BITCOIN 2017: WAS THERE A BUBBLE?

by

Anna Nazaruk

Submitted to Central European University

Department of Economics

In partial fulfillment of the requirements for the Degree of Master of Arts in Economics

Supervisor: Adám Zawadowski

Budapest, Hungary

2018

Abstract

This research examines existence of Bitcoin bubble in the year of 2017 by studying time series data within four main paradigms of the modern bubble theory. All four models suggest that Bitcoin closing price was overstated during the period. The analysis also detects Bitcoin features that could lead to the behavioral bias on the cryptocurrency market. The study suggests that investors' behavior on the crypto market should be investigated more within behavioral finance.

Key words: Bitcoin, cryptocurrency, bubble
JEL classification: G40

Table of Contents

Introduction

There were periods in history when prices for an asset were hugely overstated. Starting from tulip mania in 16th century, people were wondering what can drive such events and most importantly how they can be identified. Therefore, the price bubble theory was introduced. It uses ideas of behavioral economics to explain behavior of agents on financial markets: why people want to pay such a high price and how it distorts financial markets.

Recently Bitcoin cryptocurrency was one of the most discussed topics on the media. People who bought one Bitcoin in 2009 with a price of less than 1 dollar, got a miraculous return of 20000% by the end of 2017. In the research I am answering questions related to the particular event. Was Bitcoin overpriced at the end of 2017? Was there a price bubble? To achieve this I investigate Bitcoin within four modern behavioral finance theories. It turned out to be a hard task, because no one tried to do it before. Thus, there were no papers that I could use as a guidance material. That is why in order to answer the stated questions I had to combine knowledge about cryptocurrency market and the price bubble theory. In the research I am using papers that investigate historical bubbles, such as housing bubble, dotcom bubble and the Chinese warrants bubble. As well as analysis of cryptocurrency market and Bitcoin documentation.

All four paradigms show that Bitcoin closing price was overstated during the period from July 2016 to March 2018. These results imply that behavioral theories can be used to investigate and understand agents' behavior on the cryptocurrency market.

This research paper is made up of two main sections. The first one contains discussion of Bitcoin model and its specific features. Empirical investigation of Bitcoin data within the four behavioral models is introduced in the second part. This is followed by the results and discussion.

Literature review

Papers that I have been using during the research can be divided into two main groups: papers about Bitcoin and researches in the field of behavioral finance. Unfortunately, I couldn't find any papers that would combine these two topics together. Thus, I will discuss them separately.

The first group contains research papers that describe Bitcoin model. I need to note here, that not all of this papers were published in scientific journals. For example, research that introduced Bitcoin technology to the world by Sakamoto S. (2009) was not published, but distributed via email chain within cryptocurrency society. Moreover, authors of these papers usually a group of people who take pseudonym in order to stay incognito. That is why it is hard to talk about contribution of a certain researcher to the literature about Bitcoin. Another paper that I have been using is by Moore and Christin (2013). It examines how cyber attacks effect cryptocurrency exchanges and finds that most of them close soon after the attack. Moreover, after the closure crypto exchanges do not repay any money to their users.

Another group contains researchers that introduce theory or investigate data in a field of behavioral finance. One of the main papers that I was using during my research was the work of Brunnermeier and Oehmke (2012). This paper includes review of the main papers and results in the bubble theory. I used it to determine which models I will include into my research. Paper by Xiong, W. and Yu, J. (2013) was also used extensively. It investigates bubble on the Chinese warrant market, while introducing a few interesting estimation methods within the resale option theory and the feedback loop theory. Thus, I was mostly using ideas from it for my regression analysis. In order to understand the resale option theory better, I was using paper of Harrison J. M., Kreps M. D. (1978), which explains why short selling constraints can results in overstated prices of an asset. Besides that paper of Kahneman D, Tversky A. (1979), which introduced famous Prospect Theory was used in

addition to Barberis, N., Huang, M., Santos, T. (1999) in order to explain results from Gambling Behavior and The Feedback Loop theory chapters.

Even though there are a lot of papers that investigate triggers of pricing bubbles, it was hard to find research papers that could be applied for Bitcoin. As one could notice I am using some researches that describe main behavioral economics theories, such as: Prospect Theory, The Resale Option Theory and The Feedback Loop Theory. The goal was to apply currently existing theories in behavioral finance for cryptocurrency market and, in particular, for Bitcoin.

Cryptocurrency market

Cryptocurrency market started to evolve after publication of "Bitcoin: A Peer-to-Peer electronic Cash System" by Satoshi Nakamoto in 2008. The paper introduced blockchain technology, which allows financial transactions without involving a third party. One can imagine a blockchain as a chain of books, where the history of all transactions is kept. All of these books, or blocks as they are called by Satoshi, are kept by different people in different places. When submitting a new transaction, blocks are compared among each other and the transaction is made only in case they are all the same. This way all transactions that have ever been made are kept in the blockchain and available to everyone who has internet access. Thus, it is impossible to conceal transaction information, e.g. the notional amount or users that are involved in operation.

After introduction of blockchain technologies, a lot of cryptocurrency exchanges started to appear. Currently there are 123 different cryptocurrency exchanges with an average day volume of 7.68 billions of dollars[1].

[1] According to https://cryptocoincharts.info/markets/info

Cryptocurrency market is open 24 hours per day, 7 days a week. Moreover, it is very easy to trade a cryptocurrency there. One only needs an internet connection. There are no brokerage or fund costs, and most cryptocurrency exchanges charge a small or no transaction cost.

However, the market is still very young and immature compared to any of ordinary financial markets. For these reasons there are few issues that agents are facing while trading cryptocurrencies. First of all, there is no unified rate at which each cryptocurrency is traded. Different exchanges have slightly different rates for the same cryptocurrencies at the same time. This creates an arbitrage opportunity: one can buy at a lower rate and resell it by the higher rate.

The second big issue is cyber attacks. Due to internet space cryptocurrency exchanges are unprotected. Moore and Christin (2013) state that after severe cyber attacks, some exchanges are forced to close because of mistrust by users.

The cyber attacks problem leads us to the third point. The market is not legally regulated. This means that agents' wallets[2] are much more unprotected compared to commodity, currency or stock markets. All of this makes cryptocurrency an extremely risky investment tool.

In this research I investigate why agents were investing their money into such risky asset as cryptocurrency during 2017. I use Bitcoin as a benchmark for several reasons. The first one is that it has the most data available, i.e. the longest history of closing prices at the market. The second one is that it has the largest market cap among all cryptocurrencies. Lately transactions of Bitcoin made up to 56% of cryptocurrencies market[3]. This makes Bitcoin a good proxy for the cryptocurrency market.

[2] Explanation of this and other terms used on the crypto market can be found in Glossary in Appendix
[3] Data on Bitcoin market share can be found at https://coinmarketcap.com/charts/

Bubble in Bitcoin

What is Bitcoin?[4]

From the history of bubbles, we know that there are several main pre-requirements[5] for a financial bubbles to exist. First of all, the traded product should be innovative. As in case of the dotcom bubble or recent 2008 financial crisis, both stocks of internet companies as well as CDOs and CDSs were newly created products, which only few people knew about deeply. In our case Bitcoin is an innovation that was introduced in 2009. Moreover, the exact working system of blockchain is quite hard to understand and, in my opinion, one should spend some time to understand its influence on the financial market.

Secondly, financial bubbles usually occur within a market flooded with ordinary agents, i.e. not financial institutions, hedge funds or finance professionals. Such agents are more prone to behavioral biases and over/underreaction due to a lack of financial knowledge and resources for thorough continuous analysis.

Finally, a central idea of most theories of financial bubble is that a bubble exists only if an asset's market value is much higher than its intrinsic value. Using different valuation techniques, one can estimate true value of security. Thus my initial task was to understand where Bitcoin derives its value from and how I could estimate it. In order to achieve that, I had to understand which known asset class can be used to evaluate Bitcoin: security, currency or commodity. This way I could represent Bitcoin as one of known financial products and use related valuation model.

[4] Some ideas for reasonings in this part were taken from article "What is 1 bitcoin in USD today?" by Anson Zeall

[5] As stated in the paper of Brunnermeier and Oehmke (2012)

The Internal Revenue Service[6], the U.S. tax authority, in "Notice 2014-21"[7] states that for tax purposes all digital currencies are treated as property. Thus according to IRS holding Bitcoin is like holding gold.

First of all, Bitcoins have value and all its parts (coins) are identical to each other. Secondly, each piece of cryptocurrency can be used as a 'storage' for value, which makes it convenient to be used as a mediator in a trade process. From this point of view we can treat Bitcoin as a non-physical commodity.

However, despite all the similarity between Bitcoin and commodities, market agents can make payments in Bitcoin without exchanging it into other currencies. Moreover, blockchain technology introduces one very important advantage of cryptocurrencies: they cannot be stolen. Unlike commodities, Bitcoin can be transferred from one agent to another only with the use of blockchain, i.e. each transaction is written in the book and stored in different copies around the globe. This makes stealing and smuggling impossible. Taking all of the above into account, commodity valuation methods, such as futures analysis, cannot be used for Bitcoin.

On the other hand Foreign Account Tax Compliance Act, which is in charge of providing information from financial institution to the IRS, states that cryptocurrency exchanges should be considered financial institutions. There Bitcoins can be exchanged in the same way as any foreign currency. Moreover, they can be used to acquire things in the same way as bank cards. This means that Bitcoin as one of tradable products of financial institutions should be treated as a currency.

But unlike all existing foreign currencies Bitcoin is not issued by any country or any central authority. It exists outside of political influence. While governments can regulate usage of Bitcoin in their own countries, they cannot put laws on Bitcoin itself. Thus there is

[6] Later on in this paper I use abbreviation IRS instead of full name

[7] Text of the notice can be found at https://www.irs.gov/pub/irs-drop/n-14-21.pdf

no way particular government can influence or adjust value of cryptocurrency. Therefore the method of analysing debt, GDP and other economic factors will not help to estimate Bitcoin's value.

Finally, some investing professionals[8] try to make valuation of Bitcoin by treating it as a company or organisation. This approach does not make a lot of sense simply because Bitcoin is nothing more than a network of computers that keep blockchain entries. It does not represent any certain company, thus it does not have any intrinsic value. In this way Bitcoin cannot be treated as stocks.

Thus, we cannot treat Bitcoin as a product from any of known asset classes to determine its intrinsic value and prove that it was overpriced during 2017. However, we can use the basic models of the bubble theory, which is applicable to any investment tool available on the market. Therefore, I investigate Bitcoin inside of four different paradigms, such as: The Rational Bubbles Theory, The Resale Option Theory, The Feedback Loop Theory and special case of The Prospect Theory used within the financial market.

Data sample and descriptive statistics

I use data sample of time series that includes historical closing prices of Bitcoin, S&P500, Euro currency and Gold. While preparing sample I had to merge information from different sources. First one is Yahoo Finance[9], where I have got daily closing price and trading volume for Bitcoin, S&P500 and Euro[10] for historical period from July 2010 to March 2018. I have drawn adjusted closing price to account that dividend pay-off are not affecting stock prices in case of S&P500 and Bitcoin[11]. Besides that trading volume of Bitcoin consists data both in Dollars and Bitcoins.

[8] Interview of Chris Burniske can be found at http://fortune.com/2018/05/04/ledger-burniske/
[9] Finance Yahoo https://finance.yahoo.com
[10] Data for Bitcoin, Euro and Gold were drawn against US Dollar.
[11] Why Bitcoin might have dividends is discussed in next chapter

The second one is website of U.S. Department of The Treasury[12], where I have drawn daily treasury yield curve rates for 3 month treasury bill for the same historical period. To adjust granularity of a sample, I have changed daily treasury yield rates from yearly to daily.

Some of sample variables have been created using input variables, e.g. weekly, daily and 2-hour excess returns of Bitcoin were calculated using Bitcoin corresponding adjusted closing price and t-bill rates. You can find full list of such variables and their formulas in Table 1. Moreover, I refer to the described time series data as Sample A, which, as stated, includes full history of Bitcoin.

During regression analysis I also use a truncated version of time series, which I call Sample B. It contains data of Bitcoin and S&P500 variables from Sample A, but for shorter time period: from July 2016 to March 2018. Moreover, to perform some regression analysis I have included closing adjusted price with frequency of two hours as well as trading volume of Bitcoin into the Sample B. This data was found at Bitcoincharts.com.

As mentioned earlier, this 'short' data set contains the suggested bubble period in Bitcoin. Length of the Bitcoin bubble period was chosen experimentally by analysing descriptive statistics of main variables as well as structural breaks in Bitcoin daily closing price and volatility. From Figure 2 and Figure 4 one can see that Bitcoin was moving differently starting from mid 2016. Daily closing price is moving more rapidly and volatility is on average higher compared to the first half of 2016.

Descriptive statistics for both Sample A and Sample B can be found in the Table 2. We can see that Bitcoin daily variables in the sample B have on average higher mean, median and standard deviation compared to Sample A. This is another evidence that the proposed bubble period should be used for analysis within the theory of speculative bubbles.

[12] It can be found at https://www.treasury.gov/resource-center/data-chart-center/interest-rates/

Table 1 Created variables

Type of variable	Formula
Daily T-bill rate	$(1 + \frac{three\ month\ tbill}{100})^{1/252} - 1$
Daily excess return	Daily Return - Daily t-bill rate

Table 2.A Descriptive Statistics of Sample A

Variable name	(1) Mean	(2) Median	(3) St.Dev.
Daily adjusted closing price of Bitcoin, *BTC_closing*	1045	251	2577
Daily excess return of Bitcoin(USD), *BTC_ret*	0.01	0.002	0.11
Daily volume of Bitcoin, *BTC_volume*	$1.27 * 10^8$	$6.32 * 10^6$	$4.44 * 10^8$
Daily excess return of S&P500, *SPX_ret*	0.001	0.001	0.01
Daily volume of S&P500(USD), *SPX_volume*	$3.66 * 10^9$	$3.58 * 10^9$	$7.35 * 10^8$
Daily excess return of Gold, *GLD_ret*	0.00	0.00	0.005
Daily excess return of Euro, *EUR_ret*	0.00	0.00	0.01

Table 2.B Descriptive Statistics of Sample B

Variable name	(1) Mean	(2) Median	(3) St.Dev.
Daily adjusted closing price of Bitcoin, *BTC_closing*	2602	1189	3118
Daily excess return of Bitcoin, *BTC_ret*	0.01	0.005	0.11
Daily volume of Bitcoin(USD), *BTC_volume*	$3.04 * 10^8$	$8.3 * 10^7$	$5.5 * 10^8$
Two-hour adjusted closing price of Bitcoin, *BTC_hour_closing*	5471	4136	4445
Two-hour excess return of Bitcoin, *BTC_hour_ret*	0.04	0.08	1.59
Two-hour volume of Bitcoin, *BTC_hour_volume*	$0.93 * 10^7$	$5.1 * 10^6$	$1.3 * 10^7$
Daily excess return of S&P500, *SPX_excess_ret*	0.001	0.00	0.004
Daily volume of S&P500(USD), *SPX_volume*	$3.5 * 10^9$	$3.44 * 10^9$	$5.84 * 10^8$

Figure 1 Distributions of daily returns of Bitcoin, S&P 500, Euro and Gold

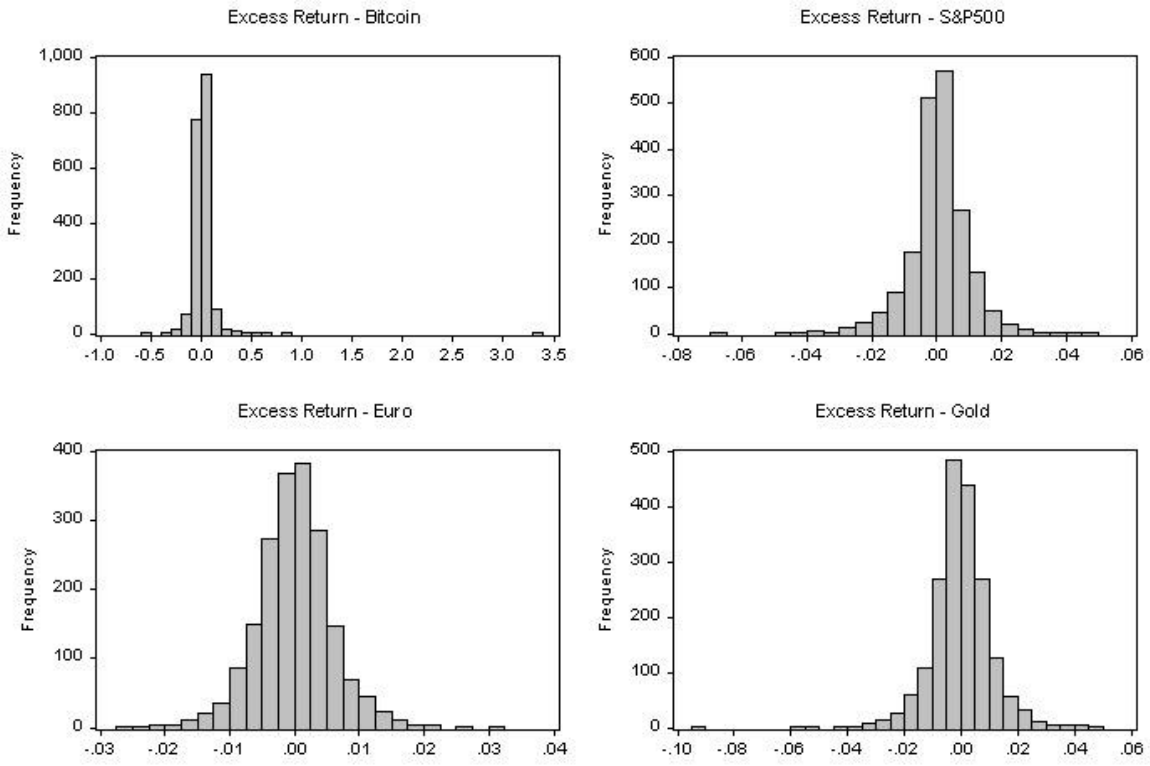


Table 2 shows some descriptive statistics, including mean, median and standard deviation for some of the main variables, such as adjusted closing price of Bitcoin, S&P500, Euro and Gold, their excess returns and 3 Month T-Bill rate.

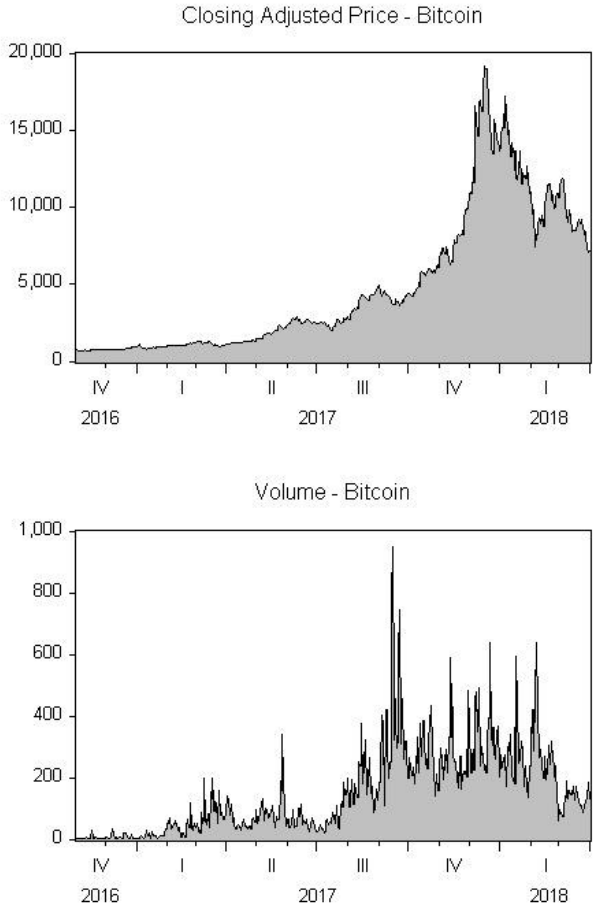
Figure 1 plots distributions of Bitcoin, S&P500, Euro and Gold daily excess returns. One should notice that x-axis for each distribution is different. We can see that plot of Bitcoin distribution has the largest scale of x-axis. Moreover, from the Figure we can get a feeling that standard deviation of Bitcoin daily excess returns is higher compared to other assets, e.g. it seems to be more than two times higher than the standard deviation of S&P500 excess returns. Moreover, Bitcoin distribution is the most positively skewed among the assets.

Statistics of plotted distributions, provided by Table 3, proves that Bitcoin seems to be much riskier, i.e. its standard deviation is higher, compared to the stock market benchmark. Moreover, we can see that distribution of Bitcoin daily returns is, indeed, positively skewed. All the stated results mean that Bitcoin introduces more risk than any available stock, commodity or currency.

Table 3 Characteristics of daily excess return distributions

	Sample A			Sample B		
Variable name	(1) Mean	(2) Standard Deviation	(3) Skewness	(1) Mean	(2) Standard Deviation	(3) Skewness
Bitcoin	0.01	0.11	16.09	0.01	0.11	0.44
S&P500	0.001	0.01	-0.46	0.001	0.004	-0.26
EURO	0.00	0.005	0.02	0.00	0.004	0.29
GOLD	0.00	0.01	-0.44	0.00	0.007	-0.41

Figure 2 Bitcoin Daily closing price and volume for bubble period



To investigate effect of Bitcoin trading volume on its closing price I make a plot of corresponding variables from Sample B, i.e. for the bubble period. We can see from the Figure 2 that high spikes in Bitcoin closing price corresponds to the period when there was a big difference in Bitcoin daily volume on the cryptocurrency market. Note, that volume here is in terms of Bitcoins, not dollars. Thus, this can be an evidence that 2017 bubble was not a result of higher valuation of Bitcoin, but behavioral biases.

The Rational Bubbles Theory

The rational bubbles theory assumes that all market agents posses same information and rational expectations. Brunnermeier and Oehmke (2008) show that by rearranging net return of an asset and taking rational expectation yields, we can get that current price is a sum of expected future price and dividends discounted by rate of return:

$$p_t = E_t[\frac{p_{t+1}+d_{t+1}}{1+r_{t+1}}] \quad (1)$$

They infer that in each time period price of any asset can be decomposed to sum of intrinsic value and bubble component:

$$p_t = \nu_t + b_t \quad (2)$$

Moreover, they prove that for securities with infinite maturities, bubble component should be growing at the same rate as its discount rate.

$$b_t = E_t[\frac{1}{(1+r)} b_{t+1}] \quad (3)$$

We know that Bitcoin will have finite maturity in the year of 2140. Thus one can argue that rational bubble model for securities with infinite maturities cannot be applied here, because agents can calculate its true intrinsic value using backward induction. I believe, it would be too complicated for agents to calculate true value of Bitcoin because of its long tenor. That is why I will stick to the proposed model and investigate Bitcoin data using it.

As I mentioned before it is not completely understandable where Bitcoin derives its true value. We already know that before August of 2017, value of Bitcoin was fully set by

market demand and supply. However, starting from mid-2017 deliberate chain splits started to take place.

Chain split[13] means a split of a 'parental' blockchain, which results in creation of a new 'child' cryptocurrency, whose initial value is connected to its 'parent' value. Later on such cryptocurrency becomes independent and starts to derive value from its own demand.

According to CNN[14] a chain split of Bitcoin was required due to increasing number of Bitcoin transactions. With the increase of Bitcoin popularity, users were forced to wait more time for their transactions to be completed. To solve this problem, cryptocurrency volunteers announced the release of a new type of digital currency that can process a much higher number of transactions per minute. In order to justify demand for a new product it was initially connected to Bitcoin. Thus owners of Bitcoin were receiving certain amount of free Bitcoin cash with a rate of 1 to 1 when the first split took place[15] in August 2017.

After the successful first split, a sequence of other chain splits took place, e.g. Bitcoin Gold, Bitcoin Diamond, etc. All of the above provided an advantage to Bitcoin owners, because with each new split they were receiving a new cryptocurrency for free, whose value was expected to rise in upcoming future.

Formula (1) of the Rational Bubbles Theory shows that the higher the expectation of future dividends, the higher the current price of an asset should be. However, in the case of Bitcoin one gets not fixed dividends, but another cryptocurrency whose initial price could be overstated. Thus, free split cryptocurrencies, that Bitcoin owners were getting, could be

[13] Information about it can be found at https://en.wikipedia.org/wiki/Blockchain#Hard_forks
[14] More at http://money.cnn.com/2017/08/01/technology/business/bitcoin-cash-new-currency/index.html
[15] More details can be found at https://en.wikipedia.org/wiki/List_of_bitcoin_forks

treated as other bubbles. Agents were expecting Bitcoin price to grow dramatically due to the future chain splits and this made Bitcoin overpriced.

Figure 2 Bitcoin daily closing price and dates of chain splits

Formula (1) of the Rational Bubbles Theory shows that the higher the expectation of future dividends, the higher the current price of an asset should be. However, in the case of Bitcoin one gets not fixed dividends, but another cryptocurrency whose initial price could be overstated. Thus, free split cryptocurrencies, that Bitcoin owners were getting, could be treated as another bubbles. Agents were expecting Bitcoin price to grow dramatically due to the future chain splits and this made Bitcoin overpriced.

We can see Bitcoin closing price and dates of chain splits on Figure 2. Wikipedia states that there are three main splits that took place on August 1, October 24 of 2017 and February 28 of 2018. I used Bitcoin daily closing price data and fitted several linear functions to it for three different periods: before the first split, after the first split and after the second split. We can see from Figure 3 that slope of the function, i.e. the bubble growth, increases a

lot after the first and second splits. These findings are in line with the point that investors were building up expectations about future splits of Bitcoin. Agents expected to get free cryptocurrency if more splits happen in the future. All of these pushed Bitcoin price to be overstated by the end of 2017. Moreover, number of splits magnified the rate of growth. This again confirms that there is connection between agent's expectations and number of splits.

Figure 3 Bitcoin closing price, dates of chain splits and fitted linear functions

However, even though Bitcoin chain splits seem to explain the recent 2017 bubble, there are several drawbacks I have found. Firstly, we can see from the Figure 2 that the structural break in Bitcoin closing price happened earlier than the announcement of the first chain split in July 2017. It seems that Bitcoin behaved differently from May 2017. It can be seen from Figure 4 that time series started to show higher volatility[16] on average compared to the 2016 - early 2017 period.

[16] Volatility was calculated as Standard Deviation of 10 days rolling window of Daily Excess Returns

Figure 4 Bitcoin volatility for bubble period

Secondly, there was another rapid increase in Bitcoin price in the year of 2013. At that time there were no splits. Thus I cannot infer for sure that Bitcoin chain splits were the only reason for the Bitcoin bubble in 2017. However, it can be one of the main factors that pushed closing price to increase.

The Resale Option Theory

Xiong and Yu (2013) discuss theory of asset bubbles introduced by Harrison and Kreps (1978). The theory states that a bubble might occur at the market when agents have heterogeneous beliefs about an asset's fundamentals and there exist short-sales constraints. In a market like this pessimistic agents can not put bet on an asset price decrease and thus prices are becoming biased towards beliefs of optimistic investors. Xiong and Yu also mention that the theory assumes fluctuation of beliefs over time. The change pushes agents to pay more than their own belief, because they expect to resell asset for a higher price to the more optimistic person in the future. Such behavioral distortion can lead to an asset price bubble. Harrison and Kreps called it the resale option theory.

Cryptocurrency market includes all features that the resale option theory is describing. First, agents cannot short sell Bitcoin. So far there is no brokerage company, that would lend Bitcoins to agents in order to allow short selling on the crypto market. Even though from the mid December of 2017[17] one could short some derivative contracts on Bitcoin, we could in the previous chapter that structural break in Bitcoin closing price happened much earlier. Therefore, at the time of the bubble formation there was a short selling constraint on the crypto market and historical Bitcoin prices can be biased towards beliefs of optimistic agents. Secondly, agents can hold different beliefs about Bitcoin price dynamics. Moreover, investors' beliefs can fluctuate over time because of constant release of new information. As stated in the theory such fluctuation can lead agents to pay a higher price hoping that after some time they can sell Bitcoin at even higher one to a more optimistic buyer.

The model of the resale option theory shows that the higher beliefs fluctuation among agents, the more they trade asset among each other. And the more trading volume is there, the

[17] More details can be found at http://cfe.cboe.com/products/bitcoin-qrg.pdf

more investors want to pay for an asset. In another words model shows that there exists positive relationship between price and trading volume. That is why as proposed by Xiong and Yu, I run a regression[18] of Bitcoin closing price on its trading volume in dollars. To make test more applied to the particular event, I have divided data into three periods and run regression (4) for each of them. The first period includes time from creation of Bitcoin, 19th July of 2010 to the beginning of a supposed bubble period, end of June 2016. The second period contains data for the bubble period, from 1st July of 2016 to 18th December 2017. And the last period covers time after the bubble burst to the end of March 2018. Besides that, I have taken logarithm of Bitcoin trading volume to make results interpretation easier:

$$Price_t = b_0 + b_1 * log(Volume_t) + \varepsilon_t \quad (4)$$

$Price_t$ is the closing price of Bitcoin on the day t and $log(Volume_t)$is the logarithm of trading volume of Bitcoin in dollars on the day t. I was interested in the value of coefficient b_1, which demonstrates relationship between closing price and trading volume.

From Table 4 we can see that result for a pre-bubble period is highly significant. With a t-statistics of 28.87 we can say that if trading volume was going up by 1 percent, than closing price of bitcoin would increase by 108 dollars. For the bubble period relationship between closing price and trading volume increases. Now we can state that there was significant positive influence of trading volume on the closing price with a t-statistics of 24.42. Moreover, during the bubble if trading volume was up by 1%, Bitcoin price was increasing by 3848 dollars. I should note here that in terms of econometric theory it is hard to prove that Bitcoin trading volume is completely independent of the residual in regression (4). Therefore, absolute values of coefficient b_1 for both periods might be biased. However, high significance levels allow me to infer the positive relationship between Bitcoin closing price

[18] I have used data set, which includes bubble period.

and trading volume. Moreover, values of two results can be compared between each other. Thus, influence of trading volume on the closing price during the bubble period was much higher compared to the pre-bubble one. This again proves that from July 2016 to December 2017 Bitcoin closing price was overstated because of the short selling constraints on the cryptocurrency market.

Results are no more highly significant if we talk about results for the period after the bubble burst. Amount of available observations for this period at the time of making research was only 69. This may be one of the reasons for insignificant results.

Table 4 Results of pooled regression analysis for The Resale Option Theory

Variable	(1) 07/19/2010-06/30/2016	(2) 07/01/2016-12/18/2017	(3) 12/19/2017-03/30/2018
VOLUME	108*	3848*	6098
(t-stat)	(28.87)	(24.42)	(3.96)
Number of observations	1485	367	69

By investigating the resale option theory, I was able to show that because of short selling constraints, Bitcoin closing price was biased towards the beliefs of optimistic agents. After regression analysis I could state that there existed strong connection between trading volume and Bitcoin price during 2017, which is an evidence of a speculative bubble.

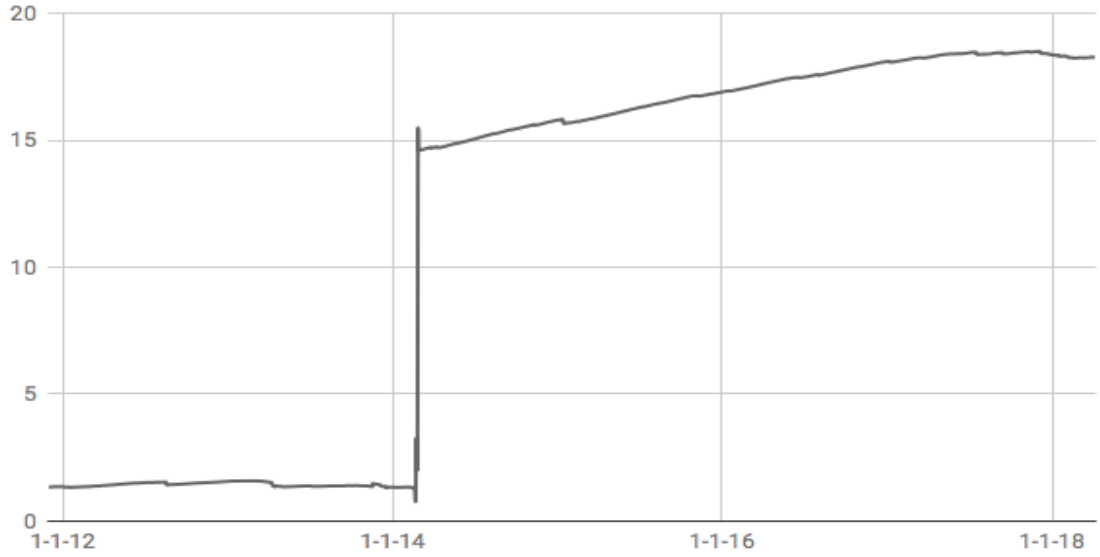
Gambling Behavior

Some agents might perceive investing in Bitcoin as investing in a lottery ticket. One would buy a lottery ticket if its outcome is positively skewed. In other words, there should be a small probability of a large positive return or large probability of a small negative return. This is shown in the famous paper of Kahneman and Tversky (1979), which describes the

prospect theory. Moreover, Xiong and Yu (2013) states that there might exist the similar risk preferences for financial instruments among investors, which can cause positively skewed assets to be overpriced. Thus positive skewness of an asset return can lead to a bubble.

Table 3 shows statistics of daily excess return distribution for the full history of Bitcoin. We can see that skewness for the whole historical period is positive and equals to 16.09. For a more thorough analysis I decided to calculate sequence of skewness values starting from a sample of 500 first days and adding up values for next dates. This way I got incremental skewness of a daily excess return distribution for a period starting from December 2011 until March 2018. Figure 5 shows how distribution skewness was changing thought history of Bitcoin. We can see from graph that its skewness was always positive. Moreover, it increases with time and hit more than 15 before the start of a suggested bubble period. This proves that agents might treated Bitcoin as a lottery ticket, which lead to its closing price to be overstated during 2017 period.

Figure 5 Skewness of Bitcoin daily excess returns distribution versus time



The Feedback Loop Theory

The behavioral finance suggests that agents might have certain behavioral biases on a market that can lead them to make investments into the assets that were showing good results in the past. This could push prices to be higher than asset's fundamental value. This idea was introduced by Shiller (2000).

I investigate this theory for Bitcoin time series for the bubble period by running linear regressions (5) and (6):

$$Ret_t = k_0 + k_1 * Ret_{t-1} + k_2 * Ret^+_{t-1} + k_3 * \Delta Volume_{t-1} + \varepsilon_t \quad (5)$$

$$\Delta Volume_t = l_0 + l_1 * Ret_{t-1} + l_2 * Ret^+_{t-1} + l_3 * \Delta Volume_{t-1} + \varepsilon_t \quad (6)$$

$Ret_t$is daily excess return of Bitcoin on the day t, $Ret^+_t = nax(Ret_t, 0)$ is a truncated positive part of daily excess return, $\Delta Volume_t$is the proportional change of trading volume on the day t. Ret^+_t is included into both regressions in order to examine asymmetry in the feedback effects.

Moreover, I run regressions for Bitcoin data with different time frequency: two-hour, daily and I also weekly data. I calculate weekly observations from daily data by taking maximum return across 5 consecutive days. Furthermore, weekly trading volume was calculated as sum of Bitcoin volume during the stated 5 days.

Running regressions (5) and (6) for samples with different frequencies allows me to test how fast agents response to the Bitcoin moves. Table 5 shows how Bitcoin returns are related to the stated lagged variables. First of all, there exist significant negative relationship between Bitcoin returns and its lag only for data with 2-hour frequency. From this I can infer

that Bitcoin market was operating at high speed. Thus, there can be seen overreaction among the Bitcoin traders.

Coefficient of the truncated positive part of lagged Bitcoin return is significantly positive for data with frequency of two hours. Thus, Bitcoin returns are increasing more in response to the positive past returns rather than decreasing in response to negative ones. Furthermore, results of relationship between Bitcoin returns and past volume changes are insignificant for samples with all frequencies. Thus, there is no evidence of intraday feedback effects in Bitcoin returns to the past volume changes.

Table 5 Results of pooled regression analysis within The Feedback Loop Theory

	Ret			$\Delta Volume$		
Sampling frequency	2 hours	daily	weekly	2 hours	daily	weekly
Lag Ret *(t-stat)*	-0.14* (-7.16)	-0.13 (-1.43)	-0.03 (-0.14)	1.16 (0.93)	1.07 (1.12)	0.03 (1.74)
Lag Ret^+ *(t-stat)*	0.15* (4.68)	0.16 (1.12)	0.5 (1.25)	-1.98 (-0.98)	-1.1 (-0.73)	-0.01 (-0.56)
Lag $\Delta Volume$ *(t-stat)*	+0.00 (2.31)	-0.00 (-0.01)	-0.63 (-0.47)	-0.01 (-0.08)	-0.23* (-4.4)	-0.26 (-2.3)

Table 5 includes results of the pooled regression analysis for volume changes. We can see that there is no significant relationship between changes in trading volume and past return across all samples. As well as there is no asymmetry in feedback effect for volume change. Moreover, there exists significant negative connection between change in Bitcoin trading volume and its lag. This means that volume change is a mean-reverting process.

Testing The Feedback Loop Theory for Bitcoin data with different frequency showed, that Bitcoin agents were responding to the changes in the closing price at very high speed. Moreover, there existed asymmetric feedback of Bitcoin returns to past returns. All these is an evidence of Bitcoin bubble existence during year of 2017.

Concluding remarks

In the research I have answered questions about recent blow up in Bitcoin price that happened in 2017. I have combined papers about cryptocurrency models with the researches about the speculative bubbles theory. I have investigated historical data by using several paradigms of the behavioral finance.

Moreover, by using knowledge of Bitcoin features, such as deliberate chain splits, I could apply The Rational Bubble Theory to the Bitcoin model. Moreover, I showed that rapid increase in its price during 2017 could occur because of the Bitcoin chain splits, that distorted agents' expectations of a future Bitcoin closing price.

The Resale Option Theory showed that short selling constraints pushed Bitcoin prices to be biased towards the beliefs of optimistic agents. By testing relationship of the Bitcoin trading volume and its price for three different time periods I could show that during the year of 2017 there existed strong relationship between the two.

By using The Prospect Theory idea in the set up for cryptocurrency market, I explained that investors could treat Bitcoin as a lottery ticket with a positively skewed returns. And, finally, I have found out that Bitcoin market was operating at a very high speed by investigating Bitcoin within The Feedback Loop Theory. Thus, I can state that Bitcoin price was overstated during year of 2017.

The research shows that cryptocurrencies can be investigated within the ideas of the behavioral finance. Moreover, there should be more papers that investigate agents' behavior on the cryptocurrency market. I should note that this research can be used as a base for more thorough analysis of cryptocurrency behavior inside of the bubbles theory.

References

Barberis, N., Huang, M., Santos, T. (1999). Prospect Theory and Asset Prices. *Center for Research in Security Prices (CRSP) Working Paper No. 494.* Available at SSRN: https://ssrn.com/abstract=169790

Blanchard J. O., Watson W. M. (1982). Bubbles, rational expectations and financial markets. *NBER Working Paper No. w0945.* Available at SSRN: https://ssrn.com/abstract=226909

Brunnermeier, M. K., Gollier, C., Parker, J. A. (2007). Optimal Beliefs, Asset Prices, and the Preference for Skewed Returns. Available at SSRN: https://ssrn.com/abstract=976962

Brunnermeier, M. K. and Oehmke, M. (2012). Bubbles, Financial Crises, and Systemic Risk. *Handbook of the Economics of Finance, Volume 2.* Available at SSRN: https://ssrn.com/abstract=2103814

Harrison J. M., Kreps M. D. (1978). Speculative Investor Behavior in a Stock Market with Heterogeneous Expectations. *The Quarterly Journal of Economics, Vol. 92, No. 2, pp. 323-336*

Jarrow R. (2016). Testing for asset price bubbles: three new approaches. *Quantitative Finance Letters, 4:1, 4-9.*

Jarrow, R. A., Kchia, Y., Protter, P. (2011). How to Detect an Asset Bubble. *Johnson School Research Paper Series No. 28-2010.* Available at SSRN: https://ssrn.com/abstract=1621728

Kahneman D, Tversky A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica, 47(2), pp. 263-291.*

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

Shiller, R. J. (2000). Irrational Exuberance. *Princeton University Press.*

Xiong, W, Scheinkman, J. A. (2003). Overconfidence and Speculative Bubbles. *13th Annual Utah Winter Finance Conference; AFA 2003 Washington, DC Meetings.* Available at SSRN: https://ssrn.com/abstract=298865

Xiong, W., Scheinkman, J. and Hong, H. (2004). Asset Float and Speculative Bubbles. Available at SSRN: https://ssrn.com/abstract=498022

Xiong, W. and Yu, J. (2013). The Chinese Warrants Bubble. *AFA 2011 Denver Meetings Paper.* Available at SSRN: https://ssrn.com/abstract=1361220

Moore T., Christin N. (2013) Beware the Middleman: Empirical Analysis of Bitcoin-Exchange Risk. In: Sadeghi AR. (eds) Financial Cryptography and Data Security. FC 2013. Lecture Notes in Computer Science, vol 7859. Springer, Berlin, Heidelberg

Appendix

Glossary[19]

Blockchain — An online ledger containing records (also known as **blocks**) of every crypto transaction. The blockchain is public and decentralized, and is maintained by a peer-to-peer network of computers.

Chain Split

Fork — Splits in the blockchain are possible when two separate computers create a block at the same time. Since both blocks are authentic, new blocks can then be built on the resulting split, known as a fork.

Mining — The process of creating blocks for the blockchain, which requires an inordinate amount of energy.

Wallet — A place to securely lock away your cryptocurrency private keys.

[19] Glossary is taken from article in Forbes magazine. Full text can be found via https://www.forbes.com/the-cryptocurrency-glossary-volume-1