6. Diagnostics Test

6.1. Normality of Residuals

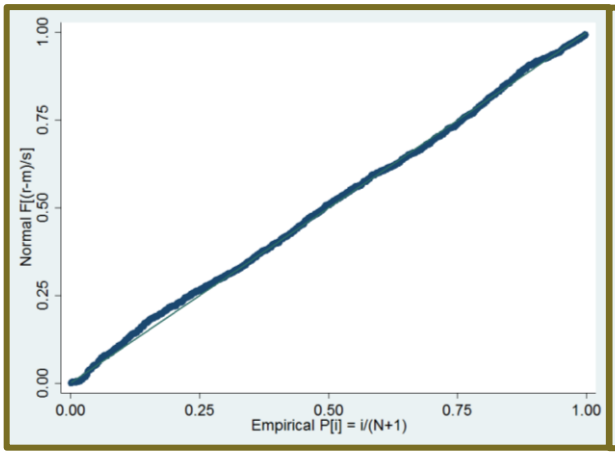
Normality assumption guarantees p-values for t-tests and F-tests will be valid, thus, it is important for accurate hypothesis testing. Figure 6, illustrates a kernel density plot of equation of residuals, we can see it closely follows a normal distribution. Figure 7 is a P-P plot which shows no indications of non-normality. Figure 8, shows a qnorm plot which are more sensitive to non-normality near the tails. This is why Figure 6 shows a slight deviation from normal at both tails, as can be seen in the kdensity. Nevertheless, this appears to be a negligible deviation from normality and we can accept that residuals are close to a normal distribution.

Figure 6. Kernel density plot of residuals



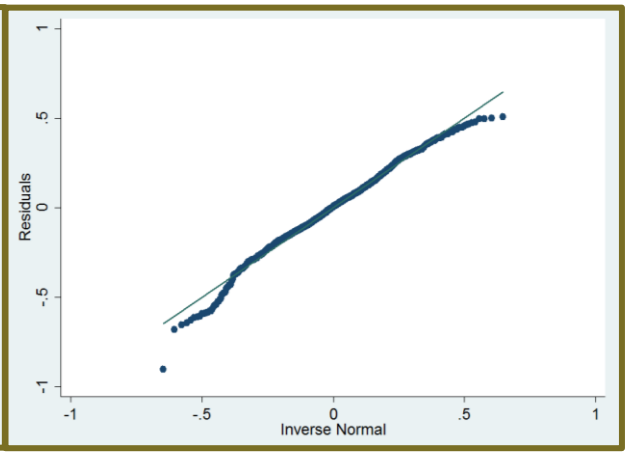
Source: From data collected

Figure 7. pnorm plot



Source: From data collected

Figure 8. qnorm plot



Source: From data collected

7. Conclusion

Although Bitcoins can be used in exchange for goods and services, it does not fulfil the three functions of money, and arguably is considered a commodity. Furthermore, Avent (2014), from The Economist, argued that its finite supply would cause deflationary problems for economies if it were used instead of "fiat" currencies. One significant finding that the regression analysis has shown is that Bitcoin's closest related commodity, gold, behaves as a substitute. Furthermore, we found that the number of Tor clients have a larger effect on Bitcoin price before the Edward Snowden's release of government documents than afterwards. This may be due to a larger percentage of Tor users before were criminals who used Tor for illegal activities, which involves Bitcoin, as oppose to using Tor for privacy concerns. Furthermore, this research cements Polasik et al (2015) results, that market participants internally drive Bitcoin market returns.

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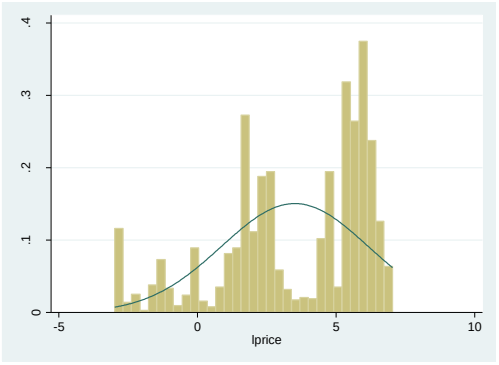
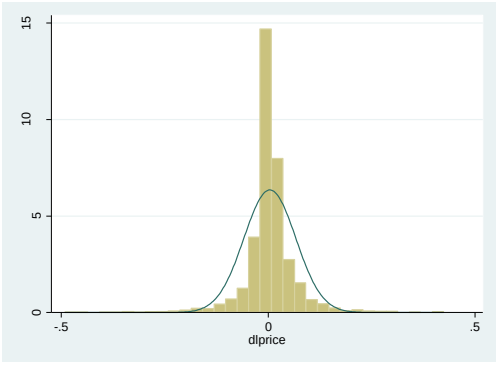
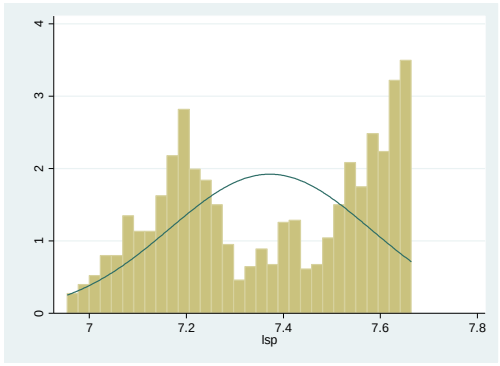
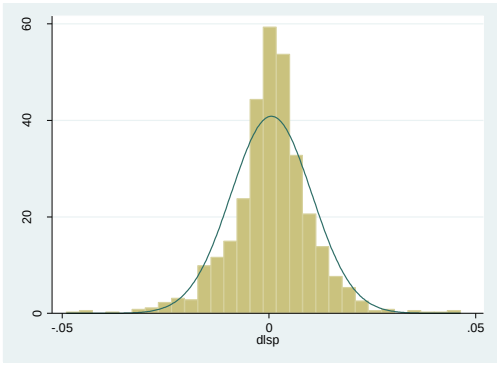
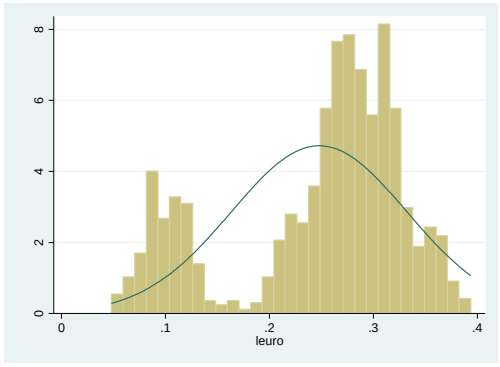
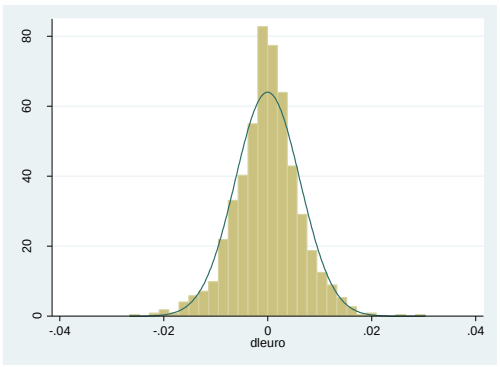
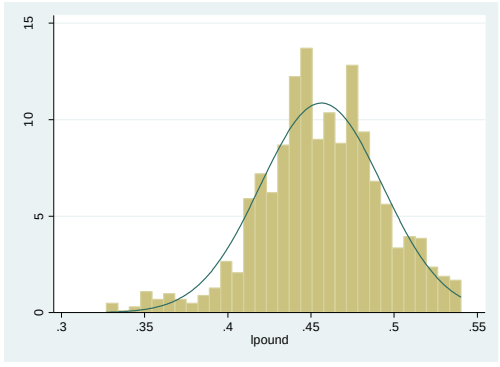
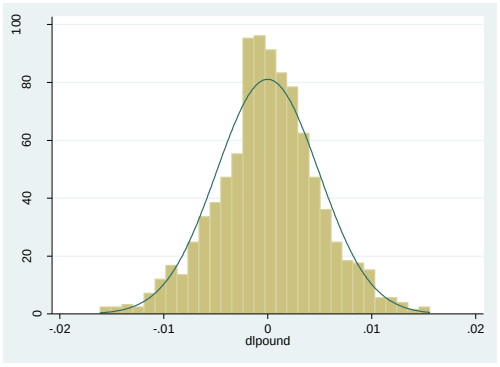
9. Appendix

9.1. Appendix 1

	Levels (Logs)	First Differences
Bitcoin/USD		
S&P 500 Index (USD)		
Euro/USD		
Pound/USD		

Source: From data collected