Macroeconomic variables' impact on Bitcoin Price change

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ABSTRACT

Bitcoin is the most popular digital currency nowadays. Despite the fact that it is intrinsically worthless, Bitcoin price is more than $1000. In order to create a model for predicting high price movements of Bitcoin, this paper analyses macroeconomic indicators influencing Bitcoin price change using ARCH framework. Results suggest that the changes of Dow Jones, SSE indexes and also USD/Euro exchange rate can be used for prediction Bitcoin price change direction.

Keywords: Bitcoin, Financial Indicators, IGARCH

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All remaining errors are mine.

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1. Introduction

During last decade many virtual currencies have been created, but Bitcoin is the best known and the widest spread among all of them. The most important thing that makes Bitcoin different from other currencies is decentralization and block chain technology. This phenomenon raised public interest and Bitcoin became one of the most discussed themes nowadays. Being introduced in 2009 Bitcoin price was 0, which grew to $13 in 2013 and reached to its maximum to $1270 by the beginning of 2017. Now Bitcoin price is $1200 with market capitalization more than $19 billion. It is worth to mention that market capitalization has increased more than 4 times during the last two years.

The unique essence of Bitcoin has also attracted researchers. They tried to study Bitcoin and find its possible applications and impact on world economy. Still there are many research areas to develop in Bitcoin. One of the main research areas nowadays is the study of Bitcoin's price volatility. Some researchers state, that if there were not so much volatilities in Bitcoin price, its market capitalization would have been much bigger. Another thing that attracts many is the fact that people spend a huge amount of money on something which intrinsically is worth nothing. The difference of Bitcoin, compared with fiat money, is in its decentralization, which means there is no guarantee that Bitcoin won't be worthless even in the next day. So it is worth to understand how Bitcoin price is derived and what factors influence on its price and volatility.

Main research points in this paper are finding a model that will help to predict Bitcoin price change and find financial indicators that influence on Bitcoin price. Creation of a precise model will give an opportunity to predict the price of Bitcoin and diminish uncertainty in that market. To find the answers of research points I studied the literature and tried to follow the recommendations of the previous researchers. I have presented the full description of researched papers in the literature review part.

In the following section detailed information about Bitcoin can be found. The description of data and its transformation for the analysis is presented in the third part of the paper. Fourth and fifth sections respectively present methodology and final results. The last part of the paper presents conclusion.

2. What is a Bitcoin?

In the late 20th century the world entered in a phase of digitalization, when many daily goods and activities started to be digitized. This digital revolution has not passed around the currencies and the payment systems. During the 2000s first virtual currencies started to appear. FTFA gives the definition of a virtual currency as follows (FATF, 2014)

"Virtual currency is a digital representation of value that can be digitally traded and functions as (1) a medium of exchange; and/or (2) a unit of account; and/or (3) a store of value, but does not have legal tender status (i.e., when tendered to a creditor, is a valid and legal offer of payment) in any jurisdiction."

Even though during the last 20 years many types of virtual currencies have been created, the most successful is considered to be Bitcoin, as it is the most prominent among them and has the highest market capitalization. Bitcoin is not issued and controlled by any government, financial institution or company. It uses cryptography and decentralized network of users for creating and transferring digital coins. Satoshi Nakamoto, an undefined programmer or a group of programmers, introduced the technology of Bitcoin in 2008 in a paper with a title "A Peer-to-Peer Electronic Cash System" (Nakamoto, 2008). In the paper Nakamoto describes Bitcoin system, which is used for direct transactions without any intermediary. It is the first digital currency that works using cryptography principles to secure transactions. Those principles include a set of mathematical and computer science algorithms that ensure secure

communication in the third party's presence. Every time a transaction happens, nodes verify it and record it in blockchain (a public decentralized ledger which records all transactions and then displays accounts history with their corresponding Bitcoin). Suppose Ani wants to make a transactions with Bitcoin. Her transaction's proposal spreads in network and finds a "miner"; person who verifies transaction. He checks Ani's "private key", makes sure that she is the owner of the account, has the sufficient amount of Bitcoin and, then, verifies the transaction. The miner checks the information with the help of Block Chain data. Algorithms go through Block Chain and check Bitcoin's history to prevent double spending. After miner's verification new block is added to Block Chain with the information about Ani's transaction. Every time a transaction occurs a new block is added to chain and miners can always check the history and verification of a block.

The process of verification of a transaction takes about 10 minutes and is quite costly. It requires huge amount of electricity, special equipment and expertise. To cover these expenses miners should be compensated. For every successful transaction miner gets new Bitcoin and transaction fee, which is quite low than bank transfer fees. The algorithm created by Nakamoto will create totally 21 million Bitcoin, so the Bitcoin reward for miners will eventually decrease up to 0. This is expected to happen in 2140. (Yermack, Is Bitcoin a real currency? An economic Appraisal, 2013)

After being introduced, Bitcoin was used only by "Bitcoin Enthusiasts" (Benjamin, 2011). With the growing interest, Mt. Gox, an online exchange, started trading Bitcoin with 5 cents price. New method of payment attracted black market in its early stage of development. "Silk Road", one of the biggest online black markets, was accepting only Bitcoins. Legal regulators, tax authorities and law enforcement agencies have always paid special attention to Bitcoin in order

to understand its nature and prevent crime. This was one of the reasons that Bitcoin was associated with illegalness. However, in 2013 Silk Road was closed and people behind it got caught, proving that it is impossible to stay anonymous in the Internet. Indeed, after a few days first Bitcoin ATM was opened in Vancouver. The usage of Bitcoin started to grow increasingly. Now, Bitcoin is accessible in more than 100 countries. Many multinational companies like Microsoft, Dell and Overstock have added Bitcoin as an option for making a payment. The price of Bitcoin reached up to $1270 at the beginning of 2017 (FIGURE 1)

Figure 1 Bitcoin Price

3. Literature review

In the previous section I gave the description of digital currency and detailed presented Bitcoin. However, later after the creation of Bitcoin many researchers started to study it to see how it

satisfies the definition of currency. One of the researchers was David Yermck. In the paper called “Is Bitcoin a real currency?” the researcher studied the historical trading behavior of Bitcoin price. He came to the conclusion that Bitcoin behaves more like an investment than like a currency. A year later three researchers studied Bitcoin and came to the same conclusion that Bitcoin behaves like an investment (Ki Hoon & others, 2014). The next year, in 2015, Anne Dyhrberg (Dyhrberg, 2015) concluded in her paper that Bitcoin can be used in portfolio management, due to its similarities with Gold and dollar.

At the same many researchers tried to find the connection between Bitcoin and economy. One of the first papers was called “What can be expected from the Bitcoin?” (Wijk, 2013) .The author tried to answer the following hypothesized question “How does day-to day financial data influence the value of the Bitcoin?” He uses world’s top stock market indices (FTSE 100, Dow Jones, Nikkei 225), oil prices and USD/Euro, USD/Yen exchange rates in the error correction model to find the indicators that have short or long term influence on Bitcoin’s value. The mentioned indicators represent the financial and economic situation of global economy and somewhat reflect the future expectations of people, which, in authors opinion is the main driver of Bitcoin’s value. The analysis show that in long run WTI oil price, USD/Euro exchange rate and Dow Jones indicators have had a significant effect on Bitcoin’s value. Nevertheless, in short run only Dow Jones index has had a significant effect. The research was based on the data from 2010 to 2013, when Bitcoin was in its first years of development and author suggests to conduct a new research in a few years. In the recommendation part author also suggests to do the analysis using ARCH/GARCH technique, as it is one of the most suggested ways when dealing with serial correlated data.

Another paper that was looked into is called “Using Time-Series and Sentiment Analysis to detect the Determinants of Bitcoin Prices” (Georgoula, Pournarakis, Bilanakos, N.Sotiropoulos, & Giaglis, 2015). This paper studies both short and long term relationships of Bitcoin and some economic indicators and collective mood towards Bitcoin, measured by tweets. The short run analysis that has been done using Support Vector Machines shows that even though public mood has a positively correlated relation with Bitcoin price, USD/ Euro exchange rate has negative impact on it. For studying the long run relationship, vector error- correction model has been used. The findings contradict with the findings of Wijk (2013). This shows that one of the main indicators of the US economy, S&P 500 index, has negative influence on Bitcoin price.

“Information, Price Volatility, and Demand for Bitcoin” paper written in 2013, was also studied for the research (Martis Buchholz, 2013). In their paper the authors studied the relationship between Google hits, transaction volume and Bitcoin. As the used variables were not cointegrated, authors decided to use vector auto regression (VAR) technique for their analysis. They found that Google hits has a positive influence on Bitcoin transaction volume. In the second part of the research authors used ARCH model to study volatility of Bitcoin and found that there is an ARCH effect. In the conclusion part of the paper authors notice that the problem of heteroscedasticity seen in ARCH model could have significantly affected VAR estimates and give no accurate results.

Another paper that has been used is called “Bitcoin, Gold and the Dollar – a GARCH Volatility Analysis” (Dyhrberg, 2015). The research has been conducted to explore the Bitcoin price sensitivity to some of the world economy indicators and to compare it with gold and dollar.

GARCH model was used as one of the most popular frameworks for analyzing financial data. The variables that were used to explain price volatility include FTSE index, dollar euro and dollar pound exchange rates and Federal Funds Rate. The results show that Bitcoin's return volatility decreases as positive shocks happen for independent variables'. The only variable that did not behave like that is dollar euro exchange rate. The author comes to a conclusion that Bitcoin is useful for investors to hedge against negative shocks in financial markets.

The next paper that has been studied is called "The Economics of Bitcoin – Market Characteristics and Price jumps" (Grownwald, 2014). This paper analyses Bitcoin price and tries to deepen the knowledge about its behavior. For the analysis GARCH model was used to capture severe price movements caused by shocks in the market. Results show that the model fits the data very well and extreme price movements characterize Bitcoin price.

The last paper included in literature review is "Bitcoin as an investment or speculative vehicle?" (Elbeck, 2015). In the research authors of the paper tried to model Bitcoin price with some economic variables including: S&P 500 index, consumer price index, Euro exchange rate and some other economic indicators. The research showed that none of the economic variables impact on Bitcoin price. Researchers came to a conclusion that Bitcoin is a speculative vehicle and its price is internally driven by traders.

4. Motivation

The increasing amount of research outcomes about Bitcoin's behavior like an investment, come to show that Bitcoin gains its value because of investors' expectations that the price will increase

during time and they will benefit from it. The future expectations of investors is very hard and even impossible to fully find out. Though, many financial indicators can represent a big part of those expectations. If I find some indicators that are statistically significant, the Bitcoin price can be somehow predicted. In the literature review part I represented some researches similar to mine, though my input in research will add other relevant variables and recent time frame. Indeed, literature review showed that it is better to use ARCH/GARCH model for my analysis as the other methods like VAR, VEC models are not efficient when dealing with heteroscedasticity and also serial correlated data. I will follow their recommendations and perform the analysis using a model from ARCH family.

5. Data

5.1 Data Description

The whole data covers period from 02.01.2013 to 27.03.2017. The data does not include weekends and also some holidays when stock market is closed and data is not available. Totally there are 1078 observations. For summary statistics you can see Table 2 in Appendix.

The first variable is the exchange rate of Bitcoin to USD (BTC). The variable shows daily closing rate, which was updated every day at 6:00 pm EST. Data is sourced from Bitstamp exchange market, which is one of the biggest Bitcoin trading markets. Data is downloaded from bitcoincharts.com.

Next two variables are exchange rates of USD to Euro (Euro) and USD to Japanese Yen (JPY). The data shows an amalgamation of different source based rates, including data from exchanges,

banks and brokerages. The raw data is downloaded from quandl.com, one of the biggest databanks in the world.

FTSE 100 index is the next variable used for research. It is a share index of the biggest 100 companies recorded in London Stock Exchange (FTSE). Listed companies are mainly multinational with headquarters based in Europe. The index is one of the best financial indicator of Europe and is used in this paper for showing the state of Europe's economy. Raw data is downloaded from Yahoo finance, which is considered as one of the best sources of financial data. Data shows closing values of FTSE 100 index and is presented in British Pounds.

Next variable is Nikkie 225 Index. It shows Japan Stock Exchange's biggest 225 companies industrial average (Nik). Nikkie 225 is the most quoted index that is used as an indicator for performance of Japan's and also to some Eastern Asian countries' economies. Data is downloaded from Yahoo finance and shows closing values of index in Japanese yen.

The sixth variable used for the research is Dow Jones Index (DJ). Dow Jones industrial average shows how 30 large U.S. based companies stocks were traded in stock market. It is one of the most watched financial indicators for the US economy's performance. Data is downloaded from Yahoo finance and shows closing price of index in US dollars.

The seventh variable used is SSE composite index (SSE). It shows the composite index of all stocks traded in Shanghai Stock Exchange. It is one of the most watched index for Chinese economy. The data shows closing rate of index in Chinese Yuan and is downloaded from Yahoo finance website.

Gold is another variable that has been used for the research (Gold). Data covers daily closing price of per troy ounce in US dollars. Raw data was downloaded from goldprice.org.

The last variable is WTI crude oil price (WTI). West Texas Intermediate is oil benchmark, which is referred as a price of crude oil. It is produced and consumed in North America, mainly in the United States and this is the reason why I chose WTI price among other kinds of oil prices. Data shows closing price of WTI price and is downloaded from the US Energy Information Administration website.

5.2 Data transformation

Having non-stationary variables is a serious problem when dealing with time-series models. The problem is that when dealing with non-stationary series any shock occurred will always be persistent making analysis impossible. Another problem is spurious regression, when we can obtain significant regression results from unrelated data, again because of non-stationary time series. So it is very important to check the stationarity of variables and make adjustments if needed. To test the stationarity of variables Augmented Dickey- Fuller test was chosen. The null hypothesis for test is the presence of unit root process in data (rho=1) and alternative hypothesis is the stationarity of data with rho<1. The test showed that all variables taken are not-stationary. The first difference method was taken for getting stationary variables. After taking the difference ADF test showed that all the variables are stationary. (Table 3)

6. Bitcoin Price and Macroeconomic Variables

As described above the indexes FTSE 100, Nikkie 225 and Dow Jones represent economies of EU, Japan and the US. These are the places where main part of Bitcoin users are located. When economy of one of these countries is not doing well stock market indexes decrease and investors try to find an investment that is not connected with the economy and make investments there. (Šafka, 2014) Bitcoin serves for those purposes and it is expected that the indexes will have negative beta coefficients. The only index that I think will have a positive affect is SSE index. Many Chinese and international sources state that Bitcoin stays the only means to export capital from the China. Having Yuan devaluated the Government strictly regulates Yuan outflow and the only way to overcome the regulations is Bitcoin. Therefore, Bitcoin is mainly used in China. The positive influence is based on the logic that the increase of SSE index generates capital which can be exported from country only by Bitcoin, which will increase the demand and also increase its price. (Šafka, 2014)

I also expect that the Gold price will have a positive coefficient. It comes from the point that Gold serves as a safe investment in case of the distrust towards the economy. Bitcoin, as was stated before, serves for the same purposes and that is why their relationship is expected to be positive.

Bitcoin price was taken as Bitcoin- USD exchange rate. That is why it is also important to somehow capture the effect of USD change. I took Euro USD and Japanese Yen USD exchange rates respectively one dollar in euro and yen. The increase of the rate means that USD appreciates it and it is expected that dollar will appreciate against Bitcoin too, decreasing its price.

The oil price, as I have stated above, is a leading indicator of general price level change. Oil price in the US, WTI, represents general price level of the US. Increasing general level of prices

brings inflation and currency's devaluation (in this case dollars). (Palombizio & Morris, 2012) So, the increase of oil price is expected to have positive influence on Bitcoin price.

7. Methodology

The first ARCH family model was introduced in 1982 by Engle (Engle, 1982). In the paper Engle suggested to relate the conditional variance of the error term at time t to the square of previous periods' error terms to model heteroskedasticity. ARCH (Autoregressive conditional heteroskedasticity) model can be represented in equations (2,3)`

$$y_t = \phi + e_t \qquad (1)$$

$$e_t \parallel I_{t-1} \sim N(0, h_t) \qquad (2)$$

$$h_t = \alpha_0 + \alpha_1 e_{t-1}^2, \quad \alpha_0 > 0, \quad 0 \leq \alpha_t < 1 \qquad (3)$$

The first equation represents mean equation, based on a constant and error term. I_{t-1} in (2) represents information available at previous period with mean equal to 0 and $h_t$represents time-varying variance. The second equation shows that error term is conditionally normal and the third equation shows that time varying variance is dependent on lagged error squared and a constant term. This states that if there is an ARCH effect, large shocks tend to be followed by a large shock and vice versa small shock tend to be followed by small shocks.

After few years Tom Bollerslev introduced Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model as an extension of ARCH model. The idea behind GARCH model is that volatility at time t, apart from being dependent from square of previous periods' error terms, can also depend on own lags. GARCH can be presented in the following equation`

$$h_t = \alpha_0 + \alpha_1 e_{t-1}^2 + \beta_1 h_{t-1} \qquad (4)$$

(4) Equation shows that time varying variance is dependent not only on lagged error squared and a constant term, but also from previous period variance. GARCH is popular because with a few parameters it captures long lags in the shocks. Here to have a stationary process we need a condition that $\alpha_1 + \beta_1 < 1$.If it does not hold restricted version of GARCH, Integrated GARCH or IGARCH model should be used. With the constraint $\alpha_1 + \beta_1 = 1$ and $\delta > 0$ IGARCH process is strictly stationariy. (R. Carter , E. Griffiths, & C. Lim, 2011)

8. Application of model and Estimation Results

The formulas above showed that for analyzing data with ARCH models residuals of another econometric model should be used. That model built for time series should remove linear dependency in the data. ARMA model was decided to be used to remove serial correlation. ARMA model is just the combination of AR (autoregressive) and moving average (MA) models. ARMA has the following form:

$$y_t = \varphi_0 + \sum_{k=1}^{p} \varphi_i y_{t-i} + e_t + \sum_{k=1}^{q} \theta_j e_{t-j} \qquad (5)$$

In the formula (5) e_t is white noise. To have a stationary ARMA model we should have only stationary AR process, which means that the module of AR coefficients should be less than one. The lags of AR and MA was chosen mainly based on literature suggestions, Akaike and Bayesian information criterion and also by using the rule of thumb: ACF and PACF plots. I chose some lags for AR and MA processes. The test was performed and the results for AIC's and BIC's for different ARMA models were very small and I chose ARMA (1, 1) model. Even

though AIC for ARMA (1, 1) was not the smallest one, literature suggests that ARCH model best fits to the first lag[1]. Ljung- Box test was also conducted to test the goodness of model and results show that the chosen model fits data very well and there is no autocorrelation in data.

Next step is checking ARCH effect for our data. I used Lagrange Multiplier (LM) test for checking ARCH effect. Indeed LM model helps to find the order of ARCH model. The results are represented in Table 4. Lags from 1 to 15 were chose. Practically having even more than six lags significance speaks about GARCH effect. In our case we can see that there is a big jump at lag 3, but the chi square continually increases and the GARCH model should also be checked. This time also Akaike and Bayesian information criterion was used to choose the orders that best fit the data. The Table 5 presents the results. I chose GARCH (1, 1/2) as Akaike information criteria is the smallest for that model. However the sum of coefficients for GARCH model is greated than 1, which indicates that we have not stationary process. It was mentioned in the Methodology section that in case of non stationarity we need to choose IGARCH model. To have IGARCH process the necessary constraint was set. After doing the necessary adjustments Ljung-Box test was conducted and with p value 0.97 we reject the hypothesis of autocorrelation.

The first results of the model with all independent variables can be seen in Table 6. Here we can see that the changes of oil price, Dow Jones and FTSE Indexes are insignificant. However, further analysis showed that Dow Jones was an insignificant because of the correlation with other insignificant variables. All the variables which were statistically insignificant were removed and the final model which was left is in the following Table1

Table 1 Final Result (Dependent variable BTCs)

	(1)	(2)	(3)
VARIABLES	Model 1	Model 1	Model 1

[1] https://faculty.washington.edu/ezivot/econ589/ch18-garch.pdf

DJs	-0.00445**		
	(0.00178)		
SSEs	0.00740**		
	(0.00373)		
Euros	138.1**		
	(55.37)		
$BTCs_{t-1}$		-0.825***	
		(0.0510)	
e_{t-1}		0.734***	
		(0.0566)	
e_{t-1}^2			0.329***
			(0.0109)
h_{t-1}			0.263***
			(0.0467)
h_{t-2}			0.408***
			(0.0394)
Constant	0.474*		9.676***
	(0.263)		(0.914)
Observations	1,075	1,075	1,075

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The significant variables left are the differences of Dow Jones and SSE indexes and Euro/USD exchange rate. It was expected that Dow Jones index will have a negative effect. It is due to the fact that Bitcoin serves for investment purposes and when US economy is slowing down investments are directed to uncorrelated or negatively correlated assets, which brings demand in Bitcoin and positive impact on its price change. In opposite, SSE index has a positive impact on Bitcoin price change. Having very strict regulations on Yuan outflow, people in China use Bitcoin to export their wealth from the country. When economy is doing well capital and wealth is generated and Bitcoin's demand increases to outflow the generated wealth. Chinese Government tries to find ways to ban the usage of Bitcoin, but still it is not successful in it. In contrast with my expectations USD/EUR exchange rate has a positive impact on Bitcoin price.

The possible explanation can be the following. Dollar appreciation means that people need to pay more Euro to get a dollar. This will lead people to do their transaction by Bitcoin as it is acceptable in many places. The increase of Bitcoin demand can bring its appreciation towards the USD.

The visual test was performed to check how well the created model is predicting Bitcoin price change. Looking to figures 2 and 3, which respectively show the predicted and real price changes of bitcoin, we can see that the created model pretty well explains the price change direction. However the range for price changes in predicted and real data are different. In predicted data the range varies from -40 to 40 while in the real data it is much wider ranging from -400 to 400. The reasons behind the difference can be the overreaction of Bitcoin users towards an external shock.

Figure 2 Predicted Price Change and Volatility for Bitcoin

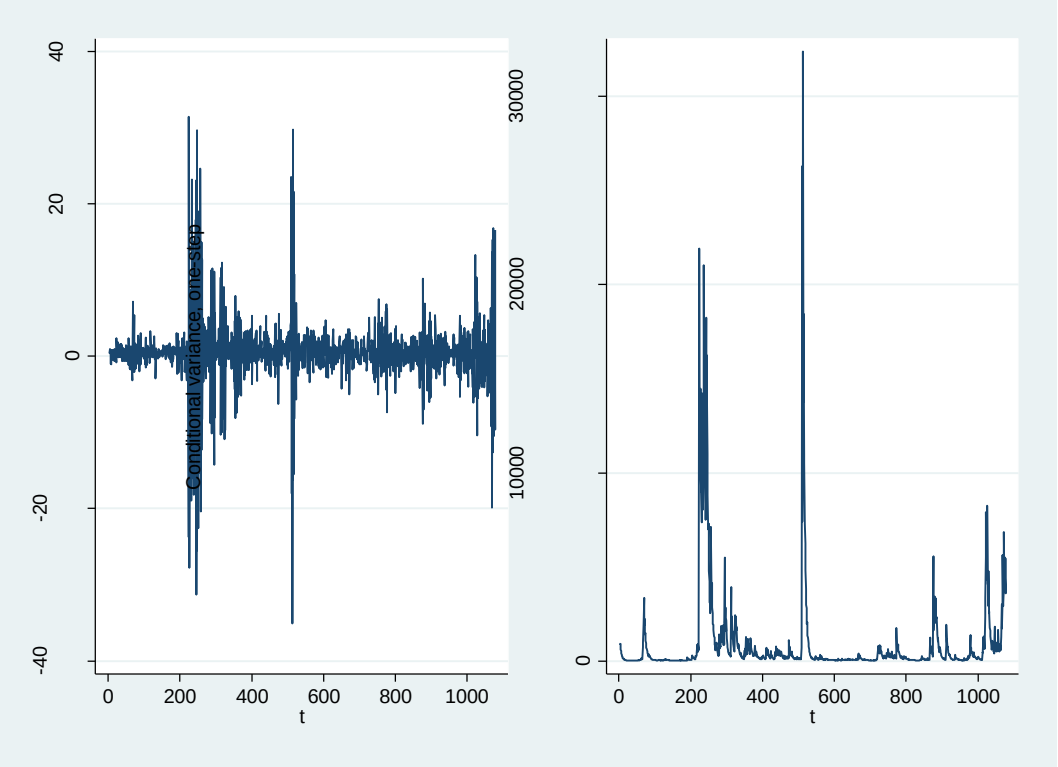
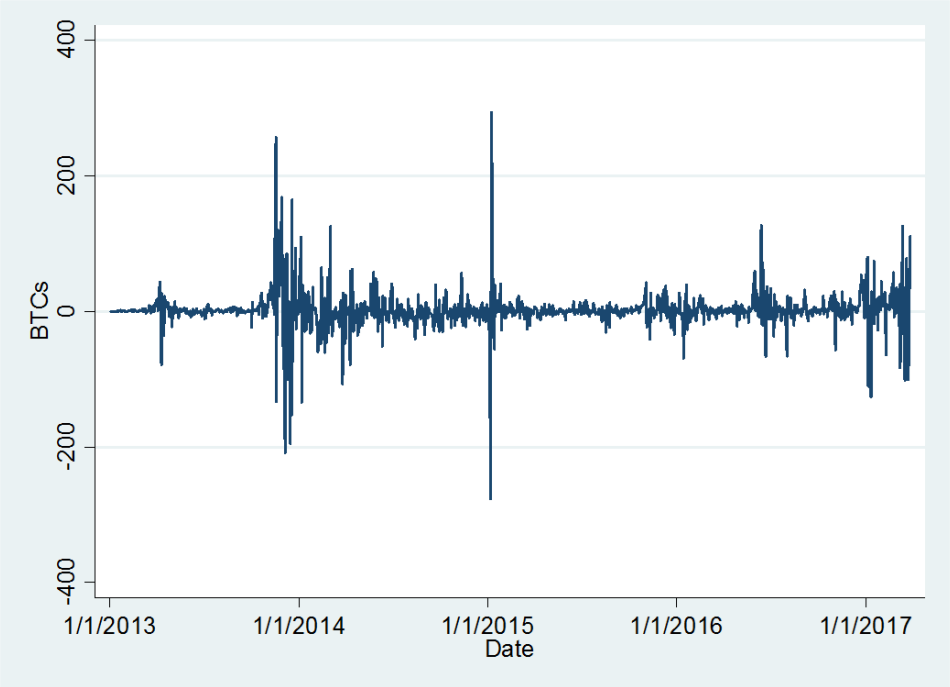


Figure 3 Bitcoin price change



9. Conclusion

Being created in 2008 Bitcoin has become the most popular digital currency in the world. Having intrinsically 0 value nowadays Bitcoin's price is more than $1000. According to researchers Bitcoin is mainly used for investment purposes and its attractiveness is in its feature of deregulation. This paper studied some macroeconomic variables impact on Bitcoin price. ARCH framework, as the one of the most popular framework in financial communities, was used for research. The analysis showed that Dow Jones, SSE indexes and also USD/EUR exchange rate are variables that significantly impact on Bitcoin price change. The performance indicator of the US economy has very small but negative impact on price change, while Chinese SSE and USD/EUR exchange rate positively impact on Bitcoin price change. The final model can be used to predict the direction of Bitcoin price change. To predict the exact change more relevant variables should be included to capture the effect of overreaction.

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Appendix

Table 2 Descriptive Statistic

Variable	Obs	Mean	Std. Dev.	Min	Max
BTC	1078	424.0337	268.5122	0	1285.33
WTI	1078	69.58765	26.04881	26.19	110.62
SSE	1076	2807.743	681.4815	1950.01	5166.35
Nik	1076	16473.91	2361.163	10486.99	20868.03
JPY	1078	108.636	9.413913	86.6	125.629
Gold	1078	1267.306	124.2212	1049.4	1693.75
FTSE	1078	6595.417	333.4641	5536.97	7429.81
Euro	1078	.8347418	.0801748	.7180297	.9638554
DJ	1078	17028.86	1532.365	13328.85	21115.55

Table 3 ADF test for variables change

		Dickey-Fuller test for unit root				
Variable		Test Statistic	1% Critical Value	5% Critical Value	10% Critical value	p-value for Z(t)
BTCs		-35.779	-3.43	-2.86	-2.57	0
WTIs		-34.91	-3.43	-2.86	-2.57	0
SSEs		-29.86	-3.43	-2.86	-2.57	0
Niks		-37.242	-3.43	-2.86	-2.57	0
JPYs		-33.541	-3.43	-2.86	-2.57	0
Golds		-32.71	-3.43	-2.86	-2.57	0
FTSEs		-31.57	-3.43	-2.86	-2.57	0
Euros		-33.69	-3.43	-2.86	-2.57	0
DJs		-33.53	-3.43	-2.86	-2.57	0

Table 4 Langrage Multiplier test results

LM test for autoregressive conditional heteroskedasticity (ARCH)

lags(*p*)	chi2	df	Prob > chi2
1	17.683	1	0.0000
2	26.919	2	0.0000
3	215.301	3	0.0000
4	215.115	4	0.0000
5	216.941	5	0.0000
6	223.048	6	0.0000
7	227.651	7	0.0000
8	231.625	8	0.0000
9	233.089	9	0.0000
10	232.857	10	0.0000
11	232.683	11	0.0000
12	234.178	12	0.0000
13	248.148	13	0.0000
14	248.332	14	0.0000
15	249.653	15	0.0000

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

Table 5 Akaike and Bayesian information criteria tests' results

	AIC	BIC
ARCH(2)	9928.51	9953.419
ARCH(3)	9708.073	9732.983
ARCH(5)	10090.09	10115
GARCH(3,1)	9457.598	9487.489
GARCH(2,1)	9450.263	9480.155
GARCH(1,1)	9101.172	9131.064
GARCH(1,2)	9166.678	9196.569
GARCH(1,1/2)	9079.031	9113.904
GARCH(1/2,1/2)	9093.824	9133.679

Table 6 First Results of IGARCH model(Dependent variable BTCs)

VARIABLES	(1) Model 2	(2) Model 2	(3) Model 2
WTIs	-0.301		
	(0.249)		
SSEs	0.00733*		
	(0.00416)		
Niks	-0.00359***		
	(0.00105)		
JPYs	1.274***		
	(0.391)		
Golds	0.0561**		
	(0.0258)		
FTSEs	0.00365		
	(0.00563)		
Euros	184.7**		
	(71.87)		
DJs	-0.00234		
	(0.00265)		
$BTCs_{t-1}$		-0.776***	
		(0.0678)	
e_{t-1}		0.674***	
		(0.0742)	
e_{t-1}^2			0.335***
			(0.0128)
h_{t-1}			0.248***
			(0.0516)
h_{t-2}			0.417***
			(0.0428)
Constant	0.511*		9.415***
	(0.266)		(1.009)
Observations	1,075	1,075	1,075

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1