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Sentiment and Bitcoin Volatility

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Abstract

Jaroslav Bukovina and Matúš Martiček: **Sentiment and Bitcoin volatility**

This paper augments the current research suggesting the less rational factors like attractiveness of Bitcoin and speculative investments to be influential for excessive volatility. In particular, it examines the sentiment as a driver of Bitcoin volatility. The paper contributes with economic rationale about a link between sentiment and Bitcoin. Further, the authors propose a unique decomposition of Bitcoin price to rational and less rational components. The paper tests this theoretical prediction with unique sentiment intraday data in the period of 12/12/2013 – 12/31/2015. The findings of the paper show the marginal presence of sentiment during the overall studied period. However, the explanatory power of sentiment significantly increases during the period of excessive volatility, especially during the bubble period at the end of the year 2013 and beginning of 2014. Moreover, the findings show that positive sentiment is more influential for Bitcoin excessive volatility.

Key words

Bitcoin, volatility, sentiment, Bitcoin bubble

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Introduction

Technological developments are changing and even disrupting the current status quo in several fields of our society. Cryptocurrencies represent such a potential change for a monetary system. Digital currencies are a part of our society since the creation of first public currency Bitcoin in 2009. Till nowadays, Bitcoin is the most popular and widely-spread digital currency. However, it became well known only in 2013 when it reached the historical maximum predeceased by exponential growth. The year 2013 triggered a society-wide discussion about the position of Bitcoin in society and its future prospects. According to current research, Bitcoin is an extremely volatile currency in comparison to the dollar, euro, sterling or yen. Despite the fact that excessive volatility threatens Bitcoin's chances to become a successful currency, academia is very interested in determinants of such volatility as well. Current literature stresses that among others, the less rational factors like speculative investments or attention of society are plausible drivers of Bitcoin's volatility. This paper enriches this discussion with the proposal of sentiment as an important driver of Bitcoin value, especially during the period of excessive volatility. In particular, the authors provide a proposal of economic rationale between sentiment and Bitcoin. Additionally, the authors employ unique intraday sentiment data and test this empirical prediction. The paper's findings show the presence of a link between sentiment and Bitcoin especially during the most volatile period in Bitcoin's history during the end of 2013 and beginning of 2014. Moreover, the driver of this volatility is predominantly the positive sentiment. In terms of the paper's structure, the next section presents the literature review. It is followed by the section "*Sentiment and Bitcoin"* focused on economic rationale showing Bitcoin's characteristics "responsible" for exposure to sentiment. The subsequent section describes the methodology, model and data, and the last section provides the paper's findings and the conclusion.

1 Literature review

Bitcoin[1] is digital decentralized currency working on a peer-to-peer network. Bitcoins are generated in a so-called "mining" process where network participants, so-called "miners", use the computing power of hardware to solve the computationally complex problems. In particular, bitcoins are a "reward" for problem solution. Bitcoin "economy" is based on BlockChain technology. BlockChain can be considered as a shared public ledger, which includes all transactions in bitcoins (Lo & Wang, 2014, Kancs, Ciaian & Rajcaniova, 2015). The deep understanding of Bitcoin and BlockChain principals

[1] In the paper, Bitcon spelled with a capital B represents Bitcoin as a network and bitcoins (small b) are meant to be individual units of this network.

requires the technical details not necessary for the main contribution of this paper. Further technical details can be found in Badew & Chen (2014).

Bitcoin was created by Sathoshi Nakamoto in 2009 (Nakamoto, 2009) but it became widely popular in 2013 when it increased literally from zero to its historical maximum of roughly $1,100 per Bitcoin. The popularity of Bitcoin was a trigger for academia to examine Bitcoin's position in the economy and its prospects to become a global currency. Mankiw (2007) defines three criteria of successful currency: a medium of exchange, a unit of account and a store of value. The evaluation of Bitcoin in comparison with these criteria is shown in Yermack (2013), Lo & Wang (2014) or Kancs, Ciaian & Rajcaniova (2015). These studies evaluate the excessive volatility as the very barrier for Bitcoin to become a successful currency. The extreme volatility in comparison to standard currencies like the dollar, euro, sterling or yen raises the interest in determinants of such volatility. Previous studies (e.g. Buchholz et al. 2012; van Wijk, 2013; Kristoufek, 2015; Kancs, Ciaian & Rajcaniova, 2015) propose the supply-demand relationship, global macroeconomic and financial development and Bitcoin attractiveness as three main factors to be influential for Bitcoin value. Moreover, Kancs, Ciaian & Rajcaniova (2015) stress the Bitcoin attractiveness as a more significant driver in comparison with others. Similarly, Garcia et al. (2014) and Kristoufek (2015) show the affirmative evidence about the link between the social activity and Bitcoin price. These studies predominantly employ Bitcoin search queries on Wikipedia and Google as a proxy for the attention of society.

This paper is inspired by the findings of previous studies about the bolder impact of less rational factors like an attention of society. In particular, this paper suggests the sentiment as an influential factor in the Bitcoin price formation. The sentiment as a price determinant has been considered before only in the study of Georgula et al. (2015) who employ the sentiment of the Twitter feed. However, they do not provide the economic rationale about this relationship. This paper fills this gap and the authors apply a unique approach of Bitcoin price decomposition to rational and less rational drivers. This theoretical prediction is studied via a much richer data set consisting of daily data in the period from December 2013 till December 2015 in comparison with Georgula et al. (2015), who employed daily data during a three month period.

2 Sentiment and Bitcoin's value

To properly evaluate sentiment as a driver of Bitcoin value, one has to incorporate the following two interrelated issues in the analysis. Firstly, Bitcoin is designed as a digital currency, but it can be considered as an investment, and according to Velde (2013) or Yermack (2013), a speculative investment. Secondly, the proper use of a term "sentiment" is necessary. For that purpose, the

authors employ the definition used in the field of behavioral finance. Baker & Wurgler (2007) describe the investor sentiment as a set of beliefs about the investment return and risk that is not proved by the facts at hand. Similarly, Kaplansky & Levy (2010) define sentiment as any misperception that can lead to mispricing in the fundamental value of an asset. In this context, Bitcoin is exposed to sentiment due to the following characteristics. Bitcoin is a new phenomenon with limited information sources. Its price formation is not well understood yet (Kancs, Ciaian & Rajcaniova, 2015). Bitcoin is a complex scheme; its understanding requires a technical knowledge of cryptography and algorithms (Badev & Chen, 2014). The story of Bitcoin mysteriously begins with an unknown person named Satoshi Nakamoto. This story is further augmented with statements of people who became rich due the small "investment" to Bitcoin in its beginnings. On top of that, Bitcoin works on a new platform BlockChain, which is not common in other fields of our economy and it is generally unknown in society. Moreover, big institutions are not a part of the Bitcoin market to increase the trust in bitcoins. Contrarily, the Bitcoin economy consists rather of small business and individuals who use bitcoins as a medium of exchange. Therefore, in parallel with theory of finance, speculative investments in Bitcoin are more likely driven by retail or individual investors called noise traders because big institutional investors are not a part of this market yet. According to behavioral finance research (Kumar & Lee, 2006; Baker & Wurgler, 2007; Barber & Odean, 2011), noise traders are prone to behave according to less rational factors like sentiment. In summary, Bitcoin is a new phenomenon not yet established in society. The supply of credible information is limited and generally respected valuation is missing. This situation creates the propensity for definition of subjective value and speculative investments.

3 Methodology

All previous studies focused on Bitcoin's price determinants mentioned above employs the price of Bitcoin as a dependent variable in econometric modeling. These studies model price of Bitcoin with several regressors like fundamentals, market forces or attention of society. However, this paper is focused on modeling of sentiment only. Therefore the decomposition of Bitcoin price into two components is applied according to the following equation:

$$BTC = \frac{T}{k} \times R \tag{1}$$

where *BTC* is one bitcoin, *T* is an average amount of transactions, *k* is a "coefficient", which captures the miners' reward per one block[2] and *R* is the average revenue per transaction. This simple decomposition defines the rational and less rational components of Bitcoins valuation. *T/k* ratio (average number of transactions per block) represents the rational component. It reflects Bitcoin fundamentals - the supply and demand relationship within the Bitcoin virtual economy. Every new mined block represents a new supply of bitcoins and number of transactions represents the demand for bitcoins as a medium of exchange within the Bitcoin "market". Figure 1 shows the average volume of transactions per one block. The transaction rate is stable with a slightly increasing trend. Increased volatility is present only in the 2nd half of 2015.

Figure 1. Average number of transactions per block.
Source: blockchain.info/charts, adjusted by authors

The second factor *R* shown in the above equation 1 is the miner revenue per transaction. In the context of the paper, it captures the less rational factors like speculative investments triggered by sentiment. This variable is a plausible gauge of sentiment. Technically, it should be close to zero because bitcoins have no intrinsic value. Therefore, their value should be determined by market forces within the Bitcoin economy as bitcoins serve as a medium of exchange already captured via

[2] Bitcoin economy works on BlockChain technology. BlockChain records all transaction among the Bitcoin market participants in so-called blocks. Miners drive the BlockChain because they confirm these transaction by solving complex cryptography methods and add them into new blocks. "Reward" for mining is related to a creation of new blocks in BlockChain. This reward is 25 bitcoins per block throughout the studied period. However, it decreases in time according to settings defined in the Bitcoin algorithm. The coeficient *k* captures this reward.

the *T/k* ratio. However, there is also the demand for Bitcoin from the real economy. This demand likely represents the speculative investments because such bitcoins are not used for the transactions within the Bitcoin market, but are held with the pure purpose of increasing in value. Figure 2 shows a time series of miner revenue per transaction. Periods of excessive volatility are clearly visible. Therefore, the variable *R* represents a dependent variable in the model below.

Figure 2. Miners revenue per transaction.
Source: blockchain.info/charts, adjusted by authors

3.1 Data

The paper studies the link between Bitcoin price and sentiment. Bitcoin price is decomposed into two components according to equation 1. Data for both components[3] is available on the web blockchain.info. The data is from the period 12/12/2013-12/31/2015 is applied due to availability of sentiment data described below.

Sentiment data is kindly provided by Harrison Kinsley and the website Sentdex.com. The main source of sentiment related to Bitcoin is the website reddit.com (Sentdex, 2016). Reddit is a social network, which works on the bulletin board system. In particular, users of this network can post a submission and subsequently other users can react via the comments and votes. These reactions determine the

[3] Component presented in this paper as Miner revenue per transaction is named Cost per transaction on the website blockchain.info. However, details about this data provide information about miner revenue.

popularity of the given submission. The Reddit website is divided into several areas of interest called subreddits. Bitcoin has several subreddits as well.

An algorithm created and used by Sentdex.com reads the initial submissions as well as related comments. Submissions and comments are analyzed via Natural Language Processing (NLP) techniques. This technique identifies the string of words conveying sentiment like adjectives and adverbs in the structure of a sentence. Furthermore, sentiment signals are defined in the interval (-3 to 6) where -3 is the strongest negative sentiment, zero is neutral sentiment and 6 is the strongest positive sentiment (Sentdex, 2016). Sentdex provides over 1.8 million intraday sentiment observations in the period 12/12/ 2013 – 31/12/2015. For the purpose of this paper, intraday data has been converted to daily data due to Bitcoin data availability in the daily form only. Daily data of sentiment represent the average cumulative sentiment per day. Seven observations are missing in the sample due to missing sentiment data.

Both modeled time series have been tested to the presence of a unit root by Dickey-Fuller and KPSS test. Time series of variable *R* in equation (1) are non-stationary, therefore the first differences have been employed.

3.2 Model

The link between Bitcoin and sentiment is modeled via the following models.

$$AR(1): revenue_t = \alpha + \beta revenue_{t-1} + \varepsilon, \quad (2)$$

and

$$AR(X): revenue_t = \alpha + \beta revenue_{t-1} + \beta sentiment_t + \varepsilon, \quad (3)$$

AR(1) model refers to autoregression of *revenue* in time *t* on its lagged value (*t-1*) where *revenue* represents the miner revenue per transaction. It is the variable *R* in equation 1. The second model defined as AR(X) is augmented AR(1) model with variable *sentiment*. These two models are compared together based on the R-square value. This simple methodology helps to understand whether sentiment helps to explain the volatility of variable *revenue.* It has been previously used in Saxa (2014).

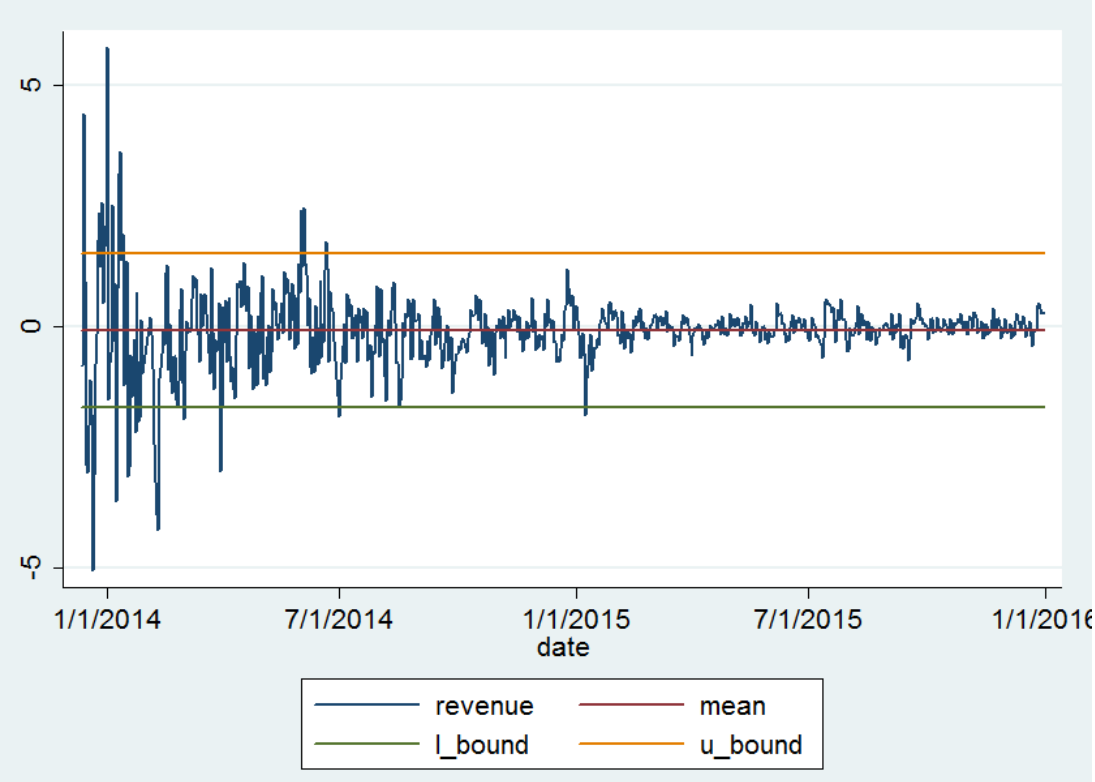

Figure 3. Miner revenue per transaction expressed in the first differences.
Note: Mean: -0.077; upper boundary: 1.511; lower boundary: -1.664
Source: Authors' calculation

Figure 3 shows the behavior of *revenue* expressed in the first differences during the studied period. Significant changes of volatility are evident over time. In this context, Velde (2013) stresses the Bitcoin as a speculative investment and Yermack (2013) implies the Bitcoin characteristics associated with speculative bubbles. Garcia et al. (2014) and Kristoufek (2015) show the bubble formation due to the interest of society in Bitcoin. Therefore, this paper defines the bubble period as well. It is defined as volatility higher than 2 standard deviations from a median value of *revenue* time series calculated for the overall studied period. The bubble threshold is given according to Siegel (2003), who provides the operational definition of asset price bubbles. The mean, lower boundary (l_bound) and upper boundary (u_bound) are shown in Figure 3 as well. The year 2015 and the 2nd half of 2014 indicate the volatility close to the mean but at the end of 2013 and beginning of 2014 indicate the excessive volatility exceeding the bubble threshold. Due to these changes in volatility, both aforementioned models have been estimated in the following periods. 1. The overall period from 12/12/2013 to 12/31/2015. 2. The overall period is divided in two parts. One period consists of the years 2013 and 2014 and the second one is the year 2015 only. 3. The most volatile period from 12/12/2013-03/31/2014. In every period, model AR(X) is estimated in three variations. In particular, variable *sentiment* is defined as cumulative, positive and negative sentiment.

4 Results

Tables 1-4 indicate the estimation of model 2 and 3 in four periods. Model 3 is estimated in three variations according to the decomposition of sentiment.

Table 1. Estimation results in period: 12/12/2013-12/31/2015

AR(1)		AR(X)	cum	pos	neg
$revenue_t$	**coef.**	**$revenue_t$**		**coef.**	
const	-.039 (.026)	const	-.145 (.035)	-.305*** (.065)	.005 (0.47)
$revenue_{t-1}$	.461*** (.033)	$revenue_{t-1}$	.432*** (.033)	.437*** (.033)	.458*** (.033)
		$sentiment_t$	.015*** (.003)	.016*** (.004)	.005 (.005)
R^2	.21	R^2	.23	.23	.21

Source: Authors' estimates

Note: The significance level ***/**/* is 10%, 5% and 1% respectively. The model is significant at the 1 % level according to the F-test.

Table 2. Estimation results in period: 01/01/2015-12/31/2015

AR(1)		AR(X)	cum	pos	neg
$revenue_t$	**coef.**	**$revenue_t$**		**coef.**	
const	-.007 (.011)	const	-.035** (.017)	-.029 (.035)	.057** (.021)
$revenue_{t-1}$	.576*** (.043)	$revenue_{t-1}$	.555*** (.044)	.572*** (.043)	.539*** (.044)
		$sentiment_t$	.003** (.001)	.001 (.001)	.007*** (.002)
R^2	.33	R^2	.35	.33	.35

Source: Authors' estimates

Note: The significance level ***/**/* is 10%, 5% and 1% respectively. The model is significant at the 1 % level according to the F-test.

Table 3. Estimation results in period: 12/12/2013-12/31/2014

AR(1)		AR(X)	cum	pos	neg
$revenue_t$	**coef.**	**$revenue_t$**		**coef.**	
const	-.069	const	-.212***	-.552***	-.037
	(.051)		(.062)	(.119)	(.085)
$revenue_{t-1}$	.452***	$revenue_{t-1}$	.413***	.412***	-.037***
	(.046)		(.047)	(.046)	(.085)
		$sentiment_t$	.024***	.035**	.004
			(.006)	(.007)	(.008)
R^2	.20	R^2	.23	.25	.20

Source: Authors' estimates

Note: The significance level ***/**/* is 10%, 5% and 1% respectively. The model is significant at the 1 % level according to the F-test.

Table 4. Estimation results in period: 01/12/2013-31/03/2014

AR(1)		AR(X)	cum	pos	neg
$revenue_t$	**coef.**	**$revenue_t$**		**coef.**	
const	-.194	const	-.369**	-1.214***	-.228
	(.168)		(.174)	(.317)	(.278)
$revenue_{t-1}$	.431***	$revenue_{t-1}$	.356***	.335***	.433***
	(.092)		(.093)	(.092)	(.093)
		$sentiment_t$	.040**	.066***	-.003
			(.014)	(.018)	(.020)
R^2	.18	R^2	.23	.27	.17

Source: Authors' estimates

Note: The significance level ***/**/* is 10%, 5% and 1% respectively. The model is significant at the 1 % level according to the F-test.

According to Tables 1-4, there is a relationship between cumulative positive sentiment and Bitcoin in every studied period. Positive sentiment is significant in every period as well with exception during 2015 only. On the contrary, negative sentiment is significant only during 2015 but the sign does not correspond with the assumption of negative impact. Overall, the sentiment explains only a minor part of total volatility, but there is a clear pattern of showing findings. In particular, R^2 value and value of sentiment coefficient increases when the studied period is closer to excessive volatility, especially in the period of the end of 2013 and beginning of 2014 in Table 5. The value of the model constant is increasing too as a consequence of high volatility at the beginning of the studied period. Moreover, the positive sentiment is more influential in comparison to the negative one. These findings are in line with studies of Garcia et al. (2014) and Kristoufek (2015) that the price bubble

period was driven by less rational factors. Similarly, positive sentiment is more influential as are the results of Georgoula et al. (2015).

Conclusion

This paper presents the idea about sentiment as a driver of Bitcoin volatility. The paper offers the novel approach to decompose the Bitcoin value between the rational and less rational components. According to the paper's findings, sentiment explains only a minor part of total volatility. The marginal explanatory value of sentiment was expected. This is due to employment of the website reddit.com as the only source of sentiment. However, during periods of excessive volatility an explanatory value of sentiment increases, especially for positive sentiment, which is in line with current research about the impact of less rational factors like Bitcoin attractiveness.

The literature review of this paper discusses the issue of Bitcoin potential to become a global currency. Several studies mentioned above see the excessive volatility as a threat for Bitcoin's future prospects. However, the Figures 2 and 3 together with the results in Table 5 for the period of the year 2015 show the volatility of Bitcoin in time is decreasing. In the context of the proposed decomposition of Bitcoin price, demand for speculative investments from the real economy decreases and the main driver is the supply-demand relationship. If this trend continues, that would mean only positive news for the future prospects of Bitcoin in the global economy.

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